1989 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

SECOND SESSION

MARCH 22, 23, 24, 1988

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1989 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 22, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:36 a.m., in room 2325, Rayburn House Office Building, the Honorable Doug Walgren (chairman of the subcommittee) presiding.

Mr. WALGREN. Let me call us to order and welcome our first witness.

As all of you here know, this is the first hearing on the National Science Foundation authorization of this subcommittee for fiscal year 1989 and this morning we have separate panels that will focus on issues pertaining to National Science Foundation programs on pre-college science and math education and on the proposed science and technology centers program.

I will defer the balance of the opening statement that I have in deference to Congressman Green, who is here. Those of you know that Congressman Green is one on the Appropriations Committee who has maintained a deep interest in the National Science Foundation. He serves on the HUD and Independent Agencies appropriations subcommittee, which really makes him the central contact for us in trying to translate our appropriations into actual actions by the administration—or translate our authorizations into actions by the administration.

He has maintained his interest in science, not only here on the Hill but in the various National Academy forums that are conducted on a national level. And for one from a distance, I really want to salute his commitment to this area.

We are pleased to have you, and welcome any thoughts and comments that you would like to provide for our record.

Congressman Green?

[The prepared opening statement of Mr. Walgren follows:]

[The prepared opening statement of Mr. Boehlert appears on p. 841.]

OPENING REMARKS OF THE HON. DOUG WALGREN (D-PA) ON THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION MARKUP

MARCH 22, 1988

THIS IS THE FIRST HEARING ON THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION FOR FISCAL YEAR 1989. WE WILL HAVE SEPARATE PANELS THIS MORNING FOCUSING, RESPECTIVELY, ON ISSUES PERTAINING TO NSF PROGRAMS ON PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION AND ON THE PROPOSED SCIENCE AND TECHNOLOGY CENTERS PROGRAM.

ON THE FIRST PANEL, WE ARE PLEASED TO HAVE DR. MYRON ATKIN, PROFESSOR OF EDUCATION AT STANFORD, WHO HAS EXTENSIVE EXPERIENCE WITH NSF ACTIVITIES IN CURRICULUM DEVELOPMENT FOR PRECOLLEGE APPLICATIONS; DR. MARJORIE GARDNER, DIRECTOR OF THE LAWRENCE HALL OF SCIENCE AT THE UNIVERSITY OF CALIFORNIA-BERKELEY, WHO HAS BEEN A RECIPIENT OF NSF AWARDS FOR TEACHER ENHANCEMENT ACTIVITIES; AND MS. HARRIET TYSON-BERNSTEIN, WHO EVALUATES MATHEMATICS AND SCIENCE TEXT BOOKS FOR PRECOLLEGE INSTRUCTION.

WE ARE CONFRONTED BY TWO DISTURBING FACTS REGARDING SCIENCE AND MATHEMATICS EDUCATION. ON ONE HAND, THE PERCENTAGE OF COLLEGE STUDENTS CHOOSING CAREERS IN SCIENCE AND ENGINEERING IS, AT BEST, CONSTANT, WHILE THE NUMBER OF SCHOOL-AGED CHILDREN IS DECLINING. AND ON THE OTHER HAND, THE PERFORMANCE OF THIS POPULATION OF SCHOOL CHILDREN ON STANDARDIZED SCIENCE AND MATHEMATICS EXAMS IS DISMAL RELATIVE TO OTHER ADVANCED NATIONS. THE SAD FACT IS DRAMATICALLY ILLUSTRATED BY A RECENT INTERNATIONAL SURVEY OF 5TH,

9TH, AND 12TH GRADE STUDENTS CONDUCTED BY THE INTERNATIONAL ASSOCIATION FOR THE EVALUATION OF EDUCATION ACHIEVEMENT.

IF THIS SITUATION DOES NOT IMPROVE, WE WILL FACT A LOSS OF THE TECHNOLOGICAL EXCELLENCE ESSENTIAL FOR SUCCESS IN INTERNATIONAL ECONOMIC COMPETITION AND FOR MAINTAINING OUR NATIONAL SECURITY. MOREOVER, CONTINUED POOR PREPARATION OF THE GENERAL STUDENT POPULATION IN SCIENCE WILL PRODUCE A SOCIETY WITH LOW SCIENTIFIC LITERACY AT A TIME WHEN PUBLIC POLICY DEBATES INCREASINGLY REVOLVE AROUND TECHNICAL ISSUES.

RECENTLY, AS A RESULT OF CONGRESSIONAL DIRECTION, NSF HAS ACCELERATED THE BUILD-UP OF PROGRAMS FOR DEVELOPING BETTER PRECOLLEGE SCIENCE AND MATHEMATICS CURRICULA AND FOR IMPROVING THE SKILLS OF TEACHERS IN THESE SUBJECTS, THROUGH TEACHER TRAINING INSTITUTES. OUR FIRST PANEL OF WITNESSES WILL ADDRESS THE IMPACT AND EFFECTIVENESS OF THE NSF PROGRAMS IN THESE CRITICAL AREAS. WE ARE INTERESTED IN SEEING IF NEW TEACHING MATERIALS SPAWNED BY THE NSF EFFORTS ARE FINDING THEIR WAY INTO THE SCHOOLS. LIKEWISE, WE WOULD LIKE TO DETERMINE IF THE TEACHER TRAINING PROGRAMS ARE REACHING SUFFICIENT NUMBERS OF TEACHERS AND IF PARTICIPATION IN THE PROGRAM LEADS TO QUANTIFIABLE IMPROVEMENTS IN TEACHING SKILLS.

ON THE SECOND PANEL, WE ARE PLEASED TO HAVE DR. DANIEL KLEPPNER, PROFESSOR OF PHYSICS AT MIT, WHO SERVED ON THE NATIONAL ACADEMY OF SCIENCES PANEL WHICH PROVIDED GUIDANCE TO NSF FOR IMPLEMENTING

THE PROPOSED SCIENCE AND TECHNOLOGY CENTERS PROGRAM; DR. JOHN SILCOX, PROFESSOR OF APPLIED AND ENGINEERING PHYSICS AT CORNELL, WHO IS CHAIRMAN OF NSF'S MATERIALS RESEARCH ADVISORY COMMITTEE; AND DR. ARTHUR WALKER, PROFESSOR OF SPACE SCIENCE AND ASTROPHYSICS AT STANFORD, WHO IS CHAIRMAN OF NSF'S ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES.

THE FISCAL YEAR 1989 BUDGET REQUEST FOR NSF PROPOSES TO INITIATE A NEW SCIENCE AND TECHNOLOGY CENTERS PROGRAM. THIS PROPOSAL SEEKS $150 MILLION IN NEW BUDGET AUTHORITY FOR UP-FRONT FUNDING OF 10 TO 15 SCIENCE AND TECHNOLOGY CENTERS FOR UP TO FIVE YEARS. WE ARE INTERESTED IN HEARING THE COMMENTS OF THE WITNESSES ON THE PROS AND CONS OF THIS FUNDING ARRANGEMENT. WE WOULD ALSO APPRECIATE HAVING THE VIEWS OF THE PANEL ON THE IMPACT OF THIS SET-ASIDE FOR NEW CENTERS ON EXISTING CENTERS PROGRAMS, ON LARGE FACILITIES SUPPORT, AND ON INDIVIDUAL INVESTIGATOR AWARDS.

BEFORE HEARING FROM THESE PANELS OF WITNESSES, I WANT TO WELCOME CONGRESSMAN BILL GREEN OF NEW YORK. CONGRESSMAN GREEN SERVES ON THE HUD AND INDEPENDENT AGENCIES APPROPRIATIONS SUBCOMMITTEE AND, OF COURSE, FOLLOWS SCIENCE AND TECHNOLOGY ISSUES VERY CLOSELY. HE HAS A PARTICULAR LEGISLATIVE INTEREST IN PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION, WHICH HE WISHES TO DISCUSS THIS MORNING.

STATEMENT OF HON. BILL GREEN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW YORK

Mr. GREEN. Thank you very much, Mr. Chairman, and let me thank you for allowing me to testify before you today, and let me also commend you for focusing on this particular aspect of the National Science Foundation's budget—science education.

I am here really in two capacities, first, as ranking minority member of the subcommittee that initiates the appropriations for NSF, and second, as the author of a bill that expands the NSF's role in science and math education that is pending before your subcommittee, H.R. 2315.

Mr. Chairman, much has been written and said about our efforts or lack thereof in educating young Americans in science and math. With the Winter Olympics just behind us, it might be illustrative to look at our standing in last year's International Chemistry and Physics Olympiads.

In the chemistry event, the American team, according to the New York Times, finished 23rd and 34th, far behind the winners, the two Germanies, the Soviet Union, and China; and in physics we really weren't close either—we won three bronze medals, when contrasted to a total of 14 bronze medals awards, so we were really pretty low down in that competition. And while this may be a rather simplistic way of looking at a very complex issue, I think the facts are pretty clear and pretty generally agreed on. Our young people are not attracted to science and math to the degree that those of other nations are.

We can draw our own conclusions about the ultimate result, but the results certainly do not bode well for our nation's vaunted technological superiority.

Let me offer a perspective from my work on the appropriations committee. Last week when the NSF appeared before us in support of its annual budget request, its own justification contained a reference to a study done by the International Association for the Evaluation of Educational Achievement. That study indicated that, "The results show the United States to have a middle position, vis-a-vis other countries at the fifth grade, a poorer position at Grade 9, and a relatively poor position at Grade 12."

The author of the study concludes that "For one of the most technologically advanced countries in the world, the United States would appear to be one of the scientifically most illiterate."

In our subcommittee we have consistently sought to increase the NSF's budget for science education and lately we have given particular emphasis to the pre-college area.

From a low of $20.9 million in fiscal year 1982, we have increased science education to its present level of $139 million. I also believe that our constant harping on the issue has had some effect on the NSF, as its request for Fiscal Year '89 is $156 million.

Speaking for myself, and I think for the rest of the subcommittee including our chairman, Congressman Boland, I think we would feel that a level of $200 million is appropriate. Now whether we'll be able to do anything approaching that will very much depend on our Section 302-V allocation, and that has been very tight these past years. But nonetheless, I think the spirit is there if we get a

little bit of help in the allocation among the appropriations subcommittees.

Now the point I want to make, Mr. Chairman, is that our subcommittee is prepared to commit significant resources to science education at pre-college and college levels and for that reason I think it is crucial on this issue and for the future of the nation that you and your subcommittee give us the guidance and lead the way on this issue.

Now let me be parochial for a couple of minutes and discuss my own bill, which has been referred to your subcommittee. H.R. 2315 amends the National Science Foundation Act of 1950 by expanding the role of the National Science Foundation to include responsibility for curriculum evaluation and development for math, science, and technology for elementary and secondary education.

Under my bill the NSF would be responsible for providing leadership and recommending math, science, and technology course content, reviewing textbooks and teaching materials and publishing the results in critical evaluations as well as identifying areas where new materials or research might be needed.

Additionally, NSF would have the responsibility to evaluate the status of developments in the application of new technologies to education. NSF would be authorized to support research on the possible uses of modern technology in the processes of teaching and learning to develop mathematics, science, and technology curricula that use computer systems and supporting materials to promote public and private cooperation in training teachers and to assist in making software available.

I was led to introduce my bill by the National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology Report of 1983. The commission, in concluding that the state of many of the nation's schools in pre-college math and science education was inadequate, stated:

> Our educational system must provide better opportunities and higher standards of excellence for all our youth, because the nation's national security, economic strength, and quality of life depend on the mathematics, science, and technology literacy of all of its citizens.

Mr. Chairman, I think that statement sums up the prevailing view on the issue and clearly delineates the challenge we are now facing. The words are as true today, in 1988, as they were five years ago.

Again, let me express my appreciation to you for having the opportunity to testify and for your consideration of these issues I raised.

[The prepared statement of the Hon. Bill Green follows:]

STATEMENT OF HON. BILL GREEN

Mr. Chairman, Members of the Subcommittee, thank you for allowing me to testify before you today. Let me commend you for focusing on this particular aspect of the National Science Foundation's budget on science education.

I appear before you in two capacities today. First, as the Ranking Minority Member of the Subcommittee that funds the NSF and secondly, as the author of a bill that expands the NSF's role in science and math education.

Mr. Chairman, much has been written and said about our efforts or lack thereof, in educating young Americans in science and math. With the winter Olympics just behind us, it might be illustrative to look at our standing in last year's Internation-

al Chemistry and Physics Olympiads. In the chemistry event, the American team finished 23rd and 34th, far behind the winners, the two Germanies, the Soviet Union and China. In physics, we fared similarly, winning only three bronze medals out of the 10 silver and 14 bronze awarded.

While this may be an overly simplistic way of looking at a very complex issue, the facts are clear, our young people are not attracted to science and math to the degree that those of other nations are. We can draw our own conclusions about the ultimate result, but it does not bode well for our Nation's vaunted technological superiority.

Let me offer a perspective from my work on the Appropriations Committee. Last week, when the NSF appeared before us in support of their annual budget request, their own justification contained a reference to a study done by International Association for the Evaluation of Educational Achievement. This study indicates that "The results show the U.S. to have a middle position vis a vis other countries at Grade 5, a poorer position at Grade 9, and a relatively poor position at Grade 12." The author of the study concludes that "for one of the most technologically advanced countries in the world, the U.S. would appear to be one of the scientifically most illiterate."

In our Subcommittee, we have consistently sought to increase the NSF's budget for science education, lately in the pre-college area. From a low of $20.9 million in FY82, we have increased science education to its present level of $139 million. I also believe that our constant harping on this issue has had some effect on the NSF, as their request for FY89 is $156 million. Speaking for myself, and, I believe for Chairman Boland, we believe a level of $200 million is appropriate. Whether or not we will have the budget ceiling to reach that level is, however, another question.

The point I wish to make, Mr. Chairman, is that our Subcommittee is prepared to commit significant resources to science education, at pre-college and college levels. We believe it is crucial for the future of our nation, and we look to you and your Subcommittee to lead the way on this issue.

Let me be parochial for a short while and discuss my own bill, which has been referred to your Subcommittee. H.R. 2315 amends the National Science Foundation Act of 1950 by expanding the role of the National Science Foundation to include responsibility for curriculum evaluation and development for math, science, and technology for elementary and secondary education.

Under my bill, the NSF would be responsible for providing leadership in recommending math, science and technology course content, reviewing textbooks and teaching materials, and publishing the results in critical evaluations as well as identifying areas where new materials or research might be needed. Additionally, NSF would have the responsibility to evaluate the status of developments in the application of new technologies to education. NSF would be authorized to support research on the possible uses of modern technology in the processes of teaching and learning, develop mathematics, science and technology curricula that use computer systems and supporting materials, promote public private cooperation in training teachers and assist in making software available.

I was prompted to introduce my bill by the National Science Board Commission on Pre-College Education in Mathematics, Science and Technology Report of 1988. The Commission, in concluding that the state of many of the Nation's schools in pre-college math and science education was inadequately stated, "Our educational system must provide better opportunities and higher standards of excellence for all our youth because the Nation's national security, economic strength and quality of life depend on the mathematics, science and technology literacy of all its citizens."

Mr. Chairman, Members of the Subcommittee, I think that statement sums up the prevailing view on this issue and clearly delineates the challenge we are now facing. Thank you for giving me the opportunity to testify, and for considering these issues I have raised.

Mr. WALGREN. Thank you very much, Mr. Green.

I appreciate your underscoring that initiative in the bill that you have introduced for us and want to certainly direct our committee's attention to that.

My only contact in that area in the past was several years ago when we had some software educational proposals which would involve the NSF in certifying certain materials, and I remember running into a lot of opposition because of the resistence to the Federal role.

Do you have any thoughts on how we can overcome that? Perhaps times have moved beyond that period.

Mr. GREEN. Well, I think we all recognize the primacy of the states and the local school boards in terms of the ultimate decision of what gets taught in schools around the country. Nonetheless, when there was general dissatisfaction with the level of science education in the immediate post-Sputnik era, the National Science Foundation did play a very important role in curriculum development in the science and math area, and I think there is probably very broad agreement that that was a very constructive effort.

And I think there is again concern on the part of the public that there needs to be work done here, and again I don't think any of that challenges the leadership role that in the end the state boards of regents—or whatever their titles are—and local school boards have to play in this process.

The other area where there is plainly a very serious problem is in terms of teachers in elementary and secondary schools who have the qualifications to teach math, science, and technology subjects. And the number of people coming out of Schools of Education, for example, with training in teaching mathematics is very, very small to the point where I recall one year recently the entire Chicago school system was able to acquire one additional instructor trained in teaching mathematics.

Again in the 1960's there was the experience, and I think it was generally given very high marks, of the National Science Foundation, essentially funding retraining types of activities for teachers during the summer vacations. I think it was felt at that time that that played a significant role in dealing with that kind of problem—and again that kind of approach I think would be viewed as very helpful by the state and local educational establishments.

Mr. WALGREN. I've heard such good things about those summer institutes of the 1960's and the early 1970's, and then we ran into the political arguments that sort of was unsupportive of almost any program that was associated with the 1960's. And my guess is we'll look back on this period feeling that the people who went before us were not all that far off the mark as to what can be constructively done to help in the area.

Mr. GREEN. No, I think it is unfortunate that for whatever reason NSF downplayed that aspect of its function during the 1970's and early 1980's, because plainly it was an important one and plainly the problem is still there.

Mr. WALGREN. Yes. One time I did just a back of the envelope extrapolation of what the science and math education was in the 1960's compared to what it was now; and if you took those numbers of the 1960's and translated them into current dollars, we were making an effort in 1966, I believe it was, at what would be a current level of effort of $300 million. And here we are at about $100 million trying to reach up in the best of our hopes to $200 million, as you say that your committee is certainly thinking could be well spent.

The question is, if $300 million was the adequate level for the post-Sputnik era, is one-third of that at this point or maybe even two-thirds of it, if everything broke right for us, is that adequate

for the potential that science has for contributing to the national interest? I think it is clearly not.

Mr. GREEN. I can well believe the numbers and the comparison you make. One point, again getting back to the concern that has been expressed as to somehow the National Science Foundation is going to dominate education if we went up to $200 million or even $300 million—the numbers we are talking about in terms of the total amount the Federal Government spends on education, let alone the total amount states and local governments spend on education is so small that there is no way the National Science Foundation is going to take over education in this country with $200 million or $300 million. What we hope they can do is provide some important leadership and some important glue money and attract attention and fill in some important niches in the problem.

I think this idea that the Federal Government is going to usurp state and local roles in education through this kind of activity is just totally belied by the numbers we are talking about.

Mr. WALGREN. Well, we really appreciate your interest in it and look forward to talking with you about it and trying to develop a commitment on this committee the same as you have on yours. So thank you very much for coming today, and we'll look forward to seeing you soon.

Mr. GREEN. You're welcome.

Mr. WALGREN. Great.

Well, as I said at the outset, we have two panels this morning. One focused on pre-college science and math education, and the other on the science and technology centers.

On the first panel, we want to welcome Dr. Myron Atkin, Professor of Education at Stanford University, who has extensive experience with NSF activities in curriculum development for pre-college applications. Dr. Atkin will be joined by Marjorie Gardner.

Dr. Gardner is the Director of the Lawrence Hall of Science at the University of California-Berkeley and has been a recipient of National Science Foundation awards for teacher enhancement activities.

And Harriot Tyson-Bernstein, who writes mathematics and science textbooks for pre-college instruction.

Welcome to our panel, all of you.

We are confronted by two disturbing facts in this area. On the one hand, the percentage of college students choosing careers in science and engineering is, at best, constant, and probably not, while the number of school age children is declining.

On the other hand, the performance of our population of school children on general standardized science and math exams is, as Mr. Green pointed out, not something that we can be proud of as a nation. And, if this situation does not improve, we clearly are going to face a loss, as a nation, of the general technological excellence that seems so important for international success, certainly in economics and ultimately in direct military applications, as well.

And we also wonder what the quality of our scientific and technological judgment, as a society, will be, if the general population becomes less and less able to appreciate the values of science and what it can contribute to us. And, certainly, in a democracy that has a central role to play.

Recently, and largely as the result of the general reaction to the reductions in funding at the outset of the Reagan Administration, the National Science Foundation has accelerated the buildup of programs for developing pre-college science and math curricula and for improving teacher skills, again, through teacher training institutes which, as I understand, is an old idea. It's certainly not new under the sun.

We have our first panel to address the impact and effectiveness of these programs, and we look forward to your perspectives on whether the new teaching materials will be able to make a real contribution through the schools. And, in addition, the teacher training programs, how effective they are and how broadly they reach the teacher population. And your perspectives on how we can do better in this area of pre-college, particularly, science education in the country.

So, with that, let's hear the panel in the order in which I introduced you to the record. And we'll start with Dr. Atkin.

STATEMENTS OF DR. J. MYRON ATKIN, PROFESSOR OF EDUCATION, STANFORD UNIVERSITY, STANFORD, CA; DR. MARJORIE GARDNER, DIRECTOR OF THE LAWRENCE HALL OF SCIENCE, UNIVERSITY OF CALIFORNIA, BERKELEY, CA; AND HARRIOT TYSON-BERNSTEIN, WASHINGTON, DC

Dr. ATKIN. Thank you, Congressman Walgren. I appreciate the opportunity to testify this morning. I would like to make four points in my introductory comments.

First, the National Science Foundation made a major difference 25 years ago in improving science education at elementary and secondary levels.

Second, scientists were central in the positive changes we saw then, and only NSF can reinvolve scientists today to the degree that they are needed in improving programs in education at all levels.

Third, the Directorate for Science and Engineering Education at the National Science Foundation is the most effective base for all NSF education activities. And its authorization level should be increased for next year, in my view, to about $200 to $225 million. In 5 years I believe that authorization should be more like $500 to $600 million.

Finally, science education centers are potentially a potent vehicle for achieving NSF's goals in education, and they would cost an additional $20 million annually in today's dollars.

Now, first, I stated the point that scientists made a major difference 25 years ago and that that was a positive period. We saw new courses in biology, physics, chemistry, earth science. I myself was co-director of a project in astronomy for middle-school children.

Content was revitalized. Teacher education activities, about which you spoke when Congressman Green was here, were expanded. And these programs that were instituted by the National Science Foundation had very broad impact.

At least until the mid-1970's, 50 percent of the biology classes taught in American high schools were taught with biological science curriculum study materials. The biological science curriculum

study was one of the efforts supported by the National Science Foundation.

As late as 1984, 43 percent of those taking the college boards physics achievement test had completed the NSF-supported physical sciences study curriculum.

There were spinoffs of the NSF activities in many countries around the world. In Australia, in Britain, in Japan, scientists were involved in the preparation of course materials, and American courses were freely translated into many languages. As a matter of fact, the Japanese used the biological sciences curriculum study materials in a greater percentage of their classrooms than was the case for the United States.

As much as anything, because of the attention of the prestigious scientific community, teachers in the 1960's and early 1970's again felt like people, to know that some of the most highly respected individuals in our society were directing their attention to problems of improving education at the elementary and secondary level. During the golden era of science curriculum reform in the 1960's, no curriculum project worth its salt didn't have at least one Nobel prize winner on its staff.

Manhattan Project scientists were disproportionately represented in the curriculum projects. These were people who appreciated the importance of scale and the results to be achieved if ambitions are appropriately high. And they were successful in persuading the Congress that large sums had to be provided.

I made the point about scientists needing to be involved, Mr. Chairman. Content is crucial, and only the scientific community, in my view, can assure that the content that's taught in elementary schools and secondary schools in the United States is content that's important and accurate.

There are structural reforms, as you know, going on in virtually all the States. Governor after Governor is staking his or her political future upon improvements in education within the States. Freshman legislators at the State level, for the first time in 10 years, are beginning to ask to be on the education committee again. Education's becoming important at the State level.

But all they can do at the State level is to make structural changes. That is, increase the salaries of beginning teachers. Very important. Make more of a career ladder for teachers. Very important. Make teaching less of a flat profession. That is, recognize those who are particularly able. Make them lead teachers. Very important.

But central to all education is what it is that is taught, and the States do not have the capability, in my view, to give the necessary attention to the content of the curriculum. NSF leadership is sorely needed in this regard. I believe that in 5 to 10 years from now there will be deep disappointment in American educational reform, if all we see are the structural changes, if the content turns out to be dismal or trivial.

Now, with respect to the appropriation, as was mentioned again when Congressman Green was here, during the golden era of NSF involvement in science education, 40 percent of the NSF budget was spent on education. That figure is now less than 10 percent. That signals an important message to the scientific community. If

the ratio of scientific research expenditure to education expenditure is not 6 to 4 but more like 13 to 1, that's a very strong signal that the Federal Government does not consider education to be that important. I believe that has to be rectified.

My final point is that, just as we are talking this morning about science and technology centers, I believe we should be talking as well about science education centers. Now, one reason—by no means, the only reason—is that we need to make it attractive again for the scientific community to get reinvolved in matters of elementary and secondary education.

Centers, with some degree of continuity, make it more congenial for scientists to spend a sabbatical, for scientists to spend a summer, concerning themselves with problems of education. While there is deep concern in the scientific community about the quality of education, it's too much to expect a scientist or a mathematician to reorient career and become a principal investigator in a curriculum project.

But with ongoing centers, they can make a modest investment, yet I think a critically needed investment. That's only one reason. I think another reason is we need to inject greater stability into our curriculum development and research activities.

The other point that I made was that the Science and Engineering Education Directorate is the appropriate base for science education activities at the NSF. Occasionally the remark is made that the education functions can be put out into the research directorates. But, if that were to happen, they would enjoy the same kind of marginal status that education enjoys on most university campuses.

For education to be taken seriously within the National Science Foundation, you need a critical mass; and, that critical mass, I believe, should be built within the Science and Engineering Education Directorate.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Atkin follows:]

EDUCATION AT THE NATIONAL SCIENCE FOUNDATION:

SOME HISTORICAL PERSPECTIVES, AN ASSESSMENT,

AND

A PROPOSED INITIATIVE FOR 1989 AND BEYOND

Testimony

U. S. House of Representatives
Committee on Science, Space, and Technology

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SUMMARY

For science to prosper in a democracy, there must be an informed citizenry as well as outstanding scientists. This point was emphasized when the National Science Foundation was created in 1950. During the high point of NSF support for activities designed to improve programs in elementary- and secondary-schools, outstanding scientists turned their attention to problems of educating children, starting with five- and six-year olds. By its involvement, the scientific community signaled to the nation the crucial importance of a high-quality schools at every level. As a result, science instruction in the United States was improved markedly. With NSF's help, new courses were developed. Thousands of teachers were brought up-to-date about scientific developments. Leaders were trained. The country began to take the teaching of science seriously.

Unfortunately, the fraction of NSF expenditures for the improvement of science education for youngsters below the college level has declined sharply during the last twenty years. From a position commanding more than 40 per cent of the NSF budget in the late 1950s, expenditures earmarked for education at the Foundation have plunged to less than one-tenth of the NSF budget in 1988. In that period, the quality of science teaching in the United States has fallen far behind most other industrialized nations.

For the 1990s, however, there are fresh opportunities for the Foundation to play a major role again in the improvement of science education for all people -- in elementary schools, in secondary schools, at the collegiate level, and outside of formal educational settings. Furthermore, it must do so if American scientific and technical advancement is to regain its preeminent position. No other agency is positioned as well as the NSF to provide the leadership the country needs for the improvement of science education.

One major opportunity for the years immediately ahead is for the NSF to create new centers exclusively for the improvement of scientific education in the nation's schools.

EDUCATION AT THE NATIONAL SCIENCE FOUNDATION

It is now well-known that at least two ingredients are necessary for scientific progress, one more obvious than the other. For science to thrive, there must be scientists of the highest quality -- and enough of them in a range of fields to have a cumulative effect, to build self-sustaining cultures, to generate the necessary momentum. These men and women, the most able the country can attract, supported often by highly specialized and expensive laboratories, create the new ideas upon which scientific and technological advancement are built. There is no substitute for such people and ideas; without them, a nation becomes derivative and dependent. It begins to rely primarily on others for its invigoration, and in the process declines in its self-esteem and external influence.

However, there is another factor essential for scientific progress, especially in a democracy -- one that is often overlooked, even by scientists themselves: for an expensive and complex enterprise like science to prosper, it needs a supportive public. At one level, funds from the public treasury are needed to do science, and wise decisions must be made about how they should be spent. Few legislators are scientists by training, yet it is they who must decide if accelerators are to be built or if fellowships are to be provided to support graduate education. Legislators also must be knowledgeable about applications and effects of scientific and technological advancement: How should nuclear power be regulated? What are reasonable standards for environmental health? What laws and regulations should govern transportation and disposal of hazardous materials? What level of support is needed for "basic" research, intellectual activity for which few practical benefits are immediately apparent?

But at a deeper but no-less-important level, there must be a disposition in the public at large to foster the development of science. It is the citizenry, of course, who elect legislative representatives. Even more basically, it is they who generate the pervasive values by which a society makes its most fundamental decisions. Should heavy investments be made in space weapons? Should evolution be taught in the schools? Should public dollars be spent on research that seems incomprehensible, or on projects whose titles sometimes seem silly? Is science worth pursuing at all if it encourages a disposition to raise questions that sometimes seem a challenge to authority and stability? It is the general attitude toward science in the public at large that in a representative democracy determines whether or not the enterprise itself is pursued, and how vigorously.

In early 1958, when many people were frightened by the fact that the first space satellite had been launched not by the United States but by the Soviet Union, Edward Teller made a related point compellingly. He said that the country did not

need a huge fraction of the population to take up careers in science, and in any event probably could secure those it needed. But able scientists in sufficient number is not a sufficient condition for science to develop adequately. He drew an analogy with sports. The country does not have a high percentage of its people engaged in professional athletics; in fact the figure is minuscule. Nevertheless, the professional sports enterprise thrives in the United States, as it does in most other countries. The reason? Fans. What the United States needs, said Teller, is science "fans."

By this provocative imagery -- offered in Congressional testimony -- Teller was making the point that in the interest of assuring the level of support for the science and engineering needed in the national defense, it is imperative to improve science education at pre-college levels. That is when people usually develop most of their life-long interests. In fact, he emphasized the key role of a strong elementary-school education in improving the state of science in the United States. Unless positive dispositions toward science and quantitative thinking are generated by the time a person is twelve- or thirteen-years old, those inclinations are unlikely to surface later. The Congress listened. Funds were provided for significant improvements in education from first grade through high school.

NSF's Impact on Education: The Golden Years

Almost a decade earlier, in 1950 in fact, the Congress had reached a similar conclusion when it created the National Science Foundation. It had decided that the advancement of science is in the national interest and could not be left entirely to state and local government, or to private industry. Furthermore, a high-quality education is essential for scientific progress, and it is a responsibility of the federal government (along with promoting research) to provide leadership for the improvement of science education, at all levels. Those who framed the legislation establishing the Foundation recognized the inseparability of research from education; neither could survive for long without the other. That conviction was fundamental in the minds of the prime movers in establishing the Foundation, and unmistakable. As a consequence, appropriations for education during the early NSF years comprised more than 40 per cent of the Foundation's budget.

The results were impressive. Starting in the mid-1950s, the Foundation launched programs in science education that were to have a profound effect, not only on education in the United States but around the world. Scientists were granted funds to develop new high-school courses, first in physics -- then in

biology, mathematics, and chemistry. Significantly, the leading researchers who turned their attention to issues in pre-college education in the mid- and late-50s were often the very people who had spent the war years designing weapons; Manhattan Project scientists were disproportionately represented among those developing new courses for youngsters. They were also those who lobbied most effectively for significant investment by the federal government in the improvement of science and mathematics education. They knew, and could argue convincingly, that important and complex projects often cost lots of money; they appreciated the advantages of ambition and scale -- and improving American education was then, as it is now, a monumental undertaking.

Not only did the central involvement of outstanding scientists assure that the courses developed would be of sound content (and science programs before the NSF initiatives were often characterized by both trivia and inaccuracies), but the commitment of these people sent an unmistakable signal to the public that science teaching is important. Teaching is not among the most prestigious of professions. When esteemed figures not only affirmed the critical function of pre-college education, but redirected their own energies toward involvement in the schools, the public began to take problems in education more seriously. Furthermore, non-scientists as well as scientists began to realize that education is not only a national priority, but that improving the schools requires the country's finest minds.

For many hundreds of university-based scientists, it became a respected part of their professional activity to devote effort to problems of improving pre-college education. A modestly sized snow-ball effect developed from the curriculum activities. In the majority of the Nation's colleges and universities, professors began devoting their time to pre-college teacher education, as well; the National Science Foundation supported hundreds of special summer and academic-year institutes for high-school teachers over a period that lasted more than a decade. Gradually, the NSF began to encourage similar programs for people in leadership positions in elementary schools, too.

The NSF's message was grasped immediately and gratifyingly by teachers. It made them feel the nation was beginning to appreciate their importance, as never had been the case before. Morale was lifted. A new vigor entered science education. And there were the predictable consequences of higher morale and energy: able people who otherwise might have left the profession decided to stay. Young people of talent contemplating their occupational choices began to look more seriously at teaching as a possibility. These somewhat intangible but nevertheless powerful benefits may be the most important results of NSF

activity in education twenty-five years ago. The 1950s and 1960s represent what now seems, in many ways, like a golden era in science education.

The NSF-supported activities during this period resulted in a significant improvement in the quality of classroom work in science and mathematics, both in high schools and elementary schools. By the mid-60s, and at least to the mid-70s, 50 per cent of the biology classes in the United States were being taught primarily from NSF-developed textbooks. As recently as 1984, 43 per cent of those taking the College Board's Physics achievement test had completed the NSF-supported Physical Sciences Study Committee course. Hundreds of people who now hold leadership positions in science education got their start in NSF-supported activities during those seminal years, and were able to continue launching significant programs of educational improvement for many years afterward.

For the first time, American schools began to attract significant and flattering attention internationally in those years. The new courses and programs for teachers were models of intellectual integrity; they captured the meaning of the scientific subjects in ways unseen before in schools anywhere. Students and teachers not only developed deep understanding of the essential content of science, they learned also about how scientific knowledge is generated. Highly motivated teachers and children, and the excitement of fresh ideas and new resources, made schools in the United States a magnet and model for other countries trying to improve their own educational systems; for about ten years, there was a steady flow to American schools of educational planners from many countries of Europe and Asia. Major spin-offs of the NSF-supported activities were launched in Britain and Australia, in which scientists in those countries, too, began to concentrate significant effort on the improvement of pre-college education. Science and mathematics texts that had been developed with NSF support were translated into other languages. In the end, some courses developed under National Science Foundation auspices were used more extensively in Japanese schools than in those in the U. S.

The new curricula had their problems and their critics. Teachers often were unable to put into practice on a large scale the very fine programs that frequently were developed under ideal conditions in a relatively small number of places, for example. We know more today about how to do such things. But, on balance and despite the problems, the net results of NSF curriculum and teacher education activities in the 50s and 60s were positive. SRI International, in a study undertaken at the direction of the Congress to outline options for the NSF in education, and completed last year, summarized the major lessons

to be learned from NSF activity during this period, as follows:*

"1. NSF can respond effectively to a national curricular 'crisis' in science and mathematics education.

"2. To be effective, curricular reform efforts need to be collaborative. [Heavy involvement by the scientific community is necessary but not sufficient.]

"3. The indirect impacts of curricular reform efforts may be as important as the adoption and use of specific curricula.

"4. NSF is well suited to the task of creating alternatives to existing practices.

"5. Curricular reform is not separable from overall reform efforts.

"6. In its classical linear form, the research-development-dissemination model is not the process by which new curricula make their way into practice.

"7. NSF faces a fundamental and deeply rooted dilemma that pervades all of its efforts at affecting curricula. [How 'innovative' and ahead of the 'market' can NSF afford to be?]"

Shifting Priorities at the Foundation

Unfortunately, and to the detriment of the country, the education element of NSF's responsibility began to decline as a priority in the late 1960s and early 1970s. It did not enjoy growth commensurate with its national importance, nor growth that corresponded with the expansion of research activities within the Foundation. Quite the contrary. The NSF commitment to education (except for graduate fellowships) fell sharply throughout the 1970s. Finally, in 1982, the Education Directorate at the Foundation was abolished. As a partial result, now, when there is a national will to improve science education, there still is no clear, federal perspective that points to what must be done, no well-defined cadre of people prepared to move aggressively to fix things.

As a direct consequence of the NSF's diminished commitment to education, participation by scientists in addressing problems

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* Opportunities for Strategic Investment in K-12 Science Education: Options for the National Science Foundation, Volume 1, 1987, pp. 94, 95.

of pre-collegiate schooling fell sharply during the last twenty years. There seems even to be less interest than heretofore in the scientific community in addressing educational problems at the undergraduate level, especially for non-majors. The message to scientists from the NSF during that period was clear enough: the Foundation considers an appropriate ratio of research expenditures to education to be something like 13 to 1, rather than the 6 to 4 that had pertained earlier.

The National Science Foundation had evolved to become a key supporter of basic research in the United States. The research directorates and divisions at NSF no more saw the improvement of teaching as a priority than did their colleagues engaged in research at the universities. And, along the way, the importance to scientific research itself of educating science "fans" was lost altogether.

The attenuated connections between two critically important elements of the American educational system -- the scientific research community and those who provide early education for specialists and non-specialists -- is not in the best interest of either one. And it certainly is not to the benefit of the country. No part of the education system is independent of the others, not the graduate-level research university, not even the special-purpose national research laboratory.

The Congress, in 1983, insisted that the Education Directorate be reestablished, recognizing better than those responsible for the decision to eliminate the program how influential the NSF had been in improving science education during an earlier period, and probably recognizing also the fact that no other federal or private agency could build as well as NSF on its own impressive history in bringing the best talents of the scientific community to bear on problems of education at all levels. But the hiatus in funding and its still-insufficient scale leaves a gaping hole in national leadership.

Sometimes it is suggested that, yes, the NSF should take education more seriously, but that the responsibility should reside with the research directorates. Fortunately, the idea makes little progress. If the NSF education functions were added to the research directorates, the result very likely would be a dissipation of the required energy and an unintegrated effort that would fall far short of the necessary critical mass. Worse, such a plan would foster a perpetual, marginal status for education because of the priority that educational programs would be accorded in the zero-sum game (between research and education) that some NSF administrators seem to see in the annual budget process. Even for the improvement of undergraduate education, it is unlikely that a hospitable base is found in five different

research directorates. Finally, accountability and the tracking of funds becomes a policy analyst's (and an educational reformer's) nightmare.

There is unlikely to be strong and effective leadership from the NSF in the improvement of scientific education unless all its specifically educational functions are tied together organizationally and strengthened appreciably. That means that the Directorate for Science and Engineering Education should be expanded to encompass all NSF educational functions, including those directed toward the undergraduate years, and its budget increased commensurately and dramatically.

Education Politics Today: A New Era for NSF Initiatives

Partly, the apparent American inability to anticipate problems in science education and head them off -- the inclination to respond only when there is an emergency -- is a general characteristic of educational policy in the United States. In 1957, the country was alarmed by the implications of Sputnik I and moved to address the problem by improving the educational system. Progress was made, impressively; but very soon, in fact by the mid-1960s, the Sputnik issue and what it implied was shunted aside by the public, to be supplanted in the competition for attention by a new crisis, this time the educational plight of the poor, particularly of racial and ethnic minorities. Such problems are likewise serious, of course, but the national response to the new awareness of limited educational opportunity for blacks and other minorities was to redirect the attention going to science education toward programs to strengthen education in the inner cities.

That priority, however, did not last long either. By the early 1970s, America seemed absorbed by a newly discovered "joylessness" in the classroom; Woodstock, Haight-Ashbury, and the flower children were having their influence. How could learning be made less deadening? How can the spirits of children be freed from the relentless drudgery of oppressive schools? Then, in the late 1970s, with a 180-degree turn in public concern that, unfortunately, is not uncommon in education, it was "back to the basics." Today it is economic competitiveness.

These abrupt shifts in the objects of national educational concern have been destructive for the schools. With each change in priority, there is a tendency to blame the victims. Why weren't schools stronger in science and math in the 1950s? Why weren't they educating the poor in the 1960s? Why were they suppressing the natural spontaneity of children in the 1970s? Surely, the teachers were at fault -- they, and the school

administrators, and the colleges of education.

In actuality, in few occupations do practitioners strive as diligently as they do in education to respond to the national will. Teachers and school administrators face the public often and intimately. They are not inclined to be fiercely independent. Schools are governed by one's neighbors, people seen almost daily. Those who enter the field of education are no less motivated to figure out the public's preferences than anyone else; usually they are more so.

Furthermore they often succeed in reaching national goals -- but by then the "problem" has changed. By the time the United States was first to place a man on the moon, the public had forgotten that it had blamed the schools for not launching the first space satellite, and it never occurred to anyone to credit the schools with the new success. By the time education in inner cities was improved dramatically, with "minimum competency" scores significantly elevated, the press was attacking schools for the decline in SAT scores, tests for those headed toward college. And one wonders why morale of teachers is so low, why bright young people do not choose to enter the occupation!

Thus, while some of America's inability to meet serious problems in science education is attributable to lack of federal leadership in recent years (including a low level of interest in the National Science Foundation), as noted above, the generally poor policy climate for education in the United States is also a factor. The public has seemed unwilling to concentrate on a problem long enough to make a dent.

In 1988, the country finds itself in a crisis atmosphere about education once again, with alarming data about the poor performance of American students compared with those from elsewhere. A recent NSF-supported study revealed that American students at fifth-grade level ranked 8th among 15 countries in science. At ninth grade, the U. S. was 15th in a field of 17. For advanced, high-school students in biology, the "advanced placement" group, the U. S. was last. Advanced chemistry students were 11th out of 13.** Intensive case studies supported by the NSF ten years ago (that still offer the best available picture of American science classroom-teaching) suggest that most

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** International Association for the Evaluation of Educational Achievement, SCIENCE ACHIEVEMENT IN SEVENTEEN COUNTRIES: A PRELIMINARY REPORT. Oxford: Pergamon Press, 1988.

instruction in science is lack-luster, at best.*** The science lesson too often is a vocabulary exercise, with children reciting back to the teacher what the text says, then memorizing the definitions. In only some classrooms is there first-hand experience, student-conducted experiments, and active investigation of puzzles and problems in the natural world.

But there are some significant differences in the policy climate today that suggest that the destructively rapid shifts in priorities of recent decades may be dampening. Furthermore, there are opportunities for the National Science Foundation to make a big difference in science education that did not exist even a few years ago.

One indication of a changing climate for education is the renewed focus at the state level on issues of educational improvement. Governors and state legislators in the 1960s and 1970s did not highlight education in their policy pronouncements. It was a risky area. The school-age population was declining. Schools were being closed. Nothing but political grief was associated with devoting oneself to education. Freshman state-legislators, asked about the committees on which they would like to serve, chose Environment, Health, Prisons, Welfare -- anything but Education.

Not so today. Governor after governor is staking his or her political future on accomplishments in education. Freshman legislators at the state level see the education committee as a useful step in career advancement. These politicians sense the intense interest of the public in matters of education, as confirmed in every poll taken on the subject during the past decade. When given a choice, voters in significant majorities state that they are willing to have their taxes raised if the funds were to go to education. They are desirous also of seeing funds diverted from military expenditure to education. There is no question about what the public wants.

Judging from the renewed political interest in the subject, it may be the case that the country has the opportunity of moving to a more stable set of policies in education, less subject to the fluctuations characteristic of the 1960s and 1970s. As a subject of policy interest, the field may be advancing to a status that environmental questions seem to have reached. For most of the century, environment, like the field of education, seemed subject to crisis politics. A particularly damaging

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*** Robert Stake and Jack Easley, CASE STUDIES IN SCIENCE EDUCATION. Urbana: University of Illinois Center for Instructional Research and Curriculum Evaluation, 1978.

flood, or a severe drought, or some other partially man-made disaster would rivet public attention on issues like conservation or flood control. Heroic steps would be taken: construction of the TVA, creation of the Civilian Conservation Corps, massive public reforestation projects. But often the spotlight shifted quickly to what seemed to be fresher and more dramatic problems, nuclear safety, for example; it was deemed uninteresting to persist with trying to resolve the "old" difficulties.

Gradually, however, Americans seemed to learn that environmental problems are unrelentingly persistent, as well as extraordinarily complex. They are not subject to a quick fix. In fact, constant attention is required just to stay even. Consideration of environmental concerns seems by the 1980s to have become a regularized feature of the policy scene; it is on the political agenda all the time. Judging from education's new place in state-level planning, this field, too, may be entering a potentially more stable policy period.

A Time for Leadership from the National Science Foundation

If so, there is a special and very new opportunity for the National Science Foundation to capitalize on and provide long-term leadership for the new determination at state and local levels to improve elementary and secondary education. The governors and other state-level authorities need guidance and stimulation to make the sound, substantive changes that should accompany the organizational reforms they are instituting so aggressively.

Especially if the possibility of stability and continuity are emerging in science education, as it seems to be, then NSF is precisely what this field and the Nation need. Not only does NSF command the attention and respect of the country's best researchers (whose contributions are critical if science education is to improve in the United States), it has the capability to view the important issues in appropriate perspective, with regard both to substance and time. The question of what should be taught in the schools will always be a central question; the disciplines change, so does the view of what students need. Teachers will need to be well-educated, always; and what they must learn depends on evolving perspectives within the disciplines themselves. New insights emerge regularly about how youngsters learn; these understandings must be incorporated in school programs as soon as they have been tested and proved effective. State- and local-level authorities do not have the capability to address such issues. The National Science Foundation does.

Questions and problems such as these are never settled once and for all. To meet the challenge of generating up-to-date knowledge that will serve as a foundation for school improvement in science education for the generations to come, a permanent national effort on a suitably large scale is required. And that effort must be guided and sustained wisely as well as indefinitely. No less than science itself, science education must be nurtured continuously and insightfully. Otherwise, the education of America's children is likely to continue to rise and fall in quality with disturbing regularity, but with the overall direction a downward one. Constant attention is required even to stay even in education, as with protection of the environment.

Special Characteristics of NSF Activity in Education

NSF initiatives must be fashioned for maximum leverage upon other resources, both financial and intellectual; NSF itself simply doesn't have the authority or the money to make significant changes on its own. It doesn't select the teachers or the curriculum; it doesn't fund the basic operations of the schools.

These circumstances dictate that NSF's influence in education be more indirect than direct, and that its effectiveness depends more on persuasion than on legislation and regulation. It also means that the visible results of NSF programs on a broad scale are best noted in the long-term rather than the short-term.

This last point may be a difficult one to sustain in a government agency because the public is impatient for change. Yet NSF must resist as best it can the pressure to demonstrate large-scale impact of NSF programs in science education quickly. If problems of obsolete and unchallenging courses, or a shortage of effective teachers, could have been solved easily, they would have been.

Several implications for planning strategies flow from a conviction that NSF's role in education, at the core, is to lead the Nation through demonstration and inspiration. For one, the quality of every activity supported by the Foundation must be unquestionable. The results of NSF efforts initially may seem unattainable for many or inappropriate for some, but they must be recognized as worthy.

For another, each activity, since it is highly visible, must bear the hallmark of NSF; that is, it must be characterized by central involvement by the Nation's most outstanding scientists and engineers. It is true that scientists and engineers must

work closely with many other people (particularly teachers, school administrators, and the producers of educational materials) to effect educational change, and today they are the first to say so, but it is also true that NSF policy and practice from the outset have been to demonstrate that leading scientists have a major, indeed essential, contribution to make to the improvement of science education at pre-collegiate as well as collegiate levels. This fact was affirmed in the SRI Report, and this unique tradition must be maintained. No other federal agency than the NSF -- certainly not the Department of Education -- has the combination of esteem, authority, and influence necessary to engage the scientific community in the immense task of improving science education, or the track record of accomplishment in the nation's schools and colleges.

Science education is weak and must be strengthened on a broad front: curriculum in elementary and secondary schools, teacher education at all levels, instructional materials. However, the climate is right for thinking about fundamental change in American schools, as well as for making some of the absolutely necessary, smaller-scale improvements. For example, a new national Board, supported initially by the Carnegie Corporation of New York, is figuring out how to certify particularly able teachers and give them more pay as well as responsibility. Such thinking is novel and can lead to significant changes in the way we organize schools. Additionally, in virtually every state, new and more-demanding programs are being instituted for entry-level licensure of teachers. (Significantly, both of these initiatives have the support of the teacher unions.) Both graduation and college-entrance requirements are being raised in most places. The changes in evidence today, these and many others, would have been difficult to imagine even five years ago.

At just as deep a level, collaborative, inter-institutional activities to improve science education are springing up all over the country. The business community has come to realize the centrality of a strong educational system in assuring economic prosperity, for themselves and for the nation; many large corporations are providing resources to the schools, in people, equipment, and, sometimes, cash. Schools are strengthening their ties to museums and universities, as well as with the private sector. Major non-profit, philanthropic foundations, like Ford and Carnegie, are providing funds to enable a range of "science-rich" institutions (including the military) to share resources with the public schools to improve science education. The National Science Foundation has a "Partnership" program directed toward the same end.

All these activities must be expanded and sustained. More,

too: improvement of "informal" science education, on television and in youth clubs, for example; and, of course, expanded, exemplary programs of teacher education. The administration budget request for FY1989 takes a very modest step in the direction of stimulating these necessary improvements in science education. However, even to expand current activities to a credible and influential level, in my view, requires an authorization closer to $200 or $225 million than $156 million for FY1989.

Further, there should be a determination and a plan to bring the total of NSF education expenditures to a level of $500 to $600 million within five years. It is difficult to know just what an ideal ratio of research to education expenditures should be in the NSF budget for scientists to the take the Foundation's efforts in this field seriously, but it is not 13 to 1. It is probably unrealistic to hope for 6 to 4, as was the case 30 years ago. A 2 to 1 ratio, however, probably reflects an estimate of what is required to address complex educational problems and begin, once again, to mobilize significant segments of the scientific community.

The public needs, and may also be ready to accept, the idea that to improve science teaching in the schools significantly, and to keep on making progress for years to come, some new organizational structures must be established. To assure continuing attention to persistent and important problems, the traditional practice of attending to important educational issues in fits and starts -- and depending on volunteers and existing groups -- should be modified. A central policy goal during this period of renewed attention to education and high resolve to make changes should be to establish mechanisms for assuring continuing attention to the difficult task of improving science education. Public interest may flag for a time when some new national crisis captures national attention. What can be done today to increase the chances of appropriate attention to science education five and ten years from now?

As a fundamental policy matter in education, it is much more sensible to have a modest and dependable level of support than to have huge sums that are here today but gone tomorrow. In science education, as in many other fields, start-up costs for significant ventures are high. What might be done now, when motivation is high, to dampen the cycles of boom-and-bust funding of science education, in favor of steady and persistent steps to produce the necessary changes? In particular, what can the National Science Foundation do to assure continuing and sustained efforts by scientists to make education stronger -- and, in the process, help prevent the Nation from sliding into second-class status. Of course, improved science education alone cannot

prevent national decline, but without high-quality education in scientific fields national decline surely will occur.

A Specific Suggestion for a New NSF Program: Centers for the Improvement of Science Education

Nothing is more important in education than the decisions that are made about what is taught to teachers and children, the curriculum. If that issue is ignored, then educational reform in the United States inevitably will fall short of its potential. The impressive structural changes that are likely to be made in the educational system in the years immediately ahead will be accompanied by disappointment, and perhaps dismay, if at the same time the country does not attend to the content of education. The National Science Foundation's special responsibility, whatever else it might do, lies in filling that critical gap, in meeting that challenge.

At the same time, problems in science education are so severe that solely a project-by-project approach will fall far short of the mark. Even the targeted solicitations that the Directorate for Science and Engineering Education has issued in recent years, though a welcome step in a desirable direction, are -- by virtue of scale, focus, and duration -- insufficient to meet the critical need for major federal leadership. The projects and solicitations must continue, but they must be augmented by larger and more comprehensive strategies.

Over a period of five years, the National Science Foundation should encourage proposals to establish several major centers for the improvement of education in the sciences, perhaps eight or ten. Whatever happens to the initiative for Science and Technology Centers at the NSF, science-education centers, as a separate set of entities, should be created to devote attention to the teaching of science at all educational levels -- elementary, secondary, and collegiate -- and in all fields. And they should focus on appropriate approaches to science education for all youngsters, not solely for those bound for careers in science, and not solely for those headed for college.

These centers should take responsibility for curriculum development and evaluation, teacher-education improvement, and the research necessary to undergird these activities. They also should create exemplary training activities, stimulate establishment of the networks necessary in the schools and colleges to implement new programs, develop assessment programs for students and schools that reflect modern approaches to the science fields, and generate periodic reviews of the status of their particular areas of responsibility, including comparisons

with other countries. Additionally, the centers should be major sites for educating the people necessary to undertake these tasks in the future.

Organizing Themes

Scientists, both from industry and from universities, must be involved centrally if the programs created for schools and colleges are to contain subject-matter worth teaching, and no other agency than the NSF has the requisite standing to encourage scientists of stature to engage themselves in the difficult task of educational improvement.

The organizing themes for the centers, each funded at a level of about $2 million per year, should be the educational level on which they focus; that is, there should at least two centers for the improvement of elementary-school science, one or two for the improvement of middle-school science, three (possibly more) for the improvement of secondary-school science, and one or two for the improvement of college science education.

One reason for such an organization is the increasing recognition that school programs must be more multi-disciplinary than most of them are at present; an exclusively single-discipline focus in the centers would reinforce conventional organization of science courses to an undesirable degree. On the other hand, it is not envisioned that the current subject-matter distinctions would necessarily disappear. They well may not. It may be desirable to have separate centers for mathematics education. But the present configuration of science course-sequences is too limiting a constraint in a probing and large-scale effort designed fundamentally to reform education in the sciences in the United States.

For example, most observers agree that quantitative thinking should permeate future high-school and elementary-school programs in science. Deep scientific understanding is impeded without adequate understanding of mathematics. Similarly, biology is difficult to comprehend without adequate background in chemistry. Chemistry students need important concepts from physics to comprehend their field. Geology students should know some key concepts in engineering.

Each center should serve as a hub not only for recruiting the necessary critical mass of scientists, but also as a base for the extensive network of key teachers and science supervisors who must carry the primary responsibility for adapting new ideas to at the separate school sites and inspiring other teachers to think about how they can improve their work. Some of these educational leaders would serve at the centers for protracted

periods -- from a week or two to perhaps a year, just as many scientists would, to help in the development of new approaches to the improvement of science teaching.

In short, each center would become not only a headquarters for the generation of ideas, but a place to provide inspiration and leadership in spreading and testing those ideas in the broader educational community.

Partly for the reasons outlined elsewhere in this document, science-education centers, including one for the improvement of undergraduate education, must stand apart from the other centers in science and engineering that may be created by the NSF. Otherwise, the education missions of the centers would have the same marginal status as they have had historically within the separate NSF research directorates. The potential for multi-disciplinary programs would be underexamined. Research and development in education, as contrasted with science and engineering, would take a back seat. There would be a tendency to repeat one of the serious mistakes of the 1950s and 1960s: development of materials almost exclusively for those headed for careers in science.

The precise characteristics of a set of science-education centers, and for each center, would have to be defined in greater detail than has been done here, of course. Some of the suggestions outlined above may be unwise, or impractical. The concept needs considerable elaboration and refinement by the many people who would have a stake in its operations and outcome. But if the suggestion to establish centers for science education is pursued, four major aims should be kept in the forefront:

1. They must assure concentrated and consistent attention to recurring problems like the better preparation of science teachers and the redesign of curriculum for schools and colleges.

2. They must make it easier for the country's outstanding scientists to focus their talents on educational improvement. Most scientists have no desire to change careers, but many are deeply concerned about the quality of science education, and significant numbers are willing to give short periods of time (summers or sabbatical leaves, for example) to curriculum design and the improvement of teacher education. Major justification for the science-education centers concept, in fact, is that it offers an ongoing structure that is congenial for short-term (as well as longer-term) participation by outstanding scholars.

3. They must create activities of the necessary scale to make a difference.

4. They must increase the corps of people qualified to take leadership positions in improving the quality of science education in the Nation's schools and colleges, and create the networks necessary for that group eventually to become self-sustaining.

5. Funding for centers must be in addition to funding for the programs already proposed by the administration for FY1989. The 21 per cent increase (to $156 million) suggested in the administration's FY1988 plan is insufficient even for the excellent programs outlined in the request. The initiatives highlighted in that document need a sum for next year more like $200 to $225 million, and a figure by 1993 more like $500 to $600 million. The centers initiative alone requires a further annual expenditure of about $20 million.

Mr. WALGREN. Thank you very much, Dr. Atkin. We appreciate that, and we'll come back in a little bit here. Let's, then, turn to Dr. Gardner.

Dr. GARDNER. Mr. Chairman, it gives me great pleasure to come before this Committee today to attest to the very real need in this country for a strong federal role in the pre-service and continuing education of science teachers in America.

As Director of the Lawrence Hall of Science, I have the opportunity to work with a unit that is a part of a major university, the University of California at Berkeley, and that is also one of the major science and technology education centers in the Nation. The Chairman of the Lawrence Hall of Science is Glenn T. Seaborg, eminent American chemist and Nobel laureate. And more than 300 dedicated, creative staff members, scientists and educators, work together in the Lawrence Hall to develop exhibits, public programming, school programming, teacher education, instructional materials, and research. The Lawrence Hall is, perhaps, the most comprehensive science education center in America. It's a place where the formal and informal systems of education come naturally together.

First, let me thank this Committee for your role this past year in increasing the budget for science and engineering education in the National Science Foundation from $99 to $139 million, a 40.7-percent increase. This help was desperately needed. It provided hope for teachers in the field and for all of us working in science education across the nation.

Next year, the budget is proposed at $156 million, a 12.1-percent increase. But that's not enough. I'd like to echo what Congressman Green and Dr. Atkin have said, to state that we need another 40-percent increase, at least. And that would take the budget to approximately $200 million, with at least $130 million of that budget dedicated to pre-college education.

As has been pointed out, the budget for science education in NSF was once between 30 and 45 percent. And then, in the 1970's, it began to decline. In the new budget that is proposed for fiscal year 1989, the overall increase for NSF is 19 percent. It's 20 percent for research, and it's only 12 percent for science education. That just simply is not enough help.

I echo also the suggestion that by 1993, 5 years from now, the science education budget should be $500 to $600 million to bring it in better balance with the research budget.

Today, I want to focus on teacher education. There is a severe shortage of adequately prepared science teachers in the nation. The pool of qualified science teachers is just far too small. We are failing to attract enough new teachers and, equally important, we are failing to inspire, educate, and keep current those teachers we do have.

We are also falling behind many other nations, as I'll note a little later. Recent research has shown that nearly all 77,000 U.S. science teachers teach out of their major field of preparation, many in three or four subjects for which they fail to meet the minimum requirements recommended by the National Science Teachers Association.

Congressman Green pointed out the effect: Our low status in the Olympiad programs—our poor performance, being in the bottom

half of 17 nations internationally that were measured for student performance in general science, biology, chemistry, and physics.

Preliminary results of a nationwide survey by the Council of State Science Supervisors is currently underway, and 24 of 25 States are reporting science teacher shortages. Physics teachers are in the shortest supply, followed by chemistry and mathematics. The need for substantial and immediately available assistance for in-service and pre-service education is therefore enormous.

I'd like to spend a minute or two on contrasts between the United States and some other countries. In the United States, only about 50 percent, 57 percent to be exact, of high school teachers are enrolled in science courses in any given year. Less than 80 percent of American students finish their secondary education. Nearly all science teachers teach out of their field of preparation, and 68 percent of the science teachers have primary teaching responsibilities out of their major field.

In contrast, in the U.S.S.R. and Eastern Europe, approximately 96 percent of students complete the pre-college program, and all of these students study science and mathematics every year through the entire secondary program. All of the teachers in these nations complete 5 years of pre-service education, and they return for the equivalent of 1 year of in-service education every 5 years.

In the United Kingdom, Western Europe, and Australia, students study biology, chemistry, physics, and mathematics concurrently during their last 3 years of secondary school. Teachers earn full science degrees, and then they prepare to teach.

In Japan, 92 percent of the students complete pre-college education. And there, too, they have a much more rigorous program of science. Japanese teachers complete a science degree, and they are paid salaries that are very nearly equivalent to that of the university professor in Japan.

Now, American teachers really want to learn. There's much evidence of that, waiting lists for any teacher courses that are available in science for the Institutes. The majority of science teachers, in fact, have earned master's degrees. This is very impressive. But these degrees are predominantly in fields of education, not in science.

This is by necessity, not by the teachers' choice. Science courses simply are not available at times when teachers can enroll, except through the NSF-funded programs. That is one of the finest achievements of the Foundation, opening opportunities through the Institutes for teachers to take science courses taught in science departments by science faculties.

As a result of the teacher shortages at the secondary level, more and more teachers are being asked to cross over from disciplines where they have a sense of confidence into one where they have little preparation. For example, a person properly credentialed in biology may very well be asked to teach physics or chemistry, with only one course in the field.

At the elementary school level, teachers rarely have had more than a single course in science. All of these teachers need help. It's a nationwide problem, and the leadership must come from the federal level. The National Science Foundation, by providing funding for pre-service and in-service teachers and for teacher networks, is

providing that all-important pump-priming role that starts the system, sets the models, and encourages others at the State and local level to become involved.

One very important new emerging area is the science and technology centers across the nation. The Association of Science and Technology Centers, ASTC, recently conducted an NSF-funded survey of its members. Of the 110 centers that responded, all of them reported that they were doing at least some beginning work in teacher education.

The Lawrence Hall is a member of ASTC, so our programs are included in these statistics. This year we are directly working with more than 12,000 teachers. The models we are working with are successful, largely because of the follow-up commitment these teachers have.

Teachers who enroll in our courses learn; they return to their individual schools rejuvenated; they serve as mentors to others in their system. And in this way their activities expand in a geometric progression that involves their students, their colleagues, administrators, and ultimately the entire community.

I'd like to be able to talk about the wide range of programs that are necessary, but there isn't time except to quickly mention three.

One is family math. That is a program where parents are brought into partnership with their children through activities that can be done in the home in the evening and that are keyed to the school curriculum.

Another is ICE, the Institute for Chemical Education, which is a program for chemistry teachers, chemists in partnership with educators, to strengthen the preparation of teachers and to promote networking and continuous innovation.

And the third one is IISME, the Industrial Initiatives for Science and Mathematics Education, where teachers are placed in industry for 8 weeks in the summer and then helped to translate what they learn into the classroom.

On the technology side, on the drawing boards is a new program, ChemSource, which will help pre-service and inexperienced crossover teachers to have access to computerized data bases, computer-assisted lesson planning, and exemplars on videotapes.

These programs all have partial NSF support. They're the kind of programs NSF should put in place throughout the United States. There's much more to say about these programs, but I've given data in the paper that I'm leaving with the Committee.

NSF is the lead agency in making science in education possible. Because of your actions and because of your recommended funding, those of us in the field are enabled to plan ways to reach teachers and to give them the assistance they must have. The teacher is the multiplier effect. Each teacher influences thousands of students in his or her career.

Funding to upgrade their knowledge, skills, and self-confidence is money well spent. It will have a major impact on increasing our scientific and technological work force, and on scientific literacy in the nation.

In this nation we need these creative, competitive, compassionate teachers that can teach with enthusiasm. As Donald Kennedy,

President of Stanford University, said at a scholarship luncheon I attended last Tuesday:

> This nation and the world ache for solutions to science-based problems: AIDS, the global environment, and progress in space. And only a strong science education program and system offers hope of solutions and fulfillment of the U.S. leadership role.

I'd like to conclude by just reminding us all again that there is an urgent need to raise the NSF budget to at least $130 million for pre-college to at least $200 million for science and engineering education. If that happens, then the formal and informal education systems of America can work separately and together to improve the preparation of our science and mathematics teachers to the level that's common in many other countries and that is far more satisfying to us.

My thanks for inviting me here today.

[The prepared statement of Dr. Gardner follows:]

Teacher Enhancement Programs
Directorate for Science, Engineering and Education
National Science Foundation

Statement of:

Marjorie H. Gardner, Director
Lawrence Hall of Science
University of California
Berkeley, California

Before the:
Sub-committee on Science, Research and Technology
Doug Walgren, Chair

Committee on Science, Space and Technology
United States House of Representatives

March 22, 1988

Testimony before the Subcommittee
on Science, Research and Technology
U.S. House of Representatives

March 22, 1988

Honorable Chairman, Members of the Committee, Ladies and Gentlemen,

It gives me great pleasure to come before this committee to attest to the very real need in this country for a strong federal role in the pre-service and continuing education of teachers in science, mathematics and technology.

I am Marjorie Gardner, Director of the Lawrence Hall of Science , a unit of the University of California at Berkeley, that is dedicated to pre-college and public science education. The Chairman of the Hall is Glenn T. Seaborg, eminent American chemist and Nobel Laureate who formerly served this nation as Chairman of the Atomic Energy Commission. More than 300 dedicated, creative staff members (under-graduates, graduates, post doctorates, teachers and a full time core of professionals and support staff) work in the Hall where we combine exhibits, public programming, after-school classes at the Hall, outreach programs delivered to the schools, teacher education, curriculum development, and research. The Lawrence Hall of Science is, perhaps, the most comprehensive science education

center in America , a place where the formal and informal systems of education come naturally together.

First, let me thank this Committee for your role in increasing the budget for science and engineering education in the National Science Foundation last year from $99 million to $139 milion, a 40.7% increase! This help was desperately needed; it provided hope for teachers in the field and all those working in science education across the nation. Next year, the budget is proposed at $156 million, a 12.1% increase, but that is not enough. **Another substantial increase to raise the authorization to between $175 and $200 million (a 25 - 44% increase) is needed.** At the pre-college level alone, an increase to $130 million is needed to fulfill NSF's leadership role and to reach enough of the teachers who need your help to have significant impact.

Let me remind us that the budget for science and engineering education when NSF was very young in the late 1950's and early 1960's was nearly 50% of the total NSF budget. Now it is a very small percentage of the whole, only 8%, but rising due to your good effort. For a decade, from 1960-1970, the science education budget was in the range of 30-45% of the total NSF budget. Then the decline began. In the newly proposed budget for FY '89, the overall increase for NSF is 19%; a 20% increase is projected for research but only a 12% increase for science education. That must not be so. If we really care about improving science education in this nation, we must do

better. Again, I urge that the science education budget be increased to 200 million dollars for FY '89. By FY '93, five years from now, it should be between 500 and 600 million dollars to bring science and engineering education back into better balance with research.

Today, I will focus on teacher education. A severe shortage of fully prepared science teachers exists in the nation. The crisis in science education is profound. Recent studies provide data and document what we educators have known for years: the pool of qualified science teachers is far too small. **We are failing to attract enough new teachers, and equally important, we are failing to inspire, educate, and keep current those teachers we do have.**

The average age of high school chemistry and physics teachers in 1986 was near 50 years. This means that many of the current classroom teachers are nearing retirement. At the other end of the pipeline, any institution that can boast one or two physics or chemistry education majors per year is unusual. Therefore, the large majority of new chemistry teachers will be "crossovers" from other disciplines for the foreseeable future. Recent research has shown that nearly all 77,000 U.S. high school science teachers teach out of field, many in three or four subjects for which they fail to meet the minimum requirements recommended by the National Science Teachers Association. Increased science requirements for high school graduation in many states have exacerbated the problem to the point where high school principals have great difficulty in

filling positions for chemistry and physics teachers with persons who are even minimally qualified. As a result, class size is steadily growing and in some instances has reached 60 students per class. This has the effect of lengthening lecture time, and cutting down on participatory discussion and laboratory time where the most important science learning takes place.

A recent report by the International Association for the Evaluation of Education Achievement indicates that American pupils consistently scored in the bottom half in general science, biology, chemistry and physics when compared to high school students from 17 other countries. **The need for substantial and immediately available assistance for in-service and pre-service teachers is enormous.**

Preliminary results from a nationwide survey by the Council of State Science Supervisors (CS^3), currently underway, indicates that science teacher shortages exist in 24 of the 25 states reporting so far. Physics teachers are in the shortest supply, followed by chemistry and mathematics. The shortages seem to be keenest in the larger, industrial states. There are many broadly based sociological reasons, but an important one among them is the fact that in urban centers, teachers who are qualified to teach physics, chemistry, and mathematics, are not given the status in pay, nor access to continuing education, to make the classroom environment attractive and one in which they can continue to grow professionally. So they

leave for higher paying/higher status jobs in business, industry, or school administration.

Here are some further data, to illustrate what American students are offered, and what is expected of their teachers, in comparison with other major countries of the world:

In the **United States**, only 57% of high school students are enrolled in science courses in any given year; less than 80% of American students complete secondary school; 68% of high school science teachers have major teaching assignments outside of their major field of study.

In the **USSR and Eastern Europe**, approximately 96% of students complete the pre-college program and all students study science and mathematics each year (mathematics for ten years, physics for five years, and chemistry and biology for four years). All teachers complete five years of pre-service education and return for the equivalent of one year of inservice education every five years.

In the **United Kingdom, Western Europe and Australia**, students study biology, chemistry, physics and mathematics concurrently during the last three years of secondary school. Teachers earn full science degrees; then prepare to teach.

In **Japan**, 92% of students complete pre-college education. At the upper secondary level, all students take a minium of 2 years of

science and 2 years of mathematics. College bound students take mathematics every year (through beginning calculus), plus physics, chemistry, biology and earth science, often concurrently. Japanese teachers complete science degrees and are paid salaries very nearly equivalent to those of college professors.

In **China**, the world's largest school system, there is a new national unified science curriculum and new textbooks. All students are required to take physics, chemistry and biology in middle schools.

In **Thailand**, a developing country, science and mathematics are taught every year from 1st through 12th grade. All high schools -- academic, vocational, commercial and fine arts -- teach science through twelfth grade. All science courses are laboratory-based.

In most other countries, especially those of Eastern and Western Europe and Japan, but not excluding the third world countries, teachers are on 12-month contracts and are paid 12-month salaries. It is then possible for them to obtain additional upgrading and updating of their science knowledge and skills every year. Teachers salaries and the special costs for in-service education are largely paid by their federal governments, through Ministries of Education or Science and Technology. That is not true in the United States. Here teachers are on 9-10 month contracts and need to work in the summer to help support their families, or, if they are in school, they need the financial assistance of some agency such as the National Science Foundation.

Teachers in most other countries worldwide complete a 4-year bachelor's degree in a science and mathematics discipline before they enter the professional sequence that prepares them for teaching. While there is a trend in this direction here in the U.S., stimulated by the recent Carnegie and Holmes reports, the large majority of our science teachers do not complete full science majors. They meet the lower state certification requirements in science; often the professional courses are integrated into a 4-year program.

American teachers want to learn. The majority of science teachers have earned Master's degrees. But these degrees are predominantly in fields of education, not science. That is by necessity, not by teacher choice. Science courses simply are not available at times when teachers can enroll except through NSF-funded programs. **That is one of the finest achievements of the Foundation. Opening opportunity for teachers to take science courses taught in science departments by science faculty.**

Let me provide you with some further figures to think about in this respect. In 1986 there were 7,100 high schools that did not teach a single physics course because they did not have a qualified teacher. About 3,600 schools did not have a chemistry course; and surprisingly 1,800 schools did not provide biology for their students. n 1986 also, 66% of the elementary and middle school teachers had

never taken a course in chemistry; 80% of these teachers had never taken a course in physics; 15% had never taken a course in biology.

As a result of teacher shortages at the secondary levels, more and more teachers are being assigned to cross over from a discipline where they have some confidence into one where they have little preparation. For example, if a person is properly credentialed in biology, they may very well be assigned to teach in chemistry and physics also, having taken no more than a single course in these fields. At the elementary school level, teachers rarely have had more than a single science course. All of these teachers need help. They cannot rely on the local or the state levels. The problem is nationwide in scope and the leadership must come from the federal level. **The National Science Foundation, by providing monies for pre-service and in-service teacher education and for the teacher networks that are now developing is playing that all-important pump priming role that starts the system and encourages others at the state and local levels and in the private sector to become involved.**

A wide variety of teacher education programs is necessary to meet the needs in American today. This must occur at elementary, middle and high school levels and in a variety of formats. Some must be focused on single disciplines, some must be inter-disciplinary. They must range in time and funding committment from several day, to summer, to academic years. They must involve both the formal and informal system of education.

One very important new area of teacher education is emerging in science and technology centers around the country. The Association of Science and Technology Centers (ASTC) recently conducted an NSF funded survey of its member centers. Of the 110 who responded, all reported having teacher programs: all together they served 65,000 teachers. 88% of these centers reported planning their educational programs jointly with schools in their area, thus having their programs respond clearly to defined needs. More than half the responding science centers have educational advisory committees, further evidence of cooperative service to and with the public.

The Lawrence Hall of Science is a member of ASTC so our programs are included in these statistics. The Lawrence Hall of Science has recognized that one of the major tasks in expansion of science education in the US is to enhance, broaden, and nurture the supply of science and mathematics teachers. Teacher preparation programs are in the forefront of activity at Lawrence Hall of Science. Our offerings are consistently filled, with long waiting lists.

The models with the most success involve follow-up commitment on the part of the teacher, and this is true whether the workshop be one day, multiple days, a summer or year-long institutes. Teachers who enroll have a strong desire to learn - to be challenged, and to grow to the point where they feel they have something of timely, current interest to share with their students. Teachers then return to their individual schools, and serve as mentors or outreach teachers to

others in their system. In this way, their activities at LHS expand in a geometric progression, involving their colleagues, administrators, students and ultimately the community.

To give you a sense of the range of needs, successful teacher education activities at the Hall include **SIRC** (Science Instruction for Rural Communities), which recognizes the need for continuing education in the less populated rural communities in California; **EQUALS** and **Family Math** which focus on techniques to inspire under-represented women and minority students in mathematics; **FOSS,** (Full Option Science System) which prepares teachers to use sensory-based curriculum materials that reach physically handicapped and learning disabled students as well as the usual elementary school student;. **MESA** (Math, Engineering, Science Achievement) which assists teachers in preparing minority students for college careers in the math-based sciences and engineering; **Mills Mid-Career Program** which brings experienced scientists and engineers from industry into teaching; **S4ST** (Science for Science Teachers), for junior high school teachers; and **MSTI** (Math/Science Technology Institute) which helps teachers make optimum use of technology (computers and video) in science and mathematics

I'd like to particularly note three LHS programs that have great potential for impact across the nation as well as at local levels. They are: **ICE** (Institute for Chemical Education), a program for chemistry teachers involving prestigious univiersities and their

scientists in partnership with educators to strengthen teacher preparation and to promote networking and continuous innovation; **IISME** (Indusry Initiatives for Science and Mathematics Education) an industry/edcation partnership that places teachers in industrial laboratories for eight weeks is bringing significant results; and a new pre-service program. on the drawing boards, **ChemSource**, which will provide pre-service and inexperienced classroom teachers with access to computerized databases, computer-assisted lesson planning and examplars on videotape. These programs all have partial NSF support at least. They are the kind of programs NSF should help to put in place in many parts of the United States. More information on these programs, and references for the earlier data on the status of science teaching at home and abroad are in the paper I will leave with the Committee.

It is clear that the mix of formal and informal education which is basic to all teacher workshops at LHS is what makes them so highly successful. Teachers attend such programs because of their desire to broaden their knowledge and skill. The very event of participation adds validity to their careers in the classroom. What they gain then, in an informal setting with their colleagues and peers, yet within a structure which makes the most of the research and resources of formal education, is not only content, but the inspiration to take that new content back into the classroom.

Good in-service education programs take advantage of the care and concern which teachers already have for their work, and add

technique, content, inspiration, direction, and excitement - those aspects of science and mathematics which they probably enjoyed in their original studies and which drew them to science education in the first place.

NSF is the lead agency in making science and engineering education possible. Because of your actions and recommended funding, those of us in the field are enabled to plan ways to reach the teachers and give them the assistance that they must have in order to teach effectively. The teacher is the multiplier factor. Each teacher influences thousands of students of his or her career. Funding to upgrade the knowledge, skills and self-confidence of teachers is money well spent; it will have major impact on increasing our scientific and technological work force and on scientific literacy in our nation.

In this nation, we urgently need more competent, creative, compassionate teachers who are self confident enough to teach with enthusiasm and to motivate all of their students to a level of scientific literacy that is acceptable to us as a leader nation in the world. As Donald Kennedy, President of Stanford University, said at a scholarship luncheon in San Francisco last week, "This nation and the world aches for solutions to science-based problems (AIDS, global environmental issues such as acid rain, CO_2 and global warming, the ozone layer, progress in space) and only a strong

science education system offers hope of solutions and fulfillment of a U.S. leadership role".

May I remind all of us again that there is an urgent need to raise the NSF pre-college budget to 130 million dollars and Science and Engineering Education overall to near 200 million dollars in FY '89, to address this need. Then the formal and informal education systems of America can work separately and together to raise the preparation of our science and mathematics teachers to the level that is common in other countries around the world.

I will close with a short quotation from the Association of Mexican American Educators in Fresno, California as they attempted to define their role. It struck me as clear and important:

"To show, to guide, to reach,
The satisfaction to say, I teach.

My thanks for inviting me to present this information before the Committee.

Appendix

Representative Teacher Training Programs at the Lawrence Hall of Science

Four Lawrence Hall of Science programs are particularly worthy of expanded mention as models. Each program is in its 2nd or 3rd year of existence, and the body of teachers who have benefitted is growing and affecting science teaching in many schools and districts around the country. Reunions of participants are becoming common occurences at national and regional science conventions. Clearly, summer enhancement encourages teachers to venture out from their own schools and to be leaders in the science teaching profession at lartge.

ICE (Institute for Chemical Education), involves summer workshops held simultaneously on the campuses of the Universities of Wisconsin at Madison, California at Berkeley, Arizona, Northern Colorado, and Maryland. Typical programs include: Chemistry Fundamentals, Laboratory Leadership Workshop, and Chemical Instrumentation Update. All are focused on providing opportunities for high school teachers to refresh and update their background knowledge of chemistry, and to add to their repertoire of practical classroom activities and techniques. Fees, expenses, and stipends are paid by participating teachers. The project is funded by NSF.

IISME (Industry Initiatives for Science and Math Education) was initiated in 1985 by a consortium of fourteen Bay Area corporations. It has grown substantially over the past three years. IISME is unique in it focus, as it seeks to improve the quality of science and mathematics education in our schools by enriching the practical knowledge and experience of teachers in those classrooms. Teachers are offered summer work in a variety of industrial settings. Science teachers are paired with mentors in industry, who provide them with meaningful work assignments for the summer and continued support through the school year. The Lawrence hall of Science augments these experiences with evaluation and activities which encourage innovative interpretations and translations of the summer experience into the classroom.

The Math/Science Technology Institute **(MSTI)** was a major state of California project, sponsored by the State Department of Education. A four week in-residence, the Institute taught 200 teachers and district coordinators each summer to make effective use of technology in their subject areas. The program also taught skills to enable the participants to return to their districts and act as mentors to their colleagues. District administrators for each participant were expected to provide 3 days of release time for follow-up training through the school year.

S4ST (Science for Science Teachers) focuses on junior high school science teachers. It is a four week in-residence program on the University of California campus, which offers lectures, workshops,

and computer labs in various departments within the UC Berkeley scientific community. Teachers are given a stipend, room and board, four units of university credit, and the opportunity to update their skills, use classroom projects specifically designed to motivate and excite junior high school students, and to increase their scientific awareness. This project receives NSF funding.

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"Teacher Supply and Demand in California: Is the Reserve Pool a Realistic Source of Supply", Policy Paper No., PP86-8-4, Policy Analysis for California Education, August 1986.

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"Opportunities for Strategic Investment in K-12 Science Education; Options for the National Science Foundation", SRI International, May 1987.

Mandated by Congress, this is a study of programs, options, and recommended initiatives and budgetary levels.

Mr. WALGREN. Thank you very much, Dr. Gardner. We appreciate it. And now we'll turn to Ms. Tyson-Bernstein.

Ms. TYSON-BERNSTEIN. Thank you. I, too, am very grateful to be asked to come here today.

I want to correct for the record, though, I am not a textbook writer. I write about textbooks. I don't write them.

The history of Federal attempts to improve science education is a short and troubled history, and I'd like to recapitulate that history briefly. The effort in the 1960's and 1970's has now been encoded in many people's minds into what I would consider to be a durable myth, which goes something like this:

In the bad old days, the Government hired top scientists to produce excellent science materials. But, because the scientists hadn't darkened the doorways of public school classrooms since they were children, they didn't understand the realities of the classrooms; their materials were too complex; the materials were rejected; and they survived only in affluent school districts or advanced placement classes.

The conventional wisdom about these 1960's and 1970's programs is that they were either a failure or a modest success. And, to make matters worse, the publishers lost their shirts, and were mad at the Federal Government.

Now, this is the myth that I hear articulated by many people who are students of history. I certainly disagree with the majority of the points in that myth.

In the meanwhile, though, the furor over what many saw as federal meddling in curriculum brought NSF programs to a halt in the late 1970's and early 1980's.

Now in the late 1980's, there has been a sea change in federal thinking on this issue and a welcome one. And although there is no Sputnik now to stimulate us, there is Japan; and, behind Japan, there is Formosa, South Korea, Singapore, and who knows what next.

Now an economic rather than a military crisis has reactivated the federal attempts to assure an adequate supply of trained scientists and engineers. In my view, the Federal Government today has used the real and presumed errors of the past as a launching pad for a new set of mistakes.

Let me briefly summarize the program that the National Science Foundation is now in the process of launching with respect to the development of educational materials. The new approach proceeds on the theory that incremental improvements are more likely to be accepted in the textbook market than dramatic improvements. Instead, then, of letting these lofty scientists develop materials, the NSF has awarded grants to curriculum development firms. Thus far, the National Science Foundation has given $2 million grants to each of three curriculum development firms to develop hands-on science materials for elementary students.

These curriculum development firms are expected to work closely with teachers, scholars, and publishers. The involvement of teachers is thought to ensure the practicability of the materials, and the involvement of publishers is thought to ensure their saleability. This approach in the NSF literature is called "a real-world perspective."

According to the plan thus far, the Federal Government is outside the loop as soon as the grant has been made. The grantee is free to negotiate a contract with the publisher of its choice. The delicate power balance between the grantee and the publisher is left to the two parties involved, and there is no specific auditing procedure. The publishers are expected to put up an equivalent amount of money, $2 million, in the development cost and to set aside a portion of their profits in a trust to support teacher training during the life of the commercial product.

The original plan, as I understood it, called for a round of elementary school projects followed by a round of junior high projects and subsequently senior high projects. But according to my conversations with a number of informed sources, the NSF officials have been dissatisfied with the fact that the first three grantees were small textbook publishers rather than mainstream publishers. Perhaps for that reason, the elementary cycle is now being repeated, and a new round of grants is soon to be announced.

I don't know who has received these grants, but I think the committee should keep close watch on the process. If the second round of elementary materials grants benefits only the industry giants who already have a substantial competitive advantage over their smaller rivals, the Federal Government could fairly be accused of stifling healthy competition.

Now let's take a look at the programs and the assumptions behind them. First, there is the assumption that the old NSF programs were rejected because they were too complex for students and too hard for children. There is some truth to this explanation, but I submit that these laboratory kits that have been the object of much criticism were not the primary reason for the limited acceptance of the old NSF programs.

For one thing, the programs steadily gained in popularity, as long as the Federal Government subsidized the in-service training programs. When the funds for that purpose were cut off, the use of those materials began to decline. Also the NSF suffered from the furor over the ill-fated MACOS program, an episode so bitter that all Federal curriculum initiatives were tarred for awhile. Moreover, the rise of the creationist movement made the NSF materials a political liability in many communities because they were discipline- based, and they gave a full treatment to evolutionary biology.

It is worth noting that now that the creationist movement seems to be waning somewhat, the NSF materials are now making a spontaneous comeback without any encouragement from the Federal Government and without any promotional activity from the publishers.

Despite clear evidence that the NSF materials were not widely used, I don't believe that the numbers tell the story of their value and influence. These materials continue to influence teaching even in classrooms where teachers use less demanding materials. Also they have influenced and continue to influence teacher training.

Another assumption is that the old program failed because it was too hard for students. My own analysis of these books from the 1960's and 1970's as compared to modern commercial materials is that these books were much easier to read and understand than

today's commercially developed textbooks and materials, mainly because they are vastly more interesting. The scholars who wrote them had something to say, and they said it beautifully and clearly. They presented the underlying principles and concepts that made the facts meaningful, and they treated topics in sufficient depth, so that students could understand them.

As a personal note, I can understand the SCS Green. I find that today's biology textbooks are gibberish. I can't understand them at all. If I can't understand them, I presume that the students can't understand them.

Thus I believe that the design of the present program is based on a partial misreading of and an overreaction to the perceived flaws of the previous effort.

Another fundamental assumption behind the present program is that publisher involvement in the development of the materials will assure what they call "a real-world perspective." But the real world I know about and the one I have been studying for the past five years suggests the following:

First, the 22 States who purchase textbooks in a centralized adoption process have created an impenetrable regulatory wall. The combined effect of these State regulations is to make science textbooks today more dense, abstract, and poorly written than ever before; and, they are unbelievably boring. In order to sell books in these profitable markets, publishers strictly adhere to and even exaggerate the counterproductive features required by adoption authorities.

It is abundantly clear to me that $2 million is not enough money to induce a publisher to produce books that fail to satisfy these detailed and often mutually contradictory requirements of the adoption States. In the present malignant regulatory environment, publishers are virtually compelled to produce prose that is compressed to the point of incomprehensibility, to avoid topics that might arouse protest, and to stick to formats that have little to do with motivating students.

Second, once a publisher has satisfied these State requirements and gotten his book on the official State list, he must then sell the book to the teachers who are the ultimate customer of this enterprise, not students. At the moment, it is clear that the teachers have little time to examine the books they buy, and therefore tend to select books on the basis of flashy graphics, personal convenience, and most of all familiarity.

New textbooks with even modest changes are apt to be rejected. I want to emphasize this point. Publishers are so obedient to this market demand for familiarity that they will even repeat known factual errors from edition to edition, because their customers often prefer familiar errors to unfamiliar truths.

Given the recent history of publisher behavior, it is unrealistic in my view to expect publishers to submit to very many of the incremental improvements that the new NSF program aims at. There is general agreement that teachers need in-service training; but, again in the real world I know, publishers have increasingly used in-service training as a marketing device. A big company with a large consultant staff can outsell a smaller company by offering allegedly free training; and, often education officials are happy to

accept the offer, even when they understand that it really isn't free, because the true cost of the in-service budget, which is always a vulnerable budget in school districts, is hidden in the textbook account.

After the books are adopted, publishers then use in-service training to bind teachers to their particular products, thus ensuring future sales. In short, publisher-conducted teacher training is no longer a disinterested matter, even if it is sometimes quite good.

The current NSF program gives substantial control over in-service training to publishers, but they are obligated to perform the training only if their materials are commercially successful. With some creative bookkeeping, it would be possible for publishers to report small profits and thus reduce their obligation to the teacher training effort.

I truly hope that the present NSF approach will summon materials that help teachers manage stimulating, hands-on programs for students and give children worthwhile materials to read. And I am sure that the developers intend to do that. But given the constraints imposed on publishers, the highly competitive nature of this industry, and the downward pull of market demands, I believe that publishers will not in the end make enough improvements to justify this effort. Their business is not to take risks but to make a profit.

A measured response to the flaws in the old NSF program would have been to make laboratory experiments more manageable, to update content, to incorporate new research on concept teaching in science, to employ new technologies, and to renew the Federal teacher training effort around the materials. The Federal Government's role should not be to subsidize timid publishers but to take the risks that the private sector cannot and will not take.

Given the overriding national interest in science education, the Federal Government should organize and support curricular improvements that are beyond the capacity of the States and localities. The National Science Foundation should set a standard for excellence and then patiently nurture its acceptance.

Thank you.

[The prepared statement of Ms. Tyson-Bernstein follows:]

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TESTIMONY OF HARRIET TYSON-BERNSTEIN
BEFORE THE HOUSE COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY

March 22, 1988

Members of the Committee and Staff:

The history of federal attempts to improve science education is a short and troubled history. To recapitulate that short history, the educational crisis produced by Sputnik stimulated an initial Federal effort to improve science textbooks. That effort has now been encoded into a durable m.th, which goes something like this: In the bad old days, the government hired top scientists to produce excellent science books and kits. Because the scientists hadn't darkened the doorways of public school classrooms since they were in kneepants, they didn't understand the realities of the classroom. Their materials were too complex for teachers to manage and too difficult for students to read, and soon the materials were widely rejected. These materials have survived only in affluent school districts or advanced placement classes.

The conventional wisdom about these 60s and 70s programs is that these programs were either a failure or a very modest success. And to make matters worse, the publishers lost their shirts and were mad at the Federal government. Is all of this true? Or only some of it? I'll return to that later.

In the meanwhile, though, the furor over what many saw as

Federal meddling in curriculum brough NSF programs to a halt in the early 1980's.

But now, in the late 1980's, there has been a sea change in Federal thinking on this issue. Although there is no Sputnik, there is Japan, and behind Japan is Formosa, South Korea, Singapore, and who knows what's next. Now, an economic rather than military crisis has reactivated the federal government's attempts to ensure an adequate supply of trained scientist and engineers. In my view, the federal government has used the real and presumed errors of the past as a launching pad for an brand new set of mistakes.

Let me briefly summarize the program that the National Science Foundation is now in the process of launching.

The new approach proceeds on the theory that incremental improvements are more likely to be accepted by the market than dramatic improvements. Thus instead of letting "lofty" scientists develop the materials, the NSF will award grants to science educators and curriculum developers. Thus far, NSF has given $2 million grants to each of three curriculum development firms to develop "hands on" science materials for elementary students.

The curriculum development firms are expected to work closely with scholars, teachers, and publishers. The involvement of teachers is thought to ensure the practicability of the materials, and the involvement of publishers is thought to ensure their salability. This approach, in the NSF] ture, is

called a "real world" perspective.

According to the plan thus far, the Federal government is out of the loop as soon as the grant has been made. The grantee is free to negotiate a contracts with the publisher of its choice. The delicate balance of power between the grantee and the publisher is left to the two parties involved, and there is no specified auditing procedure.

The publishers are expected to put up an equivalent amount of money--$2 million--toward the development costs, and to set aside a portion of their profits in a trust to support teacher training during the life of the product.

The original plan, as I understand it, called for a round of elementary school projects, to be followed by junior high school projects, and subseuqently, senior high school projects.

According to my conversations with several informed sources, NSF officials were dissatisfied with the fact that the first three grantees selected small textbook publishers rather than mainstream publishers. Perhaps for that reason, the elementary cycle is now being repeated. A new round of grants is soon to be announced. I don't know who has received these grants, but I think this committee should keep close watch on the process. If this second round of elementary materials grants benefit only the industry giants, who already have a substantial competitive advantage over their smaller rivals, the Federal government could fairly be accused to stifling healthy competition.

Lets take a look at these program elements and the assumptions behind them.

The new program is based on the notion that it is better government policy to stimulate market acceptance for small changes than to risk market rejection of highly innovative programs. This sounds very reasonable, but it rests on some assumptions that I think are faulty.

First, there is the assumption that the old NSF programs were rejected because the laboratory experiments were too complex and unwieldy for the average teacher. There is truth in this explanation, but I submit that these overly complex lab kits were not the primary reason for the limited acceptance of those programs.

For one thing, these programs steadily gained popularity as long as the Federal government subsidized in-service training programs. When funds for that purpose were cut off, the use of these materials began to decline.

Also, the NSF science materials suffered from the furor over the ill-fated MACOS program, an episode so bitter and political that all Federal curriculum initiatives were tarred. Moreover, the rise of creationism made the NSF materials a political liability in many communities because those materials presented the disciplines as they were defined by scientists, and that included a full treatment of evolutionary biology.

It is worth noting that these NSF materials are now making a comeback without encouragement from the Federal government

and without any promotional activity from the publishers.

Despite clear evidence that the NSF materials are not widely used, I don't believe that numbers tell the whole story. These materials continue to influence teaching even in classrooms where teachers use less demanding materials. They influenced, and continue to influence, teacher training.

Another assumption is that the old programs failed because they were too hard for students to read. My own analysis of those books--especially in the light of modern research about the characteristics of good instructional writing--is that they are easier to read and understand than today's commercially developed textbooks, mainly because they are vastly more interesting. The scholars who wrote them had something to say and said it beautifully and clearly. They presented the underlying principles and concepts that made the facts meaningful and treated topics in sufficient depth for students to understand them.

Thus I believe that the design of the present program is based on a partial misreading of, and an overreaction to, the previous program.

Another fundamental assumption behind the present program is that publisher involvement in the development of the materials will ensure what the publishers call a "real world" perspective. The real world I know about, the one I have been studying for the past five or six years, suggests the following.

First, the twenty two states that purchase textbooks through

a centralized adoption process have created an impenetrable regulatory aparatus. The combined effect of these state regulations is to make today's science textbooks dense, abstract, poorly written, and unbelievably boring. In order to sell books in these profitable markets, publishers strictly adhere to, and even exaggerate, the counter-productive features required by adoption authorities. It is abundantly clear to me that $2 million is not enough money to to induce a publisher to produce books that fail to satisfy the increasingly detailed (and often mutually contradictory) requirements of the adoption states. In the present malignant environment, publishers are compelled to produce prose that is compressed to the point of incomprehensibility, to avoid topics that might arouse protest, and to stick to formats that have little to do with motivating students.

Second, once a publisher has satisfied these state requirement and gotten his book on an official state textbook list, he then must then sell his book to the teachers who ultimately choose one book over another. At the moment, it is clear that teachers have little time to examine the books they buy, and therfore tend to select books on the basis of flashy graphics, personal convenience, or familarity.

New textbook with even modest changes are apt to be rejected. Publishers are so obedient to this market demand for familiarity that they even repeat known factual errors from edition to edition because teachers often prefer fam[illegible] errors

to unfamiliar truths.

Given the recent history of publisher behavior, it is unrealistic to expect publishers to submit to very many of the incremental improvements devised by the developers.

There is general agreement that teachers need in-service training in the skilfull use of new materials -- even if they are well trained in science. Many publishers now offer in-service training, but in the real world I know about, publishers have come to view this training component as a major marketing strategy. A big company with a large consultant staff can outsell a smaller company by offering "free" training. Education officials are happy to accept the offer because the true costs of in-service training--always a vulnerable budget--can be hidden in the textbook account.

After the books are adopted, publishers use in-service training to bind teachers to their particular textbook programs, thus ensuring future sales. In short, publisher-conducted teacher training is no longer a disinterested matter, even if it is sometimes quite good.

The current NSF program gives substantial control over in-service training to publishers, but they are obliged to perform the training only if their materials are profitable. With some creative bookkeeping, it would be possible for publishers to report small profits and thus reduce their obligations to the teacher training effort.

I truly hope that the present NSF approach will summon

materials that help teachers manage stimulating hands-on activities and give students worthwhile materials to read. I am sure that the developers fully intend to do that.

But given the constraints imposed on publishers, the highly competitive nature of this industry, and the downward pull of market demands, I believe that publishers will not, in the end, make enough improvements to justify the effort. Their business is not to take risks, but to make a profit.

A measured response to flaws in the old NSF programs would have been to make the laboratory experiments more manageable for teachers, to update content, to incorporate new research on concept teaching in science, to employ new technologies, and to renew the Federal teacher training effort.

The government's role should not be to subsidize timid publishers, but to take the risks that the private sector cannot take. Given the overriding national interest in science education, the federal government should organize and support curricular improvements that are beyond the capacity of individual states and school districts. The National Science Foundation should set a standard for excellence and then patiently nurture its acceptance.

Mr. WALGREN. Well, thank you very much for that perspective.

How much of the science education at NSF goes into curriculum development?

Ms. TYSON-BERNSTEIN. I don't have the figure in my mind of the portion. It's fairly small. It's a small proportion. Certainly it's smaller than the portion allocated to teacher training, and I have no comment on the appropriate relationship between those funds.

Mr. WALGREN. What's your assessment of how important a contribution new materials not presently developed have to make to moving us along on the problem of pre-college science education?

Somewhere, intuitively, I'm suspicious that what was done in the past might not have been all that bad; and, secondly, there's a built-in interest to consume money, trying to create something which has not yet been created, that may, because its testing or its measurement is off in the future, simply be moving us forward, spending money without really coming up with anything truly constructive.

Can you respond at all to that reaction?

Dr. ATKIN. To your first question about how much is spent on curriculum development, I can give you a figure that may help a bit. In the current budget, $37.5 million out of $139 million is for materials development, research, and informal education. The lion's share is for materials development, but I don't know what percentage of the $37 million that is.

With regard to your major question, yes, I think we'd be a long way ahead if materials that now exist were used in a more effective fashion and more broadly; but, there is need for new curriculum development, particularly in certain areas.

Particularly, I would submit at the elementary school level where the National Science Foundation presence was not as strong 25 years ago as it might have been; and, even more crucial today is the very difficult problem of an appropriate curriculum for middle schools. And here, the National Science Foundation did very little.

What you need at both of these levels is not the kind of discipline by discipline orientation that is prevalent at the high school level; but, you need, in my view, something that is more encompassing. For example, on our own campus, we have an initiative that is supported by the Carnegie Corporation that's trying to build the middle school program in human biology, which brings to bear not only important concepts in biology, but supporting concepts in mathematics, supporting concepts in the social sciences as well, to deal with questions such as human sexuality, epidemiology, questions about disease, health, nutrition. This is a very exciting program, and I think that—and I know that it's new. In my view, more efforts of this kind are absolutely necessary, particularly at levels before high school.

Dr. GARDNER. May I comment on this one?

Mr. WALGREN. Certainly, Dr. Gardner.

Dr. GARDNER. Because it's an area of major interest. I think the programs of the 1960's were great successes actually. The impact on textbooks and on teacher training are very apparent, and yet they did not go far enough, of course. And there's a need now for both revision of those materials and creation of new ones.

Revision of those materials is taking place now under NSF funding. The elementary projects that were mentioned earlier are most of them revising materials done in the 1960's and bringing them completely up to date. The chem study films are being revised at Lawrence Hall under an NSF grant.

But there are the new areas, some of which Dr. Atkin mentioned, middle school especially that needs to be addressed. There is, for example: Chemical Education for Public Understanding of Science, is a program just coming that is middle school, and it will address many of the social issues; the Chemistry in the Community program just off the press, senior high school level, relevant to social questions as well as science content; the possibility of a new international curriculum project that brings attention to CO_2 and global warming; biotechnology. These new areas do need to be developed as well as the revision of the old materials.

Mr. WALGREN. Any other thoughts on that?

Ms. TYSON-BERNSTEIN. Yes, I agree that the old NSF materials were wonderful and need updating. I also agree that the great need is for the development of elementary materials.

From what I hear, the contractors that are now at work on the development are doing some very creative and innovative things, trying to find ways to make laboratory and hands-on experiments more accessible to teachers.

But my only question is, will those survive the transit to the commercial sector, given its extremely conservative and timid history?

Mr. WALGREN. How are NSF-developed materials generally translated into commercially saleable projects? How does that happen? The grant goes——

Ms. TYSON-BERNSTEIN. The grant—well, this is brand new. It's never been done this way before, and I'm raising some questions about that.

The grantee is the commercial—is the development firm. Usually these are consortia of science educators and curriculum specialists who reach out to teachers to help them ground the programs in reality and reach out to scientists to help them and who look at the previous excellent materials that were developed, as Dr. Gardner noted. And I think they are probably intending to do very wonderful things and are doing wonderful things.

The only problem is that from all the—from all that I know, from having studied the textbook enterprise in the United States for the last five or six years, it is highly unlikely that very many of those innovations will survive intact. I mean, I think some of the hands-on experiments for children in elementary school will probably work their way into the system and be very welcomed.

But, given the constraints of the adoption States, as well as the constraints imposed by large cities in non-adoption States, and given the test mania that is driving the whole enterprise down the road of the lowest common testable items, and given the emphasis on memorizable terminology that makes these books read like a prosified syllabus, they're very unstimulating; they're very difficult, the ones that are created now.

Mr. WALGREN. Is some of that unstimulating nature the fact that it's the product of a group or a firm, as opposed to an individual

who must be able to grasp the range of field? Are we beyond the point where individuals develop curriculum, or is that still something you would rather see than an organization develop curriculum?

And then I want to recognize my colleagues.

Dr. ATKIN. If I might comment on that, yes, we have moved out of an era when—very largely out of an era when individual authors would propose a textbook that might be employed at the secondary or elementary school level.

The more common pattern today is for a textbook publisher to take the initiative. As a matter of fact, a lot of the writing is done in-house.

One of the things that guides the writing, as I think Ms. Tyson-Bernstein implied, is a perception of the market; that is, the kind of coverage of topics that's required if you assess the program that exists, particularly in the 20-plus States in which there is a State adoption.

Now this press for coverage means that topics like a—the topics have to be included. They are mentioned and defined. As a result, many of the science textbooks that are indeed boring are kind of dictionaries. They are lessons in science vocabulary. Words are taught to the youngsters that the youngsters are expected to repeat the definition back in recitation or back on an examination. There isn't the depth, the selective coverage, the more interesting coverage that Ms. Tyson-Bernstein was alluding to during her initial presentation.

Dr. GARDNER. However, if I might add, that's the important function of the National Science Foundation, to break that cycle and allow this creative new work to go forward. Dissemination networks are existing now, and NSF is funding dissemination networks. Hands-on programs from Hall called GEMs is being disseminated by such a grant; and, with networking with the National Science Teachers Association, there are ways to get these materials to the teachers.

Mr. WALGREN. The Chair would like to recognize the gentleman from New York, Mr. Boehlert.

Mr. BOEHLERT. Mr. Chairman, I have an opening statement that I ask be inserted in the record. (See p. 841.)

How effective are the NSF teacher training institutes?

Dr. GARDNER. May I try to answer that?

Mr. BOEHLERT. Please.

Dr. GARDNER. They're tremendously effective. I wish we had a better way of measuring how effective. But what is happening is that the NSF Institutes today, a little different from the 1960's, the ones today have a follow up aspect, a commitment on the part of the teacher to go home and take that work and share it with others. And so, there is this geometric progression that I mentioned where thousands of teachers reach tens of thousands of teachers as a result of the NSF work.

These teachers go home rejuvenated. They go home feeling proud. They go home excited, and the impact is tremendously strong.

Mr. BOEHLERT. How would you improve them?

Dr. GARDNER. How would I improve them? I wish we had more money available through NSF for more of these institutes. We're constantly having to cut back from eight weeks to four weeks, from 40 teachers to 20 teachers. More funding would help make it possible to reach many more teachers.

Mr. BOEHLERT. Dr. Atkin?

Dr. ATKIN. Teaching is a lonely profession. This has been commented upon often lately.

I think one of the things that might be done is to have people who have participated in a teacher institute, and who have begun to develop some colloquial relations, and who have begun to become excited about some new content, to stay together, to meet once in a while, to correspond—electronic communication is possible—meet occasionally, have a refresher shorter course in the future to keep in touch with one another.

I think this would be a valuable addition to many of the institutes. A real esprit is developed in the best of them; and, if this can be sustained, I believe that many teachers would appreciate it.

Mr. BOEHLERT. Of course, we can't get by the problem that we, in America, don't pay our teachers enough. That's the basic problem. Here are young graduates with a bachelors degree coming out of one of these finer schools in America, and they go to General Electric or one of the big companies, make $30,000 right off the bat, start paying back their loan; if they go on to graduate school, they want to teach, they incur further debt and then they come to the great school system that might offer them $16,000 or $17,000 a year to start. I don't know how we get around that.

Dr. GARDNER. That's a problem, and there's another related one. In this country, our teachers are on 9- to 10-month contracts. They don't have summer pay. Most other countries have 12-month contracts, and they are expected to get additional training during the summer.

So, they simply must either work to support their families, or they must have access to funds for the kind of education they need in the summer.

Mr. BOEHLERT. What do you think accounts for the wide disparity in performance when you measure United States students against Japanese or any other students from any other country?

Dr. GARDNER. Well, I've studied the international scene quite a bit, and there are a number of factors.

One is the school year is longer in other countries. Another is that the courses are more rigorous in other countries, and their expectation of students is higher. But I think the really key one is the teachers are better prepared. They go through formal preparation courses, earn formal degrees in science, then learn how to teach.

We try to push it all into—this is 5 years in most countries—we try to push it all into 4 years, both the professional sequence and the science training. And they really don't have the confidence and the strong base in science.

Mr. BOEHLERT. Any comment, Doctor?

Ms. TYSON-BERNSTEIN. I agree, but I would like to comment that I think that the low teacher's salaries are well a factor in depressing the nature of the people who come into teaching. That isn't the

only factor. There are people who are not primarily motivated by money, and a lot of them go into private school teaching which pays even less because they like the atmosphere of freedom and creativity that a private school can offer.

I think that we have to pay attention to the psychic income of teachers, similarly nurses, as well as the pay situation because I think a lot of what discourages people in teaching is being overregulated and undertrusted, as well as being underpaid.

Mr. BOEHLERT. Doctor, did you have a comment on that?

Dr. ATKIN. Just a footnote. There is some progress in the various states in these dimensions. I believe there is great sensitivity to the point that was just made about needing to make this a field where an individual can exercise greater autonomy, make some choices.

We're beginning to realize that we can't control schools remotely well from the state capitol. But a certain amount of autonomy has to be put in the hands of teachers, and they have to be given time, as in other professions, to meet with one another, to prepare; also, salaries are being raised slowly.

There are heartening reports from most education deans I've talked with at the major research universities about the quality of people choosing teaching going up rather dramatically, and we are interestingly beginning to see some yuppie burnout. People in their thirties who are in law, for example—I don't say this as a large phenomenon but it exists—or in business and deciding this isn't what they want and they're coming back to certify as teachers in their thirties, even in their forties.

Mr. BOEHLERT. You know, I'll concede that there is that psychic income that's very important, but I'm just frustrated as I look at the picture and see the typical young person today graduating with a bachelor's degree and probably $15,000 to $20,000 in the hole to start from various student loans, and thinking about graduate school, that person says well, gee, that's more indebtedness and maybe I better grab the quick buck right now and, while I would like to teach and I think it's rewarding and exciting and challenging, teaching doesn't offer that quick buck.

Let me ask something else, another line. I've often felt that we don't do a good enough job in our outreach. There's a lot of talent in the real world in business and industry, you know outside education, that we should bring into the classroom, and we don't seem to be doing that.

What do you think, is it advisable to do that, and what do you think are the main impediments?

Dr. ATKIN. I think it is advisable. As a matter of fact, my current research project is looking at collaborative activities that are springing up to improve science education between public school districts on the one hand and universities, industry, the military, museums, on the other hand.

When David Hamburg became President of the Carnegie Corporation, he established a program to encourage what he called science rich institutions to share resources with the public schools.

In that particular program, which is science education alone, about 20 grants have been made so far. But as I have begun to study this issue, I've become aware of more than 200, actual count, collaborative activities that have grown up around the country.

There's an outfit that is a subunit of the National Science Teachers Association called the Triangle Coalition that's trying to keep track of these new inter-institutional arrangements. Triangle Coalition is the name of it.

I am enormously impressed with the impact these efforts are having on individual teachers. So, for example, some industries—another feature, incidentally, of this move toward inter-institutional collaboration is that it has a strong grass roots element. It's growing up in Cleveland, in Pittsburgh, in Philadelphia, in Los Angeles, in San Antonio, in St. Louis, in Chicago, by local industry. And so, for example, they make summer employment available to science teachers.

The science teacher learns more about that company. During the year, the science teacher brings, or is invited to bring, or does bring, youngsters to the firm to learn about what goes on in that laboratory.

In Cleveland, for example, there's talk, another example, about modifying the chemistry program. And the chemistry teacher in charge of this bit of curriculum revision is meeting with people in the Cleveland Health Clinic to find the kinds of chemistry knowledge that's needed for entry level employment at the clinic, for example.

Military—there is an organization called the National Executive Service Corp, headquartered in New York, that is trying to encourage business and the military to make it possible for people in their forties and fifties to give time to the schools and sometimes serve as teachers.

Military has an experiment at Ft. Bragg and one in the San Diego area for the Navy that's encouraging retiring military officers to contemplate teaching as a career.

I'm just beginning to look at this, but it seems to have enormous potential. Congressman Boehlert, this just scratches the surface of some of these inter-institutional arrangements that are growing up to improve science teaching.

Mr. WALGREN. Will the gentleman yield for a thought on a different subject, and then I'd like to turn the Chair back to the gentleman for several minutes? Where does the Department of Education fit into this?

Dr. GARDNER. Well, let me start with a partial answer. In the 1960's the Department of Education was involved in science and mathematics education through a program called NDEA, and they were providing materials to buy equipment and to better equip the labs and help with textbooks and resource materials.

That program died; the science specialist in the USOE became generalists and that department fairly well dropped out of science education and took on other responsibilities. They have not been providing very much leadership in science education as I view them.

Dr. ATKIN. The Department of Education does not command the respect of the scientific community. The scientific communities involvement is essential for improvement of programs at elementary, secondary and undergraduate levels.

Only the National Science Foundation has the capacity, in my view, to attract scientists of the stature that are necessary.

Mr. BOEHLERT [presiding]. Well, we're just finally at the point where we can convince the Administration it shouldn't be asking for the abolition of the Department of Education, so I think we're making some progress in that regard.

I know the Chairman has to go so I'll continue for him and I will take over his chair as much as I covet it.

You know, I want to thank you for your testimony. It's enormously important. I was in the Soviet Union last April and while I was in some meetings, my wife went to a school. And, in seventh grade in Kiev in the Ukraine, these youngsters were learning English, Ukrainian, Russian, physics, chemistry, and the list goes on.

And at the end of the day, they put on a program for the visitors, My Fair Lady, in impeccable English. I don't worry about Soviet tanks coming on the beltway, but I'll tell you, I'm darned concerned about our competitive position vis-a-vis the Soviets, in the 21st Century, and unless we do more of what this Committee has tried to right along, put more money into science and math education, we're going to lose the real battle, and the battle is not going to be on some field.

Thank you all very, very much. Do appreciate it.

Dr. ATKIN. Thank you.

Mr. BOEHLERT. Our next panel is Dr. Daniel Kleppner, Lester Wolfe Professor of Physics and Associate Director of Research Laboratory for Electronics at MIT; Dr. John Silcox, Professor, School of Applied and Engineering Physics, Cornell; and Dr. Arthur B.C. Walker, Jr., Professor, Center for Space Science and Astrophysics at Stanford.

The Chairman will be back momentarily, and let me apologize just a little bit for the lack of more membership up here. I left a meeting with the President to come over here. He was beginning to talk about Contra aid. I have heard the story many times before, so I thought this was more important. And I know there are some other conflicts. The Chairman will be back momentarily.

Dr. Kleppner, if you are ready, you may proceed. Your entire statement will be in the record. You may summarize or proceed as you wish.

STATEMENT OF DR. DANIEL KLEPPNER, LESTER WOLFE PROFESSOR OF PHYSICS AND ASSOCIATE DIRECTOR, RESEARCH LABORATORY FOR ELECTRONICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. KLEPPNER. I'd like to summarize the written testimony.

Thank you for this opportunity to discuss the fiscal year 1989 NSF budget authorization with you today, particularly issues with the Science and Technology Center Initiative.

I wish to emphasize that I am speaking as an individual scientist, not as a representative of any group. However, as a member of the Academy committee chaired by Dr. Richard Zare that formulated the guidelines for the S&T Center program last Spring, I believe that I am reasonably informed as to the goals of that program.

The primary goal of the Center is, to quote from the Zare Report, is to "exploit opportunities in science where the complexity of the

problems requires advantages of scale, duration or facilities that be provided only by the center mode of research."

Professional scientific education is the central function of the Centers. They must be campus-based and led by regular faculty. Centers have the freedom to break across institutional boundaries. They should be congenial to interdisciplinary research. Most importantly, the Centers have a mandate to reach outward to the greater scientific community, to industry, and to the Federal Government, wherever appropriate.

The overwhelming response to this initiative—there were 323 completed proposals, each of which required a major effort by many scientists—suggests that the Centers can play a useful and productive role in our scientific enterprise.

However, as was pointed out in my letter of invitation to present my views, the program raises questions on several issues. A key issue is the balance between funding for individual investigators and for Centers. The Zare Committee discussed this question with the Director of the Foundation. The Foundation's long-range plans are a step-by-step increase for a budget doubling over a 5-year period, at the end of which about 10 percent would be devoted to Centers.

We judge this goal to represent a reasonable and balanced approach. The real problem is how to get from here to there. We were very concerned that the growth of the Centers might cause setbacks in individual investigator grants. We were so concerned about this possibility that we raised the following caution in the guidelines; and, this is a quote:

> There is a risk that a significant portion of Federal funds and university resources will be diverted from the support of individual investigators, especially if the Foundation budget remains static or declines. In these circumstances the projected budget to the NSF Science and Technology Centers Program should be reduced proportionately.

This advice was heeded in fiscal 1988. The budget essentially remained static, and the initiative was postponed for one year.

The first real impact of the S&T Center Program is in the 1989 budget. The budget proposed calls for an overall $350 million increase, of which $150 million is a line item for upfront funding of S&T Centers for a 4- or 5-year period.

Upfront funding goes a long way towards assuring that the S&T program will not gnaw into the research activities in the coming years. It also provides a continuity of support that allows the Centers to undertake long range planning. Both of these features are highly desirable.

However, the question still remains of a reasonable growth and support of the disciplinary programs. The total increase in research and related activities is 10 percent; but the largest single component, Math and Physical Sciences, receives only 6.3 percent. It appears that this program has been taxed to help the S&T Centers. As a strategy for launching the S&T Initiative, this may be justified. However, if the MPS budgets do not start to show real growth, the fears of the critics of the program will have been realized.

My view is that the 6.3-percent increase in this coming year is awfully small. There has been widespread dismay in the scientific community about the fiscal year 1988 budget. This growth in the

1989 budget is hardly enough to undo that damage, much less to move forward.

Mr. Chairman, you asked me as to what I see as the implications for the future of reducing the Research and Related activities part of the budget to create special programs. In my view, it would be deplorable if these special programs interfere with the essential growth of Research and Related activities. The bottom line of the disciplinary budget provides the signal to the scientific community as to whether or not it is worth writing a proposal or for that matter whether it is not worth pursuing a scientific career.

Let me cite the widespread dismay in the scientific community about the cutbacks in this year's budgets. To call the impact demoralizing would be putting it too mildly. The condensed matter community has already made its views known through its Aspen letter and Phil Anderson's letter in the New York Times, but the damage and demoralization runs through wide areas of math and physical sciences.

Funding statistics do not begin to tell the story. Anecdotal information may be more to the point. Five graduate students discussed their career plans with me recently. These were not my own students; they were other people's students. And not one would consider a university research career. A prime reason was a lack of NSF support. Every one of them specifically mentioned it.

At MIT in physics, we normally offer 60 research assistantships to incoming graduate students. This year we offered 37. Similar things are happening across the United States. The 1988 budget cutbacks have had a significant negative impact on science. If the NSF budget does not grow substantially in 1989, the disaffection of our graduate students and our scientific faculties will accelerate.

The NSF supports more than half of the university-based research in the physical sciences. Its budget is much too small for the job. That fact is the rationale for the plans to budget in 5 years, and that doubling is urgently needed. Currently the Federal Government is spending about $62 billion on R&D. The NSF supplies a large fraction of the scientific manpower and new knowledge that drives the R&D enterprise. Its budget, less than 3 percent of our R&D expenditures, is much too small to do this job.

Physical sciences in our universities is in a state of decline. Our increasing dependence on foreign scientific manpower and our universities' growing difficulties in filling faculty positions are but two symptoms of the spreading malaise.

To young scientists contemplating careers in basic research, the NSF represents a clear statement as how the nation values these activities; and, the message they got in the fiscal year 1988 budget is—not very much.

Once lost, scientific leadership could take decades to recover. I implore you to convince your colleagues of the urgency of the situation and the need to start giving the NSF the resources it needs for its essential job.

Thank you very much.

[The prepared statement of Dr. Kleppner follows:]

Testimony presented to the

Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives

March 22, 1988

by
Daniel Kleppner
Department of Physics
Massachusetts Institute of Technology

Mr. Chairman and members of the Committee:

Thank you for this opportunity to discuss the FY 1989 budget proposal of the National Science Foundation, particularly issues bearing on the Science and Technology Centers program. Although research centers are not an innovation at NSF, the S&T Centers program has attracted unusual attention because of its scope and its prominent role in NSF's plan for the next five years. The overwhelming response to the program—three hundred and twenty-three fully developed proposals—suggests that the Centers can fulfill a real need for the scientific community. However, there are widespread concerns that the program will lead to distortions in the NSF budget, and force scientists into a style of research that may be neither desirable nor appropriate. These issues were central to our discussions last spring when the Panel on Science and Technology Centers of the National Academy of Sciences, under the chairmanship of

Dr. Richard N. Zare, met to formulate principles and guidelines for the program. Our findings are presented in the report *SCIENCE AND TECHNOLOGY CENTERS* published by the National Academy of Sciences. I would like to discuss some of the issues in this report, and then go on to make a few general comments concerning the NSF budget proposal.

THE CASE FOR S&T CENTERS

The primary goal of the S&T Centers is to assist NSF to fulfill its mission of promoting the creation of new scientific knowledge and assuring that the nation has an adequate supply of trained scientists. The Centers are intended to accomplish this by supporting research in areas where the "problems require the advantages of scale, duration or facilities that can be provided only by the center mode of research". (Quotes are from the Zare report.) The integrity of their educational role is assured by the requirement, high on the list of defining features, that the Centers be "campus-based, led by regular faculty, and integrated into academic programs".

Questions have been raised about the scientific quality of the centers. The intention is that they will be reviewed critically and held to the highest standards. Whether they live up to these expectations only time will tell, but if they don't, they should be stopped. A drawback to the center mode of support is that it is inappropriate for much of the research in the physical sciences: many institutions lack the critical mass of effort needed for a center, and not all areas need the special

facilities that a center can offer. (In contrast, virtually every area of basic research would benefit from the continuity of funding that a center can provide.) Nevertheless, with more than three hundred proposals from which to choose, it would be surprising if the NSF could not identify at least fifteen that are truly outstanding.

It is important to emphasize that the goals of the S&T Centers program are consistent with the basic mission of NSF because underlying the creation of S & T Centers is the expectation that they will fulfill a second mission: strengthening our economy. There is every reason to believe that this expectation will be fulfilled, but the Panel pointed out that the important contributions to our economy will come from the pursuit of basic research over the long run, rather than in the pursuit of near term goals. Attempts to focus the program on short-range needs would be self-defeating: one cannot predict the revolutionary discoveries that lead to the creation of new technologies and new industries. (One can, however, demand that the Centers reach out to industry and stimulate technology transfer wherever there are opportunities, as described in the Zare report.)

I emphasize this point because there are misgivings that the S&T Centers program marks a turning away from basic science by the NSF. Our committee's guidelines propose no such change. From our discussions with the Director, we believe that NSF's views on this matter are in harmony with our own. Nevertheless, there remain serious questions about the impact of the program on other areas of NSF, and particularly its impact for the support of individual investigators.

BALANCE OF FUNDING

Motivated by broad concerns for our scientific future that are documented in the Packard-Bromley Report, the NAS surveys in chemistry and physics, and by many other studies, the NSF has put forward a program for a step-by-step growth in budget. The S&T Centers are one component of this program. The plan is to double the budget over a five year period, and that about ten percent of the final budget will be devoted to centers. It is difficult to argue that such a scenario for the centers would unduly distort or unbalance NSF's budget. However, the community is concerned that this scenario will not be actually followed, and that the S&T Centers may grow at the expense of support for individual investigators.

The Zare Committee was fully aware of these concerns, and fully shared them. For this reason we took the rather unconventional step of including a caution in the Executive Summary:

There is a risk that a significant portion of federal funds and university resources will be diverted from the support of individual investigators, especially if the Foundation's budget remains static or declines. In those circumstances, the projected budget of the NSF Science and Technologies Centers program should be reduced proportionately.

With respect to FY 1988 this caution has been heeded: NSF's budget did not expand, and the S&T Centers program was deferred until FY 1989. Nevertheless, the scientific community remains uneasy. The abrupt cutback of the FY '88 budget has caused

disruption in many quarters and there is a general concern that the S&T Centers program could make matters even worse next year. The underlying worry is that support for the S&T program will be siphoned from the individual investigator budgets. Are these concerns justified?

THE FY 1989 BUDGET

The FY'89 budget requests a $350M increase, with $150M earmarked to support ten to fifteen centers for the first five years. This "up front" funding of the centers incorporate two desirable features. First, it allows the centers to develop long range research plans. Second, by isolating the S & T funds from the rest of the NSF budget, the potential conflict between the centers program and support for the individual investigators is substantially diminished. In short, I believe that this mode of funding effectively responds to the concerns over conflict of funding raised by the Zare report and by members of the scientific community.

Nevertheless, the question remains of adequate growth in support for Research and Related Activities. The overall increase in this category is budgeted at 10% ($150M), but the largest single component, Mathematical and Physical Sciences (MPS) receives an increase of only 6.3% ($29.7M). Other increases, in order of dollar amounts, are Geosciences, 10.1% ($29.5M); Computer and Information Science and Engineering, 20.3% ($25.2M); Engineering, 13.7% ($23.4M); and Biological and Behavioral Sciences, 8.6% ($22.8M).

Most of the S&T Center research can be expected to lie in MPS. It is difficult to avoid the conclusion that MPS has indeed been "taxed" for the S&T initiative. Assuming that three-quarters of the research is in MPS, and that the $150M is apportioned over five years, then the total increase in support for MPS research in FY'89 is 11%, which is on a par with the other sciences, though noticeably below engineering.

There is an urgent need for a larger growth in MPS, but, as usual, the tradeoffs are not clear. If the MPS budget should continue to be taxed for the S&T Centers in FY 1990 and in subsequent years, then the community's fears will be realized. On the other hand, if the MPS budget starts to increase in an orderly fashion, then the S&T program will be viewed as having played an energizing role. The best that one can say about the FY'89 outlook for the individual investigators is that their support appears to be on an upward slope, though not much progress has been made up the hill.

In view of the history of the FY'88 budget, however, suggestions at this time on the fine tuning of the '89 budget may be completely unrealistic. In my opinion the overriding issue is the total level of the NSF appropriation. Many observers have suggested that the odds are against a substantial increase in the NSF funding. The Foundation's resources are so clearly inadequate to the needs of science, however, that any repetition of last year's budget slashing would be devastating.

If Congress should chose to cut back the NSF budget once again, it should do so

with full knowledge of the repercussion of this year's cutbacks.

THE SITUATION TODAY

In FY'88, the NSF budget for research and related activities was increased only by 3.3%. The dollars increase was spread roughly evenly between the research divisions, with the consequence that MPS received the smallest percentage increase: 1.8%. However, given an overall increase of 3.3%, the figure would have been about the same no matter how the pie was sliced.

There has been a vigorous outcry from the materials science community over the broad cutbacks in the NSF Division of Materials Research. Leaders in this field have had their budgets reduced by amounts of 6% to 12%. Considering the phenomenal advances in high temperature superconductivity, it is difficult to see how NSF could have allowed this to occur. Nevertheless, whatever the reason, this debacle should not be permitted to obscure the wide ranging effects of the broad cutbacks in NSF's budget.

It is difficult to quantify the effects of the NSF budget cut, but one relevant statistic is that MIT normally offers research assistantships to approximately sixty prospective graduate students. Last year the exact number was fifty-eight students. This year it is thirty-seven. In a time of budgetary pressure one cannot take on new responsibilities, and new graduate students represent new responsibilities.

Some anecdotal evidence may be more to the point. Within the past few months five graduate students with their Ph.D.s in sight spoke with me about their future careers. Not one failed to mention the lack of research support from the NSF; not one would consider a career of academic research. Last week a colleague on leave at a national laboratory told me that he would not return to his university: again, the lack of NSF support was a critical factor. On a personal level, I might mention that at the moment my colleagues and I are watching a European group move forward in an area that we pioneered at MIT, but from which we are excluded by lack of equipment. This, in a nutshell, is a recipe for how a nation loses scientific competitiveness.

My experiences are not unusual in the university-based physics community. Multiply them by the thousands of scientists in the universities across the nation, view them in the context of the growing shortage of faculty members in important areas of research, and you will see a picture of science in decline.

Our universities are entering an era in which their science faculties will retire at an accelerating rate. The median age of the physics faculties has climbed from thirty nine years in 1970 to fifty years today. The demographics of retirement are inescapable: by the turn of the century our science faculties must be largely replaced. In such a situation, today's scientific cutbacks will catapult us downhill.

PRIORITIES

NSF is embarking on a long overdue step-by-step program of growth. The S&T Center initiative is a conspicuous component of this effort. Tension between the S&T initiative and other needs within the Foundation may be inevitable, particularly because the program is being launched at a time when the NSF budget has been disrupted. In spite of these tensions, the Foundation, with the cooperation of its advisory panels, should be able to sustain a sensible balance of support among its various components.

A far more contentious problem is the setting of priorities between the NSF and projects such as fusion energy, the SSC, and the space station. In judging these conflicting needs, an overriding consideration is that the United States cannot hope to maintain scientific eminence if it loses its ability to educate scientists at the frontiers of knowledge. The National Science Foundation has a primary responsibility to assure the professional training of scientists: it supports more than half of the physical science research in the universities. Compared to the federal R&D expenditures of $67B, the NSF budget— $1.7B— is far too small to meet the nation's needs. I know of no scientific enterprise that deserves a higher priority than NSF's battle to halt the erosion of our universities.

Profile

Daniel Kleppner

Daniel Kleppner joined the Physics Department of the Massachusetts Institute of Technology in 1966 where he is now the Lester Wolfe Professor of Physics and Associate Director of the Research Laboratory of Electronics. Dr. Kleppner received the B.A. degree from Williams College in 1953 and Cambridge University in 1955, and the Ph.D. from Harvard University in 1959. He is a member of the National Academy of Sciences and a Fellow of the American Academy of Arts and Sciences, the American Physical Society and the American Association for the Advancement of Science. He has served as Chairperson of the Division of Atomic, Molecular and Optical Physics of the American Physical Society, and is currently a councillor of that Society. From 1983-85 he was a member of the Physics Survey Committee of the National Research Council. Dr. Kleppner's research interests are in experimental atomic physics, high precision measurements and quantum optics.

Mr. WALGREN. Thank you.
Dr. Silcox.

STATEMENT OF DR. JOHN SILCOX, PROFESSOR, SCHOOL OF APPLIED AND ENGINEERING PHYSICS, CORNELL UNIVERSITY

Dr. SILCOX. Mr. Chairman, members of the committee, I, too, appreciate the opportunity to appear before you and present my testimony on this issue.

Let me summarize the three main points, I believe, in my testimony.

First, Science and Technology Centers were well conceived, and they can and could be considerable assets to our national scientific program.

Second, the balance between individual investigator programs and Center efforts was seriously distorted; and, at this stage in the game, if priority must be given this particular year, I urge that the priority be given to the individual investigator program.

Third, the NSF, the proposed doubling in 5 years is well-conceived; and, I would urge you, if you possibly can, to proceed with the doubling of the budget over the next 5 years.

My remarks reflect a context of materials research. I would like to put forward a few remarks in connection with the nature of that field.

First, it is intellectually lively. Something like about 6 of the last 17 Nobel prizes in Physics have gone to work in this field, and three of the last three awards have gone to awards in this area. Unfortunately, all three of those awards have gone to overseas work and have not come to this country. They have been done for relatively recent work and reflect, I think, the continuing degradation of our status in this field in general.

Materials research is essentially a small science field. It factors basically the individual professor/graduate student relationship in a way that has been remarkably effective. On the other hand, it is also a multi-disciplinary field. Von Klitzing's prize in 1985 for discovering the quantum Hall effect came out of a study of solid state devices, specifically silicon field effect transistors. On the other hand, our current developments in compound semiconductor devices have drawn on years of basic fundamental work in fundamental surface science.

Applications readily emerge out of this field, and they very quickly get translated into industrial products. A recent discovery of high coercivity magnetic fields, for example, by scientists at the Naval Research Laboratory in Japan and at General Motors has now emerged in the form of electric motors that GM makes and puts on its plants.

It is easy to see why applications emerge in this field. Materials determine the performance of manufactured components. We extend the limits of the materials. We extend the performance. We make the materials cheaper, then the components are cheaper.

Let me turn now and look at the trends in the funding in this country. We have been in level funding the last three years. In fact, we have just about reached the stage wherein constant dollars to the NSF budget was where it was in 1965. We have been going

downhill while the rest of the world has been appreciating and going up for this. The rest of the country has appreciated this. We have been seeing enhancement of materials programs in physics, chemistry and engineering across the country. These represent very solid commitments with very serious bets on this area as an important area to go.

Overseas we see materials science being identified along with bioscience and information science as priority areas in places like Japan, West Germany and France. Sales of Kittel, which is a classic solid state physics text, are higher in Japan than they are in the United States.

It is this particular situation which I think gives us cause for urgency. We are losing our basic research edge, and we can't wait much longer before building the program.

Let me turn now to discuss the situation with the individual investigator programs.

Science is an individual activity. It represents individual skills and individual stubbornness in chasing individual ideas. It has been a major success of our system that we have been able to put the money exactly where it is needed at the working scientist level. We have managed to cut deans, department heads, and any administrators out of the game. The money goes exactly where it is needed, and it essentially works there to get graduate students going.

We have had level funding since 1985. We have seen growth certainly in the community since 1980. One of the effects in this is that the community has been growing. I mentioned earlier, for example, that we are seeing strengthening in academic programs in this area across the country. Parallel with this, we are seeing the 6.1 money from the DOD shrinking. There is less there for the scientist to go for. The people are coming to the National Science Foundation to get their support. One of the results of all this is that the level of discrimination for awards, grants, borders at this stage on the capricious. For every grant that is awarded, there are at least one and maybe two that are turned down for a really marginal reason.

If this continues—and, in fact, we have seen the pressure in the system growing for quite some time. And I think it is probably a fair statement to say that the aneurysm occurred in condensed matter physics this particular year, but it could have occurred in any one of a number of places. The consequences of this are going to be very serious manpower problems. Too many talented young investigators are not going to receive funding. That is going to compromise the future.

The PYI program is all very well. It helps to get the students; it gets the assistant professors started. But if they see that the prospects in their community for doing their research are dismal, the PYI program is not going to suck them into science, and they are going to go off to Bell Labs and IBM.

We are going to be killing the high-risk breakthrough potential stuff. People are going to write proposals that are very conservative, and they are not going to gamble their careers on the prospect of tackling something that is difficult and may not pay off. That to me is one of the more serious consequences of the current state.

Of course morale in general will be lowered, and the consequence of that is that we are going to find undergraduates not being attracted. They will go off to business school and similar places, and we are going to have a really serious case.

I started off saying that the science and technology centers are good, and I have given you a dismal story here.

Science and Technology Centers are an excellent program. We have actually had experience with something that is very similar to them in our field. We have had materials research laboratories around for about 25, years and they work. The field is interdisciplinary. The original program was set up to actually create graduate students who can cross disciplinary boundaries, because that is what industry wanted. They wanted people who could sort of work for the physicists one day and go over and work with a metallurgist or ceramist the other days, so that you can actually have people cut across the boundaries. At that level, these programs have worked remarkably well.

What one sees at this stage is that there is a gap between industry on the one hand and academic programs on the other. In 1965, if you looked at this country, you find magnificent basic research being done in industrial labs. I would assert that we have seen a lot of that basic research disappear. The only places that you see it these days are basically in Bell Labs and IBM.

The idea for the Science and Technology Centers was to try to plug something in that was going to fill that gap and basically start—put it on the academic side and let it feed across. I really believe that that idea is a good idea, but it builds and it depends on the individual investigator program. And if that program is in trouble, all the rest of what we are doing is going to go down the hill as well.

Mr. Chairman, thank you for the opportunity.

[The prepared statement of Dr. Silcox follows:]

TESTIMONY PRESENTED TO THE HOUSE SUBCOMMITTEE

ON SCIENCE, RESEARCH AND TECHNOLOGY

MARCH 22, 1988

John Silcox

Professor, Applied and Engineering Physics, Cornell University
Ithaca, New York 14853
Chairman, Materials Research Advisory Committee, N.S.F.

Mr. Chairman, Members of the Committee

I would first like to express my appreciation for the invitation to present my views on the proposed N.S.F. initiative on Science and Technology Centers. My background reflects experience gained during a career in materials science, a field that is intellectually fertile and alive, which is multidisciplinary and which develops knowledge often of value to industry. The style is an individual investigator style, i.e., it is "small science" even though use is made of sizeable facilities and group efforts are sometimes necessary to achieve cutting edge results. I am a member of a Materials Research Laboratory and currently serve on its Executive Committee. This seems a useful vantage point from which to view the STC initiative.

In summary, my comments are:

- The STC initiative is well conceived, can and must be run in a mode in which scientific merit is the dominant factor, and should be valuable in improving communications between academia and industry.

- If priorities must be set this year, individual investigator programs should take first priority. Existing centers and facilities have also suffered under the three-year period of level funding.

- Breaking off special programs as a separate line provides particular visibility and attention for those programs. In the long term, this appears undesirable since circumstances change. It does provide a chance for a controversial program to prove itself on a short time scale. Thus, a sunset clause should be imposed on all such programs. In this case a period of 7 years should be adequate to assess the value of the program. At that point the program should be folded back into the Research and Related Activities line if it is found of value.

- The proposed doubling of the N.S.F. budget in five years is badly needed. It addresses a number of key issues in a well-integrated coherent program. If achieved, it would be a major step in restoring U.S. academic science to a competitive level.

This last statement reflects my concern that on a time scale of 10-15 years scientific and engineering programs in this country have been on hold while our overseas competition has been developing at a rapid pace. The pace of discovery, at least in materials, has meanwhile accelerated. You do not need a reminder of the discovery of high temperature superconductivity, but the last decade has seen a number of other developments and discoveries such as scanning tunneling microscopy, quasi-crystals, quantum Hall effect, high coercivity magnetic materials and discoveries in non-linear science made possible by developments in computer science (together with many I have no space to mention) which are all widening our knowledge of materials and deepening our understanding of how materials behave and are put together. The last three Nobel Prizes in physics reflect developments in this field as do six of the seventeen awarded since 1970. All of them represent typical "small science" efforts. Unfortunately, too many of these awards have gone overseas. Our ability to control materials is extending into the nanometer scale as we learn how to tailor polymers better, configure structures in and on semiconductor wafers and carry out chemistry on a nanoscopic scale. The field is in intellectual ferment and while the superconductivity discovery may be the most visible, there is much else of importance and with considerable practical significance going on.

Increases in the science budgets in the early years of this administration permitted correction of problems that had risen since 1970 in areas such as computer science, rejuvenation of ancient equipment and in engineering but this has only been a start on what needs to be done. Progress since 1985 has been limited to only a very few areas as a result of level research budgets. Agencies other than N.S.F. have begun to take an even shorter term view and N.S.F. is becoming the only appropriate agency for more and more scientists. Even within N.S.F., the creation of new centers (ERC's and supercomputers, important as they are) represents an increase of a few percent of the total budget since 1985 and that has had to come out of individual investigator programs.

Yet there has been a growing national consensus that to survive economically, our industries must become technically more sophisticated and this in turn places greater demands on the academic system. In response to this, academic materials programs in physics, chemistry and engineering around the country have been strengthened, adding to the N.S.F. community. They are expected to contribute to the base for new industries, to enhancement of older industries and to provide much needed technical manpower. This represents a consensus judgment extending countrywide and embodied in very solid commitments. Materials, after all, are extremely important in determining the performance of manufactured articles and the degree to which we can control, manipulate and extend properties in a cost effective way will be reflected in the extension of performance limitations. Materials science (along with bioscience and information science) has been identified as a priority area by a number of our overseas competitors including France, West Germany and Japan, according to Dr. L. Schwartz of the National Bureau of Standards.

It is always hard to make decisions that reflect the priorities of one field against another, and I do not envy the responsibility carried by Mr. Bloch and senior Foundation staff for these decisions. The record is good. For example, establishment of supercomputer centers is providing this country with excellent computational resources and materials science will benefit greatly. In addition to the nonlinear science discoveries I mentioned earlier, the new resources permit a start on the problem of predicting the

properties of aggregate matter from those of constituent atoms and molecules. This is particularly important since it holds hope of predicting the properties of real materials with defects and boundaries. Calculating the properties of polymers on the basis of the constituent molecules is now being undertaken. However, this work cannot be undertaken unless the scientists are there to do it and so the question of balance between individual investigator programs and major centers is serious. It is clear that most of the other disciplinary fields at N.S.F. have also been up against level funding in constant dollars since 1985. Thus the pattern observed in materials may well hold elsewhere. With respect to my own area, I can attest that all fat in the system has been cut out (if indeed, there ever was any) and that we have actually been cutting muscle in addition to letting it atrophy.

There is also no doubt in my mind that the tax dollars spent through these programs yield extremely high value. There is very little waste. The question at issue here is rather whether enough is being done to preserve, let alone enhance, the U.S. scientific capability for discovery. No precise answer can be given to the question since it is hard to predict where discoveries will be made. Peer review attests to the quality of the proposer and proposal, but real discovery intrinsically occurs in unexpected places and these sometimes are in rather quiet areas. High temperature superconductors are a classic example. Such a discovery would never have been made under a focussed or tightly managed program. In funding only the very "best" proposals we run a great risk of overlooking areas where truly novel discoveries are waiting to be made. Thus, while we should fund only quality proposals we need also to support a broad variety of work in order to cover the areas needed.

We need to get on with the job now, rather than postpone it, for the simple reason that this field is competitive internationally and that the discoveries are likely to pay off in practical terms. In the early 1970s, we had a sufficient advantage in the size of our operation that we could move as fast as anyone. That is no longer true. Our colleagues in Europe or Japan are no longer content to synthesize new materials and let us explore the properties. They make the materials and they make the discoveries. As a result they then have a critical time advantage in exploiting those discoveries. If we want to make the discoveries and get on with the exploitation, then we must synthesize the materials too, something we have only recently begun to do. Many of our instruments are now manufactured overseas. Overseas scientists have the leverage of first crack at the new developments, and we tend to get them late in the game. We have not been undertaking enough instrument development. Yet manufacturing needs the sensing, monitoring and fabricating equipment that develop from such efforts. My colleague, Professor Robert Richardson, has been charged with carrying out a study on high magnetic fields for the N.S.F. A workshop was held in August 1987 to review the field; it identified exciting and important applications and outlined a program and a central high field magnetic facility to achieve these aims. In the intervening months, a similar proposal has been submitted to the Japanese Science and Technology Agency, has been funded and has begun at Tsukuba University. I am familiar with similarly rapid responses in my own field of electron microscopy. Our position, even in basic science, is beginning to erode.

It is in the context of this judgment that three years of no real growth in funding causes considerable dismay. Our basic research program must stay competitive in order to play its role in maintaining our technological

strength, yet we are watching it slip away. The proposed investment in the nation's research and education base by doubling the N.S.F. budget over the next five years is urgently needed. At present, our programs are of high quality and we still have not lost too much ground. My sense is that we can no longer afford the luxury of delay. We must get moving again, and I urge support of this request.

My first priority is that a sizable increase in the Research and Related Activities line for disciplinary research be forthcoming this year. Individual investigator awards are a critical aspect of the system in this country. Discovery results from individual skills and individual stubbornness in pursuing individual ideas. By providing the support directly to the working scientists, a remarkably effective mechanism for developing science and scientists has been developed. The special programs depend on this core and will succeed only to the degree that the core can support them, that is, the degree to which scientists are available to participate. The diversity of the sources to which approaches for support can be made has been another valuable factor. This ensures that a proposal gets a hearing in more than one place. Reduction in this diversity has been occurring and this is not healthy either.

The combination of level funding and increasing community size has placed N.S.F. under extreme pressure. It has been reflected since at least 1980 in steadily increasing quality levels at which funding decisions are made. These decisions are now being taken at a discrimination level that borders on the capricious. For each proposal that is accepted, there is at least one and perhaps two of comparable quality that is being rejected for relatively marginal reasons. This year the cuts and rejections have reached the very best scientists in this field at unusual levels, and I must describe concerns in the field as having risen to a crisis level. Adverse effects on manpower recruitment will surely follow. These considerations also lead to the conclusion that the primary priority must be for the Research and Related Activities line.

The initiative on S&T Centers is not a radically new departure for materials science. The Materials Research Laboratory (MRL) program recently celebrated a 25th anniversary and an important new program in Materials Research Groups is coming into full operation. This latter has become possible by reprogramming funds freed up by a decrease of the MRL system from 14 laboratories to 9. Materials research is inherently multi-disciplinary and involves physicists, chemists, ceramists, metallurgists, semiconductor scientists, electrical, chemical engineers, and so forth. Ideas and problems migrate across the interfaces if the communication avenues are open and connections get made from pure physics to the applied and vice versa. Many examples of these connections exist. Von Klitzing's 1985 Nobel Prize winning discovery of the quantum Hall effect reflected a solid state physicist making careful studies of silicon field effect transistors. Current molecular beam epitaxy techniques for growing compound semiconductor layer device have drawn heavily from fundamental surface science studies.

It has been evident for a long time that to understand a material, we have to make it, characterize it, measure properties and understand how the electronic, chemical or microstructure affect the properties. This often involves the expertise of a group of people, expensive facilities such as electron microscopes, synchrotrons, electron beam fabrication machines and highly skilled support staff. Exploitation of the materials also requires

skill in materials processing to control purity and microstructure and device development of some form or another. Thus group programs within which individual scientists contribute needed skills and expertise are common. Approximately 40% of the resources of the Division of Materials Research go to group programs and facilities. This encourages the interactions described above but also makes possible cost-effective use of expensive facilities together with associated qualified support staff. Experimental progress depends often on access to many more experimental techniques than can reasonably be expected in one individual investigator laboratory. The groups permit an organized approach to this but in a way that respects individual investigator initiatives. As a guiding rule, it seems appropriate to argue that whatever organization is needed to achieve a worthwhile scientific goal should in fact be encouraged. At the same time, the organization must respect individual contributions. The MRL system meets these guidelines. Finally, one of the ultimate and most successful achievements of the MRL program is the way in which students learn to operate in a multi-disciplinary environment. Little hesitation occurs in working with groups from different disciplines.

The experience with the MRL program leads me to see ready applications for the STC initiative. In my view, the primary difference between the situation 25 years ago and now is a decline in the basic science programs in industry. Back then, a number of industrial research laboratories had first class basic research efforts aimed at ensuring that companies had an avenue of communication with the academic research community, at actually making discoveries and as a source of very talented people. This presence is now much reduced and as a result a gap has arisen between academic basic science and industry. The STC initiative is intended to fill this gap and thus provide a communication link that would be on the academic side. Whether this will work will not be clear until it is tried. Certainly the large number of proposals, with the greatest fraction in materials science and engineering, suggests that there is no shortage of ideas and themes.

Some caveats should be entered concerning these Centers. Learning how to run a Center effectively will not happen overnight. To preserve a sharp edge, a Center must let ideas come up from the bottom, i.e., from the working scientist. Research must not be imposed from above, else an overly rigid structure will result. It takes time to get started, that is, to order equipment and hire people, and interactions develop only after individual programs are rolling. To communicate across the disciplines, it is necessary to learn something of the other person's language and values. This does not happen easily. N.S.F. will also have to learn how to review a multi-disciplinary program with multi-disciplinary reviewers and work it into a coherent process. This also does not happen overnight. It is likely to take a minimum of 5 to 6 years to come up to speed. Thus, like many scientific efforts, the investment will take some time to pay off. The dividends will accrue around 1995 to 2000.

In summary, S&T Centers can certainly be made to work and N.S.F. does have the skills to ensure that this can happen. The time scale for development of the Centers is long so that again there is urgency in getting going if these are to be effective on a reasonable time scale.

JOHN SILCOX

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Dr. Silcox was appointed Assistant Professor at Cornell in 1961 and was promoted to Associate Professor in 1964 and to Professor in 1970. He has served twice as Director of the School of Applied and Engineering Physics (1970-74, 1979-82) and has taken sabbatical leaves at Orsay, France, and Cambridge, England, with a Guggenheim Fellowship in 1967-68, at Bell Laboratories, Murray Hill, New Jersey (1974-75) and at Arizona State University (1983). He has twice been a summer faculty visitor at IBM in Yorktown Heights.

He has published over 80 papers in areas of electron microscopy, inelastic electron scattering, superconductivity, ferromagnetism, and transport properties of metals. In 1985 he was awarded the Cornell Tau Beta Pi Excellence in Engineering Teaching Award.

He has served on the Solid State Sciences Committee of the NRC (1978-82), the Microstructure Science and Technology Panel of the NRC (1978-79) and is currently Chairman of the Materials Research Advisory Committee for N.S.F. He was President of the Electron Microscopy Society of America (1979-80) and will be Chairman of the Materials Physics Topical Group of the American Physical Society (1989-90). Advisory committee service includes Exxon Corporation, University of Illinois, and electron microscopy facilities at the University of Colorado, Boulder, the Pennsylvania Muscle Institute at the University of Pennsylvania, the Center for High Resolution Microscopy at Arizona State, and the Electron Microscopy Center at Argonne National Laboratory.

He has been a member of the Cornell Materials Science Center, an MRL laboratory, is a member of the executive committee, and is a principal investigator on a proposal submitted to the N.S.F. STC program.

Mr. WALGREN. Thank you, Dr. Silcox, we appreciate that.
Dr. Walker.

STATEMENT OF DR. ARTHUR B.C. WALKER, JR., PROFESSOR, CENTER FOR SPACE SCIENCE AND ASTROPHYSICS, STANFORD UNIVERSITY

Dr. WALKER. Thank you very much for providing me an opportunity to address the Congress. I would like to just emphasize that although I am the Chairman of the Advisory Committee in Astronomy of the Foundation, I am speaking as an individual scientist.

Before I address the questions which you specifically asked me to address regarding the Science and Technology Centers and the balance of research funding for space and land based astronomy, I would like to establish a context for my remarks by talking about the funding over the past several years.

Over the past several years, the funding for physical sciences in the Foundation has been virtually level, and the funding in fact for astronomy has actually declined when calculated on a basis of the purchasing power of the dollar.

In fact, the first viewgraph, I think illustrates that. [Figures 1 and 2 in written testimony.]

The top panel shows the funding for the physical sciences, and the bottom panel shows the actual decline in resources available for astronomy.

Now this is a very critical problem; and, now as we approach 1989, it is a problem that is going to have very long term consequences unless it is addressed virtually immediately. [Table 1 in written testimony.]

In fact the next viewgraph shows that although there is a very substantial increase for the NSF as a whole, the increase projected for the physical sciences is only about 6½ percent, and the increase for astronomy is only about 4½ percent—and that really is insufficient to stand the erosion of our competitive position in the physical sciences.

In fact, in astronomy the situation is even more severe, as the next viewgraph shows. [Figure 10 in written testimony.]

If you compare the growth of the astronomy budget out of the total budget with inflation, you see that the budget has barely kept pace; but, in fact, if you exclude the funds for the major construction initiative of the Very Long Baseline Array, you can see that the actual operating funds available for research, operation of the national observatories, has actually declined substantially over the last four or five years. And, in fact, the situation in regard to 1988 is even more serious. [Tables 2 and 3 in written testimony.]

If you look at the next viewgraph, you will see that the actual request for funds for 1989 for astronomy is below the original request in 1988 for funds, although of course it is above the actual spending plan after the reductions.

So we really face a very serious problem. And, in fact, I think our competitiveness is now beginning to erode very seriously, and in some areas we have actually lost the edge. And as you know, it takes years to develop a scientific structure, but that structure can

be destroyed in only a few years with very restrictive funding. So I think this is really a very critical year.

Now I would like to now address the question of the science and technology centers. I'd like to emphasize that in fact in astronomy we already have in fact utilized this same approach for many years.

In fact, something like 60 percent of the budget of the astronomy division goes to the national centers, which I am sure you are familiar with. Astronomy, of course, is a science where very large and expensive facilities are required. And so astronomers have turned to this cooperative mode of research for the last 25 years.

In fact, even within the grants program, there are major centers at individual universities, for example, a number of large radio observatories and instruments which service the whole community, although they are run at individual universities from the grants program.

So I think that the astronomy division has already very effectively used the centers concept; and, I fear that, when one looks at the NSF budget for this year, it appears that there's essentially a taxing of the budgets for the ongoing research in the physical sciences to support a start for the science and technology centers. And certainly in the case of astronomy, I think astronomy already uses this mode significantly, and I am not sure that it is very wise to tax the operations of the basic program to support these new centers.

I believe the centers, in fact, will be very effective. In fact, our own experience in astronomy suggests that this is a very effective mode of carrying out science. I'm not sure that the very ambitious start at the very high level will produce results which in all cases are the most efficient, and I really am very concerned about cutting back on the very basic support which carries forth our basic research programs to start another program. I think the science and technology centers really must be started with funds which are additional, not funds which are taken from the basic research program.

Now in regard to the impact of science and technology centers on existing centers, I think the next viewgraph shows [Figure 3 in written testimony] that very dramatically in the case of the astronomy centers. You can see that the two largest astronomy centers, the National Optical Astronomy Observatories and the National Radio Astronomy Observatories, have actually had budgets which are basically level or have declined slightly in terms of purchasing power, so that those observatories, exclusive now of funds for construction initiatives, are actually operating with $3 to $4 million deficits compared to their situation only a few years ago.

And this is reflected in the next viewgraph [Figures 5 and 6 in written testimony] in the staffing levels. Substantial reductions in staff have become an annual ritual now, at the major astronomy observatories. But nevertheless, in spite of that, the level of service, the level of activity, has continued to grow.

The next viewgraph shows, in fact, the level of use for the National Radio Astronomy Observatory. You can see that, even though there has been a substantial loss in the budget in terms of

real purchasing power, the number of users, the use of the facility, continues to increase very substantially.

Another way in which we are mortgaging our future is in deferring maintenance, and the next viewgraph shows in fact an example of this situation at the National Radio Astronomy Observatories.

Now the Congress and the nation were very generous to provide a major investment in the Very Large Array which now provides absolutely the best facility for high resolution radio observations in the world. But we find that this facility is not being maintained. There are many millions of dollars now in maintenance which have been deferred, and the situation is getting increasingly serious.

We are not protecting this major investment that we have made, and we are endangering our lead in this area where we still have a very substantial lead.

Now I'd like to just mention the importance of some of the facilities in ground-based astronomy. It's very often difficult to make the public understand with the spectacular nature of space discoveries that ground-based astronomy is equally important, and we must have a very well balanced program.

I think the next viewgraph shows the capabilities of the Very Large—Very Long Base Line Array facility which is currently being constructed by the National Radio Astronomy Observatories.

This is a technique which essentially makes a telescope of dispersed instruments covering the entire nation, so that we have the effective response of a telescope which is as big as the entire country. And this allows us to achieve resolution at radio wavelengths of a thousandth of an arc setting, approximately a factor of 1000 better than we can do in other wavelengths. And you can see in the illustration here the very fine detail which we can see in very distant sources of very energetic phenomenon in astronomy.

So this is something which is—cannot be duplicated in space. It's something that has to be done on the ground.

Another example is shown in the next viewgraph, which is a model of how the Sun vibrates or oscillates; and, these vibrations or oscillations are very similar to the vibrations of the earth during earthquakes.

And, in fact, most of our knowledge of the interior of the earth is derived from studying the vibrations of the earth during an earthquake. And in a similar way, we can try to develop models of the interior of the sun by the same technique. And all of our understanding of the evolution of stars is based on models of stellar interiors which have not really been checked experimentally. And so this new initiative, which is being constructed at the National Optical Astronomy Observatories, to allow us to study the solar oscillations and use that technology to understand the interior structure of the sun, is extremely important for astronomers; and, of course, the current budget crisis in astronomy is slowing down that development.

So, in summary, I would like to say that we must have a very well balanced program between space and ground-based astronomy; and, ground-based astronomy, I'm afraid, is really falling behind in this country.

The next viewgraph is a table which shows you some of the initiatives which have been undertaken around the world to develop large ground-based telescopes.

Now I'm sure you are all aware of the unique capabilities of the Space Telescope; and, when it is placed in orbit, it will be able to make observations which we cannot get in any other way. But, in fact, for certain observations, a space telescope is really a very inefficient device. It has a relatively modest aperture; and, so for the study of measurements of the distance to very distant objects, it will be 40 times less effective than our proposed ground-based New Technology Telescope. But we have made no progress toward that development while, for example, the European Southern Observatory has now secured approval to build the equivalent of a 16 meter telescope; and, in fact, I understand that the Japanese have now obtained permission to build an 8 meter telescope which will be placed in Hawaii. So it's possible that the largest publicly-owned telescope in the United States will actually be owned by Japanese scientists.

So you can see that although I believe strongly that the science and technology centers will in fact be a very effective mode, I do believe that they should not be funded at the expense of our ongoing program. We must address the needs of the ongoing program. We are falling further and further behind and the 1989 plan does not address that issue at all.

[The prepared statement of Dr. Walker follows:]

Statement by Arthur B.C. Walker, Jr., Professor of Applied Physics
Center for Space Science and Astrophysics
Stanford University, Stanford, California 94305

Mr. Chairman, Honorable Members of Congress:

There is no component of the national agenda that is more important to the long term health and prosperity of our nation than basic research in the physical sciences. I wish to thank you for the opportunity to present my views on the 1989 budget of the National Science Foundation, which has the responsibility for supporting a major portion of the federally sponsored basic research in the physical sciences, and for the support of science education.

Over the past several years, allocations in the NSF budget for research in the physical sciences have increased very slowly. In terms of constant year dollars there has been very little growth over the past four years, as Figure 1 shows. In my own discipline, Astronomy, the purchasing power of the base budget (exclusive of major construction) of NSF's Division of Astronomical Sciences, has, in fact, declined (Figure 2) since 1984. The scientific community is aware, as are all Americans, that control of federal spending is crucial to our economic well-being, and that many important programs will receive allocations in the 1989 budget that fall below what could be effectively utilized. However, the budget climate of the last 4 years has, I believe, created a critical problem for the research community in the physical sciences; if this problem is not addressed in the 1989 budget, the long term consequences for the nation will be very serious. The serious implications for the physical sciences of the 1989 NSF budget request are not immediately apparent, since the overall request is 19% above the FY 1988 appropriation. The major increase, however, is for the new Science and Technology Centers (S/TC) Program; furthermore not all of the S/TC funds requested are to be spent in FY 1989. The 1989 request for the Mathematical and Physical Sciences is only 6.3% above the 1988 appropriation, the lowest increase projected for any of NSF's major program areas; and the 1989 request for Astronomy is only 4.7% above the 1988 appropriation. The implications of the budget levels for 1988 and 1989 for the physical sciences in general, and for the four largest components of the program of the Division of Astronomical Sciences, the grants program, the operations of the two largest national centers (the National Optical Astronomy Observatory and the National Radio Astronomy Observatory), and the construction of the Very Long Baseline Array radio telescope interferometer, are shown in Table 1. If the 1989 request for the Physical Sciences is approved at a level no higher than the requested level, it will result in the continued erosion of American leadership in the physical sciences; if the spending level turns out to be less than the request, a possibility which, in view of recent history is not unlikely, it will make our task of retaining leadership (or regaining leadership in those areas where our programs have already been surpassed) very difficult.

I make this statement not because I wish to argue that funding for scientific research should be immune from the budget pressures and other current concerns which the Congress must consider, but rather because of the nature of scientific research itself, and the delicate situation which presently exists in the physical sciences as a result of several successive years of budget increases which in some cases fail even to cover the impact of inflation. Contrary to the picture that many non-scientists have that advances in our scientific understanding are the result of an inspired insight by a single individual, most scientific advances are the result of sustained effort by one or frequently by several independent scientific teams, each addressing a problem from a unique point of view, and each reacting to the advances made by others. Such teams, to be effective, must be built up and developed over periods of years. If this process is interrupted by budget restrictions, which invariably fall most heavily on the youngest members of research teams, students and post doctoral scholars, the team must often be rebuilt over a period of years. Therefore, a severe disruption of the fabric of the nation's scientific establishment, lasting 1 or 2 years, may have repercussions that persist for many years. A budget which cannot sustain the basic fabric of the nation's scientific activities in a major discipline or group of disciplines, can therefore cause serious, and long lasting damage, even to a strong scientific community. Unfortunately, our national scientific community in the physical sciences is severely weakened by several years of

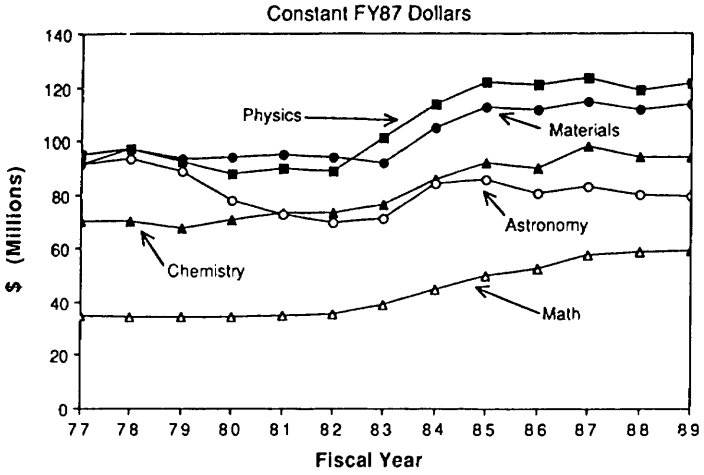


Figure 1. Mathematical and Physical Sciences Budget History

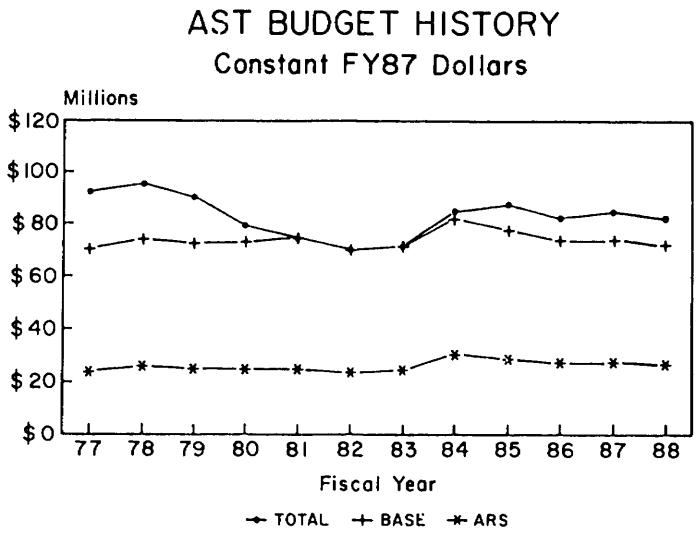


Figure 2. The base budget does not include construction funds. AFS is the Astronomical Research Section or "Grants" program.

Table 1

	1987 Actual (M$)	1988 Plan (M$)	1989 Request (M$)	
NSF Total	1623	1717	2050	(+19.4%)
MPS	465	473	503	(+ 6.3%)
Astronomy	85	86	90	(+ 4.7%)
Grants	27.66	27.89	29.21	(+ 4.7%)
NOAO (Ops)	23.10	23.30	24.40	(+ 4.7%)
NRAO (Ops)	16.83	17.30	18.10	(+ 4.6%)
VLBA (Constr)	11.40	11.60	12.00	(+ 3.5%)

very tight, and in the case of some disciplines such as astronomy, seriously inadequate, budgets.

Bearing this background in mind, I wish to first respond to the questions on which Chairman Walgren has asked for my views:

- the balance between funding for individual investigator grants and for centers and the impact on this balance by the new Science and Technology Centers
- the impart of the size of the new Science and Technology Centers program on other centers and large facilities
- the scientific merit of the Science and Technology Centers and their impact on the "Research and Related Activities" budget line
- the appropriate role for land-based astronomical observations, in view of the national space agenda.

I would then like to beg your indulgence for brief remarks on the very serious impact that the funding levels of the last several years has imposed on the astronomical sciences, and for comments on three additional topics:

- Priorities within NSF and their impact on Astronomical sciences
- The erosion of our national position of scientific leadership
- Translating research into technology, and technology into productivity
- The state of science education.

Balance Between Individual Grants and Centers: The concept of centers which can bring to bear the unique talents of scientists within a single university, or scientists from several universities or other research institutes (government and industrial laboratories, for example) on a major scientific problem or set of problems is one that is already in wide use in astronomy. The

four national centers that support the astronomical programs of the NSF, NOAO[1], NRAO[2], NAIC[3] and HAO[4] have a record of more than 30 years of distinguished service and leadership to the astronomical community and the nation. Each remains vigorous and innovative. Presently, about 60% of the NSF astronomy budget is devoted to these centers. In addition, there are major radio observatories at several universities (the Five Colleges Radio Observatory, the Haystack Observatory, the California Institute of Technology Owens Valley Observatory, the submillimeter dish just going into service in Hawaii, etc.) which are part of the grants program, but which support the Astronomical Community as a whole. Several other major centers currently under consideration, such as as a joint Massachusetts Institute of Technology/ California Institute of Technology facility for the detection of gravitational waves, and submillimeter wave interferometer arrays at the California Institute of Technology and the University of California, Berkeley, have important implications for astronomy. Clearly, the concept which underlies the Science and Technology Centers has already been very fully exploited by astronomers, so that in contrast to the foundation as a whole where 60% of the research funds go to individual grants, only 35% of astronomy funds go to individual grants. Recently, a subcommittee of the Astronomy Advisory Committee, chaired by Dr. Joseph E. Salah, examined the balance between centers and grants in astronomy, and concluded that it is at an appropriate level, now, and that a further decrease in grant support would be harmful. On the other hand, the services and leadership provided by the national centers, and by the university run centers discussed above are essential, and support the community as a whole.

Because the center concept has been so useful to astronomers, I can see how it can be useful elsewhere, and of course, these are examples of the powerful role that centers play elsewhere in the physical sciences (the Centers for Material Research, for example). On the other hand, I must strongly emphasize that "taxing" or "mortgaging" research funds that would otherwise have gone to astronomy, or the physical sciences in general, to support the development of centers in other disciplines is counter productive. Even a casual examination of the NSF budget gives a very strong impression that the physical sciences in general, and astronomy in particular, have been taxed the most heavily of any discipline to support an initiative from which they my have less to gain than other disciplines. It is ironic that although the effectiveness of the center concept has perhaps been most strongly demonstrated by astronomy, astronomy will suffer the most severely from the new Science and Technology Centers initiative, and perhaps benefit the least. The support for this new concept must come from *additional resources*, not by crippling our core programs in the physical sciences. The situation in regard to the funding for the grants program is most critical. Recently, a sub panel of the Advisory Committee of the Division of Astronomical Sciences, chaired by Dr. William A. Baum of the Lowell Observatory, examined 260 proposals for grant research in the division. The panel concluded that the quality of many of the rejected proposals is very high, and represents research that strongly merits support. The problem was especially acute in extragalactic astronomy and cosmology. It is gratifying to see that this problem has been highlighted with a new initiative in cosmology. We note, however, that without the cosmology initiative, the increase in the grants budget proposed for FY 1989 would have been even more inadequate and represents, therefore, a cut in support for other areas of astronomical research; we also note that astronomy will receive less than half of the funds earmarked for the cosmology initiative.

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1 NOAO is the National Optical Astronomy Observatory, with observing sites at Kitt Peak in Arizona, Sacramento Peak in New Mexico, and Cerro Tololo Inter-American Observatory in Chile.

2 NRAO is the National Radio Astronomy Observatory with observing sites in Green Bank, West Virginia, in Kitt Peak, Arizona, and in Socorro, New Mexico.

3 NAIC is the National Astronomical and Ionosphere Center in Arecibo, Puerto Rico which carries out research both in radio astronomy and ionospheric physics.

4 HAO is the High Altitude Observatory of the National Center for Atmospheric Research which carries out research in Solar Physics at Boulder, Colorado, and on Mauna Kea in Hawaii.

The Impact of the Size of the New Science and Technology Centers Program on Other Centers and Large Facilities: The fiscal problems of the three national centers supported by the Division of Astronomical Sciences [NOAO, NRAO and NAIC (HAO, as part of NCAR is supported by the Division of Atmospheric Sciences)] are extremely severe. Figures 3a and 3b illustrate the impact of the very restricted budgets of the last four years on the actual purchasing power of the NRAO and NOAO budgets. In spite of the decrease in purchasing power of their budget, the national observatories have supported the research of a growing number of astronomers, as Figure 4 illustrates. They have achieved this remarkable record with a declining staff, as reductions in force have become an annual ritual (Figures 5 and 6). Despite the disruptive effect of these layoffs, all of the national observatories have maintained an almost constant level of high quality service, leadership, and research. This has been achieved by the dedication of the staff, the reduction of services which has been compensated by increased efforts by the users, and by postponing critical maintenance and the development and implementation of critically needed new capabilities. The impact of the 1988 budget has been especially severe, because of the mandated reductions which occurred after the fiscal year was well under way (Table 2). The result of this has been that both observatories must cut drastically into very basic programs in 1988 and utilize all reserves, since even more drastic measures are necessary than would have been required if the amount planned for 1988 had been announced earlier. For 1989, the picture is equally daunting. Table 3 shows the budget levels proposed for 1989. Note that the FY 1989 budget request is below the original FY 1988 budget request, by $2.5 million!

The President of AURA, the consortium of universities which operates NOAO, has stated; "Long-Term curtailments or elimination of programs to reduce the NOAO budget to the level of funding scheduled to be available in FY 1989 [are necessary]. Continued operation of all sites at the current level plus the scheduled [increase] in [expenditures] for the Global Oscillations Network requires **$3 million more** than has been requested in the budget submitted by the President to Congress."

NRAO has been forced to lay off 19 employees, reduce 2 full time employees to part time, and cancel 15 open positions to meet the cost limitations imposed by the 1988 budget. In 1988, NRAO is operating the unique and powerful Very Large Array Telescope (VLA) on an operations budget, which is the same, in terms of purchasing power, as the operations budget before the VLA was placed into operation. The proposed FY 1989 budget level will not allow the many urgent problems which have developed as a result of chronic under funding of the observatory to be addressed. These include, according to the President of AUI (the consortium of universities which operates NRAO):

- The staff is overburdened and underpaid;
- Investment in future instrumentation is at an unprecedented low level;
- Deferred maintenance threatens the vitality of major facilities;
- Urgent computing needs remain unaddressed;
- The operational needs of the Very Long Baseline Array are not being met;
- The technology development program that has been so important to the success of radio astronomy in the U.S. is in danger of being lost altogether.

Clearly, the impact of the FY 1989 plan on the national astronomy centers is devastating. After studying the 1989 NSF budget plan, it is difficult to avoid the conclusion that one of the major factors driving the severe budget crisis in astronomy is the allocation of funding to start the Science and Technology Centers program at so high a level.

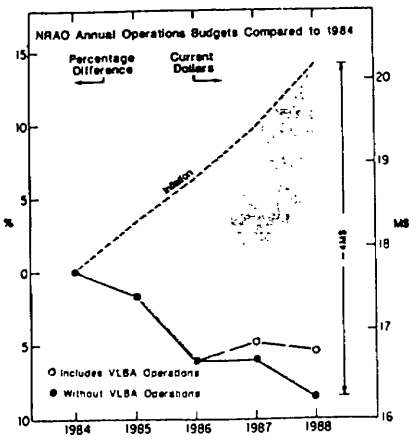


Figure 3a

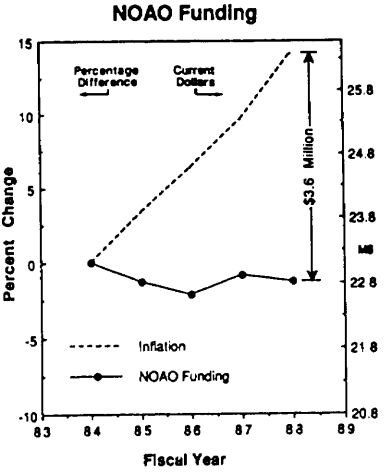


Figure 3b

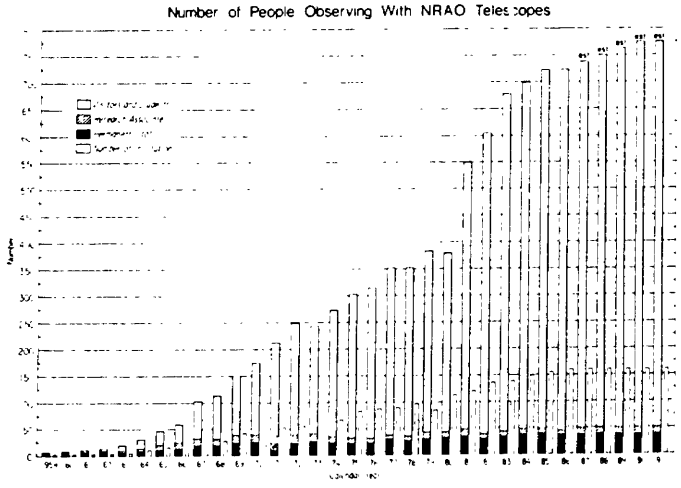


Figure 4. The number of NRAO permanent staff, research associates and visitors who use NRAO telescopes for each calendar year. The number of institutions represented by the visitors is also shown. The significant increase in visitor use in 1981 reflects the increased use of the VLA. A similar increase can be anticipated when the VLBA is fully operational.

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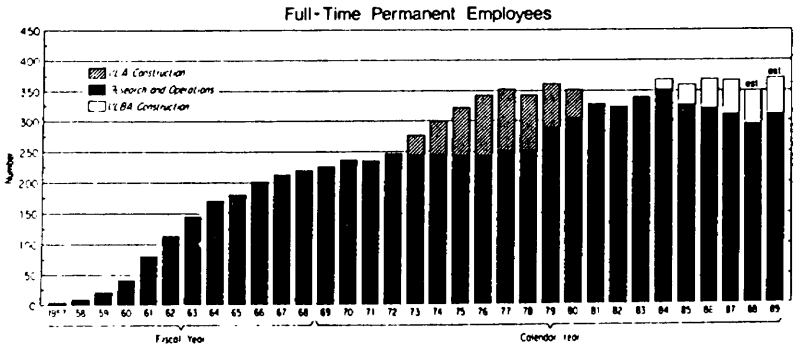


Figure 5. This figure shows the total number of NRAO full-time, permanent employees at the end of each year, projected into the future.

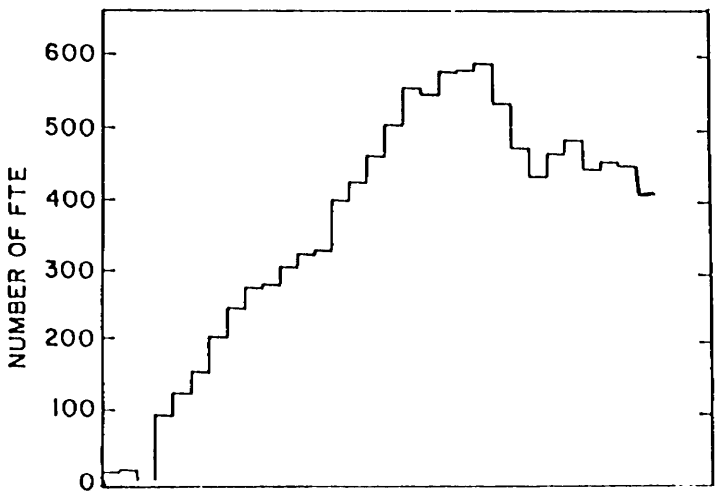


Figure 6. Employment for NOAO base programs (not including the Global Oscillations Network and the New Technology Telescope Development).

Table 2

CHANGES BETWEEN THE FY 1988 BUDGET AND THE FY 1988 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1987 Actual	FY 1988 Request	FY 1988 Current Plan	Change Dollar	Change Percent
Astronomy Project Support	$27.66	$29.51	$27.89	$-1.62	-5.5%
National Astronomy and Ionosphere Center	5.88	6.30	5.93	-0.37	-5.9
National Optical Astronomy Observatories*	23.10	25.80	23.30	-2.50	-9.7
National Radio Astronomy Observatory*	28.40	30.95	28.90	-2.05	-6.6
Total, Subactivity	**$85.04**	**$92.56**	**$86.02**	**$-6.54**	**-7.1%**

Table 3

FY 1989 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1988 Current Plan	FY 1989 Request	Change Amount	Change Percent
Astronomy Project Support	$27.89	$29.2	$1.32	4.7%
National Astronomy and Ionosphere Center	5.93	6.33	0.40	6.7
National Optical Astronomy Observatories*	23.30	24.40	1.10	4.7
National Radio Astronomy Observatory*	28.90	30.10	1.20	4.2
Total	**$86.02**	**$90.04**	**$4.02**	**4.7%**

* Includes construction and development (Global Oscillations Network and Future Telescope Technology Initiative at NOAO, Very Long Baseline Array at NRAO).

The Scientific Merit of the Science and Technology Centers, and Their Impact on the "Research and Related Activities": The Research and Related Activities (RRA) budget line of the NSF forms the principal support for the scientific infrastructure of the nation. The examples that I have given above for astronomy clearly demonstrate that, as a result of the very restricted budgets of the last 4 years, that infrastructure is beginning to crumble at an increasingly serious rate. The 1989 spending plan will only increase this rate of disintegration, and may well be the start of a collapse in that infrastructure. Although the problem in astronomy appears to be worse than anywhere else in the Foundation, the problem is a very critical one for everyone in the physical sciences. Therefore, to reduce or limit the growth of the RRA budget line, in order to start a new program, the Science and Technology Centers, is, in my view, a very serious error. Any gains that can be realized from the Science and Technology Centers will be more than offset by the loses which result in the basic program supported by RRA.

There is no question that more widespread use of the Center concept in science will have beneficial effects. It is difficult to see, however, how so rapid a startup can avoid some investments which will prove unproductive. Accordingly, I urge you to make sure that our basic scientific infrastructure benefits, rather than suffers from this new program.

The Appropriate Role for Land-Based Astronomical Operations in View of the National Space Agenda: I am especially pleased to be able to address this topic as an astronomer whose own research (on the x-ray emission of the sun) is carried out almost exclusively in space. I believe I am able to offer an objective opinion on the importance of land-based astronomy. My willingness to serve two terms on the Astronomy Advisory Committee of the NSF, which, of course, deals with land-based astronomy, demonstrates my conviction that *virtually every major question in astronomy* requires both space-based and land-based observations for *its resolution*. In many cases, it is obvious that a particular capability can only be carried out (given the limitations of present technology) in one milieu or the other. X-ray astronomy, for example, must be carried out from space, since x-rays cannot penetrate our atmosphere. The Advanced X-Ray Astrophysics Facility (AXAF)* remains the highest priority for space borne astronomy (after the successful launch and operation of the Space Telescope). An indication of the importance of x-ray observations is the discovery that the enormous volume of space between the galaxies bound in vast clusters on scales of millions of light-years, is filled with a very diffuse but hot (100,000,000 K) gas, which apparently contains as much matter as is contained in all the stars in the galaxies themselves. This matter was undetectable from the ground. I might point out that because of the long delay in funding the AXAF project, American x-ray astronomers who pioneered the field of x-ray astronomy, must now use Japanese, European, or Soviet x-ray satellites as guests, since the U.S. has no operational x-ray satellite.

In contrast, radio facilities, such as the Very Large Array and the Very Long Baseline Array, can provide resolution and sensitivity which can be matched by no other technique. These facilities are best deployed on the ground. The power of these new technologies is shown in Figure 7. The resolution of 0.001 arcsecond can be achieved by no other technique at present. In this field, the U.S. still leads the world, but the serious funding problems at NRAO hold very serious and negative indications for the future.

Another example, in this case referring to the study of a single object, the sun, is shown in Figures 8 and 9. Figure 8 is a graphical illustration of the fact that the sun oscillates in many modes. These oscillation modes are very analogous to the modes of oscillation of the Earth, after an earthquake. Just as the models that geologists have developed of the Earth's interior structure are based principally on the study of earthquake data, the sun's oscillation modes can provide a model for the solar interior. This is a critical matter for all of astrophysics, since our theory of stellar interiors and evolution is based solely on observations of stellar masses, surface temperatures, and radii. The only direct data on stellar interiors comes from the detection (by detectors located in mines deep underground) of high energy solar neutrinos generated by thermonuclear reactions in the sun's core by Dr. Raymond Davis and colleagues. This

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* *Astronomy and Astrophysics for the 1980's* , Volume I, National Academy Press, 1982

NATIONAL RADIO ASTRONOMY OBSERVATORY
ATTN: INFORMATION SERVICES EDGEMONT ROAD CHARLOTTESVILLE, VA 22903-2475 USA
TELEPHONE 804-296-0211 FAX: 804-296-0278

IMAGE DESCRIPTION/NRAO FILE NUMBER: RGW/2H

ARTICLE 1 (a) (part of this image) may be used freely [illegible] provided that [illegible] Associated Universities, Inc. (AUI) under contract with the National Science Foundation (NSF).

CREDIT LINE: Courtesy NRAO/AUI ACKNOWLEDGMENT: Observer(s) Listed Below

DESCRIPTION: 3C 120 Montage.

3C 120 is another of the superluminal sources that has been studied since the early 1970's. The radio source is in a galaxy, usually classified as a Seyfert, at a redshift of 0.033. As such it is the closest of the superluminal sources and is therefore the one that allows the most detailed studies of the environment. This montage shows the radio structure of 3C 120 on all scales from a parsec to hundreds of kiloparsecs. It demonstrates that a continuous structure connects the superluminal features and the large scale, one-sided jet. It also shows that 3C 120 has a lobe (or outer part of a counterjet) on the side opposite the jet and complicated structure on the largest scales. The brightness of the jet evolves simply over the entire length showing that the basic physical parameters are established on the parsec or sub-parsec scales and evolve in a relatively simple manner as the jet travels from the galactic core to outside the galaxy.

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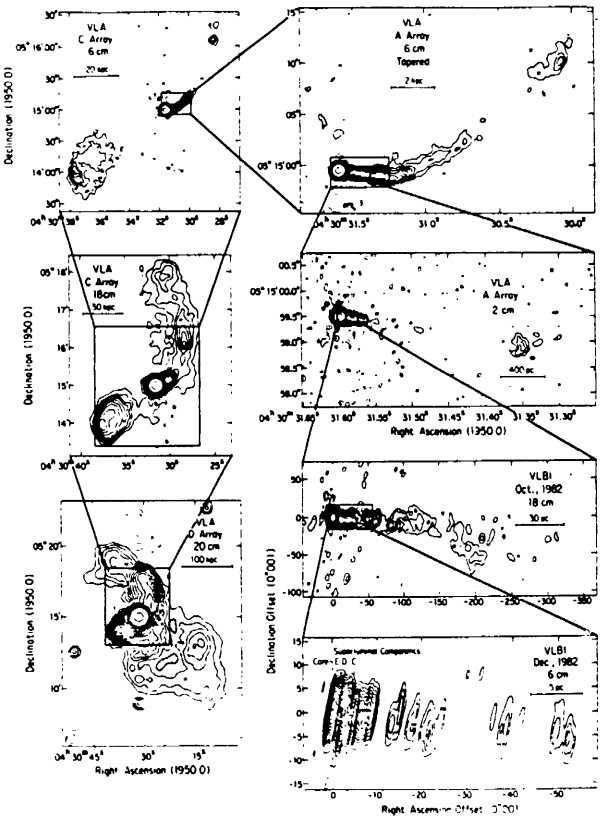
Source: 3C 120 (Seyfert Galaxy at Z=0.033)

Instruments: VLBI - U.S. VLBI Network plus EVN.
VLA - Several configurations.

Frequencies: 1.4, 1.6, 5.0 and 15 GHz.

REFERENCES:

Walker, R.C.
Benson, J.M.
Unwin, S.C.
1987, Ap.J., 316, 546.

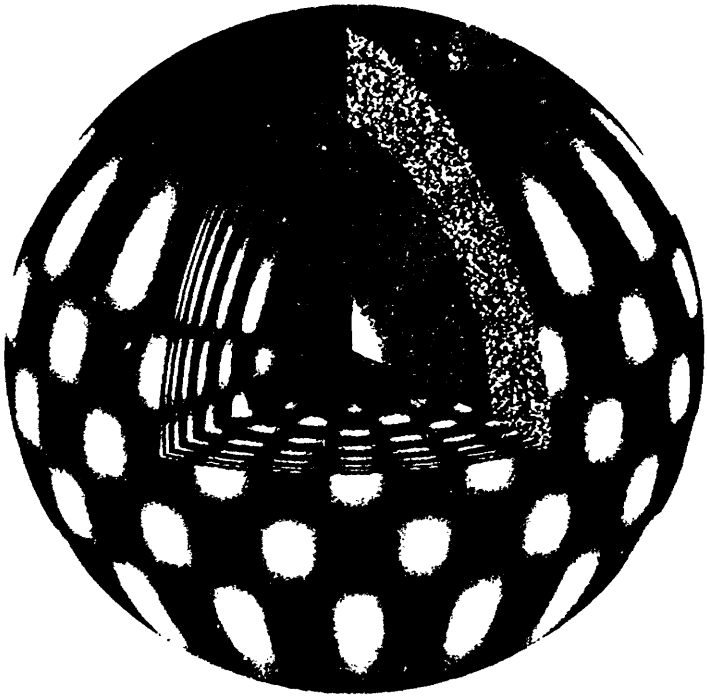


National Optical Astronomy Observatories

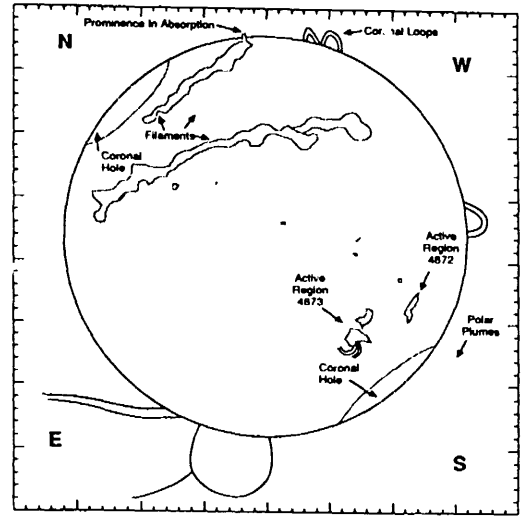
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Kitt Peak National Observatory • Cerro Tololo Inter-American Observatory • National Solar Observatory • Advanced Development Program

4103 — A computer representation of one of nearly ten million modes of oscillations of the Sun shows receding regions in red tones, approaching regions in blue. By measuring the frequencies of many such modes, and using theoretical models, solar astronomers can infer much about the internal structure and dynamics of the Sun. This novel technique, called helioseismology (for its resemblance to terrestrial seismology), is at the heart of a new NOAO program to develop an international network of instrumented stations that provide continuous measurements of such oscillations, and a greatly extended understanding of our nearest star.







THE SUN AT 1,000,000 K

Stanford/MSFC Rocket X-Ray Telescope, Flight 27.082, Oct. 23, 1987, 18:08 UT

Center for Space Science and Astrophysics, Stanford University
NASA, Marshall Space Flight Center
Lawrence Livermore National Laboratory

Arthur B. C. Walker, Jr., Joakim F. Lindblom, Richard B. Hoover, Troy W. Barbee, Jr.

This image represents the first high resolution image of the sun in the soft x-ray/extreme ultraviolet regime obtained with a normal incidence Cassegrain multilayer telescope. The image was recorded above an altitude of 100 miles during a sounding rocket flight launched from White Sands Missile Range on October 23, 1987. The telescope mirrors were coated with a Mo/Si multilayer surface, allowing the telescope to operate in a spectral regime not previously accessible with traditional Cassegrain configurations. Multilayer coated optics is a powerful new technology which promises to significantly enhance laboratory and astronomical imaging in the soft x-ray/extreme ultraviolet. The bandpass of the telescope is 171 - 176 Å, where the solar continuum is dominated by Fe IX and Fe X lines produced by coronal plasma at 0.95 - 1.3 million degrees K. This 200 second exposure was recorded on a special soft x-ray/extreme ultraviolet sensitive T-Grain emulsion recently developed by Eastman Kodak.

This research was sponsored by the National Aeronautics and Space Administration.

experiment demonstrated that our model of the solar interior must be revised, perhaps in a major way, since the measured high energy neutrino rate from the solar interior is only one-third of the rate expected on the basis of our best models. (Ironically, although the discovery of neutrinos and the first detection of neutrinos from the sun were achieved by U.S. scientists, the next step in the study of solar neutrinos will be taken by a team of Soviet and German scientists who will study low energy solar neutrinos. Funding for this experiment, which uses a different type of neutrino detector than used by Davis and his colleagues, could not be provided by the NSF.) The study of solar oscillations is an innovation developed by U.S. scientists. The major new instrumental initiative currently under development at NOAO, is a network of ground based observing stations, the "Global Oscillations Network", for the study of this phenomena. Unfortunately, as I pointed out above, the FY 1989 plan will further delay the implementation of this important project.

Figure 9 is an example of the unique role that space observations can play in the study of the sun. It is an image of the solar corona, which is sensitive to material at ~1,000,000 K, obtained by myself and three of my colleagues. It is the first high resolution image of an astronomical source using a new technique for imaging x-rays developed by Dr. Troy Barbee of the Lawrence Livermore Laboratory (Dr. Eberhard Spiller of the IBM research laboratories independently developed the same technology). Before the advent of space observations, the corona could only be studied during solar eclipses, and then only at the limb of the sun. The technique utilized to obtain Figure 9 will provide higher resolution images of the sun's corona, and other sources of celestial x-rays, than can be achieved by other techniques. This image also illustrates the interaction of astronomy and technology, since this new technique of x-ray imaging will have applications in medicine, biology, and materials science and technology.

Perhaps one more example is appropriate, involving the Space Telescope. The Space Telescope will achieve a resolution of 0.06 arcseconds, a 3-fold increase in resolving power over that which can be achieved at the best land-based sites. This will enable the Space Telescope to detect fainter objects than can be observed on the ground, greatly expanding the volume of the universe that we can sample, and will allow us to observe objects in the ultraviolet, at wavelengths that cannot penetrate our atmosphere. In view of the enormous advances that the Space Telescope is expected to achieve, some have asked why astronomers still wish to build optical telescopes on the ground. In fact, as Table 4 shows, the last several years have witnessed the greatest period of planning and fund raising for large land-based telescopes in history. Recently, the European Southern Observatory (ESO) has been given the authority to precede with the development of the VLT telescope (to consist of four 8 meter telescopes) with an equivalent aperture of 16 meters) by its member nations. The Japanese National Telescope with 7.5 meter aperture, which will be placed in Hawaii, is very near approval, raising the possibility that the largest publicly owned telescope on U.S. territory will be owned by Japan! The reason that so many nations and universities wish to build large land-based optical telescopes is that the collecting area of the space telescope is only 4.7 meters, about 2.5% of that of the proposed National New Technology Telescope (NNTT). To determine the spectra of a very distant galaxy, which is essential to determine its distance and many other characteristics, it would require 40 times as much observing time with the Space Telescope as with the NNTT. Clearly, carrying out this type of observation with an expensive and unique instrument such as the Space Telescope, rather than with a more efficient land-based telescope such as the NNTT would be a very inefficient use of a unique resource. Viewed in another way the NNTT can be 400 times as cost effective for certain types of observations as the Space Telescope. Of course, only the Space Telescope can make the many essential observations of very faint objects, observations at very high resolution and observations in the ultraviolet portion of the spectrum to which the Earth's atmosphere is opaque. Clearly, land-based and space-based observations are highly complementary to each other. A *scientifically productive and cost effective* program *must have both capabilities* in the *correct proportion*. I was privileged to have participated in the last National Academy of Sciences Astronomy Decade Study, chaired by Dr. George Field*. I believe that the plan presented by the Field Report contains a balanced program of

* Astronomy and Astrophysics for the 1980's, Volume I, National Academy Press, 1982.

Table 4: Existing and Planned Telescopes with Apertures >= 2.5 M
Apertures in Meters, Areas in Square Meters

Apert.	Name	Mountain	Area	$M		Leader	Owner
2.5	Dupont	Las Campanas	4.9	10		MWLCO	US
2.5	Newton	La Palma	4.9			Royal Greenwich	UK
2.6	Byurakan	Yerevan	5.3			Byurakan	USSR
2.6	Crimean Shajn	Simeiz	5.3			Crimean	USSR
2.7	McDonald	Mt. Locke	5.7	5.9		U Texas	US
3.0	IRTF	Mauna Kea	7.5	10		NASA	US
3.0	Shane/Lick	Mt Hamilton	7.1	3		U California	US
3.5	German-Spanish	Calar Alto	9.6			GS Astron. Obs.	FRG
3.6	CFHT	Mauna Kea	10.2	30		Canada et al	CAN
3.6	ESO 3.6	La Silla	10.2			ESO	INT
3.8	UKIRT	Mauna Kea	11.3			Royal Greenwich	UK
3.9	Anglo Australian	Siding Spring	11.9			UK et al	UK
4.0	CTIO 4 meter	Cerro Tololo	12.6	10		NOAO	US
4.0	Mayall	Kitt Peak	12.6	11		NOAO	US
4.2	Herschel	La Palma	13.9			Royal Greenwich	UK
4.5	MMT	Mt Hopkins	15.9	7.5		C f A et al	US
5.1	Palomar-Hale	Mt Palomar	20	6		Cal Tech	US
6.0	Special Astr. Obs.	Zelenchuk	28			USSR Academy	USSR
		Total:	196.9				
3.5	ARC	Apache Peak	9.6	10		U Washington et al	US
3.5	ESO 3.5	TBD	9.6			ESO	INT
3.5	Iraq 3.5	TBD	9.6			Iraq Government	Iraq
3.5	WIN	Kitt Peak	9.6	12		U Wisconsin et al	US
6.0	USSR 6	TBD	28.3			Leningrad U	USSR
6.5	MMT Upgrade	Mt. Hopkins	42			C f A et al	US
7.5	Japan NLT	Mauna Kea	44			Tokyo Observatory	JAP
7.6	Penn	Mt. Locke	45			Penn State U.	US
8.0	Magellan	Las Campanas	50			Carnegie	US
8.0	NOAO North	Mauna Kea	50	50		NOAO	US
8.0	NOAO South	TBD	50	50		NOAO	US
10.0	Keck	Mauna Kea	76	87		Cal Tech	US
11.3	Columbus	Mount Graham?	88			U Arizona	US
12.0	German 12	TBD	90			German Universities	FRG
16.0	NNTT	Mauna Kea	176	200		NOAO	US
16.0	VLT	Cerro Vizcachas	200	250		ESO	INT
19.6	UK 20	TBD	300				UK
25.0	USSR 25	TBD	490				USSR
		Total:	1,767.7				
		Total:	1,964.6				

Based in part upon material provided by Jean Goad and Jacques Beckers

both space- and land-based research. Unfortunately, very few of the major recommendations made by the Field Committee have been carried out. Indeed, several of the programs assumed to be approved and ongoing in the report, namely the Solar Optical Telescope and the Space Infrared Telescope Facility, are not yet begun. The major recommendation for land-based optical astronomy, the 16 meter NNTT, seems at this point many years in the future. The only major initiative recommended by the Field report which has been started, the Very Long Baseline Array (VLBA), is proceeding at a depressingly slow rate.

The concepts and technologies for the new generation of land-based optical telescopes were developed largely in the U.S. It appears now that U.S. astronomers will be forced to watch their European, Japanese and Soviet colleagues utilize our concepts and technologies to forge ahead of us in optical astronomy. It is interesting to note that the director of ESO recently commented that approval of the VLT project by the ESO member countries would not have been possible without the enthusiastic support of the high technology industry in those countries, who saw important advantages in the technology of the VLT for themselves. The importance of science at the very frontier of knowledge for a nation's economic health is clearly accepted by these nations.

In summary, the program proposed in the Field Report is a well balanced program which uses both space- and land-based facilities. Clearly, the European, Japanese and Soviet astronomical programs have learned the lesson that U.S. astronomers were the first to emphasize, that there is great synergism between these two ways of viewing the universe. Presently, we are in danger of falling behind (or have actually fallen behind) in certain aspects of both arenas; the danger; is most urgent, however, in regard to land-based astronomy because of the severe budget restrictions I have already discussed.

Priorities Within the National Science Foundation: The very slow growth of funding of the RRA budget line for the physical sciences in the NSF is a very serious matter of concern. I am aware that the NSF has been given new responsibilities, and that a major expansion of the NSF budget is planned to allow the NSF to effectively address these new responsibilities. Unfortunately, the pace at which these responsibilities have been, or are scheduled to be implemented,has clearly exceeded the rate at which the NSF budget has grown. It appears that this imbalance between responsibilities and resources has struck most deeply in the area of support for the basic programs of research in the physical sciences. For example, the FY 1989 proposed astronomy budget of $90.04 million, is actually $2.5 million **below** the **original** FY 1988 request of $92.56 million. Figure 10 shows how funding for astronomy has fared over the past 4 years, compared to the overall NSF budget. The situation, especially in astronomy, has now reached the point that the basic infrastructure of the national observatories, and of university based research groups has begun to crumble, and may, if the situation is not addressed immediately, suffer damage that will require years to repair. If this occurs, the competitive situation in which we find ourselves, with loss of leadership having already occurred in a few fields, about to occur in others, and with our leadership being strongly challenged almost everywhere, may deteriorate very rapidly. I urge you to address the question of the low priority accorded the physical sciences in the NSF budget, over the past four years especially, immediately in the FY 1989 authorization.

The Erosion of Our National Position of Scientific Leadership: One of the most depressing aspects of the budget restrictions in astronomy in the last several years is the loss of scientific leadership in the areas that were pioneered by U.S. astronomers. An example is the field of millimeter wave (mm wave) astronomy. At these wavelengths, it is possible to study the interstellar gas clouds that are the birthplace of stars. One the most startling discoveries made in this wavelength interval is the ubiquitous presence of *organic molecules* in interstellar gas clouds, raising the possibility that the raw materials for living organisms may have evolved in interstellar space, and then been "seeded" onto planets. Approximately 10 - 12 years ago, U.S. astronomers proposed that the NSF build a 25 meter diameter mm wave antenna, in order to exploit the observational techniques that were pioneered here. Unfortunately, the project, although once included in President Carter's budget, was not approved and started in a timely manner. Before the U.S. could exploit this new technology, German astronomers secured approval to construct a 30 meter antenna and Japanese scientists secured approval to construct a 45 meter antenna. Both of

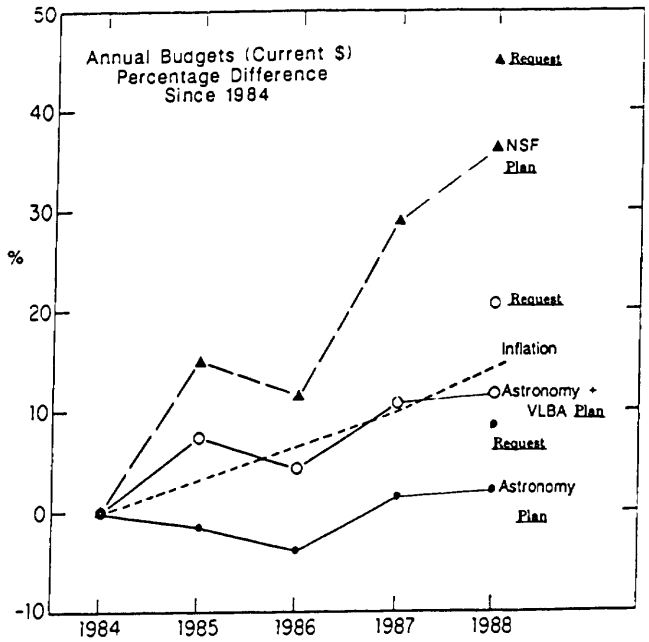


Figure 10

these facilities are now in operation, while a competitive U.S. facility was not built because we were simply too slow to act. The U.S. has now lost leadership in mm wave spectroscopy, although an excellent program is still carried out at the 10 meter mm wave antenna run by NRAO at Kitt Peak.

Recently, U.S. astronomers, principally at the University of California, Berkeley, at California Institute of Technology, and at NRAO have developed techniques to build mm wave interferometers, in order to secure the advantages of high angular resolution at mm wavelengths, in a manner analogous to the way that the VLA can obtain arcsecond level resolution at centimeter wavelengths. The NSF grants program has two very highly rated proposals to build mm wave interferometers, but has been unable to fund them. NRAO has also developed a design for a national mm wave interferometer. Unless the present trend in the NSF Astronomy Division budget is reversed, we are likely to again see a technology originally developed in the U.S., exploited elsewhere.

Translating Research into Technology, and Technology into Productivity: There is no question in my mind that the U.S. leads the world in scientific creativity. I believe that our system of open competition for scientific funding and peer reviewing is a major, perhaps the major factor, in this leadership. When it comes to translating this creativity into technology, our lead is a little less secure, and when it comes to translating our lead into productivity, whether it is scientific or industrial productivity, we often fail. I have cited several examples of this failure in the scientific sphere, and I am sure that you and other Americans can easily cite examples in the industrial and

consumer spheres. I believe that we must develop a more cooperative mode, for these no less important components of our scientific and technological activities, to complement our competitive mode which works so well in the creative arena. It is important to remove barriers to teamwork that may inhibit the process of application of creative new ideals to technology, scientific research and industrial production.

Science Education: I would like to very strongly commend the NSF for their decision to focus on Education and Human Resources in the FY 1989 plan. I know that Mr. Bloch very strongly supports these activities, and he is to be commended for the NSF's achievements in this area. As a black American, I am especially saddened by the enormous waste of so much of the human potential in those groups that have been under represented in science and engineering. I am very pleased to see the large increases in the FY 1989 plan aimed at increasing the participation of individuals from minority groups, women, and disabled persons in science. In the competitive environment of our present world, the United States cannot afford to waste any part of its human resources, and, of course, justice demands that our pledge of equal opportunity for every American must become a reality.

It is important, also, to offer incentives to universities which have demonstrated a commitment to the education of women and minority individuals. Considerable progress has been made as compared to 25 years ago, but we must do more. For example, when I was a student at the University of Illinois in the early 1960's, I was the only black student among 200 graduate students in Physics during my five year tenure as a graduate student. I do not believe that there were any Native American, Chicano or Puerto Rican students in the University of Illinois' graduate physics program during this period, and there were very few women. In contrast, we presently have at Stanford among the 200 Ph.D. students in the Departments of Physics and Applied Physics, 11 black students, which I believe represents 25% of the black students pursuing the Ph.D. degree in physics in the United States at present. This year the two departments offered admission to 8 Black, Chicano, Native American and Puerto Rican students to study for the Ph.D. degree starting in September of 1988 (I do not yet know how many will enroll). Unfortunately, with the exception of the Massachusetts Institute of Technology, no other major research university has a record in regard to educating individuals from minority groups in Physics approaching that of Stanford. I relate these statistics not so much to complement my colleagues at Stanford, although I do believe that they are due high praise for their efforts, as is our university's administration, but to emphasize that the NSF cannot accomplish its task without more cooperation from the universities. Hopefully, Mr. Bloch's strong initiative will help in securing that increased level of cooperation.

I would also like to emphasize the importance of the multi-level approach that the NSF has taken to science education, with programs at post graduate, graduate, undergraduate and public school levels. We are simply not training our students adequately in science, and we are not training enough scientists at the Ph.D. level. Recently, I read a report on a series of tests (the Second International Science Study) of science and mathematics achievement given to students in elementary, middle level and secondary schools in 17 countries* . U.S. students were not in the group of countries where achievements were at the highest levels, rather our students were in the middle group or below. U.S. elementary school students were 8th among students from 15 nations, at the intermediate level U.S. students were 15th among students from 17 nations, and at the high school level U.S. students were at the bottom of the rankings. I have sat on the Ph.D. admission committee in the Department of Applied Physics at Stanford for the last ten years, and on the admission committee of the Physics Department for the last six years. I find that over the years, the competitive position of U.S. students has declined compared to that of the applicants from Europe and Asia (the applicants from the Americas, New Zealand and Australia, the Middle East and Africa are too few in number for any trend to be ascertained). Clearly, we are not preparing our students for the highest level scientific education as well as are some other nations. We must do better, if we do not, the increased funding of the NSF science programs which I urge you to provide, will not be effective.

* San Francisco Chronicle, Monday, February 29, 1988, page A6.

BIOGRAPHY

Arthur B.C. Walker, Jr.

Arthur B.C. Walker, Jr. received his B.S. in Physics with honors from Case Institute of Technology in 1957, and the Ph.D. Degree in Physics from the University of Illinois in 1962. In 1962, Dr. Walker entered active duty with the U.S. Air Force and was assigned to the Air Force Weapons Laboratory with the rank of 1st Lieutenant. While at the Weapons Laboratory, Dr. Walker carried out research on the radiation environment of the Earth's magnetosphere. In 1965, upon completing his military obligation, Dr. Walker joined the Space Physics Laboratory of The Aerospace Corporation as a member of the technical staff. He conducted experimentation in solar physics and upper atmospheric physics, specializing in studies of the solar x-ray flux. While at the Aerospace Corporation, Dr. Walker advised a number of Air Force Project Offices on techniques for satellite-borne nuclear burst detection systems, and other satellite instrumentation problems. In January of 1974, Dr. Walker was appointed Associate Professor of Applied Physics at Stanford University. At Stanford, Dr. Walker has continued his experimental research in solar and non-solar x-ray astronomy and has taught astronomy at both the graduate and undergraduate levels. He has also supervised the dissertation research of five students who have received their Ph.D. degrees at Stanford, including Dr. Sally K. Ride, who became the nation's first woman astronaut. Dr. Walker served as Associate Dean of the Graduate Division of Stanford from 1975-1981. During his tenure as Associate Dean, Dr. Walker enhanced the programs of the University for expanding the enrollment of Black, Chicano, Native American and Puerto Rican students in its Graduate Programs. Stanford is recognized as a leader among major research universities in educating students from minority communities at the graduate level.

Dr. Walker has developed several rocket and satellite instruments for the spectroscopic study of the solar corona, including Bragg crystal spectrometers flown on the Air Force OV1-10 and OV1-17 satellites, and grazing incidence Wolter and normal incidence multilayer Cassegrain x-ray optical systems flown on rockets. He has also studied the abundance structure of the Interstellar Medium.

Dr. Walker is presently Professor of Applied Physics at Stanford University. He has served on or chaired a number of NASA, National Science Foundation, and National Academy of Science Committees which prepare recommendations on the future course of astronomy and astrophysics. Dr. Walker has also served as a member of the Harvard Board of Overseers Visiting Committee to the Department of Astronomy. Presently, Dr. Walker chairs the Advanced Solar Observatory Science Working Group for NASA and chairs the Astronomy Advisory Committee of the National Science Foundation.

In 1986, President Ronald Reagan appointed Dr. Walker to the Presidential Commission on the "Space Shuttle Challenger Accident".

Mr. WALGREN. Well, thank you very much, Dr. Walker.

The—there is this emphasis on the fact that the centers somehow should not invade the research effort that is going on in individual grants, to begin with, or the directorates, as I understand it, and that's why they are set out in a separate line item for authorization. And yet do any of you have any doubt that they would limit the ability of the elements of the NSF funding individual research from providing a level that you would feel you would want to do, before you did the centers?

As I heard, particularly, Dr. Silcox close, the thought is that individual research is—if we don't keep up on that level, then really the centers will not be able to make a critical contribution.

Dr. SILCOX. Yes. Let me try to address that issue.

First of all, let me give you a picture of how I see the centers operating. I strongly suspect the scientists that will be in the centers will operate in much the same way that scientists in our MRL's operate.

In other words, they are likely to have some of their own individual research individually sponsored; and, in addition, they will be receiving support from a center to do work that is related to what they're doing in their individual field, and yet be able to focus that in a way that can more meet the needs of the centers.

It's highly unlikely, I think, that any scientist will essentially be able to support everything that he wants to do through a particularly focused center; and, it's in that context that I fear that, if we don't have the individual scientists there following their own ideas, that we really won't be able to pull together what we need to make the science and technology center work.

And let me back off a little and comment on what seems to have happened over the last 3 years, is that we have seen the Foundation committed to the development of super computer centers. We have seen them committed to the development of engineering research centers. Those are again things that are good in their own right.

In fact, materials is likely to benefit very greatly from the availability of supercomputers. One of the things that it's going to make possible is to be able to calculate things that emerge from sort of what we know about atoms and molecules and be able to calculate up from there to a point where we can calculate what real materials should be able to do. We haven't been able to do that up till now. And so that's a real step forward.

But if we don't have the scientists around there who are willing, anxious to get in and use the computer centers, then the supercomputer is not going to be of any value. And it's at that kind of a level that I'm getting really seriously concerned.

The Foundation has been in level funding. We've had commitments to the ERCs and the supercomputers. Those have grown over that period. You can, if you look at it, see indications where it seems as though the Foundation's budget for centers has clearly grown. This has impacted back on—I mean I can't see how it can do other than to actually have taken money out of the individual investigator programs. And, you know, I talked a little bit about what I see in my community. I have seen steadily growing cutoff

levels to the point that it's getting close to ridiculous in terms of the way the peer review operates.

You're at a point where, you know, I've got two proposals that are equally good. How do I fund one and not the other? It's really a disastrous situation from that stage. And that's going to rebound. If a scientist comes—you know, thinks I come up with a real good new idea that I want to get funded and then it's a random choice whether it gets funded or not, then the morale is going to drop; students are not going to want to come into the——

Mr. WALGREN. But the premise that we should accept is—is that funding the centers is going to erode the funding for individuals?

Dr. SILCOX. That's been the pattern over the last 3 years, as far as we can see.

Mr. WALGREN. Well, let me ask one other thought here that—when we take a snapshot of people's views about what the proper balance between centers and individual research is, they always say, well, the present balance between individual investigators and centers is what would be all right; but, if we further erode the individuals, then obviously we are going to lose an important value.

Now if you look at astronomy, where 60 percent is—60 percent of the astronomy budget is now committed to centers, I gather that that was not always the case; that in times past a lesser percentage of astronomy budget was committed to centers and more was committed to individual support.

And so is the astronomical side of things an example of how the centers, once started, continued to grow at the expense of individual support?

Dr. WALKER. Well, I think astronomy is a little bit different, because we do require large facilities. The balance has not changed substantially over the last 10 years. The centers have, I think, matured; and, recently a subcommittee of the Advisory Committee to Astronomy of the NSF looked at this question. They were asked to do so by Mr. Bloch, and the conclusion of that subcommittee was that the balance was just about right for astronomy. That wouldn't say anything about other disciplines; but, for astronomy, it was just about right. But people were very concerned that any further erosion in the individual grant program would be a very serious problem because, of course, the training of students is also very closely tied to the individual grants. And so astronomers, I think, are happy with the balance; but, they would not like to see any change in that balance, particularly a change which would be at the expense of the individual grants.

Mr. WALGREN. Dr. Silcox.

Dr. SILCOX. Could I come back on that issue as well?

Roughly, in materials research, we have had about 40 percent of our budget go into centers. This includes national centers for synchrotron radiation, small angle neutron. It includes the MRL program, and it includes a new program called Materials Research Groups.

We have operated with that kind of balance in the community for about the past 10 years, just like astronomy. One of the things that has happened in the last 5 or so years is the feeling within the community that a smaller group program, somewhere between the MRL program and the individual investigator, was needed, and

that has actually come to fruition. I think the budget this year includes an extra $1.5 million to bring that up to a level operation.

If one looks at the history of that, that program has basically been funded by decreasing the MRL program. That has dropped from about 14 laboratories to about nine, and the difference in the funding that has come is what has basically funded the materials research program.

We have felt over the years that no more than 40 percent of the resources should actually go into the group programs in our field. That seems to be the right balance.

One of the concerns that one might reflect is that if one looks at the 300-odd proposals that have been submitted for science and technology centers, very close to a third of them are in materials research and technology. And if, let's say, one were to see, you know, a significant fraction of the STC program to come into this game without the additional funding for the individual investigators, that would actually significantly perturb that historical balance which has looked to work reasonably well over the past 10 years.

So all I can do is look back 10 years and on that basis.

Mr. WALGREN. OK. The Chair would recognize the gentleman from California, unless there's a further comment that you'd like to add, Dr. Kleppner.

Dr. KLEPPNER. I would like to add the comment, if I may, that this—the S&T Center program was presented to the community as part of a program for overall growth of the National Science Foundation. It was to be accompanied by growth in support for the individual investigators. I think that was part of the guidelines to our committee. It was part of the understanding, and I think it's essential that that be part of the scenario.

The exact route by which the growth takes place is difficult to predict ahead of time. I think there really is concern, though, that the 6.3-percent increase for math and physical sciences for next year represents inadequate growth. The—that is a negative signal to the community which will have negative consequences.

Mr. WALGREN. The gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

It's difficult for me to know how to question you gentlemen, because I don't think I have any major areas of disagreement with any of you. We have to act in slightly different frameworks, but the members of this subcommittee are well aware of the importance of a strong and vital program of basic research, and the importance of the individual investigator, and all of the other things that you have pointed to.

We certainly would not like to see the science and technology centers detract from any of the other programs, which raises a question. Would you rather have the members of Congress deciding how to allocate the funds, or would you rather have Erich Bloch deciding how to allocate the funds over there?

I mean that's what your alternatives are, almost, when it comes to talking about balance within the Foundation. And I'm not quite sure that I would prefer that we make those decisions over here.

Do you wish to comment, Dr. Walker? You are a part of the operation.

Dr. WALKER. Well, of course, Congress, I think, has the ultimate responsibility for allocating funds; and, when the Congress sees a problem, I assume that it will address it. But I think that the mechanisms that are in place within the Foundation for allocating funds usually work pretty well, but I think there are times when perhaps those mechanisms produce a result which is less than desirable.

Mr. BROWN. Well, I'll tell you frankly right now, I'm getting a lot of calls from the academic community complaining about pork barrel science politics, and that's because we have intervened in some of these things. I'm sure you gentlemen know that.

Dr. SILCOX. Yes. In fact, in a sense, it's part of the problem, I think, that we're facing in that the community is growing; and, you are supporting buildings and various things; and, then, they're coming back and looking for research support.

Mr. BROWN. Correct.

Dr. SILCOX. And so, you know, it's the long-term consequences of that.

Let me just comment directly to your question. I think it's bad policy. I really think in general the NSF should decide; and, Mr. Bloch, no matter the way his decisions come down, I think he should be deciding. I don't believe Congress should be deciding.

Mr. BROWN. No matter how bad he is.

Dr. SILCOX. No matter how bad he is.

Mr. BROWN. He won't be as bad as Congress.

Dr. SILCOX. I think this idea is bad policy. And one of the pieces in my testimony, actually I said, if, in fact, you do go ahead and do this this way, for heavens sake, put a sunset clause on it and get it back into the regular budget of the NSF at some later stage.

Mr. BROWN. Well, let me make a point to you and see how you react to it.

The Congress and even this committee over the years has constantly harped at the National Science Foundation to do something relevant. You understand that. To make sure that we were getting the social benefit out of these investments in basic research.

Now that's a very shortsighted point of view for Congress to take, but they take it anyway, and I would like to pose the possibility to you that Dr. Bloch, in putting emphasis upon the engineering research centers and the science and technology centers, was trying to protect basic science by putting the emphasis in this relatively new structure on the quality of the science, but at the same time trying to broaden the matter, the mechanism for the funding of science to include a greater emphasis on technology transfer, on the involvement of the private research community and so on, in effect to try and take some of the heat away that he's getting from Congress without detracting from the quality of the science that's being produced.

Now how do you react to that?

Dr. KLEPPNER. That's certainly consistent with my own observations of the development of this program and the guidelines which have been laid out for the program.

You raise the question as to whether Eric Bloch should make the decisions on how NSF spends its money or whether this committee

should. I certainly agree that the Director of the National Science Foundation should be making those decisions.

Mr. BROWN. And this committee would make better decisions than any other part of the Congress, I assure you.

Dr. KLEPPNER. Well, the issue that I wanted to raise is the question not of priorities of spending with the NSF, but between NSF and other areas of national spending. Those obviously are decisions that Eric Bloch cannot make.

Mr. BROWN. Correct.

Dr. KLEPPNER. And I think that's really where the question lies. The question is, what fraction of our federal spending on research and development should be going to generate the new scientists and the basic knowledge that drives the whole enterprise. And I put it to you that the NSF budget is much too small to sustain those needs. And that's where I would really welcome your intervention.

Mr. BROWN. Well, for us to intervene with regard to the relative proportion of the federal budget that goes to NSF versus other things gets us beyond our jurisdiction, because our jurisdiction doesn't include the other things like, let's say, SDI or some of those other things that take up a large amount of science funding.

And so we're handicapped, and you know that; you understand that we live in a faulty or a flawed system, but we all need to take some responsibility for remedying those flaws, and I sometimes bitch a little at the scientific community, because you correctly espouse the cause of more funding for science, but you don't see so much about what we have to do in order to produce that more funding for science, like reduce the defense budget or cut public housing or some of the other things which are going on precisely at this moment in the Appropriations Committee. And those are difficult things to wrestle with, I can assure you.

Dr. KLEPPNER. I can understand this is outside your power of authority. I hope it isn't outside of your power of persuasion, though.

Mr. BROWN. No. I agree with you. I'm just urging you to get into the persuasion game yourselves a little bit more.

Mr. SILCOX. Yes, Mr. Brown. I think we've been hearing lots of messages about the need to approach individual Congressmen and get our case heard on the Hill. I must admit I feel a little uncertain about how to do that, except basically approaching individual Congressmen and doing it.

Let me react—if I could react on the business with what Mr. Bloch was trying to do, I think it's very clear that that's what Mr. Bloch had in mind. The purpose of my testimony here was to try to persuade you, if you can do it, is to carry along the case for the individual research and individual investigator grants to the best of your ability in carrying the case forward in the rest of Congress.

Mr. BROWN. Well, we will certainly do this. But I'm urging you in the scientific community to force some more of your members to be elected to Congress or something like that, so you can sacrifice with the rest of us in trying to achieve some of these budgets.

I'll yield at this point, so we can recognize one of the members who made that sacrifice.

Mr. WALGREN. If the gentleman would withhold, I just would like to interpose one question.

You say on the one hand we in the Congress should be very supportive of the individual grants and we in the Congress should insist on a sunset provision in this, and yet Eric Bloch should make the decisions.

How is that consistent? Why do we need a sunset if the Director of the Foundation should make the decisions, and why should we have anything to add to whatever strength is given to the individual investigators if the Director of the Foundation is supposed to be the one where these resources go?

Dr. KLEPPNER. If I may address that question, first the idea of sunset for these centers is intrinsic in the guidelines for them. I think there is a concern in the community that once one starts a center, it can go on forever and it's quality can deteriorate, and for that reason there specific sunset clauses in the guidelines themselves.

Mr. WALGREN. But the question is, what read are we relying on? Are we relying on the Director or are we relying on the Congress?

Dr. KLEPPNER. With respect to the centers, the guidelines set up—at least call for very intensive review of each center, that they have to justify their existence. They are privileged institutions, and they have to live up to those privileges, and there are clear guidelines for stopping them if they don't.

So I think as far as the centers eroding the quality of science in the future, at least the intention is that that should not occur.

When we talk about the needs for support for the individual investigator, I think behind my own comments is concern that what happened last year not happen again next year. I think what has the community very worried is the thought that the budget might be cut, that the centers be left in as a line item, and that they really do come out of the hides of the individual investigators. And that would be a most unfortunate scenario, and that is what concerns me and many of my colleagues.

Dr. WALKER. Mr. Chairman, may I just comment very briefly on that?

Mr. WALGREN. Dr. Walker?

Dr. WALKER. One of the problems I think which Mr. Bloch faces is that he's been given more responsibilities than resources; and, when the Congress does that to a Cabinet member or a Director, I think the Congress also has to provide some advice on how to make priorities, and the Congress has to——

Mr. WALGREN. Well, I guess fundamentally that's our problem, isn't it, that having not provided him sufficient resources, we must limit his discretion in how he uses those resources or direct his discretion, if you will.

Dr. WALKER. Or at least provide some advice. It's a very, very difficult task to make those kinds of judgments.

Mr. WALGREN. The gentleman from Pennsylvania, Mr. Ritter.

Mr. RITTER. Thank you, Mr. Chairman, and thank you, gentlemen, for your excellent testimony.

Just following up on what Dr. Walker was just saying, there is right now in MPS a 6.3-percent growth overall in the budget, but that's part of a 19 percent requested increase by the National Science Foundation.

Now we know what happened last year. There was a 17 percent requested increase, and there was a 5 percent granted increase. So what we're looking at now in these request figures is pretty much the best-case scenario.

I am personally concerned about the superconductivity program. I'd like to focus on that for a moment. We've made a great deal of noise here in the Congress about superconductivity, and I am concerned that within the physics area and the materials area, we may be selling superconductivity very short.

The other day, Dr. Graham mentioned that, well, don't jump to any conclusions there, because S&T centers could conceivably handle growth in the superconductivity area.

Dr. Kleppner and Dr. Silcox, you may wish to comment on that.

Dr. SILCOX. My understanding is that there is something like about $12 million at the moment going into superconductivity in the materials type of area, and that's a very significant fraction.

Mr. RITTER. In NSF alone?

Dr. SILCOX. Yes. The whole DMR budget is around $110 million. So superconductivity has grown into a very major fraction of the activity there.

I'm not sure how much of that $12 million comes out of the DMR budget, but I know there is a significant fraction of it.

What happens is that people reorient grant programs. It's not a situation that—it's an exciting topic. People jump to it. I just came up here yesterday from the March meeting of the American Physical Society in New Orleans. There are over 600 papers out of the 3,800 papers or so that are being given to that meeting—there are 600 papers on superconductivity.

Mr. RITTER. Dr. Sillsby, if I may interject, from Cornell has said that the high-temperature superconductivity work is being supported by money that's pulled from other projects at Cornell. He's the Director of the Materials Research Lab there. "But the cuts are preventing us from expanding in that direction. There really has been very little new money for high-temperature superconductivity despite all the hoopla from Washington."

Dr. SILCOX. He's absolutely correct. There is no extra or new money. What is happening is that existing money is being reprogrammed. Our MRL this year took a 7-percent cut along with, I think, most of the other things. Yet there is a substantial effort that's been going on there. Some of this is reorientation of MRL money; some of it is reorientation of other individual investigator grants.

Mr. RITTER. Dr. Anderson from Princeton has called it Superscam. Any comment on that, Dr. Kleppner?

Dr. KLEPPNER. On Superscam, no. But on the anguish in that community, yes, because many of my friends are in that community; and, the effect of last year's budget has been very demoralizing.

As I understand it, the DMR budget actually went up 1.9 percent. The research and related activities, I believe, went up about 3 percent this past year. The NSF budget as a whole went up 5 percent.

Now that 1.9 percent was not enough to cover new commitments and to sustain old ones; and, there were, as a result, widespread cuts.

But the other areas in math and physical sciences fared little better, and the demoralization is quite wide.

Mr. RITTER. What about Raymond Bye's comments, the NSF Legislative Liaison person in the Chronicle of Higher Education that you have, even in years of substantial increases, you'll have programs that are reprogrammed, I guess, or cut?

Dr. KLEPPNER. Yes, but generally not the leaders of the field and not—well, there's never been a field like high-temperature superconductivity before. This is rather unprecedented. The public attention has been unprecedented; the federal attention has been unprecedented. And I might say that the anguish in that community over the reward for their efforts, of having their budgets cut, is rather unprecedented, too.

Mr. RITTER. Wait a second. I thought their budgets were increased.

Dr. KLEPPNER. Well, people have had their budgets cut. I don't understand the full story; but, as I gather, commitments were made for new programs and new—not initiatives, but that new programs were supported, and the program essentially became overcommitted. And when the funding wasn't there, there were broad cutbacks. So even though DMR went up 1.9 percent, the leaders in the field had their budgets cut. The materials research laboratories had their budgets cut. And the anguish was aggravated by the fact that commitments were made which perhaps should not have been made in the first place.

Mr. RITTER. Let me just interject. In the field of ceramics, which is so crucial to any success of this country in high-temperature superconductors, what happened to budgets in the field of ceramics and processing and ceramics manufacturing and engineering ceramics and the science of ceramic materials?

Dr. SILCOX. The budget component of DMR, as Dan said, I think there was an increase of about $2 million total in DMR this particular year. I think the ceramics and the electronic materials program went up by $1 million, and I think the polymer program also went up by $1 million.

The rest of the changes in the budget were essentially little factors.

The reason for those increases was that the pressure, the proposal pressure, and the quality of the work that was being done in those fields was rising to extremely high pressure levels; and, it was, I think, the key element of the judgment—and I think it's totally accurate—was that the little increase that should come this year should go into those two areas. And that's what it did.

Mr. RITTER. So from the materials side, there's been a 1 percent——

Dr. SILCOX. A 1.9-percent increase, I think. It went from about $108 to $110 million.

Mr. RITTER. Right. But in the materials side of ceramics, the materials side of the high-temperature superconductivity game, processing, manufacturing, what kind of boost——

Dr. SILCOX. It's hard to break those figures out because the money has gone to MRLs and things like that.

Mr. RITTER. But it couldn't have been more than 1.9 percent.

Dr. SILCOX. Oh.

Mr. RITTER. Or could it? Was there reorientation within the materials budgets?

Dr. SILCOX. I think there's reorientation within the existing materials programs. People that were working on other things are now working on high-temperature superconductivity.

I really think the big question that one should worry about is that, as a result of the tremendous increase of interest in superconductivity and the consequence of no funding, a lot of people have dropped what they're doing and shifted into this area. And I have had other people sort of ask me, my God, what are we letting go in order to work on this area? And that's one of the issues that really is a little troublesome.

Mr. RITTER. I have one closing question. Philip Anderson has stated that American science is dying of giantism.

Given your research facilities and your goals and dreams and that of your colleagues, how does the community out there where you live and breathe, how does it view the Superconducting Super Collider in the context of Dr. Anderson's remark?

Dr. KLEPPNER. One worries.

Mr. RITTER. What's that?

Dr. KLEPPNER. I said one worries. The SSC is of such an unprecedented scale that it's very difficult to address that question at the same time we're addressing the question of the NSF budget, where we see science across the board in trouble.

Mr. RITTER. But it does come out of the same pot.

Dr. KLEPPNER. It may not be the same pot. It is not the same pot. It's a different agency totally.

Mr. RITTER. Yeah, but—I'm sorry. I meant the same pot; it's coming from the federal budget, Function 250, in support of science.

Dr. KLEPPNER. Well, all right. I would like to make the following assertion, which is in my written statement, that the survival of science in the universities is absolutely critical to this country, that nothing should take higher precedence than that—not the SSC, not the Space Station. No other activity involving science and technology should take precedence to that, because without that, we're lost. And the NSF has a major responsibility in that area, and I have yet to find anyone who would disagree with me on that.

Mr. RITTER. You see, I think Dr. Bloch is between a rock and a hard place. They're asking for 19 percent—17 percent last year; they're asking for 19 percent this year. They don't get that.

But within the confines of that requested increase are things like engineering research centers, which do make some sense in terms of technology transfer or things like science and technology centers, which do make some sense in terms of science and technology transfer.

The problem is that the proposed doubling of the NSF budget is nowhere near reality, and we should stop deluding ourselves talking about it. We need a change in the priority-setting process in this town in order to help make it a priority.

So, you know, I want to support my colleague from California's comments that we've got to do some homework in order to get the doubling—I think the doubling of the NSF budget is about the best thing we could do in terms of supporting science in America, be-

cause that way you hit the cross-section, and you don't end up making political decisions betting on this horse or that horse. You know, it's still a horse race, and you don't know which horse is going to win.

But we're not in that mode. We're in a big political science mode. And we need your help to get in this other mode where——

Dr. KLEPPNER. If you're looking to us for solutions to that problem, then we're in very severe trouble because we can see the difficulty. Everyone wants to be helpful. If you call on any of us for help, we'll respond. But, at least for this scientist, to try to take the initiative into unscrambling an historical situation that has developed, so that the NSF budget has developed in what appears to me a rather chaotic scenario, is just——

Mr. RITTER. I think the science community has to get together and back off from this midnight raid on the Treasury in terms of appropriations bills, that un-peer-reviewed projects are being dumped into the system, and the major growth in certain institutions are coming from this divergence from the way we've operated so successfully over the years, and this kind of political science, eleventh hour appropriations bills is not helping NSF.

The problem is, the same people and the same universities that are going after NSF money are saying, hey, we can't be—we can't be frozen out of this game, because if we are, our competition is going to get it, or somebody else is going to get it, and we're not, and the community is starting to lose its integrity, frankly.

Dr. KLEPPNER. Yes. I think the pork barreling is a good indication of a system which is losing its integrity, of a system which is under pressure, is in distress; and, we're showing growing signs of distress. I think pork barreling is one side.

A growing antagonism between different fields is another side. One can see that occurring, and it's occurring because the lifeblood is stopped in science. The lifeblood, I think, flows through the NSF; and, unless we can—unless you can address that, the whole scientific enterprise is going to show more and more signs of this distress.

Mr. RITTER. Thank you very much. Thank you, Mr. Chairman.

Mr. WALGREN. I thank the gentleman. Is there a reason to provide the whole authorization for this, the science and technology center is $150 million, out of 1 year's allocation as to authority, when we don't do the same for the other centers? The supercomputer centers do not have 5-year authorizations. I don't know what some of the other circumstances might be.

Isn't this a rather unusual commitment in this instance?

Dr. KLEPPNER. As I understand it, this is a novel form of funding. It does have this advantage, that once the allocation is made, one knows, at least, this group of centers is not going to impinge on the rest of the NSF budget in the coming years. It is very nice for these centers. Their future funding is assured. I think everyone would like that.

Mr. WALGREN. Is the reason to assure the funding or to assure that it doesn't impinge on core funding?

Dr. KLEPPNER. I can't explain the reasons for it since I wasn't part of the development of that. Looking at it on paper, it meets the requirement we put down, the principles and guidelines, that

the centers not be allowed to erode future budgets—to erode support for individual scientists if the budgets go back, get cut back.

On the other hand, it does represent a major, in the sense, mortgage on the future, that this large chunk of money is being set aside for these centers, that they are protected. The individual investigator grants, the rest of the functions, are not.

Mr. WALGREN. Shouldn't the same requirements be made of the other centers as well?

Dr. SILCOX. Can I interject?

Mr. WALGREN. Certainly.

Dr. SILCOX. I think there is a precedent in the federal funding history. The Materials Research Laboratories which were funded by what was then ARPA, back in the early 1960's—they were indeed funded on a 5-year time scale. When I first came to Cornell, there was no question that the MRL at which I was working had 5 years of assured funding. What the funding process apparently did every year was to add one extra year. We always had a 5-year lead-time.

When it came to the 1970's and we were faced with starting to pay for the Vietnam war, that flexibility disappeared. I think the funding during those first 10 years were remarkably important in the feeling of stability that people had and the chance to play long term planning. And I frankly believe that it was a key factor in the success of that program as a whole.

Mr. WALGREN. I guess my question is——

Dr. SILCOX. I think perhaps you should have funded the ERCs and the supercomputer centers in the same mode.

Mr. WALGREN. That is my question.

Dr. Walker?

Dr. WALKER. I would like to comment on that as well. I actually think this is a good approach. Although I was not privy to the discussions, I suspect it has something to do with the way in which funding for major science projects has tended to oscillate. I can cite a number of NASA projects in that regard. I think in Europe, there seems to be a much different approach.

For example, for the European Space Agency, those obligations to fund that activity are in the nature of treaty obligations of the member nations. For that reason, the European Space Agency is able to make much more efficient use of its resources because it is able to plan ahead much more effectively.

I think multiyear funding for science projects is a very good idea. I think this is a good way to proceed, although one has to reckon with the implications in a given year, of course, for other programs.

Mr. WALGREN. Congressman Lujan who had wanted to be here is unable to be here, but he wanted me to raise a couple of points with you, Dr. Walker, in particular.

One is apparently: one answer, which has been offered to justify the low rate of growth in astronomy, is the apparent decision of the astronomical community that the very long baseline array is the number one priority for that community during the 1980's. Therefore, that would justify less growth or even reductions in other projects until that is completed.

As the Chairman of the NSF Astronomy Advisory Committee, is that the approach that Committee has taken?

Dr. WALKER. I don't think those were the assumptions that the community had when it made its recommendations. I'm sure you are aware of the Field Committee report which is the last decade review in astronomy. There were a number of very high priorities laid out for the 1980s. The Very Long Baseline Array was the first, but there were a number of others.

The specific assumptions which were laid out in that report were that the basic programs, the ongoing programs, were assumed to be in place and supported at what was regarded as a reasonable level to continue their effectiveness, and it was assumed that the additional new instrumentation programs were in addition to that basic support. It was never understood by astronomers that, if you get a new instrument, it is going to come out of your ongoing operations.

I think people would have thought somewhat differently about how they allocated priorities if that was understood at the start.

Mr. WALGREN. Has the Advisory Panel worked up budget estimates for NSF for 1989 to 1992? Have you gone that far in detail in budget recommendations for astronomy?

Dr. WALKER. There are recommendations as to how the 4.7 percent increase will be allocated. I think I showed those in one of the charts. Basically, it would be the same increase in each of the major areas, support of the national centers, support of the grants program and a slightly smaller increase actually, I think 3.5 percent, if I remember correctly, in the very long baseline array construction.

Mr. WALGREN. I know Mr. Lujan would appreciate it if there are any of those kinds of long term plans, if you would get them to us in this context.

Dr. WALKER. I certainly will do that. May I make one other comment, sir?

I do want to emphasize, however, that the situation with regard to some of the national observatories, particularly NRAO and NOAO, is very critical because, as a result of the late change in fiscal 1988 funding, those observatories have had to make very strenuous efforts to reduce their spending levels to what turns out now to be the actual level. They have made somewhat deeper cuts than they would have had to make if they had known what their 1988 funding levels were going to have been at the beginning; and, furthermore, they have utilized all of their reserves.

As they enter fiscal year 1989, it will be stripped bare; and, at the budget level which is projected, there are going to be very major structural cuts, I think, in basic programs within those observatories.

Mr. WALGREN. In the preparation of the Science and Technology Center's program, was the astronomy community and the Advisory Committee that you chair consulted about the application of science and technology centers as an approach in the astronomical sciences?

Dr. WALKER. We were made aware of this initiative. We were not consulted in regard to putting it in place. I believe the response of the Committee was basically that one can conceive of some centers which would be useful in astronomy but that astronomers have al-

ready utilized this concept of centers so thoroughly that it was unlikely that would have as large an impact on astronomy as it would in some other areas, which have not used this mode of research before. It is clear it has had a very substantial impact on the budgets.

Dr. KLEPPNER. If I may comment, although there was no astronomer on the Committee, we used astronomy as the prototype science which you could not immediately tie to technology. The question is, should astronomy be eligible for support in these centers?

In the original guidelines to the Committee, the Director, Mr. Bloch, asked us to name the fields which we thought would be appropriate. The Committee debated that at some length and decided that all fields should be appropriate. I think Mr. Bloch agreed with us on that. There certainly can be S&T centers in astronomy or for that matter, in cosmology. We were very much aware of that community and its needs.

As I understand it, I believe there have been proposals submitted in astronomy.

Mr. WALGREN. Also as suggested by Mr. Lujan, that we raise this question. Apparently, European industry has moved their governments to make the commitments to the world's largest telescope for construction in South America on the grounds that it would help Europe be more competitive. The NSF is seeking to make the United States more competitive as a goal, of course, but is giving less, not more emphasis to basic research, such as astronomy.

Do you feel that the Europeans are on a better track than we are right now in the value that they attribute to basic research and astronomy?

Dr. WALKER. I think they are. I think you also have to realize that astronomy is extremely technology intensive. For example, I have a colleague at Stanford who has developed a very high resolution detector specifically for astronomy. But, in fact, that detector won a technology award because it is and it does represent the application of very high technology to astronomy, but it will be useful in other areas as well. I think the Europeans appreciate this very clearly, both in their space program and in their land based astronomy program. Unfortunately, our project for a very large optical telescope has really not moved very far from where it was when it was first proposed as part of the Field Committee report.

Mr. WALGREN. The Chair would like to recognize the gentleman from New York, Mr. Hochbrueckner.

Mr. HOCHBRUECKNER. Thank you, Mr. Chairman.

I apologize for my tardy arrival but I am compensating by leaving early to vote. Unfortunately, we have had a conflict with other subcommittees.

I'm not certain if this question is appropriate for this particular forum; but, it was raised to me and I thought I would raise it to you based on who you are with and where you are from.

I have received word that people in the science community who normally would be receiving NSF funding for other programs not related to superconductivity are being told that, in essence, there may not be any funding for their projects because, this year, the trend seems to be to provide greater funding on superconductivity.

Would you please comment on that in light of what this particular hearing is about? It seems to be a conflicting thing, but I would like to know your views in terms of what you have been hearing from your colleagues about other projects being cut off because superconducting research is being supported.

Dr. SILCOX. I'm not sure I would really say it is because superconductivity is being supported in a special way. I think there is a considerable amount of movement of existing funds, and there is to some degree—I think there may be as much as $1 million going into a superconductivity initiative in a sense. But the kinds of cuts I am seeing are coming basically because everything is tight. It is coming because the proposal pressure is extremely high. We are looking across the board at very high quality proposals, and it is very, very difficult to choose which proposal to fund over the other.

I don't think the superconductivity is distorting the picture badly. I think there may be some distortion of the picture and that may be worth it. I am concerned that in fact individuals are re-orienting their programs and that a lot of people are actually moving into superconductivity at their own free will, and I am concerned as to what they are leaving behind.

There is a big question here, how much is enough? There is about ten percent of the community that I represent that has gone into that. There certainly hasn't been 10 percent of money coming in. This means they are dropping a fair fraction of other activity. There may be some very important stuff that is being dropped in order to do this.

Mr. HOCHBRUECKNER. Thank you, Mr. Chairman.

Mr. WALGREN. Thank you. On behalf of the Subcommittee, we appreciate your joining in these discussions, and we appreciate your contribution to the record. Thank you very much.

[Whereupon, at 12:15 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

1989 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, MARCH 23, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. WALGREN. Let me welcome you all to this second day of hearings on the National Science Foundation Authorization for 1989.

We want to welcome this morning Erich Bloch, the Foundation's Director, along with Dr. Roland Schmitt, the Chairman of the National Science Board, and Dr. John Moore, accompanying Mr. Bloch, all to present plans and discuss priorities for this new budget year.

At the hearing yesterday we had an opportunity for nongovernmental witnesses to comment on the Foundation's programs for pre-college science and math education, and on the proposal to fund, in advance, several new science and technology centers.

In addition, tomorrow we are going to have witnesses talking about the status of the NSF Engineering Research Centers, and the status of the National Supercomputer Centers.

The proposed NSF budget for fiscal 1989, as you know, provides for an increase of some 19 percent over the previous year. This increase is a first step toward the goal of doubling the total NSF budget in five years, as has been set out by the Administration.

We support this goal during this authorization process; and we supported it last year; and we are pleased that the Administration is pursuing it the way they are.

NSF programs support the discovery of new knowledge and support the education and training of new generations of scientists and engineers, and as such are critical to the long term economic health and well being of our country. And even in a period of severe budget restrictions, there is much in this area that is a basic investment for the future that we would be foolish not to make.

This morning we are glad to have the opportunity to hear how NSF will balance the competing demands of support for individual investigator awards, as opposed to the ongoing centers, along with facility support and upgrading, and the kind of new initiatives that they are proposing.

We are particularly interested in the Foundation's plan for science and engineering education. This area has received significant funding increases, as most know, with the support of this Committee; and, we were pleased last year that the appropriation followed the direction that we had gone in our authorization strongly. It's an area that we are deeply committed to.

But with that, let's turn to our minority member, Mr. Boehlert, for opening thoughts that he would like to present, and then we will hear from other members.

Mr. BOEHLERT. Thank you, Mr. Chairman.

Circumstances have conspired to confront NSF with that most volatile of political situations: a crisis of rising expectations.

Researchers may feel betrayed by unrealized promises of budget growth and threatened by new forms of funding. NSF officials, feeling stymied by Congress and academic conservatism, may rush efforts to start new initiatives.

In such a climate, it is our job to help preserve both balance and optimism.

We can start by declaring our unswerving support for the President's $2 billion budget request. This funding level recognizes the importance of the foundation's work, and the House Budget Committee's actions have shown that it can pretty well be achieved despite budget constraints.

We are off to a promising start, and if we all work together, the foundation can be back on the path toward doubling its budget. It's worth remembering that even last year's disappointing appropriations were a sign of support for the foundation, given the available options.

The trickier question, of course, is how to allocate the money. I want to be sure that current programs are funded adequately before we embark on any new ventures.

Supercomputer centers, for example, seem to be in danger of stagnating at current spending levels.

Even more vexing is determining the proper balance between centers and individual grants. It's utopian to believe that this question will ever be resolved. I think the best we can ever hope for is the uneasy truce well captured in one of Woody Allen's fractured proverbs: "The lion and the calf shall lie down together—but the calf won't get much sleep."

The analogy is especially apt. Researchers know that the lion, though docile at times, has a growing appetite that can lead it to devour the calf. We know that although the lion is capable of great strides and attracts much attention, it is the defenseless calf we depend on for our future sustenance.

Well, that's it for playing Aesop for today. Determining precisely what budget decisions should follow from that moral must await the conclusion of these hearings. It's important, though, that these subordinate distribution questions not obscure our unity on the primary task. A strong, healthy, growing basic research and education enterprise is our goal.

I once again pledge my support for the National Science Foundation, the one Federal agency whose mission is, at base, the search for truth.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mr. Boehlert.

Are there other opening comments that members would like to make? Mr. Valentine?

Mr. VALENTINE. I don't have any, Mr. Chairman, not knowing whether or not to wander into the zoo or walk on the farm after that last. [Laughter.]

Mr. VALENTINE. Thank you.

Mr. WALGREN. Well, it's about par for the course around here, I think.

Miss Schneider.

Miss SCHNEIDER. Thank you, Mr. Chairman.

The Administration's budget of $2.05 billion would put us back on a track to double the NSF budget in the next five years. The budget would certainly improve educational opportunity in the United States, because it targets many of the secondary and undergraduate education programs with a significant increase from $130 to $173 million, and the special programs that are designated for minorities, women, and disabled, would grow by 63 percent. I think that this is a significant earmarking, in that as we look at the demographics for the future, we become very cognizant of the fact that we are going to be dealing with a potential work force that is not going to be English-proficient; that will be made up primarily of minorities and women.

As a matter of fact, by the year 2000, 7 out of every 10 new people entering the work force will be women. So it is critical that we have well skilled individuals in these particular areas to take on the technological challenges of the future.

This budget would also assist the development of new technologies so far as disciplinary research and also facilities which are the backbone of scientific work. They would receive $1.2 billion.

The increases included in the programs for materials research, for chemistry, for biological experimentation, for communication, also manufacturing, certainly should move us ahead to capture the edge in the competitive global economy that we are currently attempting to address.

This budget also would transfer some new technologies to the private sector, and the current centers would experience a 10 percent increase; $150 million would be provided to the new science and technology research centers that didn't receive sufficient money to begin their work last year.

So I believe that this budget is a very good start, but it's quite clear, as one reads between the lines, that there still remains an enormous amount of hard work and many difficult choices remain to be made.

There is no question in my mind that it will require the involvement of those who are about to testify this morning, in addition to the members here, the members of Congress, but also representatives from the academia and the private sector; we are counting on the participation of each and every one to help us make the right choices and provide adequate funding where we can best achieve the maximum potential possible.

Thank you, Mr. Chairman.

Mr. WALGREN. I thank the gentlelady.

Are there other members who would like to make any opening comments?

Well, with that, we welcome the witnesses. We are pleased you are here, Mr. Bloch, and as you know, any written text that you would like will be reproduced in the record in full, and you can feel free to underscore or outline the points that you would like to make in the most direct way that makes sense. And so we are pleased you're here.

[The prepared opening statements of Mr. Walgren and Mr. Brown follow:]

[The prepared opening statement of Mr. Boehlert appears on p. 843.]

OPENING REMARKS OF THE
HONORABLE DOUG WALGREN (D-PA)
ON THE
NATIONAL SCIENCE FOUNDATION AUTHORIZATION HEARING
MARCH 23, 1988

THIS IS THE SECOND HEARING ON THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION FOR FISCAL YEAR 1989. WE ARE PLEASED TO HAVE WITH US THIS MORNING, MR. ERICH BLOCH, THE FOUNDATION'S DIRECTOR, AND DR. ROLAND SCHMITT, CHAIRMAN OF THE NATIONAL SCIENCE BOARD, TO PRESENT PLANS AND TO DISCUSS PRIORITIES FOR THE NEW BUDGET YEAR. A HEARING YESTERDAY, MARCH 22, PROVIDED AN OPPORTUNITY FOR NON-GOVERNMENT WITNESSES TO COMMENT ON THE FOUNDATION'S PROGRAMS FOR PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION AND ON THE PROPOSAL TO PROVIDE UPFRONT FUNDING FOR SEVERAL NEW SCIENCE AND TECHNOLOGY CENTERS. IN ADDITION, IN A HEARING TOMORROW, MARCH 24, WE WILL CONSIDER THE STATUS AND DEVELOPMENT OF THE NSF ENGINEERING RESEARCH CENTERS AND NATIONAL SUPERCOMPUTER CENTERS.

THE PROPOSED NSF BUDGET FOR FISCAL YEAR 1989 PROVIDES FOR AN INCREASE OF 19% ABOVE THE PREVIOUS YEAR. THIS INCREASE IS A RENEWED FIRST STEP TOWARD THE GOAL OF DOUBLING THE TOTAL NSF BUDGET IN FIVE YEARS. WE SUPPORTED THIS GOAL DURING THE AUTHORIZATION PROCESS LAST YEAR AND ARE PLEASED THAT THE ADMINISTRATION HAS CHOSEN TO CONTINUE TO PURSUE IT. NSF PROGRAMS SUPPORT THE DISCOVERY OF NEW KNOWLEDGE AND TRAIN NEW GENERATIONS OF SCIENTISTS AND ENGINEERS. THESE PROGRAMS ARE CRITICAL TO THE LONG-TERM ECONOMIC HEALTH AND WELL BEING OF OUR NATION. EVEN IN A PERIOD OF SEVERE BUDGET CONSTRAINTS, WE MUST NOT FAIL TO MAKE THIS INVEST-

MENT IN OUR FUTURE.

THIS MORNING WE ARE GLAD TO HAVE THE OPPORTUNITY TO HEAR HOW NSF WILL BALANCE THE COMPETING DEMANDS OF SUPPORT FOR INDIVIDUAL INVESTIGATOR AWARDS, ON-GOING CENTERS, FACILITY SUPPORT AND UPGRADES, AND NEW INITIATIVES. WE ARE ALSO PARTICULARLY INTERESTED IN FOUNDATION PLANS FOR SCIENCE AND ENGINEERING EDUCATION. THIS AREA HAS RECEIVED SIGNIFICANT FUNDING INCREASES WITH THE SUPPORT AND ENCOURAGEMENT OF THIS SUBCOMMITTEE.

TO OUR SECOND PANEL, WE WELCOME DR. RITA COLWELL, DIRECTOR OF THE MARYLAND BIOTECHNOLOGY INSTITUTE AT THE UNIVERSITY OF MARYLAND, DR. VERA ALEXANDER, DIRECTOR OF THE INSTITUTE OF MARINE SCIENCES AT THE UNIVERSITY OF ALASKA, AND CAPT. ROBERTSON DINSMORE FROM WOODS HOLE OCEANOGRAPHIC INSTITUTE.

NSF IS A PRINCIPAL SPONSOR OF RESEARCH IN THE ARCTIC AND IS CHARGED WITH MANAGING ALL U.S. ACTIVITIES IN THE ANTARCTIC, INCLUDING ALL LOGISTICS NECESSARY FOR MAINTAINING THE U.S. PRESENCE THERE. WE INVITE THIS PANEL TO ADDRESS NSF PLANS FOR RESEARCH AND RESEARCH SUPPORT IN POLAR REGIONS IN LIGHT OF PERCEIVED NEEDS AND OPPORTUNITIES. OF PARTICULAR INTEREST IS THE STATUS OF VESSELS AVAILABLE FOR RESEARCH SUPPORT AND REQUIREMENTS FOR ADDITIONAL ICEBREAKERS OR ICE-CAPABLE VESSELS.



Statement of Congressman George E. Brown, Jr.

Hearing on FY 1989 National Science Foundation Authorization

Subcommittee on Science, Research and Technology

Committee on Science, Space and Technology

March 22, 1988

Mr. Chairman, it pleases me to have the opportunity to participate in these important hearings, and I thank you for inviting these highly qualified witnesses to testify on behalf of the National Science Foundation. NSF plays a crucial role in promoting scientific and technological expertise in our nation. NSF programs and funding have directly contributed to the professional success of many scientists and engineers throughout our society.

We have all come to recognize that our strength as a nation is highly dependent on the ability of our citizens to synthesize information, to think critically, and to make intelligent decisions. Educating our children, who are indeed our future, must be taken very seriously. In my opinion, however, we have not treated this challenge seriously enough. Too many high school graduates cannot perform simple calculus, and too many cannot read or write at the level required to operate in a highly complex and technological society.

I believe the federal government has an important leadership role to play in science education. NSF is uniquely qualified to support educational research and curriculum development to improve the teaching of science, mathematics and technology. The pre-college Science and Engineering Education program, by identifying and funding those who can increase the number of qualified teachers and develop innovative curricula and effective classroom materials, reaches extremely large numbers of young people. For example, one well-written textbook could stimulate an interest and appreciation for some aspect of science or engineering in hundreds of thousands of children. Studies have shown

that the majority of adult scientists developed their inclination toward science at a very young age, somewhere near the fourth grade. It is certainly true of this program that a little bit can go a long way.

The population of technically literate adults in our society will decrease as the school-age portion of our population continues to decrease, unless we can encourage a larger portion of young people to enter the science or engineering field. Efforts by NSF to attract more women and minorities to physics, math, chemistry, engineering, and the like have been successful in the past. Continued success in this area will be crucial to maintaining a viable and diverse technical work force.

NSF is requesting only $108.5 million to fund their pre-college Science and Engineering Education Program. Although this request represents a 20.6% increase over last year's spending level, such an increase is necessary to bring the program back to pre-1981 levels. Moreover, this figure reflects the administration's request to double the NSF budget over a period of five years. In my opinion, the amount requested represents a vital investment in our children, an investment that deserves our fullest support. Thank you again, Mr. Chairman, for holding these hearings and I look forward to today's testimony.

STATEMENTS OF ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC, ACCOMPANIED BY JOHN MOORE, DEPUTY DIRECTOR, NSF, AND BASSAM Z. SHAKHASHIRI, ASSISTANT DIRECTOR FOR SCIENCE AND ENGINEERING EDUCATION, NSF; AND ROLAND SCHMITT, CHAIRMAN, NATIONAL SCIENCE BOARD, WASHINGTON, DC

Mr. BLOCH. Thank you, Mr. Chairman. I appreciate the opportunity to be here to discuss the budget request for 1989.

This is a budget with a very strong emphasis on the effect of our national economic well being for education and basic research in science and engineering.

Over the past few years, debate over economic matters has come to focus more strongly on science and technology. Increasingly, we understand that we must look to our own educational, research, industrial, and governmental institutions to make us competitive.

I'm not satisfied, however, and I doubt this Committee is satisfied, with the actual progress we have made in strengthening our educational and research systems.

Although there is a growing consensus on the need, our fiscal problems have so far prevented us from taking the actions we must, and I hope this can be the year when that changes decisively.

Science and technology are concerned mainly with two of our most important national goals: economic prosperity and national security. NSF focuses strongly on the former. We support science and engineering in ways that contribute directly and effectively to national economic competitiveness.

There are three important elements of science policy that are expressed in NSF programs. The first one is the development of human resources, because people are our most important asset.

The second one is the support for university basic research, because universities are the main source of new knowledge and play a key role in education.

And thirdly, efforts to link the universities more tightly to industry, in order to use our technical resources most effectively.

People, as always, must have the first priority. Trained and educated people are the major resource of any modern society. We are all pleased with the resurgence of the education programs of the Foundation and the general focus of our programs on human resource developments.

Our 14-year-old appropriations for Science and Engineering Education have risen from $16 million in 1983 to a requested $156 million in 1989, almost a tenfold increase; and, we are showing that to you in figure 1 attached to my written testimony.

You will also note that, this is not a very dramatic progress, but equally important, the focus and distribution of these dollars is primarily to pre-college, about 70 percent go to pre-college.

Equally important, the numbers of scientists and engineers supported by NSF programs at all levels, from high school through senior scientist, are projected to rise sharply, as shown in Figure 2 attached to the testimony, where we are showing a 1989 or a 1987 level, and a projected 1989 level, which essentially shows an in-

crease from 47,000 people to 61,000 people that the NSF programs are addressing.

From high school students through pre-college, teachers to undergraduate students, to senior scientists and post-docs, this is almost a 30 percent increase going from 1987 to 1989.

The positive trend of the budget, however, should not obscure the dismal state of science and mathematics education in our schools. Only two weeks ago, the Foundation announced the results of a new survey of international science student accomplishments; and, once again, the United States did not place well. Dr. Schmitt will address that problem in a minute.

Our 14-year olds tied for next to last place, while Hungary and Japan took the top places. With these concerns in mind, our proposed 1989 budget again makes human resources development a major theme. We propose total investment of $265 million, up more than 20 percent over 1988 in this very important area.

The Foundation's pre-college programs are the largest piece of this effort. They have grown rapidly and will rise again by nearly 21 percent in 1989 to a total of $108 million. Even at these levels, however, NSF's role is small in dollar terms. Our resources are used to stimulate others to innovate and to lead.

The main effort must come from the states which bear the principal responsibility for education under our system of government.

The second major part of the effort is our undergraduate programs. As programs deferred this year in 1988 come on line, this level will show the biggest increase, rising 62 percent to $65 million in the proposed budget.

I want to emphasize that all parts of the Foundation bear responsibility for education. It does not stop at the Science and Engineering Education Directorate. Neither does it stop at the end of high school. It goes all the way through undergraduate education into graduate education.

Most pre-college and some advanced programs are in the Science and Engineering Education Directorate, but much of the effort at advanced levels is undertaken in the research directorates. And this is how it should be, in order to link the science and research community in these very important efforts of education at all levels.

A pressing problem is to attract enough students to science and engineering. Almost no science is taught in elementary school, and less than a quarter of high school graduates are qualified to do college-level science or engineering.

In the long run, stronger pre-college programs are a necessity.

Everyone who will complete a Ph.D. by the year 2000, however, is already in high school. Nothing we are doing in the pre-college area will have any effect on these students, but efforts at the undergraduate level and above may stimulate many of them to choose science or engineering careers.

Focusing on those students will help us to meet the needs of industry, government and society that we expect to develop in the 1990s.

Figure 3, attached to the written testimony, is essentially showing the whole pipeline from high school sophomores through the Ph.D. degrees and the attrition that occurs throughout that par-

ticular pipeline. The attrition occurs at many points in the spectrum, and we can talk about that one later on.

We need a focus on these students at three critical transition points: from high school to college, from college to graduate school, and at the master's degree level.

At each of these points, a substantial proportion of the Ph.D.'s drop out of this process. At each of these points, the next stage must be made attractive enough to keep the rest of these students involved. A large part of any solution to the people problem must come from broader participation. We have made some progress in encouraging women to join the science and engineering community, but we are far from where we should be. And there is some evidence that the participation rate of women is leveling off and leveling off at a relatively low level.

With minorities, however, we have had less success, although in time, the new Minority Resource Centers may have an important effect. We are making special efforts in our education programs at all levels to work on these problems.

A good example is a cooperative effort led by the University of South Carolina to train better science and mathematics teachers for the schools. The program involves significant numbers of minority teachers in summer workshops and other training activities.

Importantly, this NSF project has stimulated major state and university support.

In addition to concern for people as individuals, we must be concerned with the institutions in which they work. This means that we must broaden participation beyond the institutions that already compete well. NSF has sought to do this, especially through the EPSCoR program, with encouraging results.

A point that is not well known is that NSF is especially important in the states that receive relatively little federal R&D support. We provide about 10 percent of the total going to the bottom 10 States, compared to less than 3 percent of the total for the top 10 States in research and development.

Our focus on both human resources and broadening participation in the research enterprise are not empty promises. They are being borne out by results and facts that I just related.

The second requirement for better economic performance is stronger university basic research capability. I would hope that 1989 is the year in which progress in this area can match what we have recently accomplished in human resources and education.

University basic research is more important today than ever before. The world is rapidly shifting to a knowledge-based economy, and in our system new basic knowledge is produced mainly in universities.

In contrast to education, however, this support has not been rising in recent years, and figure 4 attached to the written testimony makes that particular point.

In constant dollars, the NSF Research and Related appropriations for 1988 is almost exactly where it was in 1985. Let me just mention that NSF's Research and Related appropriations represents about 60 percent of the federal funds for academic research in the physical sciences and engineering.

Therefore, any kind of stagnation period, like we have seen over the last three or four years, make themselves felt right away in the community; and, many of the voices and noises, I should say, that Mr. Boehlert referred to before are due to this particular fact.

Overall Federal investment in basic research and in civilian R&D has grown slowly and erratically in the past few years. By contrast, research investments by our major trading partners continue to advance strongly.

We are not matching their effort in civilian R&D, as you can see in Figure 5 attached to the written testimony. While we have increased our R&D effort in defense, DOD support of universities has declined. This is not good for universities and it's not good for military programs. They need basic research results, and they depend on a steady flow of new scientists and engineers.

In nearly every field that NSF supports, the opportunities to make important advancements have outrun the available support. Superconductivity is but one area in materials research that promises important economic benefits. There are many others, obviously.

And, by the way, we have increased our funding for superconductivity last year as well as in 1988, significantly.

In mathematics, chaos theory is almost entirely new in just the past few years. The revolutionary progress in biology and biotechnology is well known, and there are many examples of this sort.

American manufacturing appears to be starting a comeback, as it must, if we are to prosper. But manufacturing will change dramatically over the next decade as robotics, new materials, computer-aided manufacturing and other new technologies emerge from basic research.

The world is in an unprecedented period of technological development. We know that nothing like the present has been seen before, and a reasonable guess is that the future will be even more intense and fast-paced.

In this situation, any nation that wishes to lead economically, militarily, or politically must lead in science and technology. This is impossible without rising levels of basic research support. Unless the United States is willing to cede its long position of world leadership in science and engineering to others, we must find the resources for the necessary investment.

Effective linkages among the various sectors of our economy is the third element of an effective science and technology policy, and the third theme of our proposed budget. This is especially important in the United States, because our research system is built on the research university. This keeps research and education tied closely together, which is a major strength and one of the reasons why our universities are the best there are. But in this, as elsewhere, there is no free lunch. The drawback of our system is tendency for university research to be isolated from economic reality.

We need explicit mechanisms to make sure this does not happen and that the results of our laboratories flow smoothly into industry and into the marketplace.

NSF has been a leader in developing new ways to bring the various players in science and technology more closely together. Our Engineering Research Centers, the first of which we established in

1985, have stimulated significant industrial and state support and brought new resources to universities.

Each NSF dollar has been more than matched by industrial contributions and State support. Even more important is the contribution of industry in committing their time and people to help make the centers work. This is especially crucial to knowledge transfer, getting new ideas out of the university and into practical use.

Our budget for 1989 requests funding to extend the ERC concept to other areas in science. We propose a new appropriation of $150 million, sufficient to fully fund 12 to 15 centers for up to five years. Our intention is to provide full funding up front to avoid committing the Foundation's future resources and to answer the concern of those who fear that the centers might displace traditional support mechanisms.

Again, commitments by industry in the 350 proposals we received is running at the 70-percent level. Both this number and the number of proposals received is a confirmation of the need for this initiative, as seen by the academic and the business sector of our society.

I need to clear up some misunderstanding about this $150 million appropriation line in our budget. The $150 million is a five-year number, not a yearly number. On a yearly basis, it's a $30 million appropriation.

This compares to a $150 million increase, $150 million increase for 1989, that we are asking for for individual investigators and disciplinary research. So the balance or the comparison which has been made at times of $150 million for this and $100 million for that is incorrect.

Mr. WALGREN. Give me that again. If you would just restate that.

Mr. BLOCH. Well, what I was saying essentially is the following:

The way the appropriation request is written, the way the $150 million I defined for the Science and Technology Centers is up front funding over five years for these centers. The yearly outlay, if you take a very primitive kind of an approach, with this kind of overstating the case, it's about $30 million per year. The first year it will be less than $30 million because of the lead time that you need.

Now if the $150 million for the Science and Technology Centers for the five years had been compared with the $150 million that we are asking for as an increase in the disciplinary research and individual investigator work, they are not comparable. So the better way of comparing, the more real way of comparing, is $30 million on that line for 1989 versus $150 million increase for the year.

Mr. WALGREN. Well, if the Committee would indulge me, and I don't mean to interrupt and stop the flow of what you're thinking of, but that would mean, would it not, that we should feel free then to authorize an amount greater than is expected to be appropriated this year and greater than the Budget Committee might allow for outlays, because you are essentially asking for a multi-year authorization in one year and breaking it away from the number that the Budget Committee is shooting for, for outlays?

Mr. BLOCH. Well, let me say it a little bit differently. Why we are asking for $150 million budget authority appropriation—that $150 million is a new year appropriation and will be spent over five

years. The outlay part of the calculation on that particular line is something like $30 million for the first year or less for the first year.

So I think one has to keep two numbers in front of one's self. We are definitely asking for a budget authority of $150 million. The spending outlay, the outlay, however, the spending on the yearly basis, is what I stated before. It's a fifth or less than a fifth in the first year, really, of that total appropriation.

And as you know, the Appropriations Committees look both at outlays and budget authority as they go through their process.

The point I wanted to make is that many of the comments that you hear, especially from the community, confuse that particular point. But what the community sees in 1989 is $150 million for a center, and it sees $150 million for disciplinary research. But the two are really on two different levels. One talks to an outlay as well as a budget authority of $150 million in 1989, and the other one talks about a budget authority but not the same outlay in 1989.

Let me focus a little bit more on this particular problem because I think it is very important to understand essentially how this $150 million, or $30 million in 1989, how that one adds to the center activities of the Foundation and how that one stacks up against individual grants and disciplinary research.

In Attachment 6 or Figure 6 of your particular chart, you see essentially Research and Related budget including the center budget for the Science and Technology Centers. You see essentially the relationship of the various parts that make up this particular budget.

At the bottom essentially, you see the support for individuals, disciplinary support and support to individuals, which is at a greater than 60 percent level and you see that it has stayed flat essentially for the last few years at that particular level. In fact, it is at one of its high points, if you go back in time to the 1970's and 1960's.

The center line, which is on top, which causes a lot of the comments, is a relatively small percent of the total funding of the Research and Related areas in the National Science Foundation.

The Foundation support for individuals will continue to be our primary concern as it has been in the past.

I would also note that many individual researchers work in centers or are seeking to establish centers. Among those who have sent a proposal in for our current competition, there are 350 currently active NSF principal investigators.

The traditional organization of research in our universities into disciplinary departments has been tremendously productive. It is still the best single way to do science. We want to support it. It is not the only way. New ways must be tried. In some contexts, an interdisciplinary center tied closely to industry would be more effective. A responsible national science policy must balance between these two approaches. We have been spending a lot of time in the Foundation and with the Board, the National Science Board, in making sure that our balance is the right one and that we are not overreacting in one case or in another case.

I need to make a few points about the special aspects of our 1989 authorization bill. First, it is important that we have an authorization bill. I understand the difficulties that made it impossible to

pass a bill last year. I just want to emphasize to you that having the judgment of this Committee and the Congress as expressed in the authorization bill is important to the Foundation.

Second, I would point out that once again we have submitted a draft five year bill. This proposed authorization bill reflects the commitment of the Administration to a doubling of the Foundation's budget over the next five years. This kind of commitment from the OMB is rare, as you know very well, and it is important that it receives the endorsement of your Committee.

The multi-year authorization is also important because it would provide a framework within which the Foundation could develop and implement initiatives that require a long term perspective as most of the research requires.

Third, there is an important proposed amendment to the NSF Act in the draft bill concerning payment of certain benefits for rotators. I know you are familiar with the increasing problems we are having in hiring senior scientists and engineers, who are often compensated well above the Government pay ceiling. We are not proposing anything that would affect that ceiling.

What we are proposing is that we have the authority to pay certain benefits that would compensate university or industry people for the special costs they must pay if they come to NSF as rotators. These include travel costs, moving costs or per diem, and the fraction of their insurance and retirement benefits that would otherwise be paid by their home institutions.

These costs, which are over and above normal living costs and which are incurred by a rotator as a direct result of accepting a temporary position with NSF, should be payable without regard to the limits on direct salary.

In closing, Mr. Chairman, I would like to say something about responsibilities and priorities. Within the Foundation, there is a constant need to make our programs fit the available resources. We cannot accomplish everything, and we must constantly reassess existing projects in order to make resources available for new ones.

It is more difficult in a tight budget year, but it is also more necessary. We have made specific choices and many of the choices that we have made were very difficult, let me assure you, to make. Some of these priority choices produce a reaction in the community. It is not possible to make everyone happy. That reaction is really an indication that we are making meaningful choices, not just increasing or decreasing everyone's grant by an equal percentage. That sort of mindless action would be easy, but it would not serve either the nation or the community well in the end.

The 1989 budget was developed with this need to set priorities in mind. Our first priority is on people, both in developing human resources and in research support as well as in education. We stress the value of individual investigators, but we also recognize the value of group efforts and centers.

The Congress has the same problem. We understand there are other needs than science, and you must judge their relative merits.

I would point out that nearly all Federal missions depend on scientific and engineering expertise and will benefit from new knowledge and new technologies. This is especially true of the space sta-

tion, the supercollider and other major scientific and technical initiatives.

NSF provides the base on which the success of these other programs will be built. Providing that base is what the Foundation is all about and what we are trying to accomplish. That is why I strongly believe that our request needs and deserves your full support.

Thank you very much. Dr. Schmitt would like to make a few comments.

[The prepared statement of Mr. Bloch follows:]

TESTIMONY OF

MR. ERICH BLOCH

DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH & TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

WEDNESDAY, MARCH 23, 1988

MR CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

I am pleased to have this opportunity to discuss the Foundation's budget request for FY 1989. Education and basic research in science and engineering have a direct, long term relation to national economic well-being. Our budget request highlights the Foundation's potential to contribute to this relationship.

SCIENCE, TECHNOLOGY AND NATIONAL GOALS

I think we can be pleased that recent debates over economic matters have come to focus more strongly on science and technology. Increasingly we understand that we must look to our own educational, research, industrial, and governmental systems to make us competitive. This understanding is only a first step, but it is very important.

Although there is a growing consensus on the need for strengthening our educational and research systems, fiscal problems have so far prevented us from taking the action we would like. I hope this can be the year when that begins to change in a decisive way. It requires a long-term view, and a determination to identify and support national priorities in the difficult environment of fiscal constraint.

The Federal budget request for FY 1989 proposes to address urgent national priorities within the terms of the bipartisan budget agreement. In identifying high-priority areas that must be

funded adequately, science and technology are singled out for their contributions to long-term improvement in national productivity and global competitiveness.

A nation that wishes to lead -- economically, militarily or politically -- must also lead in science and technology. Investments now provide the base for future strength. Increased support for basic research, particularly at universities, will help to generate the new knowledge necessary for continued innovation and will help to assure the future availability of high-quality scientists and engineers.

NSF BUDGET REQUEST

The FY 1989 budget request for the National Science Foundation is $2.1 billion, an increase of more than 19% over FY 1988. It includes a proposed new appropriation for Science and Technology Centers.

Table 1
NSF FY 1989 Request
(dollars in millions)

Research & Related Activities	$1603.0
Science & Technology Centers	150.0
U. S. Antarctic Program	141.0
Science & Engineering Education	156.0
Total	$2050.0

We believe that the request reflects the dynamic forces in today's research as well as the fundamental relationships which underpin the health and vitality of the science and engineering enterprise. It returns to a rate of growth which doubles the Foundation's budget over the next five years. This significant growth is a central feature of the Administration's commitment to science and technology.

The request is formulated around three strategic themes:

- Education and human resources -- because people are our most important asset;
- Disciplinary research and supporting facilities -- because universities are the primary source of new knowledge; and
- Research centers and groups -- because we must foster interdisciplinary investigation and build stronger links between universities and industries to use our technical resources most effectively.

We must be concerned with breadth, flexibility, and the changing nature of investigation. And we must extend our efforts to find and encourage all scientific and engineering talent.

We have noted a gradual transition in the nature of scientific inquiry in the last decade. Technologies such as satellite communication and large scale computing enable scientists to work with data sets of great size and complexity. These and other tools have opened completely new avenues of experimentation and illustrate the gradual shift to greater interdisciplinary collaboration as well as the increasing need for large-scale facilities and sophisticated instrumentation. Such collaborative centers and large-scale facilities must be assured a stable funding environment if they are to direct their energies to producing high quality science. It is simply not cost-effective to "power-down" productive, large-scale activities simply because of short-term vagaries in the funding cycle.

In this regard, I would point out that once again we have submitted a dreft five-year authorization bill. It reflects this Administration's commitment to doubling the Foundation's research budget over the next five years. Moreover, it reflects the realization that long-range planning must be accompanied by long-range commitment. While passage of this bill will not preclude annual revisitation of its provisions by the Congress, it will be an important acknowledgement of the importance of developing a strong scientific base for the long-term scientific, as well as economic health of our country.

PEOPLE: EDUCATION AND HUMAN RESOURCES

A basic tenet of our long-term view is that people must be our highest priority. Trained and educated people are the major resource of any modern society.

We have developed a broadly based approach for support of education and human resources; all parts of the Foundation are engaged in this effort. Most precollege and some advanced programs are in the Science and Engineering Education Directorate, while the research directorates support much of the effort at undergraduate and advanced levels.

Appropriations for Science and Engineering Education have risen from a low of $16 million in 1983 to a requested $156 million in 1989 -- almost a ten-fold increase. (Figure 1)

Even more important, the actual numbers of scientists and engineers supported -- at all levels from high school through senior scientists -- are rising sharply. Across the Foundation, the FY 1989 increase will support over 14,000 additional people -

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- a 30% increase over FY 1987. This is indeed a positive development. (Table 2, Figure 2)

Table 2
National Science Foundation
Support for Human Resources

	FY 1987 Actual	FY 1989 Estimate
Senior Scientists.....	15,800	18,900
Postdoctorals.....	3,400	3,800
Graduate Students.....	14,700	17,100
Undergraduates.....	6,400	9,300
Pre-college Teachers.....	7,200	9,500
High School Students.....	<100	3,000
Total Number Supported...	47,600	61,600

The positive trend of the budget, however, should not obscure the dismal state of science and mathematics education in our schools. Only two weeks ago the Foundation announced the results of a new survey of international science student accomplishments. Once again the United States did not place well. Our 14-year olds tied for next to last place, while Hungary and Japan took the top places.

With these concerns in mind, our request includes $265 million for education and human resources, up more than 20% over 1988. Activities are designed for all levels of education, academic career initiation, all types of institutions, and all regions of the country.

The Education Pipeline

The Foundation's precollege programs are the largest component of the education and human resources effort. Precollege support has grown rapidly, and will rise again by 20% in FY 1989 to a total of $108 million. On a national scale NSF's role at the beginning of the education pipeline is small in terms of dollars, because our resources are used to stimulate others, to innovate, to lead. The main effort must come from the States, which bear principal responsibility for education.

One mechanism for multiplying the impact of NSF investments is to promote linkages among all concerned sectors. Ongoing projects for materials development involve education developers, publishers and school systems. New projects are planned in FY 1988 and FY 1989 for partnerships between the private sector, local schools, colleges and universities. Over 35 States are represented in proposals currently under review to develop model

cooperative precollege education efforts on a local or regional scale.

Undergraduate programs are another area of major emphasis. The Foundation has developed a comprehensive range of programs to address critical needs identified by the National Science Board and other groups. As activities deferred from FY 1988 are initiated or expanded in FY 1989, support will rise to $65 million -- a 62% increase -- for activities for students, faculty, curriculum, instrumentation and laboratory development, and underrepresented groups.

Recruitment and retention of scientists and engineers is a pressing problem. Almost no science is taught in elementary school, and less than a quarter of high school graduates are qualified to do college-level science or engineering. For every 10,000 high school sophomores, only 20 eventually earn doctorates in natural science or engineering. This is not enough to meet the needs of industry, government, and society as a whole.

In the long run, we hope that efforts at the precollege level will yield greater participation in science and engineering. But we must recognize a more short-term fact: new PhDs for year 2000 are entering college now. We must have strong efforts focussed at the undergraduate level and above. (Figure 3)

Broadened Participation

A large part of any solution to the shortage of human resources must come from broader participation. The Foundation's investments to broaden participation total almost $49 million in the FY 1989 request, and increase of nearly 30% over FY 1988.

We have made good progress in encouraging women to join the science and engineering community, although we are far from where we should be. We should also be concerned about evidence that the participation rate is leveling off.

With minorities our programs have not shown the desired change. We have instituted new activities for minority research and resource centers and for minority students which may have an important effect. We are making special efforts in both education and research programs to address this issue.

A good example is the South Carolina Cooperative Plan for Professional Development of Science and Mathematics Teachers in Grades 7 - 12. Significant numbers of minority teachers are involved in summer workshops, through a consortium of five universities and colleges. Other institutions in the region are beginning to replicate the activity. State and university resources have been committed to the project.

People work and develop in institutions, which means that we must be sensitive to the need to broaden participation beyond the institutions that already compete well. NSF has sought to do this especially through the Experimental Program to Stimulate Competitive Research (EPSCoR) program, with encouraging results in thirteen States and territories.

A point that is not well known is that NSF is especially important in the States that receive relatively little Federal R&D support. We provide about 10% of Federal R&D funds going to the bottom 10 states, compared to less than 3% of the total for the top 10 states.

UNIVERSITIES: DISCIPLINARY RESEARCH AND FACILITIES

The second requirement for better economic performance is a stronger university basic research capability. I would hope that 1989 is the year we can move forward in this area.

The Foundation continues to make its largest investments in this area. The FY 1989 request includes more than $1.2 billion for disciplinary research and research facilities, an increase of 8% over FY 1988.

University basic research is more important today than ever before. The world is rapidly shifting to a knowledge-based economy. In our system, basic knowledge is produced mainly in universities.

Trends in Support

I want to highlight briefly some trends related to basic research:

- In contrast to education, research support has not been rising in recent years. In constant dollars, the NSF research and related appropriation for 1988 is almost exactly where it was in 1985. (Figure 4)

- Overall, federal investment in civilian R&D has grown slowly in the past few years. By contrast, research investments by our major trading partners continue to advance strongly. We are not matching their effort in civilian R&D. (Figure 5)

We must do better than this. In nearly every field that NSF supports the opportunities to make important advances have outrun the available funds.

Emerging Research Areas

Superconductivity is but one area in materials research that promises important economic benefits. There are many others.

In mathematics, chaos theory is almost entirely new in just the past few years. It already promises to help us understand complex phenomena that have eluded us in studies ranging from weather patterns and fluid dynamics to distribution of biological resources.

Biotechnology continues to be an area of accelerating development. New knowledge from basic research promises new applications. Recent emphasis on biological communication, how chemical signals operate between cells and between organisms, has significant implications for agriculture and human health. Major new industries -- only dimly visible today -- will stem from today's basic research.

American manufacturing appears to be starting a comeback, as it must if we are to prosper. But manufacturing will change dramatically over the next decade as new materials, computer aided engineering design, robotics and other new technologies emerge from basic research. Studies in neuroengineering are comparing neural networks in the human brain with computer circuitry. Findings will be of direct use in development of robot visual systems, computers that recognize and respond to human speech, and other advances with industrial applications.

Research on global change is focusing on unprecedented studies of the planet Earth as a complex system of interacting processes. We are at the threshold of understanding the far reaching implications of natural and man-induced environmental changes. This undertaking requires not only direct support for research, but large-scale operations and logistics support.

The Antarctic, because of its major influence on world climate, has a unique role in research on global change. Operations support here is critical. Only one research ship with ice strengthened capability, the Polar Duke, is available following the decommissioning of the Coast Guard's Glacier. Current requirements for 300 days per year for each of two ships cannot be met. The Foundation's FY 1989 request includes provisions for leasing a new ship.

The world is in an unprecedented period of technological development. We know that nothing like the present has been seen before, and a reasonable guess is that the future will be even more intense and fast-paced.

Science and technology are critical factors in the nation's global stature. Unless the United States is willing to cede its

historic position of world leadership to others, we must find resources for the necessary investment in basic research.

LINKAGES: CENTERS AND GROUPS

Cooperation among the various sectors of our economy is the third element of an effective science and technology enterprise. It is encompassed in the third theme of our proposed budget, support for research centers and groups.

This is especially important in the United States because our research system is built on the research university. This keeps research and education tied closely together, which is a major strength and one of the reasons why our universities are the envy of the world.

The drawback of our system is a tendency for university research to be isolated from economic reality. We need explicit mechanisms to make sure this does not happen, and that the results of our laboratories flow smoothly into industry.

NSF has been a leader in developing new ways to bring the various players in science and technology more closely together. Support for research centers and groups totals $477 million in the FY 1989 request, an increase of $188 million over FY 1988. The new program for Science and Technology Centers is a significant feature of the proposed increase.

Research Centers and the Organization of Research

The Foundation's Engineering Research Centers (ERCs), established in 1985, have stimulated significant industrial support and thereby brought new resources to the universities. Each NSF dollar has been more than matched by industry contributions. Even more important, however, is the contribution that industry has made by committing time and people to help make the centers work.

The centers concept has also stimulated interagency cooperation, notably the FY 1988 Plant Sciences Centers, jointly supported by NSF and the Departments of Agriculture and Energy.

Our budget for 1989 requests funding to extend the ERC concept to other areas in science through the Science and Technology Centers (STC) program. The STC program, originally proposed for FY 1988 was not initiated because of severe budget constraints. However, over 300 proposals from 124 institutions in 42 States were received, and merit review is proceeding.

We propose a new appropriation in FY 1989 of $150 million for Science and Technology Centers, sufficient to fully fund 12 to 15

centers for up to five years. Our intention in keeping this appropriation separate and in providing full funding at the outset is to avoid committing the Foundation's future resources to an unwise degree, and to answer the concern of those who fear that the centers might displace traditional support mechanisms.

We understand this concern, but think it is unfounded. The Foundation's support for individuals has been and will continue to be our primary concern. (Figure 6)

I would also note that many individual researchers work in centers or are seeking to establish centers. Among those who have submitted center proposals are 350 currently-active NSF principal investigators.

The traditional organization of research in our universities into disciplinary departments has been tremendously productive. It is still the best single way to do science. But it is not the only way. Research groups crossing disciplinary lines, and interdisciplinary centers tied closely to industry for more effective knowledge transfer, provide healthy diversity. A responsible science and technology policy must balance these approaches.

PRIORITIES

I would like to focus for a moment on responsibilities and priorities.

Within the Foundation there is a constant need to make our programs fit the available resources. We cannot accomplish everything, and we must continuously reassess existing areas of support in order to make resources available for new research directions.

The FY 1989 budget was developed with this in mind. Our first priority is people, both in developing human resources and in research support. We stress the value of the individual investigator, but we also recognize the value of group efforts and centers. We have also made difficult choices between specific disciplinary areas, providing increases for the most important areas at the expense of others.

The Congress has the same problem. You have before you proposals for a number of large projects, some of which are entirely science projects and some which serve other goals as well. Scientists and engineers can tell you why our programs are important, but have no special expertise with respect to other choices.

We do know, however, that nearly all Federal missions -- from highways to health -- depend on scientific and engineering expertise, and will benefit from new knowledge and new technologies. The most important thing is to make sure we have highly trained people, and that we keep our research programs diverse and broadly based. Neither the space station, nor the super collider, nor the human genome project will be successful without the right people, and all are heavily dependent on new technology.

SUMMARY

The National Science Foundation has put forward a proposed budget for FY 1989 that will make significant progress in strengthening our science and engineering enterprise:

- We focus on people, because everything else depends on that most basic resource.
- We emphasize university basic research, because universities are the core of our research capability.
- We are mindful of balance, among different areas of science and engineering, and among different modes of support, because diversity provides the richest environment for inquiry and innovation.

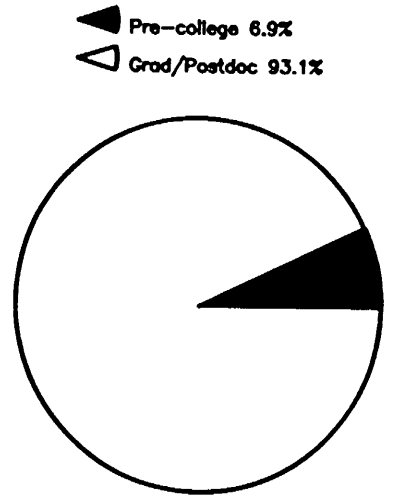
These themes are at the heart of the Foundation's mission to promote the health of science and engineering research and education. They delineate the Foundation's fundamental contribution to the nation's global leadership.

This committee has played a lead role in building the vital recognition of the links between research, education and the welfare of our nation. I hope we can count on your support for our request.

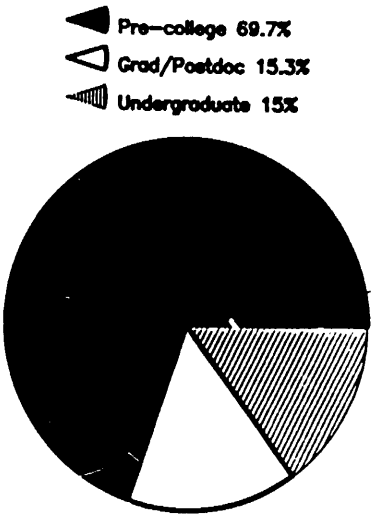
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Figure 1

SCIENCE AND ENGINEERING EDUCATION SUPPORT BY EDUCATIONAL LEVEL FY 1983 – FY 1989



FY 1983 (TOTAL = $16.09 MILLION)



FY 1989 (TOTAL = $156.00 MILLION)

Figure 2

NATIONAL SCIENCE FOUNDATION SUPPORT FOR HUMAN RESOURCES

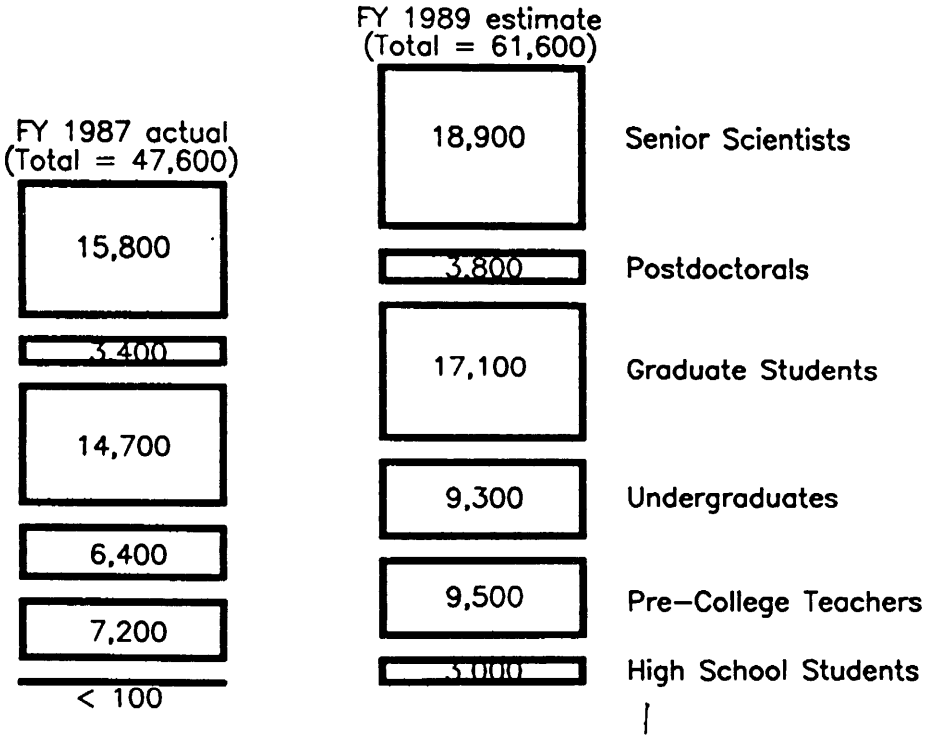


Figure 3

PERSISTENCE OF NATURAL SCIENCE AND ENGINEERING INTEREST FROM HIGH SCHOOL THROUGH PH.D. DEGREE

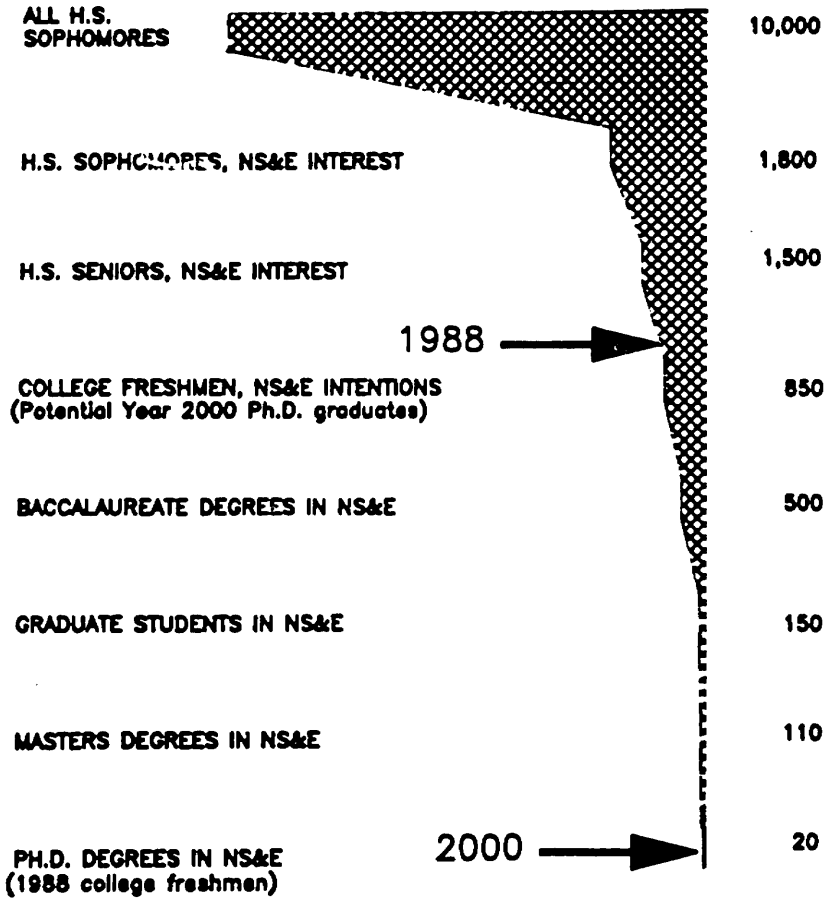


Figure 4

NATIONAL SCIENCE FOUNDATION
BUDGET TRENDS
RESEARCH AND RELATED ACTIVITIES

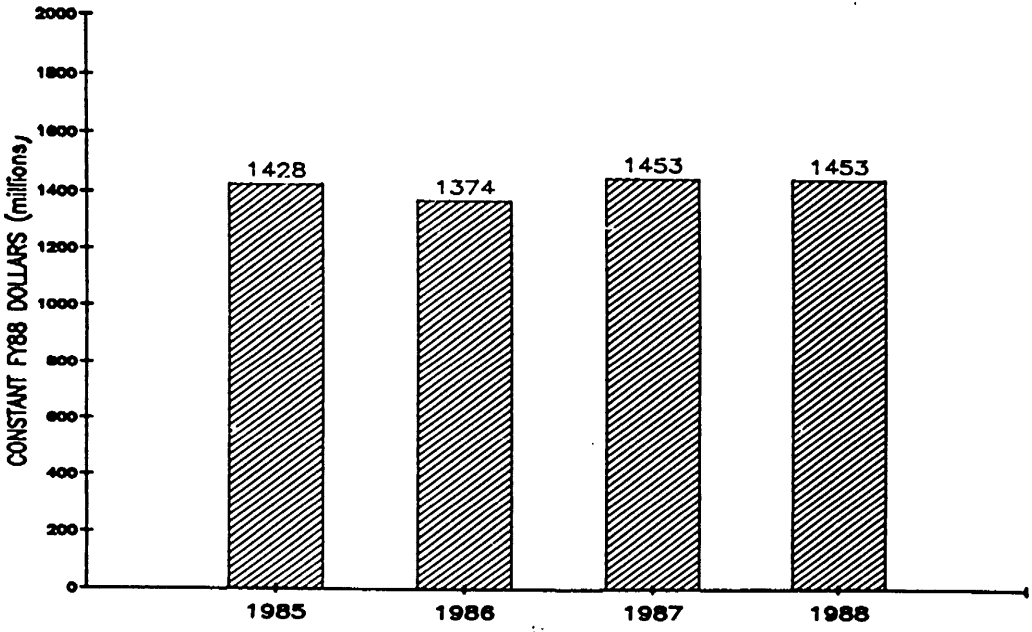
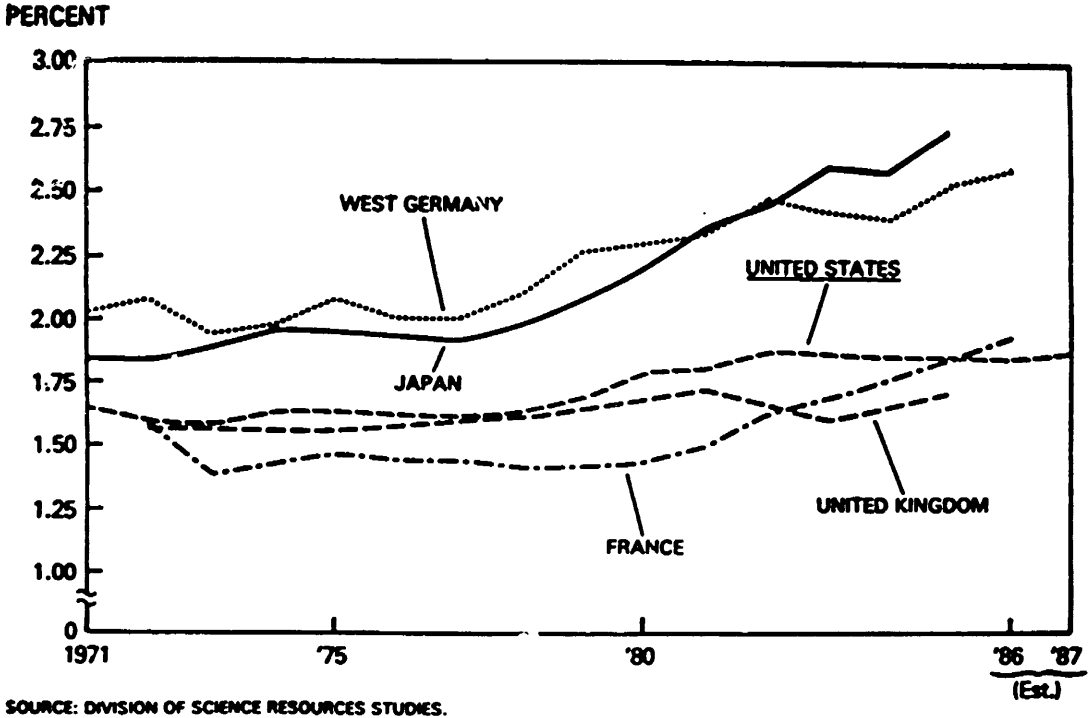


Figure 5

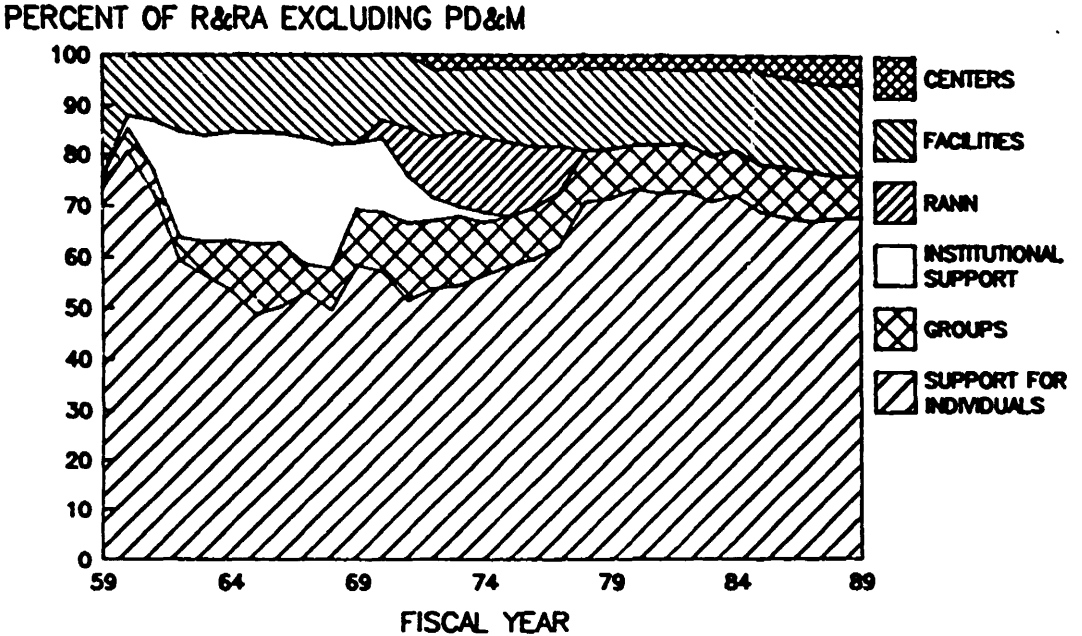
NON-DEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT (GNP) BY COUNTRY



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

Figure 6

RESEARCH & RELATED ACTIVITIES
TRENDS IN CATEGORIES OF SUPPORT



NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

ERICH BLOCH
DIRECTOR

Erich Bloch was confirmed by the Senate to be Director of the National Science Foundation on August 6, 1984. As Director, he is responsible for an agency charged with strengthening the national scientific research potential, with improving science and engineering education at all levels, and with increasing the interchange of scientific information among scientists in the United States and abroad. The Foundation has an annual budget exceeding $1.7 billion and the annual award of 12,000 to 14,000 grants for research in all fields of natural and social sciences.

Before joining NSF Mr. Bloch was Vice President for Technical Personnel Development at IBM Corporation which he joined in 1952 as an electrical engineer. During his career at IBM, Mr. Bloch was the engineering manager of IBM's STRETCH super computer system in the late 1950's and early 1960's, developed under contract from Los Alamos National Laboratory of the Atomic Energy Commission. In 1962, he headed development of the Solid Logic Technology program, which provided IBM with microelectronic technology for its System/360 computer. Subsequently, Mr. Bloch was appointed a vice president of the company's Data Systems Division and general manager of the East Fishkill facility, which is responsible for the development and manufacture of semiconductor components used in most of IBM's product line. He was elected an IBM Vice President in 1981.

From 1981 to 1984, Mr. Bloch served as chairman of the Semiconductor Research Cooperative, a group of leading computer and electronics firms that funds advanced research in universities and shares in the results, and was the IBM representative on the board of the Semiconductor Industry Association.

In February 1985, Mr. Bloch was awarded the National Medal of Technology by President Reagan. The award was made for his part in pioneering developments related to the IBM/360 computer that "revolutionized the computer industry." He also received an honorary Doctorate of Engineering degree from the Colorado School of Mines and honorary Doctorate of Science degrees from the University of Massachusetts at Amherst, George Washington University, State University of New York at Buffalo, the University of Rochester, and Oberlin College.

He is a member of the National Academy of Engineering and is a Fellow of the American Association for the Advancement of Science and of the Institute of Electrical and Electronics Engineers and a member of its Computer Society. He received his education in electrical engineering at the Federal Polytechnic Institute of Zurich, Switzerland, and a bachelor of science degree in electrical engineering from the University of Buffalo in 1952.

September 1987

Mr. WALGREN. Thank you very much, Mr. Bloch. We appreciate that. Welcome, Dr. Schmitt. We are pleased you are here.

Dr. SCHMITT. Thank you. I am very pleased to appear before this Committee. I am here, as you know, as Chairman of the National Science Board, but I also appear before you with the views and perspectives that I've gained in both my prior career as head of R&D for a corporation, namely GE, and my present position as President of the Rensselaer Polytechnic Institute, one of the nation's strong research and education universities, especially in engineering.

From that perspective, I'd like to comment on the balance in NSF's 1989 budget proposal. As Mr. Bloch has indicated, there are three strategic themes in this budget: first of all, education and human resources; second, disciplinary research and supporting facilities; and third, research centers and groups.

In my view, these are exactly the right strategic themes to guide the NSF budget at this moment in time. I would like to comment very briefly on each of these and especially on the issues that pertain to the balance among them.

The total scope of NSF's investment in education and human resources, the first strategic theme, really goes beyond the Science and Engineering Education Directorate budget alone and even within that directorate, beyond the pre-college education budget alone.

Because there is, quite rightly in my view, so much interest in pre-college science and math education, we may not be talking quite enough about undergraduate education and perhaps even graduate education. Both of these areas are just as vital for the development of the human resources needed in the United States as of that of pre-college education.

I would like to dramatize this with some observations on this report that has become quite well known, having been issued a few days ago, the report on "Science Achievement in Seventeen Countries," which Mr. Bloch has commented on. It is a comparative study of the status of science knowledge in grades 5, 9, and the last year of high school. The study has been widely quoted as showing how poor the United States is compared to other nations; and, unfortunately, that is true.

I want to point out to you one other interesting result in this study that has not been commented on. There are three countries in it, England, Hong Kong and Singapore, that also rank very, very low in science achievement in grades 5 and 9; but in the same three countries, they rank at or near the top in achievements in physics, chemistry and biology in the last year of secondary school.

I believe these results show that a lot can be done by proper education in later years even with a very poor early showing, so that strong investments in the right kind of education programs in later years can in fact make a difference. This in fact will carry through the undergraduate years as well.

Therefore, the programs in all the directorates, Science, Engineering and Education Directorate included, devoted to undergraduate education are, I believe, just as important for the development of our human resources as are the pre-college programs.

It is well known, for example, that in Japan, college level education is not as stringent as is pre-college. Industrial firms therefore

consider intensive training programs necessary after hiring fresh engineers. Thus, the United States beats Japan in both college level education and in academic research. The result has been that the United States has made one generic technological advance after another, from transistors, to microprocessors, to genetic engineering, to fiber optics, to lasers, to magnetic resonance imaging, and on and on, while Japan has made none.

Moreover, in each of these fields, the United States has been first to market with the products based on these generic advances, a contradiction of the popular belief that Japan is always first to market with a new technology.

Japan's process, which is in fact innovative in its own style, has been in the second, third, fourth wave of products, not in the pioneering te hnical advances nor in the first products based on them.

This is a competitive advantage that we have in the United States and that we have to preserve while we are fixing all the serious problems of pre-college education that seem uppermost in people's minds.

In the second area, disciplinary research and supporting facilities, NSF has valiantly maintained the investment in this area in spite of the lack of real growth in the Research and Related Activities since 1985. It is going to be more and more difficult to do that unless that part of the budget grows. One needs to emphasize again that, because so much of NSF's investment goes to academic institutions, these research expenditures, too, are vital for the development of human resources as well as new knowledge. They cannot be allowed to languish.

The part of these that are devoted to centers, especially the established Engineering Research Centers and the new Science and Technology Centers, is in my view essential for the continued strengthening of American industrial technology. The link between academic research and industry has always been stronger in the United States than in other nations, and it has been one of our key competitive advantages up to now.

The initiative represented by centers is the next logical step in further strengthening that linkage without jeopardizing the openness of academic research. The concept of centers, which generally entail multidisciplinary programs, is ideal for speeding up the transfer of advancing knowledge from universities to industry. Why is that so?

The reason is that most industrial applications of science and technology are multidisciplinary. Industry has often had to tap various different streams of separate basic disciplinary work and integrate them for particular ends.

To have these streams of disciplinary work coming together at the outset in an academic environment is going to speed up the whole process in my view, both because of the kind of knowledge generated and the kind of students, both graduate and undergraduate, that are produced.

Thus, from my perspective, this initiative is of utmost importance, even though it is still only a small fraction of NSF's budget. For these reasons, I believe that the balance between the complementary and competing needs that have been struck in this budget

is a good one. I would urge you seriously to consider that balance as well as the total amount requested.

Thank you.

Mr. WALGREN. Thank you, Dr. Schmitt. Dr. Moore, any thoughts you would like to share with us?

Dr. MOORE. Thank you, Mr. Chairman. I just have a couple of comments, essentially underscoring what has been said by Mr. Bloch and Dr. Schmitt, and in particular focusing on a point that Mr. Bloch made about the fact that our research budget has been essentially constant in real terms now since 1985.

I think the members of the Committee know that in science and engineering these days, we are faced with an incredible wealth of opportunities. We also know that science and engineering are becoming increasingly costly. We also know they are becoming increasingly competitive, as other nations increase their investments and we do not.

Our constant budget for the last few years has caused us to make some very, very hard choices. This year, as you know, we did not begin the Science and Technology Centers initiative. We have had to cancel some very promising pr' 'ects and so forth.

I think it is very important that we take steps to redress that particular problem for our competitive position, the nation's competitive position, not only in economics, which we believe we have been focusing on a great deal but also in science and engineering themselves.

It is also important f\ r the purposes of human resources development. We need, as Mr. Bloch has emphasized, to somehow stop up the leaks in the pipeline, particularly as students get through their undergraduate careers and choose graduate education.

I would just urge the Committee to view the entire budget and its balance, its impact on all of the Foundation's responsibilities.

Mr. WALGREN. Thank you very much.

Obviously, what leaps out at anybody from a distance looking at this budget is the dominance of the Science and Technology centers' funding, in terms of the amount of the increase in the authorization that is asked for—that is allocated to that new effort.

I appreciate that the outlays are not anticipated to be in that year or any individual year, the full $150 million.

What is the increase in the outlays from 1988 to 1989 that you expect; what percentage increase in outlays would there be in the Foundation's budget? We use this 19-percent figure but I gather that includes the $150 million. We are not anticipating increasing outlays by 19 percent.

Mr. BLOCH. That's correct. The 19 percent that you refer to is really the bottom line increase, 1988 to 1989, in budget authority but not in outlays.

Mr. WALGREN. What is the increase in outlays?

Mr. BLOCH. The increase in outlays, we have approximately—let me break it down for you. We have $150 million in the Research and Related area as the budget authority increased. Between Antarctica and Science and Engineering Education, we have another $35 million. That is about $185 million in budget authority. Of that $185 million, we are outlaying at about a 50-percent rate in those areas.

The increase in outlays would be about $90 million stemming from these three appropriation lines. The outlay on the $150 million, as I said before, in an overstated case, is about $30 million. I would say it is probably closer to $20 million. Add another $20 million to that. You have an increase in outlays of about $100 million, roughly speaking.

Mr. WALGREN. $100 million on a base of?

Mr. BLOCH. On the base of $1.7 billion of our budget, but it would be close to that, on a base of $1.7 billion.

Mr. WALGREN. As a percentage of the actual increase in effort this next year, it is not 19 percent but it is 6 percent?

Mr. BLOCH. Yes, 6 percent in outlays.

Mr. WALGREN. Is that what explains the fact that your future projection for future years is as low as 4 percent in 1990, as I understand it?

Mr. BLOCH. We have to be careful on that one also because of the 1989 construction of the budget. The way it is constructed, you see, essentially the whole $150 million assumed in the base when you make your increase calculations, going from 1989 to 1990. There is a distortion being introduced in 1989 because of the $150 million. Therefore, if you now figure out the dollar increase next year and percent dollar increase next year, it is essentially against this 1989 base because there is no new line or new dollars in there for Science and Technology centers. They all have been essentially, for five years, put into 1989. That distorts the next year to a 5-percent level.

Mr. WALGREN. As we measure our true effort or true change in effort or increase in effort, if we focus on outlays, we are going to come out with something in the range of 5 percent this year. Is that right?

Mr. BLOCH. Additional outlays.

Mr. WALGREN. A little less than 5 percent.

Mr. BLOCH. The real way to focus on it is by line item essentially. I think that is a better way of focusing on it than adding it all up because you are really comparing over two years, apples and oranges.

Mr. WALGREN. It is raised first with the public that we are doubling this budget over five years, and I hope we do. And as you indicated in your statement, that is a rather unusual commitment from OMB. The last time I remember that was in the last year of the Carter Administration, when there were lots of commitments made to increase future budgets. Of course, it didn't happen.

I just want to be sure we are looking and measuring as clearly as we can what the actual increase in effort is; and, although we hope that 19 percent comes to fruition sometime in the future, we are really talking about a much different and lower percentage increase this year in real effort.

Mr. BLOCH. In real outlays.

This is the second year that we are submitting with OMB's agreement a five year doubling effort for the Foundation. It is not just that it came up this year. It came up last year. We submitted it last year. It was a 17 percent increase for 1988. Because of what the allocation was and the appropriation for us, we really had to reset many of the numbers and start over again in 1989.

The point I want to make is it is the second year that commitment is being made by this Administration and by OMB. It is not the last gasp in the last year of an Administration.

Mr. WALGREN. There is a lot of ground to cover. I particularly want to get into the community college area with you and see what progress is being made there.

Instinctively in this commitment to centers, particularly when we are being asked to make an absolute commitment, where all the funding is put up in one year, compared to other centers that the Science Foundation has offered, where all the funding was not put up in one year and centers like the supercomputer centers that have been under varying pressures from year to year as the programs have developed, the question comes as to why should we leap so completely with these centers when we were not asked nor recommended to leap with the others, particularly in view that our experience with centers is relatively new? I think we have only had one review of the Engineering Research Centers, and that resulted, as I understand it, in some real recommendations for changes in the program and perhaps the closing of some centers.

How comfortable should we be making this total commitment of what is a very large amount of money in view of the pressure that puts on individual investigators and the like?

Mr. BLOCH. First of all, centers are nothing new. We have had centers since the 1970's. MRLs were established in the 1980's, Materials Research Laboratories. You mentioned the ASCs which were established in 1985.

I don't know what you mean by jumping completely. We are not asking for 100 centers or something like that. We are asking for 12 to 15 centers to be established over five years. That is about the number of centers that we have established in the Engineering Research Center category, 14, since 1985. The numbers are comparable.

Secondly, the ASCs, we established all five ASCs at the same time, in 1985, and one in 1986. If you have an initiative like that, you have to have some kind of a critical mass for it. The funding that we are proposing is a little bit different; no doubt about it. Before, we made commitments, by the way, for five year funding on the Engineering Research Centers and five year funding on the ASCs, even though the appropriation was only for one year. Our commitment to the universities in the Engineering Research Centers is clearly for five years, and that is a commitment that we have been implementing and are implementing.

It is not that much different. You can't establish a center for one year and not tell anybody what happens in the second year. It doesn't make any sense. It takes a long time for a center to develop. You have to give it some kind of horizon, and five years seems to us an optimum kind of horizon. It is not a maximum horizon, and it is not a minimum horizon. It is an optimum horizon. We are evaluating the Engineering Research Centers after three years, as you just mentioned.

I don't think it is a leap into it, as much as the leap—as the leap into the Engineering Research Centers or into the Advanced Supercomputer Centers.

Dr. Schmitt, would like to comment on that?

Dr. SCHMITT. I just want to make one comment on this issue of centers, which gets so much attention and so much emotion attached to it. When I first joined the National Science Board almost six years ago, the first issue that I had to address was as chairman of a committee to look into three centers that were then in existence and up for review. One was the Center for Theoretical Physics in Santa Barbara, California, and there were two other math centers. Those centers have now become well established, and they are functioning, and no one gives them a second thought.

The concept of centers seems to evoke a lot of emotion, when you first talk about establishing them, and a lot of discussion. It is a quite valid discussion to have, but the only thing I want to point out is the issue of centers versus individual. It is one that has perpetually been before NSF for a long period of time in the past. It is not really a new issue.

Mr. BLOCH. I think, sitting here and listening to this discussion over the last few minutes—I think we have an optics problem more than a real problem. The optics problem essentially is the fact that we are asking for five year appropriation, all in one particular year or all in one appropriation submission.

Last year, in 1988, we came in exactly with the same number for the Science and Technology Center, and this Committee approved of it. We had $30 million in 1988 in there which would have given us exactly the same thing. One year funding for about 12 to 15 centers, not any different. Nobody questioned that. Not any different than the $150 million now.

Mr. WALGREN. As I understand it, you are saying the NSF has felt it had made multi-year commitments to centers in the past. The Congress never did; and, so in a sense, this is a first-time leap for us. It may not feel like much a leap for you.

Mr. BLOCH. That's absolutely right, and that is what I call the optics problem, I guess. But let me make one point. Research—and not only centers, by the way—the same applies to individual grants—one year is an arbitrary period for a grant for a piece of research which lasts two or three years, and the individual just like the Center has to essentially know what is in the future.

Now everybody realizes that, depending on the allocation from Congress, many of the "commitments" might fall by the wayside. But that is a better way of operating than only focusing on one year.

Mr. WALGREN. The Chair recognizes the gentleman from New York, Mr. Boehlert.

Mr. BOEHLERT. I like the concept and I like your approach with the Science and Technology Centers, but an area of concern to me is it seems that when we make some commitments we don't always follow through on them.

Can you tell us where we are right now with the Supercomputer Center funding and the cooperative agreements? Aren't we behind?

Mr. BLOCH. Yes, thank you for that question.

Mr. BOEHLERT. You're not surprised that you got it?

Mr. BLOCH. No. Not really surprised that we got that question. It is again one of these very difficult areas that we are dealing with. Let me make the following point. We have established five centers, and you have got to look at each and every center where it stands

today compared to what our agreement has been—because the history of the centers are different.

Let me take one center for a minute out of the discussion, because it is a very different kind of a case, and that is the Von Neumann Center. The Von Neumann Center has had problems since its inception on getting a machine which was not designed at the time—was under design at the time when we agreed to the establishment of that center. And that machine program, the ETA-10 machine, has had untold delays essentially. And as a consequence, it was not shipped on time; and as a consequence we did not pay; and as a consequence we asked essentially the manufacturer to supply free of charge other kind of facilities for us that we could use in that particular center. So that center is somewhat—in a class by itself.

Mr. BOEHLERT. I understand.

Mr. BLOCH. All the other centers are within a $1,000,000 to $1,500,000 of the original kind of commitment up to and including 1989.

We had in 1988 a severe kind of a problem because of the 3 percent increase. We wanted to make sure that we could move forward on networking in parallel with it, put a lot of money into networking; and, that essentially reduced the money that was available for these centers themselves.

Mr. BOEHLERT. Mr. Bloch, for the record, could you submit the details of the cooperative agreement with the five centers——

[Material referred to follows:]

ADVANCED SCIENTIFIC COMPUTING CENTERS--NSF FUNDING 1985-1988

CENTER	1985		1986		1987		1988	
	C.A.	Act.	C.A.	Act.	C.A.	Act.	C.A.	Act.
San Diego	4.7	4.7	9.1	9.1	12.1	11.5	12.1	11.1
Illinois	5.0	5.0	7.0	7.0	8.5	8.5	8.6	7.7
Pittsburgh	---	---	2.0	2.0	4.0	4.0	8.0	7.4
JVNC	8.3	8.3	9.0	5.0	11.7	8.5	13.1	9.6
Cornell	4.9	4.9	6.3	5.3	6.2	5.2	4.1	5.25

NOTES: Cooperative Agreements for San Diego, Illinois, Pittsburgh, and JVNC expire in 1990. Cornell C.A. expires in 1988. Renewal is under review at present time. 1988 Actual for Cornell includes funds for several months beyond the original C.A. duration to continue operation until review is complete.

Mr. BLOCH. Let me just give you what, on a cumulative basis from 1985, when we started this program, the San Diego Center is down about $1,500,000 out of about—it is down about $1,500,000 cumulatively; the Illinois Center is about down $800,000 up to 1989; Cornell is down about $2,500,000. We are running roughly—and they are all different but, for instance, San Diego—we are running about a $12 million rate, so it is so far about $50 million is in that Center. In Illinois we are running about at a $9 million rate, so it is about $45 million. In Cornell we are running at about a $7 million rate, so that one is on a $30 million kind of a base. In Pittsburgh—it has been running of late at a $10 million rate; much lower in the beginning, about $4 or $5 million. And that is down about half a million dollars.

Mr. BOEHLERT. Are we talking 1988 or 1989?

Mr. BLOCH. 1989.

Mr. BOEHLERT. 1989.

Mr. BLOCH. I said in 1988 we had a severe kind of a problem, and we took some money out of those centers. What has happened to the centers as a consequence is, instead of trying to upgrade—upgrading some of their capabilities in the 1988-89 timeframe, we are not going to be able to upgrade before the 1990-91 kind of a timeframe.

Mr. BOEHLERT. Isn't that a little bit short-sighted?

Mr. BLOCH. Is it short-sighted? Well, let me say the following way. Would we want to do it as soon as a machine is available? Obviously, certainly. Can we always do that? No, I don't think so; and, it means that essentially, instead of upgrading in the 1988-89 timeframe, we are postponing that by one to two years. Is that a complete disaster? No, that's not a complete disaster. Is it something that the individual centers like to see? No, that is not true either.

Mr. BOEHLERT. Well, isn't it something we would like to avoid?

Mr. BLOCH. If you had adequate dollars, we certainly would avoid it.

Mr. BOEHLERT. Well, my concern is, and I am excited about the S&T proposal, but we are going ahead with a new initiative and we are not adequately funding the existing, exciting initiative. I understand at Princeton the situation; that is a little bit different.

Mr. BLOCH. That's different.

Look, as I said before, you know, we have been flat in constant dollars on our Research and Related accounts since 1985. And I think that is being felt; is being felt in many areas. Therefore, you have to make certain decisions here and there. You also have to look at the balance between the various fields and the various activities.

Now let me get to your point of why do we start something new when we cannot adequately support what is already in existence. That again is one of those problems that I think we are facing. For if you have taken that approach for three years, we wouldn't have done anything new because for three years we have been at a flat kind of a rate. I don't think you can have a system, a science research system, that is staying constant for three, four years and does not add new initiatives to it.

When there is that much ferment in all of the sciences and engineering, you have got to move forward. And that is a balance question, and it is a judgment question.

Mr. BOEHLERT. How well were you treated at OMB? I mean, we see the final document, but where have they failed to see the wisdom of your ways?

Mr. BLOCH. I should say everywhere. [Laughter.]

Look, I think, in 1989 or in preparation for the 1989 budget, we had a completely different kind of a relationship with OMB than we ever had before. Before, it was essentially—the question was on that one year that was laying on the table. The argument was about increases here and increases there. I think this year we had a different kind of a conversation, because of what we put in place in 1988—namely the acknowledgment that the Foundation needs to double its budget.

That sets the stage for an entirely different conversation; and, we didn't focus very heavily, to be very honest with you, on each and every program element of the Foundation. We focused on the bottom line. We focused on the strategy for the Centers—you know, this one-time appropriation. Yes, we asked obviously for more money than we got in total because we wanted to keep on the original five-year line of doubling, which would have made essentially 1988 the first year. But with 1988 what it was, that did not happen. That's the only difference that we had with OMB.

Mr. BOEHLERT. I welcome it and I'm sure you do the refreshing change in attitude, but where did you take the big hit?

Mr. BLOCH. Where did we get the big hit? Probably we got a big hit in the baseline itself, inasmuch as we wanted 1989 to be the new 1989—to be the same as the projected 1989 of last year. That's where we saw the big——

Mr. BOEHLERT. So, for example, a specific item like science education—you weren't arguing so much about the amount there. It was the bottom line?

Mr. BLOCH. That's correct. In science education, by the way, we had obviously some discussions on that. If you remember correctly, last year we came in with the five-year doubling—with greater than a five-year doubling of the Science and Engineering Education bottom line. We came in with a 2.3 kind of an increase over five-year timeframe. We did not know when we started the discussion with OMB what the upshot was of 1988. If you remember correctly, we only found out in December. We submitted two budgets for the Science and Engineering Education line: first, budget based on the fact that we would get the increase that we are asking for—we got more than the increase that we asked for—and the second line, where we assumed that we would get more than the increase we asked for and therefore saw a natural projection of that one into 1989. So, we gave them two numbers. The number came out somewhere in between.

Mr. BOEHLERT. Mr. Chairman, others want to get into the questioning. I hope we can come back.

Mr. WALGREN. We certainly will.

The gentlelady from Rhode Island.

Miss SCHNEIDER. Thank you very much, Mr. Chairman. I thank my colleague. Regrettably, I have to run over to a markup soon, so

Mr. Chairman I would like to ask unanimous consent to include in the record the report on the small business study that was done for transferring technology to small businesses by NSF, and I'd like to submit some questions in writing to Mr. Bloch on that topic.

[Material mentioned above will be in appendix p. 675.]

Miss SCHNEIDER. Now, on another subject, I understand that the National Science Board some time ago had asked the Committee on International Science to give an assessment of what is our level of scientific knowledge in the area of biological diversity, and I wonder if you could share with us what the status of that is and when it will be complete.

Mr. BLOCH. Well, first of all, there is a committee that has been appointed by the chairman to look into this matter, and it is a long term—obviously it is a long-term kind of a study. It probably will last for a year or could be for even longer than a year, and maybe Dr. Schmitt wants to comment on it.

Dr. SCHMITT. Yes. In recognition of the importance of that subject, we established a Board committee consisting of Dr. Neirenberg as chairman of it. It is put under the auspices of the Committee on International Science because of the international implications of the whole issue, basically; but, it is separately constituted in that it has some additional members of the Board.

But probably equally important, we have invited as permanent members of that committee some distinguished outside people—four outside distinguished people who have joined that committee as permanent members to participate in the discussion: Dr. Wilson of Harvard; Dr. Theodore Smith of a consulting group on biodiversity in New York; Dr. Gardner Brown of the University of Washington; and Dr. Peter Raven of the Missouri Botanical Gardens, all very distinguished scientists in their own right and very knowledgeable in this area.

The committee has taken a very thorough and broad look at that issue. We haven't given them a deadline yet on when they are to bring in the report, but normally it would be 12 to 18 months.

Miss SCHNEIDER. Well, I am hopeful——

Dr. SCHMITT. They are launched and working very hard on it too.

Miss SCHNEIDER. Good. Well, I am hopeful that you will provide a deadline to them because this issue is moving very rapidly and on the international front it seems that a convention or a treaty may be in the offering and I think that it would be ludicrous to us to move too quickly on that front unless we have the scientific data that is so very needed.

I think that we have the talent and the expertise, as is witnessed by those you have selected to serve on this committee, so I commend you on that.

Let me also ask you, OTA did a report in 1987, CEQ did one in 1985, all suggesting that NSF establish a program in conservation biology. I think that perhaps conservation biology tends to be a little bit mission-oriented. Perhaps it has fallen through the cracks. I wonder what is the current thinking at NSF on the whole discipline of conservation biology?

Mr. BLOCH. I consider conservation biology to be really the engineering implementation of biodiversity scientific findings, and I think what we need to understand better is—that's why the com-

mittee that has been set up—is essentially what biodiversity problems are all about.

What can be done to put a scientific underpinning under these problems before we march forward on essentially rectifying situations that we don't understand yet.

I think it's—I would prefer to see it as a follow-on to the bio-diversity study instead of jumping ahead with this particular study.

Miss SCHNEIDER. Well, there are a couple of universities—Wisconsin, California, Princeton—that have recently initiated graduate programs or other specialized courses of study in conservation biology, and I wonder if NSF would consider making some of these fledgling programs eligible for competitive training grants.

Mr. BLOCH. I don't see any reason why not because we are not excluding—to the best of my knowledge—we are not excluding any discipline or any activity from that. They would qualify in the same way as any other science and engineering programs qualify.

Dr. MOORE. Could I make one additional comment? We do support research and conservation biology as you probably know. We have provided support for the project on the Amazonian floor for some time.

We have research with the University of Washington on functional biology, on chemistry of the Amazon River, that we have supported. We have worked through the Organization for Tropical Studies on research in Costa Rica; and worked with the La Salva field station in Costa Rica.

So, there is a good deal of research effort already going on in NSF on this subject and, in addition to the new task force on——

Miss SCHNEIDER. So, you're suggesting that you are, NSF, is considering it a priority in the various disciplines?

Dr. MOORE. I'm just reporting on what is in existence today and has been for some time.

Mr. BLOCH. If I remember correctly, the OTA study really asked for a long-term kind of strategy——

Miss SCHNEIDER. An assessment, yes.

Mr. BLOCH. And that's what I was addressing when I said it really has to follow in a more sequential way for that kind of an endeavor.

Miss SCHNEIDER. Well, I thank you all very much for your extremely fine testimony and I'm sure we'll be chatting more about this in other topics. Thank you kindly.

Mr. VALENTINE. Let me, before I begin my questions which, as was stated, I'm sure, Mr. Bloch, will not be unexpected—I want to say that I appreciate the testimony also. As we approach the problems which you've described, it's with the spirit of cooperation.

There is a matter which concerns me and involves Duke University, which is in the district which I represent in the Congress. Last March, about a year ago, the National Science Foundation announced that it had agreed in principle to award Duke some $14 million to establish an NSF Engineering Center for cardiovascular research.

Duke soon learned that its engineering center grant had an unusual string attached to it. That is, full funding, they were advised by NSF, is dependent on Duke getting what amounts to a matching grant from the National Institutes of Health or NIH.

Now, as you know, I hope that you and your colleagues who are here know that, since I have been in the Congress, I have been, and I hope I am perceived as, a strong supporter of the National Science Foundation.

But as you know also, I and my colleague, Mr. Price, who represents the adjoining district, have very serious questions about the way that NSF has handled the Engineering Research Center at Duke University.

I'd like to avoid, if possible, an exhaustive consideration of all the questions that I have in mind at this hearing, and I hope you agree with that. Maybe we can address the main question that's troubling me. If we can address that, some of the other matters could be dealt with through an exchange of letters and so on.

The major problem, of course, is the unprecedented requirement imposed by NSF that Duke secure one third of the funding for this ERC from the National Institutes of Health.

As a condition for full NSF funding, I was disturbed to see a chief official of the NSF quoted in the November 14, 1987 issue of Science Magazine as saying, "As of now our present position is that if Duke can not get NIH money, the whole thing is over after this year. Dead. Kaput."

Now, that somewhat drastic assessment doesn't seem to square with the statement attributed you in which I understood you to repeat here today, that our note says, in the October 1987 issue of Engineering Times, when you said that "You can't turn a center off and on in a year. It's a waste of taxpayers' money."

I would say that we are getting mixed signals, of course; and, I realize that Duke is waiting for a decision from NIH and that the Duke proposal—and, at least until that decision is announced, that you can not tell us what precise agreements might be required to achieve full NSF funding on this issue.

But, it would be extremely helpful if you could clarify the contradictory messages which are coming out of NSF by reaffirming your statement and confirming that NSF does not plan to walk away from the Duke ERC regardless of the decision on the current proposal of NIH.

That's the end of my statement and question. The question is, of course, are you prepared to make such a general commitment here today?

Mr. BLOCH. Well, if you ask me that question in a direct way, the answer is no, obviously, because I think what I need to explain to you—it's one of those questions that doesn't have a no/yes answer.

Mr. VALENTINE. I don't certainly want to ask you that kind of question. Feel free to make whatever estimation——

Mr. BLOCH. As you know, Mr. Valentine, we have met on that particular subject. We have had a number of discussions. I had a discussion yesterday on that subject again with your colleague in the Senate, Senator Sanford——

Mr. VALENTINE. Yes, I don't want to interrupt you, but we met on it in Senator Sanford's office months and months ago.

Mr. BLOCH. Yes we did, and we outlined the plan in that office that is being executed right now.

Mr. VALENTINE. Which is what?

Mr. BLOCH. Which is that Duke has to pursue NIH; and, the NIH decision, in my opinion, to the best of my understanding, has not been rendered.

Mr. VALENTINE. If you were facing a meeting with the corporate supporters at Duke, of the ERC, bearing in mind that this was not a situation where your organization itself went to the National Institutes of Health, but what you did was take the unprecedented step of saying to the officials at Duke that we'll give you this money if you go to them and get it, didn't you?

Mr. BLOCH. Mr. Valentine, I mentioned that point to you before. We took an unprecedented step in the case of that particular proposal.

Mr. VALENTINE. Why?

Mr. BLOCH. Just a second. Let me tell you what the unprecedented step was—not to turn it down. We took an unprecedented step realizing quite well that, while it was not fully compatible with the NSF mission, 100 percent compatible, that it was in part compatible with the mission and that, therefore, we should not walk away from it.

We could have declined it also. That was the unprecedented step. The second unprecedented step, you're right, was to ask the Engineering Research Center proposers that they carry the ball forward to NIH.

The first unprecedented step, really on our part, was that, while it was not fully commensurate with the mission of the National Science Foundation, that we didn't walk away from it.

Mr. VALENTINE. Mr. Bloch, I understand that a number of ERC's have been awarded by the National Science Foundation for research in areas supported by other federal agencies: the ERC's at MIT, at Brigham Young, at UCLA. Is it correct to say that none of these institutions were required to secure co-funding from other government agencies as a condition to receiving full NSF funding?

Mr. BLOCH. The MIT Biotechnology Center was fully commensurate with our mission. We just asked NIH in that particular case if they didn't want to participate in it because they had one interest in that particular center—not the engineering work—engineering research work—that was going on but the training work that was going on there.

And they would get some benefit out of the training, and that's why we asked them to participate in that which they did, by the way, to a minor point.

Mr. VALENTINE. So, what you are saying is that the institutions that I named, MIT, Brigham Young and UCLA—that of those, you're saying, yes, MIT did have funding from the National Institutes of Health, aren't you?

Mr. BLOCH. By the way, I don't know what the UCLA problem is. The UCLA's Engineering Research Center is for toxic waste research and disposal.

Mr. VALENTINE. I don't mean to suggest that UCLA has a problem. I just mentioned these institutions as institutions that have been treated differently from Duke University.

Now, going back to what I asked you, you are saying to me, in answer to my question sir, I understood you to say, that yes, MIT

did receive funding from the National Institutes of Health. That's correct, isn't it?

Mr. BLOCH. MIT what?

Mr. VALENTINE. Did receive some funding from NIH?

Mr. BLOCH. Absolutely.

Mr. VALENTINE. But, in the MIT situation, you folks went to the National Institutes of Health, didn't you?

Mr. BLOCH. That's what I said.

Mr. VALENTINE. Yes, sir. Well, why didn't you do that in the Duke situation? Why do you say to Duke that, well, we'll give you this money if you go to NIH and get the money?

Mr. BLOCH. Mr. Valentine, again, I'll say it's the same thing. Let me read you—NSF normally will not support biomedical research with disease related goals including work on the geology diagnosis or treatment of physical or mental disease.

This particular proposal that we are discussing, this particular Engineering Research Center proposal that we are discussing, straddles the line of that. We could have had—if we wanted to have been bureaucratic about this whole thing, we would have said "not our mission, turn it down" on that particular basis.

We didn't do it because we recognize that there was an engineering component in it, that engineering research component in it, that was extremely important—extremely important from a research viewpoint, extremely important from an industrial viewpoint. And we made every effort to find a way of funding that particular center.

The one way that the Board essentially focused on was just like the Foundation focused on—was splitting it on a two-third, one-third, two-third for us, by the way; one-third for NIH—splitting it between the two agencies.

And, by the way, we have funded Duke at $666,000 despite the fact that we don't know what the upshot of the NIH discussion is. We funded them $660,000 last year in anticipation and as an interim kind of a point, to show essentially our interest in our support for that center.

And I think, looking at it from that viewpoint which is the only viewpoint NSF can look at, I think we made an unprecedented step in this particular area; and not what you're saying is an unprecedented step, that we are asking Duke to carry their own request forward to NIH. That's not where the unprecedented step is.

Mr. VALENTINE. Isn't that the effect of it? That you have put the burden on Duke to get the additional funding?

Mr. BLOCH. Certainly, we have put the burden on Duke. The burden is always on the university that proposes something. They are coming in with the proposal. It's their center. They are asking for funding. They have to make the case. We can't make the case for Duke.

Mr. VALENTINE. Well, that was not the case at MIT, though. Was it?

Mr. BLOCH. The case for MIT was a little bit different. There, it was essentially the case that we wanted to have other agencies, and they have been highly unsuccessful by the way. We wanted to have other agencies to participate in the Engineering Research Centers, especially in those areas where they had a stake in the

ground. We tried with DOD. We tried it with DOE. We tried with NIH; and, in that particular case, in the case of the MIT biotechnology center, NIH saw the value of it from one viewpoint—not the research itself that was done there, but from the value of training.

Mr. PRICE. Mr. Chairman, will you yield for a question?

Mr. VALENTINE. Yes.

Mr. PRICE. Mr. Bloch, you mentioned some question about whether this project falls within NSF's mission as the basis for the requirement for joint funding. Is it not true, though, that that goes against the recommendation of your own site visit panel?

Mr. BLOCH. The site visit panel, recommended from a technical viewpoint, that this was an outstanding proposal.

Mr. PRICE. Well, let me quote from there.

Mr. BLOCH. Can I just finish?

Mr. PRICE. Yes, sir.

Mr. BLOCH. The site panel has only one responsibility to make recommendations. They are not making the final decision. It's the Foundation that is making the decision; and, in the case of Engineering Research Centers, because it exceeds a certain amount of dollars, it's the National Science Board that makes the final decision.

Mr. PRICE. Well, of course, I understand——

Mr. BLOCH. Not the site visitation people.

Mr. PRICE. Of course, I understand that. But here we are trying to get at the merits of this case and the parameters of this project. The site visit team, as I understand it, submitted the following statement to you:

"NIH is not likely to fund this. It is not clinical, but truly interdisciplinary engineering dealing with a multi-billion dollar industry which, very truly, is in the heart of all of us."

Now was that evaluation considered in imposing the requirement that Duke obtain co-funding from NIH? And what were the expectations that Duke could fulfill this condition in the precise form required by NSF?

Mr. BLOCH. Well, the precise form we did not specify. We specified essentially that one-third of the funding should come from NIH, but the precise form of that funding, I don't think was specified by us.

Mr. PRICE. And NIH learned about this requirement in the newspapers. Is that true? NIH had no prior notice from you about——

Mr. BLOCH. From us? No. No prior notice from us. That's correct. It was up to Duke to acquaint NIH of this issue.

Mr. VALENTINE. Well, as a matter of fact, did Duke have any—excuse me. Did Duke have any prior indication that such a requirement would be placed on it?

Mr. BLOCH. Prior to what?

Mr. VALENTINE. When they—when they made the—when they made the application for the money. Did Duke have any prior indication that such a requirement might be imposed on—by NSF?

Mr. BLOCH. No, I don't see how that they could have had that prior to applying for this center because we hadn't seen the center proposal either at that time.

Mr. VALENTINE. And, of course, as my colleague pointed out, NIH didn't have any prior indication that unlike MIT, that—where you dealt with the--you dealt with the other agency.

Mr. BLOCH. In that particular case, we dealt directly with NIH, that's correct.

Mr. VALENTINE. But in this situation, for the first time, you said to Duke, we'll give you this if you go out and get the rest of it.

Mr. BLOCH. Yes. And I explained to you why we did that.

Mr. PRICE. Mr. Chairman, if you'd yield for one further question. Mr. Bloch, you just said that you did not specify the precise form of support from NIH that would be required. Is that true? Did I understand you correctly?

Mr. BLOCH. Well, that's right. What I meant to say was that the only specification that we put on Duke was that one-third of the support for that center must come from NIH.

Mr. PRICE. Yes. So beyond that, it was not specified. Now as I'm sure you know, several Duke researchers, including the Director of the ERC, have been awarded a number of individual and multi-investigator NIH grants that do relate directly to the research to be conducted at the ERC.

Now the combination of these grants, they have already been awarded, and the excellent prospects for substantial additional NIH support in the future does demonstrate already a strong commitment by NIH to fund appropriate research that contributes directly to the ERC.

Now since the NSF has no clear policy in this area and since you yourself have just stated that you did not specify the exact form in which this co-funding must take, I don't see any reason why this already present NIH commitment should not count as fulfilling the conditions of the ERC award. Could you explain to me why it does not?

Mr. BLOCH. Yes, I will explain to you that. Engineering Research Center are not a collection of individual grants. They are essentially the—a plan must exist to execute a research agenda that is truly interdisciplinary in nature, number one, that takes into consideration many aspects of a particular research project, not just one slice out of it. It's not a—we are making that point with all of the centers. It's not a collection of individual grants which are flying under one flag but have no connection whatsoever internally to it.

And Duke, therefore, has a responsibility of satisfying us that that's what they are doing and what they can do under the grants that they are asking for under the allocation of dollars—budget that they are asking us for from NIH.

Duke presented, to the best of my knowledge—and I haven't read it—but they have presented, to the best of my knowledge, a submission to NIH that essentially says what they request from NIH. That request has not been acted on yet from NIH. So why don't we wait and see what comes out of that? And then we can discuss the subject further, instead of discussing it in midstream where we don't know what the result of that submission is.

Mr. PRICE. Well, Mr. Chairman, if you will just yield further, it seems to me Mr. Valentine has made quite clear already why that advice that we continue to wait on is problematic. It's been a year

now. The question of corporate support, the question of the future of this center, is placed in doubt by this continuing delay. We already have NIH participation to a very significant degree.

I don't understand the advice that we should wait several more months, have more uncertainty, and in the meantime have the whole question of NSF highly open to doubt.

Mr. BLOCH. Well, look, I met with you and with Mr. Valentine and Senator——

Mr. PRICE. Sanford.

Mr. BLOCH [continuing]. Sanford a few months ago. I promised you at that time—and I'm not walking away from it—that, once we see what the outcome is, we are going to talk. Now I don't know what else I can tell you at this point in time. And I hope you remember that conversation.

Mr. VALENTINE. Our colleague, Mr. Buechner, has other commitments, and we will come back to this in just a minute.

Mr. BUECHNER. Thank you, Mr. Chairman.

Mr. Bloch, I have no universities in my district that have any particular problem that I'm aware of; but, I'm sure if they do, they will call me.

I would like to ask a question, and as you know and Dr. Moore knows, I have been working with the 250 functions within the Budget Committee. NSF is requesting a five-year appropriation of $150 million for the 12 S&T centers.

Now as a member of that Budget Committee, I worked on getting those funds, but I think it's fair to say that budget resolution, as everyone here knows, is nonbinding, and it's only the first step in what will probably be a long process, and it is possible that the NSF budget may be scaled back by the time it gets to the President.

If this is the case, if it is scaled back and NSF cannot maintain this increase, I'd like to ask you—and it certainly doesn't lock you in, but you must have some sort of contingency plans—how would you choose your priorities if it were scaled back and what changes could you make to compensate for a reduction in these S&T centers?

Now I don't want you to do like Cap Weinberger, because I had breakfast with him one time, and members of the Republican Congress were looking for some ways to pare back, and we asked him what he would do, and he'd say, oh—he said, "Well, we have no Army, no Navy, no Air Force, no ships, no planes." And when we said, "Well, that's kind of disingenuous." He said, "Well, you know, if I start making my priorities, then," he said, "the wild animals will begin to attack on those that I have designated as the weakest."

So I don't think that's the case here, and I wish you'd kind of give me some guidance, more than anything else.

Mr. BLOCH. Well, I had a similar answer prepared. [Laughter.]

Mr. BUECHNER. Is that a Germanic trait we're dealing with here? Is that——

Mr. BLOCH. It's the only way you survive in government, I guess, that you have answers like that. Instead of armies and navies and things like that, I would have said: we have no centers; we have no grants; we have no graduate students——

Mr. BUECHNER. I was afraid you were going to say that.

Mr. BLOCH [continuing]. And no education. Or something like that. But that's not a fair answer, obviously.

The question always—by the way, I want to thank you, first of all, for your support in Function 250. We appreciate it very much, and I realize, unfortunately, that's not a binding resolution. But I think every little bit of support that we can get helps, and we appreciate your support.

This question gets asked time and time again, you know, what are you going to do if and when. And I'm very reluctant to answer that kind of a question for, I'm sure, the same reason that Secretary Weinberger didn't want to answer it.

At any point in time you can really only have one program in front of you and take it seriously. Soon as you have three or four, people don't take you seriously. You don't take yourself serious, and things get into a mess in a hurry.

But let me give you essentially some indications of what we would have to do. Obviously we would have to scale down many of the activities. It's not a question of eliminating activities, necessarily, but certainly scaling them down. And we have done a lot of that in 1988, scaling down certain activities. Instead of a 10- or 12-percent increase for astronomy, as we had planned, a 2-percent increase for astronomy, as an example.

I think it's a little bit more problematic, what we would do with the Science and Technology Centers, which is one of the lines that you focused on, because I need to tell you the story. We went out with a solicitation for Science and Technology Centers in 1987. That solicitation closed in March or in the last few weeks of this particular year.

The idea was originally to fund some of these centers out of the 1988 budget. Because of the 1988 budget of 3 percent of the bottom line for Research and Related, we are not funding these centers out of 1988 budgets. But we are taking the input that we got, the requests that we got, and putting them through peer review.

We are going to finish that particular process, and hopefully we can fund the centers out of the $150 million that we are asking for in 1989.

If we get less than that on a particular line or nothing on that line, we have a decision to make, how we are going to handle the solicitation. We postponed it already by one year. Again, as I mentioned before, I don't think in a dynamic area that we are essentially involved in—namely, science research, you cannot postpone things forever. So we might, even in a tight 1989 environment, try to fund some of the centers—but certainly not all of them—fund some of the centers from our appropriation. And obviously it would be a one-year kind of funding, unless something survives on that $150 million line. But that's about the best answer I can give you.

Mr. BUECHNER. I have one other question, Mr. Chairman, and then I am going to go over to—over and fight for space. That doesn't mean I'm trying to find a place to live.

Over the last four years, Mr. Bloch, NSF has had consistent increases for pre-college education, and for FY 1988 pre-college education received a 40-percent increase. This year's budget contains a

20-percent increase in the science education, I think is what they are requesting.

This account for research, though, has been frozen since what, FY 1985? Can you explain why that account has been frozen, the account for research?

Mr. BLOCH. Well, that's the point that I made before. It hasn't been frozen in that sense. The increases we've received on a constant dollar basis since 1985 have been essentially zero; so it has been essentially flat. It hasn't been frozen in that sense, but it has been flat.

Why that is? Well, I think that's obviously what Congress decided when it allocated the dollars that it had available to allocate. There were a lot of the increases for the Foundation went into education, especially precollege education, and rightly so. But the total dollars available to various—to committees, Appropriations Committees, were not sufficient to——

Mr. BUECHNER. Let me interrupt you. I don't like to do that, but let me interrupt you. Actually requested no increase, though, for precollege last year. The extra money was added by Congress; is that correct?

Mr. BLOCH. I think, if I remember correctly, for last year, we asked for a $6 million increase for precollege. I think that was the right number. Was I right?

A 10-percent increase last year, about $6 million on the $60 million base.

Mr. BUECHNER. Okay. All right, thank you very much.

Thank you, Mr. Chairman. I appreciate it, gentlemen, for your help.

Mr. VALENTINE. Thank you, sir.

Mr. Bloch, I do have just one or two other questions. And let me say at the outset that all my dealings with you have been most pleasant, and we appreciate what you do. You're a great guy, and none of the things we say here—we speak from a sense of frustration because we have a situation there that these people, that great university, have to face the corporate people. And it's going to go down the drain unless we can get it back on the right track.

So this is nothing personal; and, if I raised my voice, I'm sorry. I spent 20—I mean 31 years in another life doing something else besides this.

But I've just got one or two other questions, and then I'll be through.

Was the Duke proposal for this ERC reviewed by the same peer review process through which all ERC proposals are evaluated?

Mr. BLOCH. The answer to that is absolutely yes.

Mr. VALENTINE. All right, sir.

Mr. BLOCH. It was the same process, the same procedure; wound up exactly where the other ones are winding up, namely in front of the National Science Board for a decision.

Thank you for your comment before. There is also some frustration on this side of the table.

Mr. VALENTINE. I understand.

What was the conclusion of that peer review process?

Mr. BLOCH. Well, the conclusion of the peer review process was essentially to fund that particular center or to acknowledge that

that center is a fundable center, and also that's a priority in, you know, stacking it up against all the other competing centers.

Mr. VALENTINE. Gave it an A+.

Mr. BLOCH. It came out very high. It came out very high. Many centers are fundable without us funding them because we don't have the money, but it came out very high.

Mr. VALENTINE. All right, sir.

Mr. BLOCH. When we looked at the total activity, or the total request essentially, and the content of that center, that's when the mission problem and its relationship to NIH came to the surface.

Mr. VALENTINE. All right.

Mr. BLOCH. But it went through exactly the same peer review process as any other center.

Mr. VALENTINE. All right. What was the recommendation of the site visit team which went to Duke?

Mr. BLOCH. To the best of my knowledge, they recommended funding of that center.

Mr. VALENTINE. What was the recommendation of the NSF staff on this proposal?

Mr. BLOCH. The NSF staff on that proposal was also to fund that particular center.

Mr. VALENTINE. All right. Given the fact that all of this review—how was the decision reached to impose the unprecedented co-funding requirement on Duke?

Mr. BLOCH. Very simple. When I reviewed that center proposal or that request for a center with the Assistant Director for Engineering, the issue that I saw on that center was essentially the one of mission. Can we fund that particular center with the activities in there the way they are being described? And I pointed that out to the National Science Board as an issue when we submitted that center for review by the National Science Board. The National Science Board discussed the issue, and the decision was made to ask for co-funding by NIH.

Mr. VALENTINE. Would you—this is my last question, and I'll yield to Mr. Price—would you agree that Duke has been treated differently from all other ERCs?

Mr. BLOCH. Because the subject matter is different from any of the other centers, Duke was treated differently; and, as I said before, Duke was treated in a way that—in my opinion, quite different, inasmuch as we did not walk away and were hiding behind bureaucratic kind of niceties but essentially acknowledged that there was something in there from an engineering viewpoint that was important and that was fundable by NSF. But not the totality was fundable.

Yes, they have been treated differently because of the subject matter.

Mr. VALENTINE. All right, sir. I yield to you, Mr. Price.

Mr. PRICE. Thank you, Mr. Chairman.

I wonder if we could just pursue this a bit further and not impose too greatly on the other members. But I do appreciate your responsiveness, Mr. Bloch, and I do hope we can get some resolution of this in fairly short order.

I do want to probe a little bit on this question, though, of NSF's mission and the way in which your definition of that mission has

led you to this unique demand that Duke go out and secure co-funding.

Now you say you treat Duke differently because of the area of scientific research that's involved in the ERC. Isn't it true, though, that you have supported at NSF—you have supported biomedical engineering research for some 20 years and that, even as we speak, you're spending $4 million a year on bioengineering research? There's ample precedent, isn't there, for NSF involvement in this area?

Mr. BLOCH. No doubt about it. And the accent on that particular program is on engineering, biomedical engineering, a very important discipline in the engineering area. And that's why we are funding it.

What happened in this particular center is a need for much closer tie-in to the medical side of it, not just the engineering side. And it's that part of it that is equally important, by the way, or maybe even more important than the engineering part—is where we are essentially saying NIH has a mission for that. We do not; and, therefore, we want their participation.

Mr. PRICE. Even though your own peer review team indicated that NIH funding of this particular project was unlikely, that it would not likely fall within their purview.

Mr. BLOCH. That's their opinion.

Mr. PRICE. An opinion which you did not share?

Mr. BLOCH. An opinion which I have no way of ascertaining if it's right or if it's wrong. And that's why we are going through—you know, that's why we asked Duke to submit a proposal. I recommended—by the way, we recommended. We didn't ask them. We recommended it to them. If they wanted the center to get off the ground, they needed to seek support from NIH; but, it's up to NIH, not to us, to decide if their submission is fundable or not.

Mr. PRICE. Yes. But even if you come to that conclusion, that some kind of co-funding is desirable—and let me just clarify here that I think certainly I, and I believe Mr. Valentine, would support the principle of cooperative efforts of this sort. I don't think that's the issue at all. The question is how you go about securing that cooperation.

There is some precedent, isn't there, in the MIT case, for NSF undertaking to collaborate with the agency, with NIH in this case, to develop a cooperative approach?

What seems unprecedented is the demand placed on Duke to go out and resolve this interagency situation itself. That's what seems to be unprecedented and seems to be highly problematic and, I must say, unfair to the recipient institution, that this burden of interagency cooperation be placed on Duke, that NIH not be brought into the process in advance. In fact, NIH learns about this in the public press.

Mr. BLOCH. Mr. Price, the easiest thing for the Foundation would have been to turn that proposal down altogether, and I told you we didn't do that. And we didn't think that was the right approach. But in light of all the discussion that we had in the meantime, I probably would change my mind on that one.

Mr. PRICE. But isn't it true that there was ample precedent? You just said there was ample precedent in terms of what NSF has

done for 20 years, to accept this project. I don't understand why it was such a——

Mr. BLOCH. It was not a project; it was a center.

Mr. PRICE. All right.

Mr. BLOCH. And that's a little bit different than a grant.

Mr. PRICE. But it is operating in areas, the areas of biomedical engineering research, where you've had programs for years.

Mr. BLOCH. Correct. But it also involved, and it needed the participation of the clinical part of that investigation and of that issue.

Mr. PRICE. I think, again, the dispute is over the way in which this was done, not any kind of question that we have about the desirability of this kind of joint funding.

Now let me return to the question of what NIH is already doing at Duke. It is true, isn't it, that several of the researchers, including the Director of the ERC, have been awarded a number of grants by NIH that relate directly to the research that the ERC will be conducting?

You've said today that you do not have any particular stipulations as to the form that NIH support takes. So my question is: with NIH already involved to the degree that it is, why this insistence that we wait yet another round for more NIH support? What stands in the way of accepting what seems quite plain: that NIH is already deeply involved not just in general at Duke but in this area of research?

Mr. BLOCH. I can only repeat what I said before. A center is not a collection of individual grants, and that applies if the grants come from NSF or NIH or DOE or DOD. That's not the intent.

The intent in an Engineering Research Center—and it was reflected in the proposal by Duke; otherwise the Duke proposal wouldn't have fared as well as it did in the peer review—was essentially to set up an interdisciplinary kind of an activity which involved the medical part of that university, as well as the engineering part of that university.

So it's not to be judged by individual grants. Otherwise, all we would have to do is hoist the flag over a university and call it a center, if there are some individual grant proposals already existing in that facility. That's the only thing I can tell you.

Mr. PRICE. But this is not just a random assortment of grants. These are, after all, multi-investigator grants.

Mr. BLOCH. I don't know. I don't know what they are.

Mr. PRICE. They're grants that involve the Director of the ERC directly. They're not just random grants. It's not just a cooked-up proposal. These are grants that pertain directly to the work of the ERC.

Mr. BLOCH. I'm sorry. But I don't know what the content of those grants are.

Mr. PRICE. Well, it seems to me that it's important to know what the content of those grants are; because, that seems to me to be relevant information in determining whether you must wait for yet another round of NIH decisions——

Mr. BLOCH. I can't speak to that.

Mr. PRICE. To come to some resolution of this matter.

Well, I thank the chairman for his indulgence. I do think this year-long delay has been very damaging, very unfair. It seems to

me that Duke is caught in the middle in a kind of squaring off between two agencies. And there are potential supporters of this ERC that have been remarkably patient throughout this year of uncertainty, but they need to know—have to have some evidence that this ERC will be moving forward, or that critical support is likely to erode.

The Duke Board of Trustees has under consideration a proposal to obtain a sizable loan for the ERC. Again, however, the long-term prospects are a critical factor in the trustees' decisions on whether to make this commitment.

So it is a very difficult situation for the university. It's one that we need very badly to resolve. We, of course, applaud the decision to support this center. We think this work is vital. What we're distressed over is the continuing difficulty in getting this center on track.

Mr. WALGREN. The gentleman from California, Mr. Brown.

Mr. BLOCH. May I just make one comment?

Mr. WALGREN. Certainly.

Mr. BLOCH. Mr. Price, let me assure you, it's not a squaring off between two agencies. We don't square off. That's not what's behind it. It's a sincere attempt to fund the center despite the fact that it essentially does not fall within the whole—with the mission of the National Science Foundation in its entirety.

Secondly, we did not let them hang for a year. That is not correct. We funded them to the tune of $660,000 to make sure that they could get going, and that shows our good faith in the matter.

Mr. WALGREN. The gentleman from California, Mr. Brown.

Mr. BROWN. Mr. Chairman, I ask unanimous consent to insert in the record at the beginning of the hearing a brief opening statement focusing particularly on my strong support for the Antarctic Research Program.

Mr. WALGREN. Without objection.

Mr. BROWN. Mr. Bloch, I commend you for your patience in responding to these queries from the committee which—all of whom identify themselves as strong friends of the agency. I hate to think what would happen if we were enemies. [Laughter.]

Mr. Bloch, I have had an exchange of correspondence with you over another project which bears a similar theme, not enough money; and, in your response this week, you stated, because of this year's budget constraints, there are many programs that have been seriously impacted, and we have established priorities within the funds available to us.

I know you have done that and done it to the best of your ability. And this leads me to ask you a question that I already know the answer to. Isn't this situation due to the fact that the Congress did not fund the 1988 fiscal year budget request at the level requested by the President?

Mr. BLOCH. Absolutely.

Mr. BROWN. So that a good part of the problems raised here—maybe not all of them—stem from the fact that the Congress itself didn't appropriate an adequate amount of money?

Mr. BLOCH. Well, in the case that you are referring to in particular, you know, and in the case where we exchanged letters.

Mr. BROWN. Well, only partially. The point that Mr. Boehlert made about the superconducting centers and the reduction in funds there. I wonder if you would be good enough to supply to the committee, because I think it would be useful to us, some of the other areas in which there have been funding constraints so that we could, in making our impassioned plea for full funding of your budget, recite some of the problems created by our failure to fund.

Mr. BLOCH. We can supply that to you in great detail, by division, as well as by project area.

Mr. BROWN. I would appreciate it if you'd do that for the record.

[Information to be furnished follows:]

EFFECTS OF BUDGET CONSTRAINTS ON NSF PROGRAMS

NSF's FY 1988 Appropriations amount for the Research and Related account was $182 million below the FY 1988 Budget Request. This reduction had impact on nearly all the activities and subactivities throughout the Foundation.

Included with the material which follows is an internal staff memo from the Director outlining the general impact and priorities for the Foundation. In the FY 1989 Budget Estimate to the Congress, there is a more detailed description of the changes at each subactivity (divisional) level. They appear under the heading: CHANGES BETWEEN THE FY 1988 REQUEST AND THE FY 1988 CURRENT PLAN.

Besides the cutback in the Cajon Pass Drilling project within the GEOSCIENCES activity,(referred to at the Hearings), a few selected examples of programs typifying the effects of the budgetary constraints follow:

Subactivity	FY 1988 Request	FY 1988 Current Plan	Change Amt.	Change %
		(millions of dollars)		
MATHEMATICAL AND PHYSICAL SCIENCES (MPS)				
Physics	$131.33	118.21	-13.12	-10.0
ENGINEERING				
Cross-Disciplinary Research	51.50	36.33	-15.17	-29.5
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE)				
Networking & Communications Research & Infrastructure	13.37	11.55	-18.2	-13.6
SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS (STIA)				
International Cooperative Scientific Activities	11.96	10.73	- 1.24	-10.3

- In MPS' Physics division, the University of Illinois' Microtron construction project will be cancelled.
- In Engineering's Division of Cross-Disciplinary Research, original plans called for at least four new enginering research centers in FY 1988; two will most likely be initiated.
- Reduced funding in CISE's Networking and Communications Research and Infrastructure division limits network improvement and expansion, and reduces regional network development.
- The $1.24 million reduction in STIA's division of International Cooperative Scientific Activities will result in a reduced budget for the U.S./Japan initiative.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

OFFICE OF THE DIRECTOR

M E M O R A N D U M

DATE : January 19, 1988

TO : NSF Staff

FROM : Director, NSF

SUBJECT : FY 1988 Appropriation

Last month Congress finished its consideration of the FY 1988 Budget and passed an omnibus appropriation for the year, signed by the President on December 22. With the exception of the Science and Engineering Education programs, NSF did not fare as well as we had hoped, receiving a total appropriation of $1717.0 M. This represents an overall increase of 5.8% over 1987. In terms of the three individual appropriation accounts, the figures are:

	88 Request	88 Approp	88/87
R&R	$1635.0 M	$1453.0 M	3.3%
USAP	143.0	124.8	6.7%
SEE	115.0	139.2	40.6%

This is short of our requested growth, largely because of the deficit reduction squeeze which affected every phase of the budget considerations. This squeeze overwhelmed the strong support we received from our Congressional committees, the academic community and industry for the aggressive budget plan that the Administration submitted for FY 1988. We will go forward with a request for FY 1989 that regains our planned momentum.

The stringency of our FY 1988 appropriation requires that we allocate resources with particular care. Our FY 1988 request had three central themes: disciplinary research and facilities, centers and groups, and education and human resources. To the extent possible, we intend to preserve the priorities expressed through these themes and the balance among them.

Support for individual investigators through direct grants and provision of specialized facilities remains the largest part of our effort to promote the health of science in the U.S. In disciplinary research, some increases will be possible, but these must be focussed in a small number of critical areas such

as mathematics, in order to continue momentum begun in earlier years. Significant increases in grant size and increased numbers of individual investigator awards will not, in general, be possible this year, nor will any new starts in facilities projects. We will undertake the task of examining all our facilities with the objective of phasing out or down those of lesser priority or productivity and we will stretch out or defer upgrades to existing facilities except where there is compelling justification to proceed.

The new Science and Technology Centers (STC) Initiative will be slowed. We will proceed with the review and evaluation of the proposals submitted in January 1988, but we will not make any STC awards in FY 1988. Awards will be made as early as possible in FY 1989, with the number of center and planning grants depending on the FY 1989 appropriation. We will however proceed with the new interagency plant science centers and new biological and engineering research centers, as well as additional Minority Research Centers of Excellence.

Development of human resources for the future remains a high priority. Efforts to increase participation of women and minorities in science and engineering will be enhanced, largely through the Minority Research Centers of Excellence and expansion of programs in Science and Engineering Education. Cross-directorate efforts will be maintained at or above their FY 1987 levels.

The precollege area received a major increase through the SEE Appropriation. Most existing programs will be incremented and a new program for secondary school students will be started.

At the undergraduate level, efforts will be increased, but at a slower rate than planned. Support for instructional instrumentation at 2- and 4-year institutions will be increased but the initiation of this program for Ph.D. institutions will be deferred.

In graduate education, we plan to increase the number of NSF Graduate Fellowships as planned. Within the limits imposed by the small increase to the R&R account, we will continue to emphasize the support of graduate students on research grants. In addition, we plan to make about 100 new Presidential Young Investigator awards.

Funding for Program Development and Management (PD&M) was reduced. We do not anticipate furloughs or reduction-in-force, but staffing will remain tight and be closely monitored.

The Administration remains committed to doubling the NSF budget in the next few years and we are encouraged by the results of our recent negotiations with OMB over our FY 1989 request

level. As you talk with researchers and administrators, I hope that you will take the opportunity to keep them apprised of this commitment and our plans for 1988.

I want to thank you for your support and understanding during the protracted budget deliberations. It was an extra burden and a frustrating experience for all of us. We now need to devote our energies to the implementation of the 1988 programs and look to the future with optimism.

Erich Bloch

Distribution: F

Mr. BROWN. Now, you know my longstanding interest in earthquake hazard programs and the seismology research that goes back for at least 15 years; and, as I understand it, the adjustments that you have made will permit for the next fiscal year, for this fiscal year, for the remainder of it, funds for the analysis of the data produced by this deep drilling project; and, you expect to request additional funds in the 1989 budget to continue with the actual drilling itself?

Mr. BLOCH. Yes. The way it shapes up, Mr. Brown, is the following:

We made the decision, based on the 1988 budget that we had available to us, that the best we could do under the circumstances is to stop the drilling around the 11,500 foot kind of a level and use the time that we have and the money that we have—and by the way, we are—about half of the dollar increases in that particular division are going to the drilling project—that we can use through the rest of 1988 and part of 1989, the time best to analyze what has been learned from the drilling up to that particular level.

We also are making provisions in the hole itself that one can reenter the hole at a later point in time, not that we are foreclosing that capability. So I think, you know, coming at it from the scientific end of it, what can best be done under the circumstances, I think the community did the right thing. And I would hope that in the 1990 budget we would have some new drilling dollars that could be made available, after we——

Mr. BROWN. Well, I think you have acted with great prudence under the circumstances to protect the hole, so that it can be reentered and deepened, and also to analyze the data. Having examined some of the stream of data coming out of this project, I am well aware of the need for a considerable amount of analysis; and, over past years, we have also seen very important projects that were funded for the accumulation of the data but inadequately funded for the analysis of the data.

I recall in one case the astronomical community was deeply concerned about some lack of balance along that line.

I want to go just a step further, however, with regard to this; and, I will read into the record, with your indulgence, a statement from your National Earthquake Hazard Reduction Program Expert Review Panel, this paragraph. It says:

> Although the NSF Earth Sciences Division may spend its NEHRP—that's the National Earthquake Hazard Reduction Program—funds outside the seismology program on projects that may not directly focus on earthquake phenomenon, these projects may be within the original broad mandate of the act and subsequent guidelines. The spending may be justified because if NSF focuses narrowly on the subjects directly related to earthquake processes, it may miss important factors that are not apparently related to earthquakes but that may fundamentally affect scientific thinking about earthquakes. On the other hand, if NSF does not focus its research directly on earthquakes, it may be diverting some of the funds from this act to research projects having products unrelated to earthquake hazard reduction. The problem becomes serious for the NEHRP when projects specifically focused on earthquakes are rejected because of pressure to support projects that are not directly related to earthquakes.

That's an internal problem that you have; but, it raises these questions, which the expert review panel also set forth, that their recommendations are increase support for fundamental studies of

earthquake processes as they result to the objectives of the act; that the NSF Earth Sciences Division clearly define its NEHRP related research and focus its funds on activities that are clearly identified to be earthquake-related; and thirdly, that the NSF maintain an appropriate balance between the support of large projects and individual investigator grants.

I want you to comment on these recommendations from your expert review panel, and assure me that you are in fact giving adequate consideration to all of these points.

Mr. BLOCH. I really think we are giving adequate recognition to all of these points. The mix of approaches that we are using, as you know very well, is small grants or grants to individuals—sometimes they are not small, by the way—and the other one, we established an earthquake engineering research center a year or two ago, and that's a more comprehensive interdisciplinary kind of an approach.

And then also what is going on in some of the other areas besides—outside of engineering, namely in the earth sciences area, obviously has a bearing also on this subject, and it serves a number of purposes, obviously. And we need to extract out of all of these activities the best we can get—the best information and insight and science that we can get that covers the earthquake as well as the geology question, that we are trying to address.

Mr. BROWN. Well, I do not wish to second-guess you because, as I have said in other contexts, I'd much rather have you making these decisions than a committee of the Congress.

However, in the event that I should probe into your activities and find that some of your national earthquake hazard reduction money is going to projects which are not directly related to that, I wouldn't want to embarrass you by calling that to your attention.

Mr. BLOCH. Well, you won't embarrass me. You can call it to my attention, anyway. I hope you don't find that to be the case.

Mr. BROWN. Well, as you know, it was only my request, and the other Congressman who joined in it, was only that you examine this situation and see if there was such a possibility that might lead to some reprogramming of funds here.

I have great respect for whatever decision you might make in that regard, but obviously I am deeply concerned about this project, even though it is not in my district. But it is essential to the overall understanding of the earthquake phenomenon along the San Andreas Fault in California.

And with that, Mr. Chairman, I will yield back the balance of my time.

Mr. WALGREN. I thank the gentleman.

The gentleman from North Carolina is recognized.

Mr. VALENTINE. Mr. Chairman, one request. We beg leave of the committee to submit questions in writing——

Mr. WALGREN. Without objection.

Mr. VALENTINE [continuing]. To the gentlemen if we deem that appropriate.

Thank you, Mr. Chairman.

Mr. WALGREN. Without objection.

The gentlelady from Maryland, Mrs. Morella.

Mrs. MORELLA. We play committee tag. We just had a meeting going on in the next room, and I notice that Mr. Nagle just joined me also, and he came from that. We were talking about the commercially developed space facility. So I am pleased to be here to kind of catch up.

I notice that—I've got a couple of questions for you. One is I notice at six engineering research centers evaluation took place, an assessment. And two of them were determined not eligible not to continue to exist.

What I'm curious about is what is the criteria that you have established by which to measure whether one continues to operate or does not?

Mr. BLOCH. Well, let me clarify a couple of things first.

You are correct in saying that six centers have just been evaluated. These are the six that were first established—established in the first year of the Engineering Research Centers. The procedure is to commit for five years for funding to these centers but evaluate the center after the third year. And in the third year, make a decision if these centers should exist beyond the five-year timeframe originally funded. And that's a point I really want to stress.

Mrs. MORELLA. The midlife crisis.

Mr. BLOCH. It's more or less a midlife crisis, right. But the point is that denying funding for another five years doesn't mean that these centers are being cut off the next morning. They are continuing their five-year cycle, even the ones that are not being funded; and, that's what I wanted to stress, because the way you put it, it almost sounds——

Mrs. MORELLA. Sounds like it was going to be immediate.

Mr. BLOCH [continuing]. That it was immediately, and that is not the case.

Mrs. MORELLA. They don't lose their incentive or initiative because they know they're going to be closing in two years, do they? Do you evaluate that also?

Mr. BLOCH. They should increase their incentive because of that.

Mrs. MORELLA. Because they might well be eligible again?

Mr. BLOCH. Well, you can always come in to the Foundation with a new proposal. You can always do that. What I meant by saying that one is not getting another five-year, new five-year funding, they still have two years to go. And in those two years they could do a lot of valuable things, and I hope it's not detracting from their incentives. I hope it adds to their incentive of proving a point, how wrong the National Science Foundation can be.

Mrs. MORELLA. Do you evaluate—speaking of that, do you then evaluate again after the two years——

Mr. BLOCH. No.

Mrs. MORELLA [continuing]. The final two years?

Mr. BLOCH. No, we do not.

Mrs. MORELLA. So how do you know if they've done something exciting during that time?

Mr. BLOCH. That's what I said before. They can come in any point in time with a new center proposal or a new project proposal stemming out of the work that went on in the center. Just like denying a request to an individual investigator doesn't mean that he

cannot come in the next morning with the same request or a revised request or a completely new request. That is true for centers.

Mrs. MORELLA. Right.

Mr. BLOCH. The same way.

Mrs. MORELLA. Now, Dr. Bloch, what criteria are used to make that determination?

Mr. BLOCH. The criteria that are used in evaluating the centers are many-fold. It has to do with the quality of the effort essentially that has been going on in that center for three years. It has to do with meeting their plans that they themselves outlined in the beginning. It has to do with the fact how they addressed education. As you know, there is an educational component associated with the center, both at the undergraduate and graduate level. And how well did they do with regard to that educational proposal. The involvement and the support from industry is being judged essentially. How that one has involved obviously the management of the center's leadership of the center. The attraction of the center to some of the researchers, that they try to attract, either on a part-time basis or on a full-time basis. The involvement of graduate students in the center itself, and how many graduate students did they attract. What kind of papers came out of that center. For instance, what kind of results came out of that center that were published in either paper form or in a patent form. Many—the other one is university support to the center is being obviously evaluated, if that one is commensurate with the original plan and the original promises.

So, you see, it ranges all the way from research results, to education, to the management of the centers themselves, and to the activities, the attraction of the centers to industry and also research.

Mrs. MORELLA. It sounds like it's very, very thorough and comprehensive.

Would you care to comment on where those two centers failed?

Mr. BLOCH. Well——

Mrs. MORELLA. I'm not saying that—I'm not making any opinion whether they should have or should not have. I'm just curious, was there a particular vulnerability or weakness?

Mr. BLOCH. I think each one had different vulnerabilities. In the case of one of the centers—and I really don't want to mention names——

Mrs. MORELLA. You don't have to mention them.

Mr. BLOCH [continuing]. The educational component was very good, but the research results were kind of disappointing.

In the other case, there was no focus on one particular aspect of what that center was supposed to do in a research kind of a sense, and it was felt to fall short in that area. So it was research results primarily that were the disappointing part of those results.

Mrs. MORELLA. I'd like to ask you one other question, and that has to do with site selection, because I understand there is perhaps some money in the budget for planning or looking ahead for National Science Foundation to expand, to relocate.

Mr. BLOCH. No, to relocate.

Mrs. MORELLA. Relocate, all right.

Mr. BLOCH. Not to expand, to relocate. Yes.

Ms. MORELLA. Would you like to comment on whether you are planning to look for any places in Maryland?

Mr. BOEHLERT. Upstate New York. [Laughter.]

Mr. BLOCH. We are looking at all places. Let me say first why we want to relocate. We are in a 20-year-old building that we are sharing with the Secret Service. The Secret Services needs expansion space. They have more of reasons of staying in that building than we do, because they have put fairly heavy installations into that building which cost a lot of money to tear out again, since they have made significant changes to the structure of the space that they are occupying.

Secondly, they have a real need to stay close to the White House, obviously, and we don't have quite that kind of a need for that geographic location. So somebody has to move out.

Thirdly, the building is really inadequate for our purposes today, not so much from a total space availability viewpoint, but what one can do with the space. We have changed to automation in a significant kind of a way, and it is very difficult to accommodate local area networks, work stations and computers and things of this sort. So, because we are sharing that particular building with somebody else, we don't have any control over it ourselves. We have to go for everything that we want to GSA, and that is not the best way of running an operation like the National Science Foundation.

It would cost a lot of money to upgrade the space to where it might be desirable, and that money probably is better spent looking for a new location. We would like to stay close to downtown, because we have a lot of traffic going through the Foundation because of the researchers that are coming in, the various panels that are meeting at the Foundation for peer review. Many of the National Science Board comes in at a frequent kind of an interval. Many of our advisory committees, of which we have a large number and should have a large number, are coming in at frequent intervals. So we have a lot of traffic—therefore closeness to the airport is very important. If you can do something in one day by flying in and flying out, that is a lot better than having to stay overnight. We have a lot of people staying overnight; so closeness to hotels is a very important kind of an aspect.

All of these things essentially are pointing to the fact that we should stay close to downtown, but we are not foreclosing any of the locations. In fact, as soon as we can break it loose from OMB, we want to go out with a solicitation for space, and then that solicitation is open to all localities essentially. But we would like to stay close to downtown. In the end the decision will be based on the cost of space here versus cost of space there.

Ms. MORELLA. Just very briefly, what is the procedure? You said GSA then really doesn't enter into it? You said when OMB gives you the approval, you will then——

Mr. BLOCH. We already have gone through GSA. We have done that. Now OMB has to see what we are asking for, and they have to release that particular solicitation. That has not happened.

Ms. MORELLA. Okay. So they release the solicitation and then people will bid and then you make the decision—or does OMB make it?

Mr. BLOCH. I hope so.

Ms. MORELLA. Well, you never know.

Mr. BLOCH. That's why I hope so. [Laughter.]

Ms. MORELLA. My colleague, Mr. Boehlert, told me to ask you what you are doing for lunch, but I will hold off on that until you get the OMB—thank you very much.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mrs. Morella.

The gentleman from Iowa, Mr. Nagle.

Mr. NAGLE. First, let me congratulate you. I am generally very favorably impressed with the budgetary proposals and resource direction of your agency.

Last year, however, in a question that is kind of a follow-up of where we were last year on this, there is report language in which the committee authorized an additional $20 million in additional support for teacher institute programs. Our report language, but not in our legislation, we urged NSF to increase the number of teacher institutes and as a direct result increase the number of pre-science and mathematics teachers participating in the program.

In pursuit of that goal, we said the committee expects the NSF to make a determined and systematic effort to ensure equitable geographical distribution of funds and teacher institutes so as to raise the quality of science and mathematics instruction in every state of the union.

I know you testify a lot—I don't expect you to remember, but the committee expressed—the foundation of that was that some states don't have money for matching funds. Their financial resources are flat. Their economies are in trouble, particularly in the 25 intercoastals—agricultural-based states. And we went on to say, since the amount of resources vary from state to state and region to region, NSF should give consideration to the local resources available for teacher participation in this program and in determining where the teacher institutes will be located. This will help ensure that, although some areas of the country may lack local resources to support local teacher participation in these institutes, they will have the opportunity to benefit from this program. That was the report language and foundation of our discussion.

How, in lay language, how did you do?

Mr. BLOCH. Very well.

Mr. NAGLE. Very well; thank you very much.

Mr. BLOCH. I think we want to answer your question as explicitly as we possibly can. Why don't I ask Dr. Shakhashiri to come forward and speak to that particular point? He is Assistant Director for Science and Engineering Education Directorate, and he can speak to this problem.

Dr. SHAKHASHIRI. The direct answer to your question is that we did very well in terms of both the geographic distribution and the emphasis that we have been placing on increasing the participation of under-represented groups in those teacher institute activities.

As a result of the funding situation that we have in fiscal year 1988, we are able to expand both the scope and the magnitude of these efforts in a variety of locations, especially in rural locations, but also in high density population locations.

In fact, the Foundation is quite proud of the distribution of its teacher institute activities across the country. We received propos-

als from all—from a variety of different groups from all states, I think, this year, with one exception, and I don't recall what that one exception is right now; and, we have been most active in cultivating contacts with local and state educational agencies to see to it that high quality proposals continue to come to NSF.

Mr. NAGLE. And how is that addressed in the budgetary request of the agency this year?

Dr. SHAKHASHIRI. The request this year speaks directly to that issue and builds on what we are doing in FY 1988. The request for FY 1989 speaks to increasing the number of projects that we would fund in that year, again both paying close attention to the urban setting as well as to the rural settings.

Mr. NAGLE. Have you found in the administration of this program or any other programs that lack of local resources is a problem in terms of access to these programs?

Dr. SHAKHASHIRI. There have been occasions when that has been a problem, and we have tried as hard as possible to see to it that the participation of the local and state educational agencies is such as to try to address that difficulty.

I might mention in this regard that we have been successful in leveraging the funds that are available through the Department of Education to local and state educational agencies to see to it that they are used to help support teacher participation in the NSF-sponsored institutes.

Mr. NAGLE. I wonder if you could furnish me—not today—but could you furnish me a specific breakout of those funds and where they went?

Dr. SHAKHASHIRI. We publish every year a complete listing along with abstracts of the projects that are funded in the Directorate for Science and Engineering Education, and the FY 1987 Directory will be published in early April. We will be more than happy to provide you with that.

Mr. NAGLE. Well, if it is in that report, I can look it up myself. I won't have a problem. If it is in the report, you don't need to furnish it. I'll read. Okay?

Dr. SHAKHASHIRI. This report is also indexed state-by-state, and so it would be easy to find the various projects that we have.

Mr. NAGLE. Now the second question is kind of a long one——

Ms. MORELLA. Would the gentleman yield? I just want to ask a question on the education. I have always wondered, because I think teacher training for math and science is critically important in terms of who is going to get involved in math and science—women, minorities, everybody. So it is a perfect opportunity. Do you have any follow-through with whether or not there is in abundance an increase of people who get involved in math and science as a result of the teacher training that you have done and that has been done through NSF?

Dr. SHAKHASHIRI. There is a great deal of evidence. We run into this everywhere we go, in terms of the influence that NSF's projects continue to have on the training of teachers and the quality of teachers in science and mathematics. There is hardly a teacher in the country that has not been touched directly or indirectly through the activities that the NSF has been sponsoring since the late 1950's and early 1960's.

Our efforts in the past couple of years have been focused in expanding that participation, and we have assessment plans in place. We have follow-up activities with the teachers, and we have follow-up activities with the institutions of higher education and the local and state educational agencies that are partners in these efforts. So we do have indicators that these activities are effective.

I should also mention in this connection that there are barriers that teachers face that the NSF for a lot of reasons cannot do much about—namely teachers' salaries and the quality of the facilities at the local level in terms of laboratory facilities and so on. In response to a directive from this Committee, we will be in the fall of this year providing a report dealing with a study that has to do with one of those barriers—namely, teachers' salaries.

Ms. MORELLA. I would think that that would be very good. I guess what I am saying is that we're also looking for measurements in terms of how many students actually follow through over a period of time and go into science and go into math, in addition to—you say you touched the teacher. Obviously, you are going to touch the teacher. Does the teacher touch the students with a permanent impact? I don't want to take up any more time, but I think that is something valuable to look at too, because that is your ultimate goal

I thank Mr. Nagle, the gentleman from Iowa, for the time and I yield back.

Mr. NAGLE. If I could, we had testimony last year from a variety of agencies that the majority of the graduate students we were getting into science and mathematics and engineering, those three fields, were coming in fact out of small colleges rather than from universities, or at least a substantial portion of them were.

What steps if any is the agency taking to address the curriculum development, teacher training, etc., of our small colleges?

Mr. BLOCH. Well, we are doing a number of things. What you remembered from last year, that is correct. Undergraduate colleges, or undergraduate institutions I should say, contribute a greater part than their percent of students essentially—of those groups that go for their Ph.D's. That's absolutely right.

We are doing a number of things with undergraduate institutions. We have some research programs that are tailored to undergraduate institutions essentially that acknowledge that there has to be some research going on there if you want to attract competent kind of instructors and competent kind of teacher and keep them at the leading edge of science and engineering. So we have programs of this sort.

Secondly, this is the second year that we are mounting a major program in undergraduate education, and that applies to four-year colleges as well as research universities.

The undergraduate program has a number of components to it. It has, for instance, an instrumentation component—instrumentation for laboratories. And by the way that one is restricted to the non-research universities; it is only for the four-year and two-year colleges essentially.

We have a component in there on new curriculum development in calculus, for instance, and in engineering. Now obviously that

new curriculum applies to small—the undergraduate universities and institutions, as much as it applies to the research universities.

Faculty training obviously is one component that applies equally across the board.

Finally, essentially making sure that students in their undergraduate years participate in the research effort, and that one applies to students from small colleges as well as research universities. At times they are being placed in the research universities to do that research—like during summer months and so forth—but the eligibility is for the participation of the small colleges.

So a number of programs in the undergraduate development area or undergraduate activity area are part and parcel of those that are available to small colleges.

Mr. NAGLE. Is there an allocation of funding for it? Is there a formula to it; or is it just based on a need; or an application; or first come, first served? How does it work?

Mr. BLOCH. No, it is not first come, first served; and, there is no allocation.

Mr. NAGLE. I didn't think there was.

Mr. BLOCH. It is really on the proposal itself, coming in with a request—coming in with a proposal, and then getting it evaluated in light of the total requests that we have.

Mr. NAGLE. The funding for that type of program last year versus the requested funding for this year is what to what?

Dr. MOORE. This year it is about $40 million; next year, for 1989, it is proposed about $65 million.

Mr. WALGREN. The gentleman's time has expired. I apologize.

Mr. NAGLE. Pardon me. Thank you very much for your answers.

Mr. WALGREN. We have another panel left, and I have got to get moving faster.

I would like to recognize the gentleman from New York.

Mr. BOEHLERT. Mr. Bloch, what percentage of your education initiatives is devoted to K through 12, for science and math education?

Mr. BLOCH. I am sorry. I didn't understand the question.

Mr. BOEHLERT. For science and math education, what percentage of your overall science education budget is devoted to K through 12?

Mr. BLOCH. K through 12—in 1989?

Mr. BOEHLERT. In 1989.

Mr. BLOCH. In 1989, it is $60——

Dr. SHAKHASHIRI. It's $108 million out of a request of $156 million.

Mr. BOEHLERT. You are moving in the right direction. You know, the conventional wisdom in this town, and parenthetically I should say the conventional wisdom in this town is usually wrong, is that we are the great innovators and our principal competitor, the Japanese, are the great imitators. But that isn't exactly so if what I read of late is accurate, and Dr. Schmitt, I would like to take advantage of your presence to ask you if you are familiar with that recent study on patents, which pointed out, among other things, that the Japanese have 20 percent of the patents issued in the United States, and that is on the increase, and secondly, on patent

citations, which the scholars say is a good indication of things, they are dramatically increasing the number.

Dr. SCHMITT. Yes. The observations about the number of the United States patents granted to the Japanese being on the increase is absolutely correct. As a matter of fact, for some years now, several Japanese firms have been among the top recipients of U.S. patents each year. I am sorry to say that my ex-employer, G.E., was knocked from the top position, which it occupied for decades in terms of the number of U.S. patents received, by Hitachi last year, surprisingly. So that number is correct and is in my view not a good indicator.

The figure on citations—the citation technique was devised in analysis of the importance of scientific papers, and I think it's a valid technique there.

I still, quite frankly, have some reservations about it as a measure of the importance of patents because citations, in the patent function, play a very different role from citations in scientific publication.

It's a legal requirement that has to be met or that one is dealing with there. So, I'm not convinced that the citation study is a true measure of the significance of the patents at this moment in time, but I don't know that it isn't either. I just have a serious question about the validity of it there as compared to the validity of it in scientific publication.

Mr. BOEHLERT. Well, just bring it up in the focus on science education K through 12 because I strongly believe that we have to start from the beginning and I applaud what you're doing in the National Science Foundation and so does this committee.

While I'm hitting on applause I would like to particularly note the great service, Dr. Schmitt, that you have rendered to the nation in your service on the National Science Board. I understand your term expires in May. I hope this will not be your last appearance before this committee in any capacity.

But I do think the committee and the nation owes you a debt of gratitude and I wanted to recognize that service.

Dr. SCHMITT. Thank you very much. Whatever the future holds I'm going to be deeply involved in the issues that this committee deals with for years to come; so I look forward to seeing you in some capacity in the future.

Mr. BOEHLERT. Thank you.

Mr. WALGREN. Thank you, Mr. Boehlert. Mr. Bloch, the committee last year tried to direct the Foundation's attention toward the community colleges, and I understand that there is a very broad plate to be dealt with, and you are spread thin.

Again, it's also true that the community colleges are the ones who we look to directly to train people dislocated from innovation and the rush of science's impact on the economy. We want to encourage you in that direction.

I understand that there is, from Williamsport College, a proposal that deals with relating community college, and neighboring community college to one of the Engineering Research Centers, trying to develop technician training.

Can you tell us how you've attempted to respond to our interest in community colleges and whether you see an ability to pursue technician training curriculum in particular?

Mr. BLOCH. Let me comment on it. First of all, on the total question of community colleges, beginning in fiscal 1988, as you know, the two-year colleges are eligible, just like the four-year colleges have been in the past, for the CSIP program or for the instrumentation program for undergraduate laboratories.

I think we have received something like close to 200 proposals in this year's, 1988, proposal submission from two-year colleges.

The final decision on those, like on all of the other ones, is expected sometime in the May time frame. That's really a major step forward to make the colleges eligible for laboratory instrumentation and laboratory equipment on the same basis as four-year colleges.

Secondly, most of our programs, obviously, don't differentiate between two-year colleges and four-year colleges or four year colleges and universities, in terms of being eligible to submit proposals.

As a consequence of that one, we receive proposals from two-year colleges. In 1987 we received about 45 proposals from two-year colleges for research awards of all kinds. We awarded eight out of the 45; so that's not an insignificant number, a total of about $330 thousand.

Most of the proposals came from the biological—or came into the biological sciences area; but, there were proposals also across the spectrum from MPS, from geosciences, engineering. And obviously SEE had a number of proposals from the two-year colleges.

Mr. WALGREN. So, we have them working in, supposedly, in the research function; but, I'm particulary interested in their role in science education.

Half of the people that go on to the four-year colleges start in these two-year colleges; and, the question really is whether we can, through the National Science Foundation, develop a particularly helpful role in the education function, either through curriculum or something that—this Williamsport project sounds very logical, in a sense, whereas I understand that they have proposed to develop the ability to train technicians in the local community college, in the kind of thing that is being focused in the engineering center.

My regret is—is that we are reacting rather than creating a program that responds to that need. And I think our obligation is to be reaching out for what we can do in this area rather than just sitting back.

Mr. BLOCH. Let me make a point on the undergraduate curriculum development that I mentioned before.

Obviously, the outcome of that development, of course, in calculus or in some of the engineering sciences obviously can be utilized by two-year colleges as well, and we would hope that they would utilize that.

With regard to the Williamsport College, I understand that they have a unique capability in terms of robotic equipment, which they have available, essentially, robotical automation, which they have available.

And we have encouraged them to consider essentially a workshop, which we would fund, that would essentially try to explore the capabilities that they have and see what could be done with it.

Their focus, obviously, is on technology transfer—and that's right—and technology between colleges as well as universities. So I think the ball is in their court right now to come forward with a proposal for a workshop and set up a workshop, to really look into the capabilities that they have and see how that could be harnessed in a broader kind of sense.

Mr. WALGREN. I would hope that one of the things that would come out of that would be some real focus on how we train technicians. The functions of community colleges, in many ways, is to serve and pick up the dislocation in these communities that is very real; and, it is an area that has not been addressed by many other parts of our system.

Dr. Shakhashiri, can I ask you for your response on how community colleges and technician training capabilities come into play in science education?

Dr. SHAKHASHIRI. Mr. Chairman, if I may just make a comment about something you said a moment ago with respect to NSF being only reactive, and then I'll come to your question about the technicians, we have begun in a very earnest way to do outreach activities to community colleges, to the National Association of Two-Year and Community Colleges. I have spoken at their national convention.

My staff have targeted for, beginning with late FY 1987 and throughout FY 1988, many activities that two-year colleges should become involved in, that NSF is interested in supporting.

We have seen a tremendous increase in the number of proposals that we get from two-year colleges. I say tremendous increase because the number was so small to begin with; but, nevertheless, it is a significant increase. As the Director has indicated, in the College Science Instrumentation Program alone, we have almost 200 proposals.

We are also on our Advisory Committee to the Director for Science and Engineering Education—we have excellent expertise in the person of a chancellor of a community college.

We are seeking on our staff additional expertise, program staff from community colleges; so we are making some serious efforts in that direction.

The activities that pertain to technicians and technician training are activities that we are seeking advice on how best NSF can impact that area.

As the Director has mentioned, the developments in the calculus curriculum, for example.

Mr. WALGREN. When will you get that advice back?

Dr. SHAKHASHIRI. We are in the midst of getting it right now; and, I expect that, again, by some time in the summer, late summer, we should have a much clearer picture about the kinds of things that NSF can consider doing in the technician training area.

Mr. WALGREN. Well, I would hope that you would let us know immediately of any suggestions that you get along the education line and any conclusions that you come to with respect to the ques-

tion of how NSF can strengthen the role that community colleges are playing.

It just seems to me that we didn't wait for the secondary and elementary schools to come in and apply for various programs. We said there's an education reach of NSF that is our obligation to initiate and—when I look at the number of people and the role that technicians play in the whole pursuit that we're after—and the fact that we have an obligation to initiate an educational program in that area if we are addressing the broad range of science and engineering education; it seems to me.

And, I would hope the Foundation would embrace that approach.

Mr. BLOCH. Let me make a comment on that. We have had some discussions with the Department of Labor on exactly that point of two-year colleges and technician training.

Unfortunately, the people that we talked to, namely the Secretary and the Under Secretary, both left as you know very well; and, now we need to start the conversation up again.

Again, there could very well be a good connection between the two agencies. We could furnish, certainly, the intellectual underpinning—the development of curriculums, if it's curriculum, the peer review on instrumentation and so forth—whereas the Department of Labor could really be the distribution point, or function as a distribution point, because they can reach out into every locality and into every college.

That was essentially the symbiosis that the we envisioned when we first talked to the Department of Labor. I would encourage you to help us in that regard in focusing the Department of Labor on that issue together with us so that we can move forward together.

The Foundation by itself won't be able to deal with the problem, just like we can't deal by ourselves with pre-college education.

Mr. WALGREN. Well, it may be that we could really start with the development of some model curriculum of some kind, or model programs of some kind, which would have ability then to be picked up by others and replicated.

As you know, the committee sort of tried to make a suggestion in that area last year in the authorization bill.

Mr. BLOCH. Let me make another point, a more general point. I'm glad you are focusing on this particular area because too many times, when we talk about education, we are essentially cutting things off at the high school level.

I need to remind us all the time that education goes beyond that to certainly two-year colleges, four year colleges, undergraduate education, graduate education, post-doc education. And unless we look at the total span of education, we're going to miss something horribly.

Second, the part of the education that is funded, partially in undergraduate already but certainly in the graduate education area and beyond, is really through the grant mechanism primarily and through the grants and centers that we are establishing.

So, I think that aspect of our budget, the research and related aspect of the budget, is not pure research. It's education as well, and we are not making that point often enough.

Mr. WALGREN. Well, as you know, some emphasize that, although there is indirect education involved in that, they do look to

the Science and Engineering Director for the real punch when it comes to educating or filling the responsibility that the Science Foundation has in education.

That was the testimony yesterday and maybe we'll——

Mr. BLOCH. Well, it is certainly that for the pre-college part of it. My point is we have to look at the total educational pipeline and not just chop off at one particular point.

Mr. WALGREN. How do we view the—the National Science Board had its Undergraduate Science Task Force, as I understand it, which recommended increasing by $100 million the effort in undergraduate level education. And, we apparently were able to do $65 million of the $100 million.

Is that—have we met that goal of the $100 million in view of this spinoff that Mr. Bloch raises, Dr. Schmitt?

Dr. SCHMITT. I think that, without remembering the detailed comparisons, I think we've slipped about a year in the plans that they had recommended that NSF follow.

Mr. BLOCH. I think that's correct because, as you remember, in 1988, our request for undergraduate education was greater than what we finally wound up with in that particular area, so a one year slippage about correct.

Mr. WALGREN. Mr. Boehlert asked earlier, and I just want to focus on it for the record—the OMB's pass back to you on Science and Engineering Education was what? And then what do we have for a submission?

Mr. BLOCH. Well, what you have for submission in that particular line is really $156 million, that we are showing in our budget request. The request to OMB, as I said before, was twofold.

We had to make our request in September at a point in time when we did not know what the upshot would be of our 1988 budget. At that time we had in front of Congress a request of $115 million. We asked OMB for $300—or $434 million.

We also put in an alternate request a few days later, where we asked OMB for $165 million, and we wound up with $156 million.

Mr. WALGREN. Very good. That's good for the record.

Let me just ask. You, in your testimony, indicate that $265 million for education and human resources. That 265 million number includes the 156 for the science education——

Mr. BLOCH. Yes.

Mr. WALGREN [continuing]. And then what else is in that 265?

Mr. BLOCH. A lot of other things in there, obviously. They are—all the minority programs are in there; all the special women programs are in there; the undergraduate education in totality is in there, even though only a part of it is funded in the SEE request; anything that has to do essentially with human resources per se and with education per se.

What did I leave out? I'm sorry, the Presidential Young Investigator Program, which is a significant program, is included in there because it addresses exactly the same problem. So it's a cost cut across all the whole Foundation, and picking out those programs that talk to human resources and broadening of participation in total.

Mr. WALGREN. Well, all right. Well, let me thank you all, and particularly salute Dr. Schmitt. We've appreciated knowing you

over these several years. I know that that will continue, and we want to recognize, as Mr. Boehlert did, your service in these capacities. And that's certainly very much appreciated by the public and recognized, I know, by your peers.

Thank you, Mr. Bloch, for all your forthcomingness. We appreciate your responsiveness and look forward to talking to you about these things as they develop.

Dr. Moore, good to see, and we'll see you some time soon.

Thank you, Dr. Shakhashiri.

The next panel is focused on polar regions and the NSF's involvement in it. Dr. Rita Colwell, the Director of Maryland Biotechnology Institute at the University of Maryland——

Mrs. MORELLA. Gee, Mr. Chairman, I feel everybody is leaving us.

Mr. WALGREN. Well, we can't control that.

Dr. Vera Alexander, the Director of the Institute of Marine Sciences at the University of Alaska, and Capt. Robertson Dinsmore from Woods Hole Oceanographic Institute.

As you know, NSF is the principal sponsor of research in the Arctic and is charged with managing much of the U.S. activities there, including the logistics necessary for maintaining our presence.

We want to invite this panel to come forward and comment on the NSF plans for research and research support in the polar regions, and we know there's lots of problems, including icebreakers and airplanes and the like. And we appreciate your coming and joining us for this part of our record.

Let's start first with Dr. Alexander. And, as you may know, written statements will be reproduced in the record for the use of all those who do use the record, and you can feel free to focusing in any way you would like to underscore the points that you feel should be highlighted.

Dr. Alexander.

STATEMENTS OF DR. RITA R. COLWELL, DIRECTOR, MARYLAND BIOTECHNOLOGY INSTITUTE AND PROFESSOR OF MICROBIOLOGY, UNIVERSITY OF MARYLAND, COLLEGE PARK, MD; DR. VERA ALEXANDER, PROFESSOR AND DIRECTOR, INSTITUTE OF MARINE SCIENCES, UNIVERSITY OF ALASKA, FAIRBANKS, AL; AND CAPT. ROBERTSON P. DINSMORE, WOODS HOLE OCEANOGRAPHIC INSTITUTE, WOODS HOLE, MA

Dr. ALEXANDER. Thank you very much, Mr. Chairman. I am delighted to be here today, ladies and gentlemen.

The National Science Foundation has conducted over the years a very excellent and diverse program in the Antarctic which I think is a model among nations for how polar research should be conducted.

There is now emerging some problems, however, in terms of the logistic support. I know the argument is often made that logistic support uses up a large proportion of the budget, and this is something that is inherent in polar research, because it is—these regions are not easy to work in. Right now what's happening is that a lot of the marine work that needs to be done, high priority work

that has the scientific merit to be supported, cannot be supported because there is no platform for carrying out this work.

The Coast Guard traditionally has supported a lot of the research with their icebreaking capability. The Coast Guard fleet is down now to the point where it can no longer fulfill these requirements, and the scientific community as a whole has been adamant that there needs to be a change in the approach to logistic support and that an icebreaker, which is dedicated to the program, to the National Science Foundation program, is now essential and should be a very high priority.

And I'm echoing the opinion of the scientific community which has been corroborated very strongly in the National Academy Polar Research Board recent report on the icebreaker problem. And so I think this is the first point I'd like to make.

In order to be brief, I'll skip now to the Arctic and—oh, I should also mention, though, however, one other point, and that is this program that NSF has conducted is also responsive, as you can see by the response to the ozone hole problem in the Antarctic. There are likely to be more such events in the future, since the polar regions respond more rapidly to global climate change than any other region. These will show up there, and the effects can be quite dramatic.

The same is true in the Arctic. You can already see changes, even short-term changes, such as El Nino are reflected very strongly in high latitude oceans and there are some indications of climatic changes in the Arctic now which could have very severe consequences in terms of coastal erosion, sea level changes, and so on and so forth.

So these—some of these reasons can be given for a high priority for polar research altogether.

Another example of the importance of high latitudes and again this applies to both poles in a sense—both have extremely rich renewable resources and nonrenewable resources. For the North, the world's major fisheries all occur at that interface between Arctic and sub-Arctic waters for high latitude temperature waters. A lot of it is relating to Arctic water masses, and these are also high priority areas for research, which have economic importance as well as scientific.

There has been a great lack of focused research in the Arctic. This has changed now with the Arctic Research and Policy Act. The agencies are working together. There are a lot of tools that are applicable to Arctic research; but, here again, the one place in which the United States is way behind a number of other nations is in the ability to support marine research in ice-covered seas. We do not have that capability.

At least one, if not two, of such vessels are needed in order to maintain a reasonable program for what is really an Arctic nation, because the United States is indeed one of the major arctic nations.

The usefulness of such platforms has been clearly shown by the German research vessel, *Polarstern,* which has been doing an excellent job and has carried out work as far as 85 degrees north. And I think I won't go into much more detail, because I know you're running out of time and I know you have the written text. But I definitely want to support this—the acquisition of ice-breaking capabil-

ity through the National Science Foundation and in such a way that these vessels are dedicated to research and do not have other primary missions.

Thank you.

[The prepared statement of Dr. Alexander follows:]

Testimony to the United States House of Representatives Committee on Science, Space, and Technology, Subcommittee on Science, Research and Technology. Authorization Hearings for the FY1989 Budget Proposal for the National Science Foundation.

Vera Alexander, Professor and Director, Institute of Marine Science, University of Alaska Fairbanks.

Mr. Chairman, and members of the Committee, I welcome this opportunity to participate in today's polar panel, and to discuss the National Science Foundation polar research activities. I have conducted research in polar regions for almost thirty years and have had ample opportunity to observe the National Science Foundation's polar involvement from the perspective of a scientist and, more recently, as administrator. The National Science Foundation supports an excellent and diverse program in the Antarctic regions, providing not only national leadership, but leadership among nations. This long tradition is well-established, the research program is dynamic, and it deserves continued and enhanced support. The program is also responsive, as illustrated recently by the rapid response to the question of the cause and effects of the ozone hole over the southern continent.

Logistic support of terrestrial as well as marine research requires a capability for navigating in ice-covered waters. Although U.S. Coast Guard support in providing access to the shore bases has been good, the capability of the Coast Guard to support research activities is very limited, and the prospects for improvement are not favorable. I will elaborate further on the reasons, but it is clear that such support is now insufficient, and that the time is ripe for the National Science Foundation to secure an icebreaker dedicated to the United States Antarctic Research Program. The R/V *Polar Duke*, presently operated in the Antarctic Peninsula region, is not an icebreaker, although she has some ice capability. In addition to supporting research, she is occupied during the field season with duties relating to Palmer Station. High priority research programs are prevented from collecting data due to tight schedules and the lack of ice worthiness. Proposals of high scientific merit must be declined due to our inability to provide the needed logistic support. The vessel which NSF is proposing is urgently needed. Its procurement would put the United States on a par with other Antarctic Treaty nations, many of which have dedicated icebreaking vessels available for their programs. I strongly support the NSF proposal to lease, with a possible option for purchase, an icebreaker for the Antarctic pogram.

Until recently, there was little concerted focus on United States scientific research in the Arctic, and it is gratifying to note the dramatic change which has taken place since passage of the 1984 Arctic Research and Policy Act. The United States is a major Arctic nation. Although the number of residents living in the U.S. Arctic is small the U.S. Arctic embraces a large area and has an extensive coastline and continental shelf, with bountiful resources. The United States Arctic is a major asset and resource, and yet we have little knowledge about this region. Research has been conducted there for many years, and a number of federal agencies have been active in or have supported Arctic research, most notably the National Science Foundation,

the Office of Naval Research and the National Oceanic and Atmospheric Administration. Several academic centers have developed Arctic expertise. However, the scientific community has long expressed its concerns about the lack of U.S. capability to support research in the Arctic, and in many ways this capability is diminishing rather than improving.

I would like to examine briefly some of the scientific considerations. We are recognizing more and more that we cannot understand global atmospheric or oceanic processes without considering the Arctic regions. There is strong coupling of Arctic atmospheric and oceanic processes with global processes. This is especially relevant with respect to the prospects for climatic change, since there is clear evidence that global warming will produce the largest effect at high latitudes, and that the signal will be detectible there first; indeed, recent climate models suggest that the temperature increase could occur in rather sudden steps. On a shorter time scale, it has been established clearly that waters of the Gulf of Alaska, and possibly the Bering Sea, respond to El Nino events, although we don't know the implications of such responses in terms of the fisheries resources. We do know that the Arctic responds rapidly to episodic climatic and oceanic events occurring at low latitudes as well as to more long-term global climatic trends. Such long-term trends could have enormous world-wide consequences, including the melting of the Arctic Ocean ice cover and melting of the permafrost. These in turn would affect sea level, coastal erosion, glaciation, cloud cover and a number of other conditions, all of which are little understood. The National Science Foundation's Global Geoscience initiative will go a long way towards addressing these concerns, and, in particular, the Arctic Systems Science initiative will ensure that the critical northern studies can proceed in a timely manner.

The world's major fisheries occur at the southern boundaries of the Arctic seas, and in many cases these depend on hydrographic conditions and processes at the boundaries between polar and northern temperate water masses, and between sea ice-covered waters and the open waters of the north Atlantic and Pacific Oceans. The newly-emerging field of fisheries oceanography is beginning to develop an understanding of how such features influence recruitment and production. The National Science Foundation's basic research program in oceanic processes, including the World Ocean Circulation Experiment (WOCE), the Global Ocean Flux Study (GOFS) and the proposed recruitment initiative will play a major role in advancing this understanding, if work carried out under these programs extends into the far northern regions.

Understanding Arctic marine ecosystems has been identified as a primary research topic by several working groups, including the Arctic Research Commission and the Polar Research Board of the National Research Council, and such research plays a prominent role in the 5-year plan of the Interagency Arctic Policy Committee (United States Arctic Research Plan, Interagency Arctic Research Committee, July 1987, 334 pp.). The National Science Foundation has traditionally taken a leadership position in supporting such research. Such studies involve interdisciplinary work on the biological, chemical and physical interactions, including the role of sea ice and ice-related oceanic structures in ice-covered seas.

A study of polynyas, ice-free oases in the Arctic seas, needs to be pursued because of their importance to marine life.

Knowledge of the circulation of the Arctic Ocean itself and of its dynamics and chemistry is rudimentary, and research is needed to address the structure of the interior Arctic Ocean, its interaction with bordering shelf seas and the consequences of exchange with the seas to the south. The tools now exist to carry out such work, and these include, in addition to standard physical oceanographic work, a number of tracers such as chlorofluoromethanes, tritium, helium-3, radiocarbon, strontium-90 and radium and cesium isotopes. There is also a lack of geological and geophysical data from the Arctic Ocean. Only three sediment cores are available from the Arctic Ocean which penetrate to a sufficient depth for paleoclimatic work. The background information is vastly inadequate to support any future drilling program in the Arctic Ocean.

Much of the research discussed above requires a circumpolar perspective and can best be approached through international cooperative programs. Participation by United States scientists in international Arctic progams is an important avenue for accomplishing Arctic research. Such programs include the World Ocean Circulation Experiment and a program currently in the planning stages, the International Biosphere Geosphere Program. It is very important that such programs have a strong Arctic component, in that the Arctic plays a major role in global processes. For Arctic research, a circumpolar perspective and the ability to share logistic support, are compelling arguments for international collaboration.

One major constraint to United States Arctic research remains. New research tools are enhancing our ability to work in remote regions. Approaches such as drifting ice islands, drifting ice buoys, moored or tethered instruments, satellite remote sensing, aircraft and submarines are all very useful, but there is no substitute for a research vessel with icebreaking capabilities. In this respect, the United States is falling ever further behind other nations, many of them with no Arctic lands. A recent compilation of Iceworthy Ships of the World is presented as Appendix I.

The practicality of research icebreaker platforms has been demonstrated by the West German R/V *Polarstern*, which has supported research in both Arctic seas (as far north as 86°N) and in the Southern Ocean (Antarctic). New iceworthy research vessels are under construction in Sweden, Finland and Poland. The United States will not be able to conduct an Arctic research program effectively until a suitable vessel is made available. I will use the marine mammal problem as an example of our limited capabilities. Most of the marine mammals that inhabit Alaskan waters, and particularly those which are of greatest interest to the scientific community and are of subsistence value, reside in ice-covered waters. Access to these regions in the Bering and Chukchi Seas has been made available to U.S. scientists for several years, primarily aboard Soviet vessels. The mandate of the Marine Mammal Protection Act requires that sufficient research into the ecosystem relationships of marine mammals be performed to support

the application of the best available information relating to the health and stability of the marine ecosystem upon which the successful conservation and management of those species depends. This is impossible to accomplish at present, because all marine ecosystem research must be conducted outside ice-covered areas. The only United States research vessel operating in the Arctic which has any ice-strengthening is the National Science Foundation-owned R/V *Alpha Helix;* which, although very well equipped, is minimally iceworthy and must avoid entering even first-year ice. Since the Coast Guard wind class icebreaking vessels are at the end of their useful lives, and the *Glacier* (possibly with the best research capability among the entire icebreaker fleet) has been decommissioned, the possibility of using these Coast Guard vessels as ships of opportunity has diminished. This reduction in the fleet size implies a full commitment of the remaining vessels to the primary Coast Guard missions, and the time is ideal for a commitment to new vessels dedicated to and operated exclusively for polar research. The most urgent need for Arctic marine research, in terms of logistic support, is for at least one ice-worthy research vessel in addition to an icebreaker for the Antarctic program. Such a vessel would also serve the needs of other agencies in the Arctic, including the Department of Defense and agencies responsible for environmental monitoring and geological surveying in addition to the needs of basic research supported by the National Science Foundation.

VERA ALEXANDER
Professor and Director, Institute of Marine Science
Acting Dean, School of Fisheries and Ocean Sciences
University of Alaska
Fairbanks, Alaska 99775-1080

MARCH 23, 1988

Appendix I

ICE-WORTHY RESEARCH SHIPS OF THE WORLD

Robert Elsner

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

1988

ICE-WORTHY RESEARCH SHIPS OF THE WORLD

including icebreakers and polar supply vessels of limited scientific capability and availability

This compilation of ice-worthy research ships includes a variety of vessels. They range in ice-worthiness from "Ice-capable" to "Polar Research Vessel" and "Icebreaker". The definitions for these categories as described in the 1984 U.S. Coast Guard report, *United States Polar Icebreaker Requirements Study*, are:

"**Ice-capable:** A vessel able to operate in open pack (4/10 to 6/10 concentration), first-year thin/medium level ice, which is 1.5-4.0 feet thick. The vessel is structurally strengthened around the waterline, has an ice-breaking bow form, and has more horsepower than required for transit through ice-free waters. Safe navigation can be accomplished independently in very open pack; however, in open pack (or grater concentration) it is prudent to navigate with an ice escort. For independent operations, the vessel must navigate at slow speed using available leads in the pack ice and/or by pushing the ice out of its path. An example of this vessel type is the South African vessel *Agulhas*.

Polar Research Vessel (PRV): An ice-capable vessel dedicated primarily to research, designed to operate independently in the marginal ice zone and in unconsolidated pack ice during the summer melt season. It would be designed to ABS Class 1A or 1AA ice strengthening, capable of breaking 2.5 feet of first year thin, level ice continuously, have 60-day endurance..... A good example of a modern PRV is the Norwegian vessel *Polarbjørn*. It is 162 feet in length with 2,500 SHP.

Icebreaker: A vessel able to operate independently in close pack (or greater), first-year thick to multi-year ice, which is greater than 4.0 feet in thickness. The vessel is structurally strengthened around the waterline, has an ice-breaking bow form, and has added horsepower and displacement to continuously break level first year medium to second year ice, which ranges from 2.5 to 8.0 feet in thickness. The vessel can operate in first year pack ice without risk of hull damage. Vessel endurance, facilities and berthing are dependent upon the design mission needs. Examples of this vessel type are USCGC *Westwind* (3.1 feet of level ice at 3 knots) and *Leonid Breshnev* (7.5 feet of level ice at 3 knots)."

ICE-WORTHY RESEARCH SHIPS OF THE WORLD

	Year Built	Name	Length (loa, feet)	Displacement (tons)	SHP	Remarks
Argentina	1952	*General San Martin*	280			IB
	1979	*Almirante Irizar*	386	12,000	16,200	RIB
	1979	*Puerto Deseado*	250			R
Brazil	1957	*Barao de Teffi*	247			Formerly *Thala Dan*
Canada	1954	*Labrador*	269	5,300		IB
	1956	*Baffin*	285	4,200		R
	1960	*John A. MacDonald*	290	9,000	15,000	IB
	1963	*Narwhal*	251	2,220		S
	1963	*Hudson*	296	4,660		R
	1965	*Endeavour*	207			R
	1967	*Dawson*	196			R
	1968	*Louis St. Laurent*	345		24,000	IB
	1976	*Polar Circle*	162		2,500	PRV, Charter (Carino Shipping Ltd.)
	1951-77	*Polaris V*	175			Charter (Carino Shipping Ltd)
	1978	*Pierre Radisson*	320	8,300	13,600	IB "R" Class
	1979	*Franklin*	320	8,300	13,600	IB "R" Class
	1983	*Polar Duke*	216		5,500	Charter (Carino Shipping Ltd) to U S Antartic Research Program (NSF)
	1986	*Earl Grey*	224			IB
Denmark	1982	*Dana*				R, Also 5 icebreakers
Federal Republic of Germany	1955	*Anton Dohrn*	205			R, Also 4 icebreakers
	1973	*Explora*	234		3 500	R
	1982	*Polarstern*	389		20,000	RIB
	1984	*Ice Bird*	349			Polar resupply
Finland	1953	*Aranda*	173			R, Refurbished in 1976
						9 Baltic icebreakers
						PRV under construction

ICE-WORTHY RESEARCH SHIPS OF THE WORLD
(continued)

	Year Built	Name	Length (loa, feet)	Displacement (tons)	SHP	Remarks
France	1961	*Jean Charcot*	246	2,100	3,300	Antarctic supply and research
	1969	*Cryos*	160	800		
	1972	*Marion-Dufresne*	365			
Japan	1965	*Fuji*	325	9,000	12,000	IB
	1982	*Shirase*	403	17,600	30,000	RIB
Norway	1958	*Johan Hjort*	172			F
	1960	*H.U. Sverdrup*	127			F
	1968	*Kvitbjørn*	135			Charter (Rieber Shipping A/S)
	1970	*Kvitungen*	135			Charter (Rieber Shipping A/S)
	1975	*Polarbjørn*	162		2,500	PRV, Charter (Rieber Shipping A/S)
	1981	*Lance*	198	2,175	3,200	R, Norwegian Polar Institute
	1981	*Polar Queen*	216		5,500	Charter (Rieber Shipping A/S)
Poland						PRV under construction
Sweden	1979	*Ymer*	344	9,660	22,000	IB, Arctic research 1980
						5 icebreakers
						PRV under construction
Union of South Africa	1961	*RSA*	223			S
	1978	*Agulhas*	354		6,000	Antarctic supply and research
United Kingdom	1956	*John Biscoe*	220		1,350	
	1956	*Endurance*				Formerly *Anita Dan*
	1962	*Discovery*	260			
	1970	*Bransfield*	325	4,800	5,000	Antarctic supply and research

ICE-WORTHY RESEARCH SHIPS OF THE WORLD
(continued)

	Year Built	Name	Length (loa, feet)	Displacement (tons)	SHP	Remarks
USA	1943	*Westwind*	269	5,300	10,000	IB
	1945	*Northwind*	269	5,300	10,000	IB
	1975	*Polar Star*	399	12,000	18,000 - 60,000	IB
	1977	*Polar Sea*	399	12,000		IB
						(*Polar Duke*, Canada, chartered by NSF)
USSR	1952	*Polyarnik*	126			R
	1954	*Ob*	426			R
	1956	*Pervenets*	128			R
	1956	*Okeanograf*	128			R
	1956	*Aysberg*	225			R
	1957	*Mikhail Lomonosov*	335			R
	1958	*Shtorm*	132			S
	1964	*Akademik Knipovich*	280			F
	1966	*Professor Vise*	408	6,900		R
	1966	*Petr Pakhtusov*	221			S
	1967	*Akademik Shirshov*	407			R
	1967	*Professor Zubov*	408	6,900		R
	1969	*Priliv*	319			R
	1970	*Dimitriy Laptev*	224			S
	1970	*Dimitry Ovtsyn*	219			S
	1971	*Stepan Malygin*	217			S
	1971	*Dimitry Sterlegov*	224			S
	1972	*Nikolay Kolomeytsev*	224			S
	1972	*Valerian Al'Banov*	224			S
	1972	*Edward Toll'*	224			S
	1973	*Vladimir Sukhotskiy*	224			R
	1974	*Nikoley Yevgenov*	224			S
	1974	*Sercey Dravkov*	224			S
	1975	*Mikhail Somov*	437	13,000		R, AARI

ICE-WORTHY RESEARCH SHIPS OF THE WORLD
(continued)

	Year Built	Name	Length (loa, feet)	Displacement (tons)	SHP	Remarks
USSR (continued)	1975	*Vsevold Bereskin*	180			R
	1976	*Professor Bogorov*	226	1,654	2,000	R
	1976	*Professor Kuventsov*	226	1,654	2,000	R
	1976	*Professor Vodjantskiy*	226	1,654	2,000	R
	1976	*Fedor Matisen*	226	1,654	2,000	S
	1977	*Georgiy Maksimov*	226	1,654	2,000	S
	1977	*Ivan Kireev*	226	1,654	2,000	S
	1977	*Pavel Bashmakov*	226	1,654	2,000	S
	1977	*Yakov Smirnitskiy*	226	1,654	2,000	S
	1978	*Otto Schmidt*		3,650	5,400	R, AARI
	1978	*Rudol'f Samoylavich*				R, AARI
	1979	*Professor Shtokman*	226	1,654	5,000	S
	1980	*Akademik Mstislav*	401	5,500	5,800	R
	1982	*Akademik Shokal'skiy*	235	2,050	3,100	R
	?	*Akademik Shuleykin*	235	2,050	3,100	R } For assignment to
	?	*Professor Mul'tanovskiy*	235	2,050	3,100	R } AARI, Far East
	?	*Professor Khromov*	235	2,050	3,100	R } and Murmansk
	?	*Professor Molchanov*	235	2,050	3,100	R }
	1987	*Akademik Fedorov*	456	12,000	19,000	R, UC
		Details lacking:				
		Mayak				S
		Stvor				S
		Matisen				S
		Sedov				S
		Keldysh				?
		Shenkursk				?
		Professor Kurentsov				(heads 9 geophysical ship flotilla)

ICE-WORTHY RESEARCH SHIPS OF THE WORLD
(continued)

	Year Built	Name	Length (loa, feet)	Displacement (tons)	SHP	Remarks
USSR (continued)		**Icebreakers:**				
	1954	*Kapitan Belousov*	273	3,375	10,500	
	1956	*Kapitan Voronin*	273	4,375	10,500	
	1956	*Kapitan Melekhov*	273	4,375	10,500	
	1959	*Lenin*	440	16,000	44,000	N
	1960	*Moskva*	401	12,840	22,000	
	1961	*Leningrad*	401	12,840	22,000	
	1965	*Kiev*	401	12,840	22,000	
	1968	*Murmansk*	401	12,840	22,000	
	1969	*Vladivostok*	401	12,840	22,000	
	1974	*Yermak*	442	20,240	36,000	
	1975	*Arktika*	492	23,400	75,000	N, 1977 voyage to North Pole (1983, temporarily renamed *Leonid Brezhnev*)
	1975	*Admiral Makarov*	442	20,240	36,000	
	1976	*Kapitan Kosolapov*	185	2,045	3,400	
	1976	*Kapitan M. Izmaylev*	185	2,045	3,400	
	1977	*Sibir*	492	23,400	75,000	N, 1987 voyage to North Pole
	1977	*Kapitan Sorokin*	434	14,900	22,000	
	1978	*Kapitan Nikolayev*	434	14,900	22,000	
	1980	*Kapitan Dranitsyn*	434	14,900	22,000	
	1981	*Kapitan Khlebnikov*	434	14,900	22,000	
	1982	*Mud'yuga*	290		12,400	Fitted with Thyssen/Waas bow system, 1986
	-	*Rossiya*			75,000	N
	-	*Dikson*			10,000	
	-	*Magadan*			10,000	
	-	*Taymyr*			52,000	UC
	-	*Vaygach*			52,000	UC
	1986	*Leonid Brezhnev*				

ABBREVIATIONS:

R	Dedicated research vessel
F	Fisheries research
S	Survey vessel
IB	Icebreaker
RIB	Research Icebreaker
PRV	Polar Research Vessel
AARI	Arctic and Antarctic Research Institute, Leningrad
SHP	Shaft horse power
N	Nuclear powered
UC	Under construction

NOTES:

Some U.S. ships, such as R/V *Alpha Helix*, have modest ice-strengthening insufficient for sustained, unaided operations in sea ice.

Poland has modern ice-worthy trawlers and at least one research vessel which have been used in exploratory Antarctica krill investigations.

USSR information incomplete, many modern ice-worthy trawlers and cargo vessels in national fleet, *Zverobo*ı class stern trawlers (237 feet, 3,300 SHP) used occasionally for marine mammal-fisheries research in sea ice. Several icebreakers built in Finland. Extensive operations on Northern Sea Route, including year-round activity in the Kara Sea.

German designers have developed a new approach to icebreaking technology, the Thyssen/Waas System. Model testing and full-scale trials with the converted icebreaker, *Max Waldeck*, show favorable prospects for this technology.

The Wartsilâ shipyard in Finland is the primary supplier of icebreakers to the world, having built at least one-half of all existing tonnage in this category.

Canada: Dome Petroleum Ltd. has two experimental icebreakers operating in the Beaufort Sea, *Kigoriak* (1979) and *Robert Lemeur* (1982). Two other privately owned icebreakers: *Kalvik* (1983) and *Terry Fox* (1983). A "Polar 8" icebreaker is under construction.

Australia is planning a research ship specifically for antarctic work.

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Wärtsilä AB, Finland
G. C. Rieber Co., Norway
Carino Co., Ltd., Canada
J. Lauritzen Lines, Denmark
German and Milne, Montreal
Dr. T. Armstrong, Scott Polar Research Institute

Compiled by R. Elsner
1971, 1973, 1978, 1980, 1982, 1983, 1984, 1988

Mr. WALGREN. Thank you, Dr. Alexander. We appreciate that.

Dr. Colwell.

Dr. COLWELL. Thank you, Mr. Chairman, and members of the committee. I am very pleased to have this opportunity to testify before the—about the NSF polar research. I won't be very long, again, because I realize we have had a very busy and tiring morning. But I would point out that even though my testimony is in a private role, more than as a member and representative of the National Science Board, I shall draw heavily on the information that I gathered while chairing the NSB's committee on the NSF role in the polar regions, and also the report has been entered into the record. And I will also draw on my experience as a marine scientist.

I will present a very brief review of the committee's mode of operation, the status of its recommendations, and try to address the questions that were raised by your committee concerning polar research vessels.

The listing of the committee members is in the report, and we had a very extensive series of meetings over a period of year. And it might be helpful to let you know of the procedures that we followed.

The committee held a series of six meetings at which experts from various fields of polar science and from organizations concerned with polar research made presentations.

Now these topics included scientific needs and opportunities, logistic support, research policy, and trends in support of research.

There was a substantial amount of background papers and related material that supplemented these oral presentations, and they are listed in the back of the report.

Now those six meetings provided important information for our report which we noted, particularly the importance of the polar regions to global environmental change.

Now the polar regions are major determinants of climate, but they themselves are very sensitive to climatic change. So improved understanding of arctic and antarctic oceans and terrestrial systems is really very basic to prediction, detection, and response to the impacts of climate change.

Global warming that results from increases of the so-called greenhouse gas in the atmosphere is one well-known manifestation of such change, and I know that you are familiar with the seasonal depletion of antarctic ozone, which is another manifestation of such change.

However, the science being carried out, or the science planned, is not limited to environmental research. It ranges across the disciplines, and quite literally it goes from the ocean bottom to beyond upper atmosphere to the stars.

And with respect to the more mundane—that is we have to consider the mechanics of how the research is done—we also examined the logistics necessary to do scientific research in the polar regions.

Now the logistics is a component of the first recommendation in the list of 15 recommendations made by the polar region committee, and I would just touch on three of those recommendations because they are relative to the discussion today.

The first recommendation, No. 7 and No. 15, the first is key. Scientific needs and opportunities should determine the research conducted in both polar regions, with the logistics deriving from and supporting the research, rather than dictating it.

This is a key point, and I really would like to underline it and put an exclamation point on it.

The recommendation No. 7 is that a research vessel with ice-breaking capability should be acquired for the U.S. Antarctic Program, and a research vessel capable of scientific and engineering research in arctic seas should also be acquired.

And the 15th recommendation is, and I really want to emphasize it, may be the 15th and the last, but it is not the least, and it is not the least important. Over the next three years, in addition to funding for the recommendations of our report, core funding for polar research should be increased to a level twice that budgeted for fiscal year 1988.

Now to implement these recommendations, the recommendations for doubling the funding of the polar programs is really the number one priority, and that should convey to you the importance we attach to polar research.

Now the research vessel issue—that directly relates to one of the questions I was asked to address today. I fully support the recommendation as a marine scientist actively involved in doing microbiology research, much of which is done at sea, and as a member of the National Science Board.

I am very pleased with the progress that NSF has made toward obtaining a research vessel with ice-breaking capability to use in the antarctic program. I think such a vessel can provide a very effective platform for year-round research related to climate, marine biology, as well as the history of the earth.

Without the vessel, the U.S. Antarctic Research Program will be very limited in its scope and diversity.

Now recommendation 7 of our report endorses acquisition of an arctic research vessel as well, with its importance clearly emphasized. Because of the fiscal climate, we realized that we had to prioritize; and, we concluded that the needs for scientific research support in the South, in the Antarctic, as well as the progress that was made in obtaining partial funding for the antarctic ship, placed it really as the first of the ships that should be acquired by NSF.

Now in answer to the questions raised about other options for NSF, including the Coast Guard playing a larger role in providing research support, let me say that the terms by which a dedicated research vessel is provided should derive from a very careful consideration of the scientific benefit, on the one hand, and financial costs on the other, and that is properly left to the normal contracting process.

But let me speak to the Coast Guard ice-breakers. Such vessels, in my view, are not a viable alternative. The fundamental premise of the committee, which I chaired, of the National Science Board is that logistics should derive from and support research, not dictate it. That is very important.

Among the experts, of which there were approximately 50 in number who provided background information, was Dr. Gunter

Weller, the chairman of the Polar Research Board. His report to us indicated clearly that the research experience of scientists on Coast Guard ice-breakers was, on the whole, not satisfactory.

The basis of his statement which, incidentally, is shared by an overwhelming majority of the scientists working in the polar regions, is that the design and equipment are deficient, as is the way the ice-breakers are operated.

Now the deficiencies in design and equipment could be remedied by a considerable investment on the part of the Coast Guard. But the operations problem results, in part, from the training and the attitudes of the officers and crew who understandably have a primary job to do. The multi-purpose nature of Coast Guard ships, therefore, really doesn't lend itself to the primacy of scientific research.

Both the university-operated ships of the UNOLS fleet—and Capt. Dinsmore will speak to that—and the contractor-operated Polar Duke of the Antarctic Program, have proven far more satisfactory for research, based on testimony of the users; and, I suppose that is the most important testimony.

This conclusion is not unexpected since UNOLS and the Polar Duke have a clear purpose. Their operators are dedicated to ensure the scientific research gets done. A serious problem with Coast Guard ice-breakers is that they are not available for year-round research, and that's critical for the study of inter-annual changes, climate changes, global changes.

Also I understand that the Coast Guard ice-breakers now are in short supply, even for ice-breaking.

Implementation of the National Science Board's polar regions committee's report is underway, with a task committee continuing to follow up on the activities that had been initiated to implement its recommendations; and, I really want to repeat, we are delighted to see the significant increase in the arctic climate-related research that has come forward from the geosciences in their FY 1989 request, as part of the attempt to implement our recommendations.

We endorse unequivocally the increases in funding for antarctic research and support enthusiastically the recommended increase for the research vessel with ice-breaking capability.

In our view, it is necessary for a vigorous leadership of the United States in the Antarctic and the Arctic, we think, for the leadership role of the United States in science, for the security of the nation, and for the future, we really must support vigorously our polar programs.

I will be very happy to answer questions you may have.

[The prepared statement of Dr. Colwell follows:]

THE UNIVERSITY OF MARYLAND
MARYLAND BIOTECHNOLOGY INSTITUTE

Office of the Director

March 20, 1988

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Congressman Walgren:

Thank you for the invitation to address the Subcommittee on Science, Research and Technology, which I am pleased to accept. It is, indeed, an honor to be given this opportunity. Although I am a member of the National Science Board and Chairman of its Committee on NSF's Role in Polar Region, I will be testifying as an individual and not as a Board representative.

Enclosed with this letter is a copy of the National Science Board Report on The Role of the NSF in Polar Regions, prepared by the Committee I chair. Because of the comprehensive nature of this report and its timeliness, I submit it as my written statement. My oral testimony will draw upon the content of the report and I will be prepared to respond to the questions stated in your letter of invitation.

Once again, I thank you for this opportunity. I look forward to seeing you and your Subcommittee on March 23, 1988.

Yours sincerely,

Rita R. Colwell, Director
Maryland Biotechnology Institute
and Professor of Microbiology

RRC/vh

Enclosures: National Science Board Report
Abbreviated Curriculum Vitae

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BIOGRAPHICAL SKETCH

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EDUCATION

B.S. (with Distinction), Bacteriology, Purdue University, Lafayette, Indiana 1956
M.S. Genetics, Purdue University 1958
Ph.D. University of Washington, Seattle, Washington 1961 (Thesis title: "Commensal Bacteria of Marine Animals. A Study of Their Distribution, Physiology and Taxonomy")

D.Sc. (Hon.) Heriot-Watt University, Edinburgh, Scotland, 1987.

EXPERIENCE

1957-1958	Research Assistant, University of Washington
1959-1960	Predoctoral Associate, University of Washington
1961-1964	Assistant Research Professor, University of Washington
1961-1963	Guest Scientist, Division of Applied Biology, National Research Council of Canada, Ottawa
1963-1964	Visiting Assistant Professor of Biology, Georgetown University
1964-1966	Assistant Professor of Biology, Georgetown University
1966-1972	Associate Professor of Biology, with tenure, Georgetown University
1980-1981	Acting Director, Center for Environmental and Estuarine Studies
1977-1983	Director, University of Maryland Sea Grant College
1972-	Professor of Microbiology, University of Maryland
1983-1987	Vice President for Academic Affairs, University of Maryland
1987-	Director, Maryland Biotechnology Institute, University of Maryland

RESEARCH INTERESTS

Marine and estuarine microbial ecology; microbial systematics; marine microbiology (ecology, physiology, genetics, and fine structure of marine and estuarine bacteria); temperature and high pressure effects on marine bacteria; microbial degradation; applications of computers in biology and medicine.

PROFESSIONAL ACTIVITIES

Phi Beta Kappa; National Commercial Company Research Award; Washington Academy of Sciences, Fellow; American Association for the Advancement of Science, Fellow; Sigma Delta Epsilon; American

Academy of Microbiology, Fellow; Alpha Chi Sigma Professional Service Award; Society for Industrial Microbiology, Board of Governors, 1976-79; Washington Academy of Sciences, Board of Managers, 1976-79; Canadian College of Microbiologists, Fellow; Microbial Ecology, Editorial Board, 1972-; Applied Microbiology, Editorial Board, 1969-81; Estuaries Editorial Board; Canadian Journal of Microbiology, Associate Editor, 1972-75, Assistant Editor, 1975-80; Journal of Washington Academy of Sciences, Editorial Board, 1980-; International Union of Microbiological Societies (IUMS), offices at various times include: Secretary-Treasurer, Vice Chairman and Chairman of Bacteriology Division; ICOME National Organizing Committee for the 3rd International Symposium on Microbial Ecology, 1980-83; American Society for Microbiology, Chairman and member of various committees; American Society for Microbiology Steering Committee for IUMS Congress, 1979-82; ASM Foundation Lecturer, 1981-1982 and 1985-1986; ASM Washington Area Branch, offices held at various times include: Executive Committee, Vice-President, and President; American Society for Microbiology, President-Elect, 1983-84; ASM President 1984-85; Fisher Award, ASM, 1985; American Type Culture Collection, Board of Trustees, 1970-85; Chairman, 1980-81; American Institute of Biological Sciences Governing Board, 1978-82; Marine Technology Society Governing Board, 1980-86; National Science Foundation, service on various committees; Classification Society (Cambridge, England, Charter Member); Member, Board of International Organizations and Programs, National Academy of Sciences, 1973-79; National Academy of Sciences, Member Steering Committee to update 1975 Report, "Petroleum in the Marine Environment," 1980-84; International Union of Biological Sciences, Chairman, U.S. National Committee; Society for Experimental Biology and Medicine, Distinguished Scientist and Lecturer Award, 1979; Journal of Washington Academy of Sciences, Editorial Board, 1980-; Chairman, Organizational Committee for a Federation of Systematic Biologists, 1980-; Presidential appointment to National Science Board 1984-1990.

PUBLICATIONS

Author or editor of eleven books; produced award-winning film, Invisible Seas, a 28-minute, color, sound film on marine microbiology.

Author or co-author of 365 papers, articles, and chapters, 53 reports and 193 abstracts or presentations.

Most recent publications (1983-):

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Deming, J.W., H. Hada, R.R. Colwell, K. Luehrsen and G. Fox. 1984. Ribonucleotide sequences of 5S rRNA from 2 strains of deep-sea barophilic bacteria. J. Gen. Microbiol. 130: 1911-1920.

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Roszak, D., and R.R. Colwell. 1987. Metabolic activity of bacterial cells enumerated by direct viable count. Appl. & Environ. Microbiol. 53:2889-2893.

Mr. WALGREN. Thank you very much.

Captain Dinsmore.

Captain DINSMORE. Thank you, Mr. Chairman. I provided a written statement which you have and which has most of my discussion; so I will be brief and extract from it.

You also have been given my background and from that it should be evident that I am a strong advocate for a robust U.S. capability in the Arctic and Antarctic.

There is a tired old cliche which bores the listener with the fact that the oceans cover 70 percent of the world, but a less well known fact is that 15 percent of that ocean is covered with ice.

Among others, the polar capability involves a well balanced fleet of iceworthy vessels. This includes ice-breakers, research vessels and supply vessels. In the U.S. inventory, we have neither a well balanced fleet nor much of a fleet at all.

Of the specific category of ice-breakers, we are now witnessing a reduction in capability to an alarming state. It is my understanding that two Coast Guard Polar Class ice-breakers are all which remain. And this is occurring while other nations are building. The Soviets have 20 polar ice-breakers and three more under construction.

The number of polar ice-breakers required to meet U.S. interests has been the subject of some argument which is continuing.

An interagency report, "Polar Ice-Breaker Requirement Study," 1984, examined all available requirements for arctic and antarctic ice-breakers and the issues surrounding them. It recommended a U.S. fleet of four modern ice-breakers. The Coast Guard and the minority statement recommended five. I support a fleet of four ice-breakers as the minimum number of ships to meet U.S. needs and protect our interests in the Arctic and Antarctic.

On the subject of polar research vessels, there may be even less agreement. On one hand, it's argued that general purpose Coast Guard ice-breakers properly equipped can meet research requirements in ice-encumbered areas. The opposite view supports dedicated research vessels to more closely link science requirements and, more recently, even to the extent of a research vessel with ice-breaking capability.

I believe that I can safely state that the science community is in full support of this latter view. For many years there have been frequent expressions of dissatisfaction with the Coast Guard ice-breakers as research vessels.

In fairness to the Coast Guard, it stems mostly from inadequate outfits, unsuitable design, and secondary mission effect.

The prospect of a true polar research vessel is an exciting one. We have viewed the German *Polarstern* and the Soviet *Feodorov* with admiration and no little envy. By the same token, however, it would be equally unfortunate if a research vessel were reassigned to nonresearch missions, such as logistics, harbor support and a rescue standby.

This is the role of the Coast Guard general purpose ice-breakers.

To the science community, then, the acquisition of a research vessel with ice-breaking capability has become a priority matter. No existing U.S. ship appears suitable, and the dearth of U.S.

design technology in this area may require we take a hard look at foreign technology and design.

Clearly the Soviets and the Finns hold the lead in this area, with the Germans and the Canadians coming up close behind.

I have had recent occasions to visit Finnish shipyards and found highly advanced ice-breaking research and development groups willing to share, for cost.

To date, most of their support has come from the Soviet Union, and they have been a major contributor to the USSR capability.

We could do worse than avail ourselves of this technology.

I'm speaking here of design and engineering, not actual shipbuilding. I believe that U.S. shipyards are capable of constructing a modern research ice-breaker.

What then is the role of Coast Guard ice-breakers? Their role as general purpose ice-breakers, supporting national interests, should not be materially altered. The number of ships, four, as reported in the interagency study remains, I feel, a valid requirement.

Perhaps this should be reaffirmed by a supplemental add-on study in view of a dedicated NSF polar research vessel.

The 1984 study is somewhat ambiguous in this area. Certainly all Coast Guard ice-breakers should carry a reasonable scientific outfit for participation in projects on an opportunity or a special assignment basis. But the scientific outfit should not drive the design of the replacement ice-breaker, as occurred in the recent Coast Guard preliminary design.

In that case, overambitious scientific design resulted in an extremely large and costly hull, without significantly adding to ice-breaking capability. It has not captured the support of the scientific community, nor is it likely to.

By reasonable scientific outfit, I would propose a capability certainly superior to existing Coast Guard ice-breakers, and probably more compatible with research ships of the 150 to 200 foot length as defined in the standard requirements of the Federal Oceanographic Fleet.

But first and foremost, Coast Guard ships should be good ice-breakers.

Finally, I would make a statement on behalf of an ice-capable vessel within the university fleet segment of the overall federal fleet. This fleet, numbering about 20 seagoing ships and operated by 15 university laboratories, carries out much, if not most, of the basic research within the national oceanographic program.

Presently there are no ice-capable ships in this fleet. There ought to be. We think that at least one planned replacement should be capable of Arctic service; not an ice-breaker, but certainly at home in the ice. We would envision such a vessel, considerably smaller than an ice-breaker, and operated by a university laboratory, would nevertheless be part of the U.S. polar fleet.

In conclusion, I have attached three graphs in my prepared statement I have given you, comparing modern polar ice-breakers. These chiefly portray the clear Soviet dominance in this field.

For those concerned with Arctic and Antarctic policy and operations, these should not be taken lightly.

Thank you very much for your attention.

[The prepared statement of Captain Dinsmore follows:]

POLAR RESEARCH VESSELS

Statement of Captain Robertson P. Dinsmore
Woods Hole Oceanographic Institution
presented to the Subcommittee on Science, Research and Technology
of the Committee on Science, Space and Technology
U.S. House of Representatives

23 March 1988

Mr. Chairman, it is a pleasure to appear before the Subcommittee and present my views on the needs for ice worthy vessels to support research activities in the Arctic and Antarctic. It is a subject in which I have had a role extending back to 1951, both as a research ship operator and captain, and as a participating scientist. I am presently at the Woods Hole Oceanographic Institution where I have served as Executive Secretary of the University-National Oceanographic Laboratory System (UNOLS) and as Chairman of the Marine Operations Department. As a former Coast Guard Captain, I served on icebreakers and the International Ice Patrol. I hold a graduate degree in Physical Oceanography from Scripps Institution of Oceanography and am the author of 17 scientific publications mostly dealing with Arctic ice and its formation, drift and forecasting.

Having said this, it should be evident that I am a strong advocate for a robust U.S. capability both in the Arctic and Antarctic. There is a tired old cliche which bores the listener with the fact that the oceans cover 70% of the world. Less well known is that 15% of that ocean is covered with ice.

Among others, a polar capability involves a well balanced fleet of ice worthy vessels. This includes icebreakers, research vessels, and supply

vessels. In the U.S. inventory, we have neither a well balanced fleet nor much of a fleet at all. Of the specific category of icebreakers we are now witnessing a reduction in capability to an alarming state. It is my understanding that the two Coast Guard Polar Class icebreakers are all which remain. And this is occurring while other nations are building. The Soviets have twenty polar icebreakers and three under construction.

The number of polar icebreakers required to meet U.S. interests has been the subject of some argument which continues. An interagency report: "Polar Icebreaker Requirements Study", DOT, 1984, examined all available requirements for Arctic and Antarctic icebreakers and the issues surrounding them, and recommended a U.S. fleet of four modern icebreakers. The Coast Guard, in a minority statement, recommended five. I support a fleet of four icebreakers as a minimum number of ships to meet U.S. needs and protect our interests in the Arctic and Antarctic.

On the subject of Polar Research Vessels, there may be even less agreement. On one hand it is argued that general purpose Coast Guard icebreakers, properly equipped, can meet research requirements in ice-encumbered areas. The opposite view supports dedicated research vessels more closely linked to science requirements, and more recently, even to the extent of a research vessel with icebreaking capability. I believe that I can safely state that the science community is in full support of this latter view. For many years there have been frequent expressions of dissatisfaction with the Coast Guard icebreakers as research vessels. In fairness to the Coast Guard, this stems mostly from inadequate outfits, unsuitable design and a secondary mission effect.

The prospect of a true polar research vessel is an exciting one. We have viewed the German POLARSTERN and the Soviet FEODOROV with admiration and no little envy. By the same token, however, it would be equally unfortunate if a research vessel were reassigned to non-research missions such as logistics, harbor support and rescue standby. This is the role of the Coast Guard general purpose icebreakers.

To the science community, then, the acquisition of a research vessel with icebreaking capability has become a priority matter. No existing U.S. ship appears suitable, and the dearth of U.S. design technology in this area may require that we take a hard look at foreign technology and design. Clearly the Soviets and Finns hold the lead in this area with Germans and Canadians coming up close behind. I have had recent occasions to visit Finnish shipyards and found highly advanced icebreaking research and development groups willing to share - for a cost, of course. To date, most of their support has come from the Soviet Union and they have been a major contributor to the USSR capability. We could do worse than avail ourselves of this technology. I am speaking here of design and engineering - not actual shipbuilding. I believe that U.S. shipyards are capable of constructing a modern research icebreaker.

What then is the role of the Coast Guard icebreakers? Their role as general purpose icebreakers supporting the national interests should not be materially altered. The number of ships - four - as reported by the interagency study remains, I feel, a valid requirement. Perhaps this should be reaffirmed by a supplemental add-on study in view of a dedicated NSF polar research vessel. The 1984 study was somewhat ambiguous in this area.

Certainly, all Coast Guard icebreakers should carry a reasonable scientific outfit for participation in scientific projects on an opportunity or special assignment basis. The scientific outfit should not "drive" the design of a replacement icebreaker as occurred in the recent USCG preliminary design. In that case, a possibly over-ambitious scientific design resulted in an extremely large and costly hull without significantly adding to the icebreaking capability. It has not captured the support of the scientific community, nor is it likely to. By "reasonable scientific outfit", I would propose a capability certainly superior to existing Coast Guard icebreakers, and probably more compatible with research ships of class III (150-200 ft. length) as defined in the standard requirements of the Federal Oceanographic Fleet. But first and foremost, the Coast Guard ships should be good icebreakers.

Finally, I would make a statement in behalf of ice-capable vessels with the University Fleet segment of the overall Federal Fleet. This fleet, numbering about twenty seagoing ships operated by fifteen university laboratories, carries out much if not most of the basic research within the National Oceanographic program. Presently there are no ice-capable ships in this fleet. There ought to be. We think that at least one planned replacement should be capable of arctic service - not an icebreaker, but certainly at home in the ice. We would envision such a vessel, considerably smaller than an icebreaker, and operated by a university laboratory, would nevertheless be a part of the U.S. Polar Fleet.

In conclusion, I have attached three graphs comparing modern polar icebreakers. These chiefly portray the clear Soviet dominance in this field. For those concerned with Arctic and Antarctic policy, and operations, these should not be taker lightly.

Thank you very much for your attention.

Principal Features of the Large Soviet Polar Icebreakers in Comparison to the World Fleet. Only Icebreakers with 20,000 or More Shaft Horsepower Are Listed. Note the Fleet Size and Diversity of Classes of the Soviet Union.

Country	Class (No. Vessels)	Year Delivered	SHP[1]	Tonnage	Length (m)	Beam (m)	Draft (m)	Power[2] Plant	Icebreaking[3] (m)
* USSR	ARKTIKA (4)[4]	1975-Present	75,000	23,460	148	30	11	N	2.4
USA	POLAR (2)	1976-77	60,000 18,000	13,000	122	26.2	9.5	GT DE	1.7-2.0
* USSR	TAYMYR (2)[5]	Building	52,000	22,000	150	26.2	7.8	N	1.7
* USSR	LENIN	1959	44,000	19,240	134	27.6	10.5	N	2.1
* USSR	YERMAK (3)	1974-76	36,000	20,241	135	26	11	DE	1.5
Japan	SHIRASE	1982	30,000	17,600	134	28	9.3	DE	1.5
Canada	LOUIS ST. LAURENT	1969	24,000	13,800	112	24.4	9.5	TE	1.2
Canada	KALVIK (2)(Private)	1983	23,200	7,000	88	17.5	8	GD	1.35
* USSR	MOSKVA (5)	1959-69	22,000	15,360	122	24.5	10.5	DE	1.35
* USSR	KAPITAN SOROKIN (4)	1977-81	22,000	14,900	132	26.5	8.5	DE	1.35
~~USA~~	~~GLACIER~~	~~1955~~	~~21,000~~	~~8,800~~	~~94~~	~~22.6~~	~~8.8~~	~~DE~~	~~1.1~~
FRG	POLARSTERN	1982	20,000	15,000	118	25	10.5	GD	1.0

Notes:

1 Shaft Horsepower

2 Power Plants: N=Nuclear, GT=Gas Turbine, DE=Diesel Electric, TE=Turbo-electric GD=Geared Diesel

3 Estimated continuous, level icebreaking at three knots (ice thickness in meters).

4 LEONID BREZHNEV, SIBIR and ROSSIYA (1985) in service. Fourth ship of the class under construction in the USSR.

5 Two ships under construction in Helsinki by the Finnish shipbuilder Wartsila. Reactors to be installed in the USSR.

Soviet Icebreaker Fleet Profile for 1987

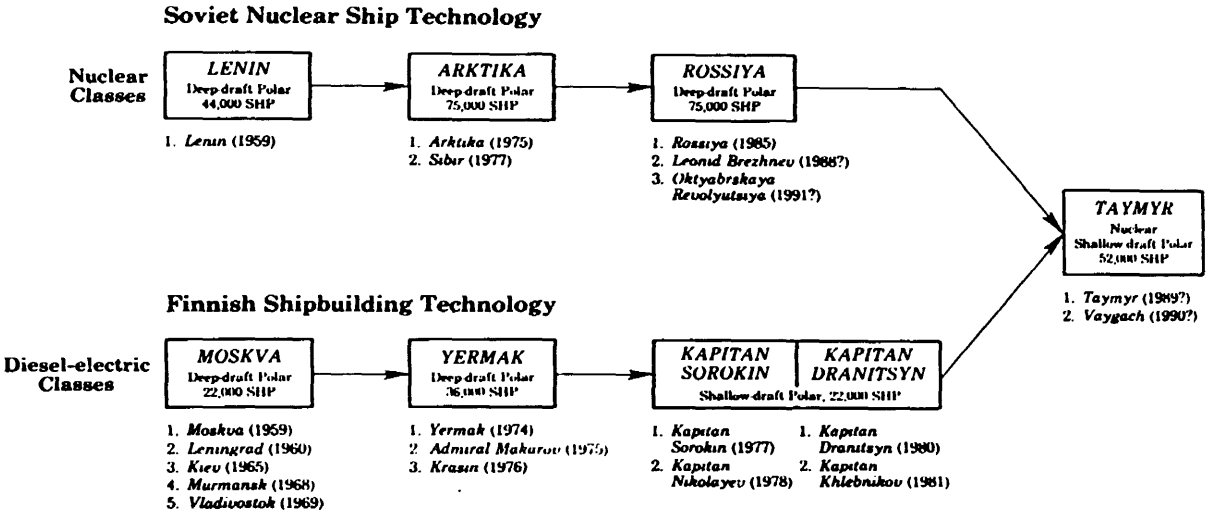
Number		Type	Class or Name
16		Polar [1,2]	*LENIN* (1), *ARKTIKA* (2), *YERMAK* (3), *MOSKVA* (5), *KAPITAN SOROKIN* (4), *ROSSIYA* (1)
36		Subarctic [3]	
	20	Merchant Marine	*DOBRYNY NIKITICH* (14), *KAPITAN BELOUSOV* (3) [4], *MUDYUG* (3)
	9	Soviet Navy	*DOBRYNY NIKITICH* (7), *IVAN SUSANIN* (2)
	5	KGB Maritime Border Troops	*IVAN SUSANIN*
	2	Polar Research	*VLADIMIR KAVRAYSKIY* (Navy), *OTTO SCHMIDT* (Academic)
7		Salvage	*STROPTIVY*
13		River	
	6	Shallow-draft	*KAPITAN CHECHKIN*
	7	Extreme shallow-draft	*KAPITAN EVDOKIMOV*
3		Large Harbor	*KAPITAN IZMAYLOV*
1		Conventional LASH [5]	*ALEKSEY KOSYGIN*
1		Nuclear LASH	*SEVMORPUT* [6]
16		SA-15 Icebreaking Cargo	*NORIL'SK* [7]
93	Total		

Notes:

1. Polar icebreaker defined as a ship capable of operations in multi-year ice of the polar pack.
2. Four nuclear-powered polar icebreakers under construction: 2 shallow-draft, *TAYMYR* and *VAYGACH*, by Wartsila in Helsinki; 2 *ROSSIYA* class, *LEONID BREZHNEV* and *OKTYABRSKAYA REVOLYUTSIYA*, in Leningrad.
3. Subarctic icebreaker defined as a ship capable of operations in seasonal, first-year ice.
4. Three ships of the *KAPITAN BELOUSOV* class built 1954-56 are at the end of their service lives.
5. LASH = lighter-aboard-ship.
6. Launched in February 1936 and undergoing completion.
7. Three more SA-15 ships building in Finland to be delivered.
8. Of the 93 Arctic ships, 36 were constructed in the USSR (4 nuclear polars, 2 LASH, 30 subarctic) and the remaining 57 in Finnish yards. Not included in the table are the more than 100 ice-strengthened and ice-capable freighters and tankers that sail in the Soviet Arctic. The USSR also operates several icebreaking research ships in the Antarctic, including the *MIKHAIL SOMOV* and the new *AKADEMIK FEDOROV*.

CDR Lawson W. Brigham
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Woods Hole Oceanographic Institution
Woods Hole, MA 02543 USA
December 1987

Design Evolution of Soviet Polar Icebreakers



SHP = Shaft Horsepower

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December 1987

Mr. WALGREN. Thank you, Captain Dinsmore.

You have said that the Finns and the Soviets have better technology, and somebody over there was willing to share costs of some kind. What was that?

Captain DINSMORE. I said they would share their technology for a cost. I'm saying we can buy it; they won't hold back on us.

Mr. WALGREN. I see. But you would anticipate such a ship being able to be built in American yards?

Captain DINSMORE. I would certainly think so, yes, sir. The American shipyards are just as capable as a Finnish shipyard. It's design technology that's been built up over the past 20 years that you don't capture that right away. We indeed fell down on that job.

Mr. WALGREN. Mrs. Morella, any——

Mrs. MORELLA. I think you've been wonderful. I thank you for waiting so long, too, throughout the earlier hearing, and I can tell you that we are going to work hard to try to get you that research vessel with the ice-breaker. That's one of the many things that you mentioned. It came through very clearly that it is absolutely imperative that we follow through.

Now I guess I understand there is some money at least being suggested, authorized, if this committee will continue, for a start of like $4 million. Is that correct?

Dr. COLWELL. Yes.

Mrs. MORELLA. How much do these vessels cost? I couldn't find a final figure.

Dr. COLWELL. Well, actually the POLARSTERN was about $80 million, and they can run up to $100, $200 million. They are not inexpensive vessels to build.

Mrs. MORELLA. So might we lease? I mean is that a possibility also?

Dr. COLWELL. That's being considered. A lease-purchase.

Mrs. MORELLA. A lease-purchase. And Captain Dinsmore said he would ideally like to see four—is that what you said?

Captain DINSMORE. What I'm saying is the Coast Guard proper for ice-crunching, real ice-breaking in the national interests probably still needs more ice-breakers, which have a modest scientific capability. I think we are talking here about a research ice-breaker to meet those requirements. It's probably not the—as expensive as a full-fledged ice-breaker, but it—as Dr. Colwell said, it could easily reach $150 million, if you buy it new. Lease-purchasing is good, and I think it's probably the way to go at this point.

Mrs. MORELLA. I know Dr. Colwell had pointed out, as you all have inferred, that you really shouldn't have to rely on the Coast Guard, you really need your own, and I think it's very interesting what the Chairman also pulled from what you said about the fact that the Soviet Union and the Finns are ahead of us. Of course, they've got the climate, I guess, that would induce them to get involved in that research earlier, but it's an area where I think we haven't focused enough attention.

Dr. Colwell, you may live in my district, but I know that your credentials would just fatigue me terribly, they're just so lengthy, particularly the articles that you have written on subjects I don't even understand, let alone able to pronounce.

Dr. Alexander, I know you've got to get a plane to go back to Alaska. I particularly appreciate you being here. And Captain Dinsmore, I've been up to your area at Woods Hole.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mrs. Morella.

If it is a big purchase like that, are lease- purchases available? When you lease-purchase, are you talking about constructing it new, or——

Captain DINSMORE. Oh, yes. A lease-purchase arrangement ideally, the construction is to the user's specifications, except you avoid the up-front money, you know. So you're able to get—to bring a ship online somewhat quickly at modest means.

Over the years you wind up paying for it. It's just you avoid the up-front money and are able to get going quickly. But it is—if you do it right, it's to your specifications and we'll give you what you want.

Mr. WALGREN. Are we presently using any international ice-breaking capability, as—these other countries apparently are ahead of us, and they have the facilities. Are we—have we tried to piggy-back on their vessels?

Dr. COLWELL. Oh, indeed. Many scientists do, but you understand that that means that you always are second, third or fourth priority, and you have to fit into whatever program is being carried out. There are cooperative programs, and those are very, very successful. But there are—there is research that we need to do as U.S. scientists that we can't get done because we don't have access to planning a whole year for the vessel.

Dr. ALEXANDER. May I make a comment on that? And then after that, may I be excused to go and catch my plane? My comment is that most of the marine mammal research that is carried out in U.S. waters, ice-covered waters, is carried out onboard Soviet vessels right now, because they are the only ones available. And similarly in the eastern Arctic, our U.S. program up in the Greenland Sea is being carried out onboard primarily the German vessel *Polarstern.* And so, yes, there's a lot of that.

And I'm really sorry, I have to run.

Mr. WALGREN. Not at all. We all should end, and we appreciate very much your contribution to the record. I'm sure it will not be lost on the Committee.

Captain DINSMORE. Mr. Chairman, I brought a couple of publications. One is from Woods Hole, an issue that deals with the Arctic. I'm not going to take it back. Can I leave it for——

Mr. WALGREN. Sure. We'd be happy to have it and look at it.

Captain DINSMORE. And a couple of propaganda brochures on our university center.

Mr. WALGREN. Very good.

Well, thank you very much for your contribution to the record.

[Whereupon, at 1:00 p.m., the subcommittee was adjourned.]

1989 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MARCH 24, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (chairman of the subcommittee) presiding.

Mr. WALGREN. We should start, because we have a long day of witnesses, some 13 witnesses today, which programs ought to somewhat over two hours of direct testimony, and we may even be interrupted. So, I want to say at the outset that we are going to have to be disciplined about the time that each of us takes, and I want to ask for the cooperation of the witnesses in that vein.

This is the third hearing on the National Science Foundation's authorization for Fiscal Year 1989. And we're going to have this morning separate panels addressing the engineering research centers program and the national supercomputer centers program.

In previous hearings we focused on pre-college science and math education, along with the NSF proposal for the new science and technology centers program, and NSF's involvement in the polar regions. Yesterday we had Mr. Bloch, the director of the Foundation, and Roland Schmitt, the chairman of the National Science Board to talk, generally, about the range of the NSF budget that they are proposing.

This morning we are pleased to welcome the first panel that will address the Engineering Research Centers Program. That program is designed to provide support for inter-disciplinary research in areas having commercialization potential, or relevance to the technology needs of the civilian sector in our economy.

The engineering research centers requires the participation by industry in providing financial support and in influencing the direction and the goals that the programs are designed to pursue. As you know, the first group of six centers received third year reviews this past summer, and that assessment is now being digested.

The panel we will hear from this morning includes representatives from industry, who are supporting the ERCs, the chairman of the National Academy of Engineering Committee, which has been providing guidance and assessments of the program, along with a community college president who has been exploring ways to establish ties with the engineering research centers for the transfer of

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new knowledge to upgrade technical training programs. And we look forward to hearing their views on the potential of these programs.

After that we are going to turn to consideration of the supercomputer centers that the National Science Foundation has been supporting these several years. There will be two panels addressing that subject, and we'll make more specific introductions when we get to that point.

As most know, the supercomputer centers were our answer to identified national requirements for advanced scientific computing. And some of the goals were to provide university researchers with access to the most advanced scientific computers, and to provide training for the newer generations of students and engineers in the use of supercomputers, so that their capability to use them be brought along as quickly as we could.

We want to explore this morning how well these centers are fulfilling these goals. And, particularly, in view of the fact that they suffered reductions in their funding in the mid-term adjustment last year, and that the Foundation itself is not proceeding in full fulfillment of the original expectations.

We are especially concerned about the possibilities for upgrading the equipment at these centers, and for providing the staffing levels that are required to deliver the product.

And, finally, we will be welcoming Dr. Terry Walker, who is the director of the Center for Advanced Computer Studies at Southwestern Louisiana University, who has some perspectives on research evaluation and some of the practices at NSF, and he will be our last panel.

You can see that it is a full morning and, therefore, the need for each of us to be disciplined in our presentation. Written statements will be made part of the record without more. And when this record is assembled and the staff and the members work with it, they'll have the full text of anything that each of the witnesses would like to submit in writing.

So, you can feel free in oral testimony to pull out points that you would like to really underscore in any focused way that you feel would be best, particularly in view of that timeframe.

I would like to recognize other members for any opening comments that they would like to make.

The gentleman from New York, Mr. Hochbrueckner.

Mr. HOCHBRUECKNER. Thank you, Mr. Chairman. I have no opening comments.

Mr. WALGREN. The gentleman from California, Mr. Brown.

Mr. BROWN. I have no opening comments.

Mr. WALGREN. Well, everybody is cooperating. Okay. Well, the first panel, begins with Dr. Don Kash, who is a professor of science and public policy at the University of Oklahoma, and is chairman of the National Research Council's cross-disciplinary engineering research committee.

Dr. Kash is joined by Dr. Robert Breuder, president of the Williamsport Area Community College, and Dr. Robert Dean, the chairman and chief executive officer of the Synosys Corporation, along with Dr. Kumar Patel, the executive director for research,

materials, science, engineering, and academic affairs at AT&T Bell Laboratories.

Gentlemen, we're very pleased that you could join us and contribute to our review of what we're trying to do through the National Science Foundation in this area. Let's go through the panel in the order in which I introduced you to the record, and we'll start with Dr. Kash.

[The prepared opening statement of Mr. Walgren follows:]

OPENING REMARKS OF THE
HONORABLE DOUG WALGREN (D-PA)
ON THE
NATIONAL SCIENCE FOUNDATION AUTHORIZATION HEARING
MARCH 24, 1988

THIS IS THE THIRD HEARING ON THE NATIONAL SCIENCE FOUNDATION'S AUTHORIZATION FOR FISCAL YEAR 1989. WE WILL HAVE SEPARATE PANELS THIS MORNING ADDRESSING THE IMPACT AND EFFECTIVENESS OF THE ENGINEERING RESEARCH CENTERS PROGRAM AND THE VITALITY AND FUTURE PROSPECTS FOR THE NATIONAL SUPERCOMPUTER CENTERS. PREVIOUS HEARINGS ON MARCH 22 AND 23 FOCUSED ON ISSUES CONCERNING PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION, THE NSF PROPOSAL FOR A NEW SCIENCE AND TECHNOLOGY CENTERS PROGRAM, AND NSF RESEARCH AND RESEARCH SUPPORT ACTIVITIES IN POLAR REGIONS. ALSO, THE NSF DIRECTOR AND CHAIRMAN OF THE NATIONAL SCIENCE BOARD APPEARED ON MARCH 23 TO DESCRIBE PLANS AND PRIORITIES IN THE PROPOSED FY 1989 BUDGET.

WE ARE PLEASED TO WELCOME THE FIRST PANEL THIS MORNING DR. DON KASH, PROFESSOR OF SCIENCE AND PUBLIC POLICY AT THE UNIVERSITY OF OKLAHOMA AND CHAIRMAN OF THE NATIONAL RESEARCH COUNCIL'S CROSS-DISCIPLINARY ENGINEERING RESEARCH COMMITTEE; DR. ROBERT BREUDER, PRESIDENT OF WILLIAMSPORT AREA COMMUNITY COLLEGE; DR. ROBERT DEAN, CHAIRMAN AND CEO OF SYNOSYS CORPORATION; AND DR. KUMAR PATEL, EXECUTIVE DIRECTOR FOR RESEARCH, MATERIALS SCIENCE, ENGINEERING AND ACADEMIC AFFAIRS AT AT&T BELL LABORATORIES.

THE ENGINEERING RESEARCH CENTERS PROGRAM IS DESIGNED TO PROVIDE

SUPPORT FOR INTERDISCIPLINARY RESEARCH IN AREAS HAVING COMMERCIALIZATION POTENTIAL FOR OR RELEVANCE TO THE TECHNOLOGY NEEDS OF NON-DEFENSE INDUSTRIES. THE ERC PROGRAM REQUIRES PARTICIPATION BY INDUSTRY IN PROVIDING FINANCIAL SUPPORT AND IN INFLUENCING RESEARCH GOALS AND DIRECTIVES. THE FIRST GROUP OF SIX ERC'S RECEIVED THEIR "THIRD-YEAR" REVIEWS THIS PAST SUMMER AND, ALTHOUGH STILL RELATIVELY NEW, CAN BEGIN TO BE ASSESSED FOR PERFORMANCE.

THE PANEL WE WILL HEAR FROM THIS MORNING INCLUDES REPRESENTATIVES FROM INDUSTRY WHO ARE SUPPORTING ERC'S, THE CHAIRMAN OF A NATIONAL ACADEMY OF ENGINEERING COMMITTEE WHICH HAS BEEN PROVIDING GUIDANCE AND ASSESSMENTS OF THE PROGRAM, AND A COMMUNITY COLLEGE PRESIDENT WHO HAS BEEN EXPLORING WAYS TO ESTABLISH TIES WITH ERC'S FOR TRANSFER OF NEW KNOWLEDGE TO UPGRADE TECHNICAL TRAINING PROGRAMS. WE LOOK FORWARD TO HEARING THE VIEWS OF THIS PANEL ON THE CURRENT STRENGTHS AND WEAKNESSES OF THE ERC PROGRAM, AS WELL AS THE IMPLICATIONS FOR THE PROGRAM OF THE PROPOSED NSF BUDGET FOR FISCAL YEAR 1989.

WE WILL NEXT TURN TO A CONSIDERATION OF THE NSF NATIONAL SUPERCOMPUTER CENTERS AND WILL HEAR FROM TWO PANELS. THE FIRST WILL BE COMPRISED OF DR. CLIFFORD RHOADES FROM LAWRENCE LIVERMORE NATIONAL LABORATORY, WHO CHAIRED AN NSF COMMITTEE WHICH RECENTLY EXAMINED THE ADEQUACY OF THE BUDGETS OF THE SUPERCOMPUTER CENTERS; DR. KENNETH WILSON, PROFESSOR OF PHYSICAL SCIENCE AT CORNELL, WHO HAS BEEN CLOSELY INVOLVED WITH THE INITIATION AND DEVELOPMENT OF THE CENTERS; AND DR. FRED WEINGARTEN FROM THE OF-

FICE OF TECHNOLOGY ASSESSMENT, WHO HAS ALSO CLOSELY FOLLOWED THE EVOLUTION OF THE CENTERS. THE SECOND PANEL WILL BE COMPRISED OF THE DIRECTORS OF THE FIVE NSF NATIONAL SUPERCOMPUTER CENTERS: DR. LARRY SMARR FROM ILLINOIS, DR. DOYLE KNIGHT FROM PRINCETON, DR. SIDNEY KARIN FROM SAN DIEGO, DR. LARRY LEE FROM CORNELL, AND DR. RALPH ROSKIES, ACCOMPANIED BY DR. MICHAEL LEVINE FROM PITTSBURGH.

THE NSF NATIONAL SUPERCOMPUTER CENTERS WERE NSF'S ANSWER TO IDENTIFIED NATIONAL REQUIREMENTS FOR ADVANCED SCIENTIFIC COMPUTING. SOME OF THE GOALS OF THE CENTERS WERE TO PROVIDE UNIVERSITY RESEARCHERS WITH ACCESS TO THE MOST POWERFUL SCIENTIFIC COMPUTERS, TO TRAIN A NEW GENERATION OF SCIENTISTS AND ENGINEERS TO USE SUPERCOMPUTERS, AND TO STIMULATE THE DEVELOPMENT OF MORE ADVANCED SCIENTIFIC COMPUTERS AND NEW APPLICATIONS SOFTWARE. THIS MORNING WE WILL EXPLORE HOW WELL THE CENTERS ARE FULFILLING THESE ANTICIPATED GOALS, PARTICULARLY IN LIGHT OF THE RESOURCES WHICH HAVE BEEN AVAILABLE AND WHICH ARE PROJECTED IN THE FISCAL YEAR 1989 BUDGET FOR THE CENTERS. WE ARE ESPECIALLY CONCERNED ABOUT THE PROSPECTS FOR UPGRADING THE HARDWARE AT THE CENTERS AND FOR ESTABLISHING THE STAFFING LEVELS REQUIRED FOR PROVIDING USER SERVICES, TRAINING, AND DEVELOPMENT OF APPLICATIONS SOFTWARE.

FINALLY, WE WELCOME DR. TERRY WALKER, DIRECTOR OF THE CENTER FOR ADVANCED COMPUTER STUDIES AT THE UNIVERSITY OF SOUTH WEST LOUISIANA. DR. WALKER WILL PRESENT COMMENTS ON RESEARCH EVALUATION AND MANAGEMENT PRACTICES AT NSF.

STATEMENTS OF DR. DON E. KASH, GEORGE LYNN CROSS RESEARCH PROFESSOR, SCIENCE AND PUBLIC POLICY PROGRAMS, UNIVERSITY OF OKLAHOMA; DR. ROBERT L. BREUDER, PRESIDENT, WILLIAMSPORT AREA COMMUNITY COLLEGE; DR. ROBERT C. DEAN, JR., CHAIRMAN/CEO, SYNOSYS CORP.; AND DR. C. KUMAR N. PATEL, EXECUTIVE DIRECTOR, RESEARCH, MATERIALS SCIENCE, ENGINEERING AND ACADEMIC AFFAIRS DIVISION, AT&T BELL LABORATORIES

Dr. KASH. Thank you, Mr. Chairman. I'm pleased to have the opportunity to testify before you and the members of the Committee. In my opening statement I want to emphasize two points.

Mr. WALGREN. Turn your microphone on.

Dr. KASH. Are we in business now?

Mr. WALGREN. Those mikes have to be pulled pretty close and spoken directly into. They're very directional. So, know that you've got to have that mike five inches or less to project to the back of the room.

Dr. KASH. The first point that I want to emphasize is that the engineering research centers have been oversold.

Mr. WALGREN. Pull that mike in a little bit more. I want to be sure that everybody can hear easily.

Dr. KASH. You want to be sure that, if I say anything exciting, it's heard. Okay.

The second is that the engineering research centers are being overevaluated. The Engineering Research Center Program was created as a response to the nation's competitiveness problem. And, while I believe over the long run it can make an important contribution to that problem, it's simply preposterous on its face to think that the centers offer a major portion or short-term answer to that competitiveness problem.

When the engineering research centers sometimes happen to get identified as a major component, and sometimes as the major component, of the national government's response to the competitiveness problem, one can only shiver. Free-standing inter-disciplinary research organizations with an applied focus are a new and interesting experiment on university campuses. But, in fact, the competitiveness problem will require changes that are very broad-based throughout American society.

The idea that these centers can, by themselves, make a significant short-term contribution, it seems to me, just loads too much on their shoulders. This is a $33 million program this year. It's a very small part of the NSF's budget. It involves a very small number of people.

The point I want to try to emphasize is that this is a small program in size, and it is new, three years old essentially, and it is being subjected to a kind of microscopic investigation, which, in many ways it seems to me, is a major barrier to the program working as well as it might.

The first six centers have just gone through an evaluation by the National Science Foundation. The General Accounting Office is studying the program. This Committee is holding hearings. The National Science Board, as I understand it, wanted an evaluation of the first six centers before it took action on new centers.

In truth, I sometimes wonder how these centers get anything done. They spend a great deal of time responding to questions about what they're doing and how well they're doing it.

Now, the reason I want to emphasize this point is that engineering research centers are, in fact, a significant experiment on American campuses. In the context of the university, three years is really a very short period of time. The hiring cycles of universities are such that, if you get a grant at a particular time in the year, before you can add new people it's another year. If you want to add a new course, it's another year. And, effectively, in the third year we're evaluating something which takes a long time to put in place.

There's a strong tendency in government organizations, and a particularly strong tendency when programs of this type receive so much media attention and so much attention within Washington, to want to get out the yardstick and measure the performance of these centers at far too early a stage.

It is terribly important, it seems to me, to recognize that interdisciplinary research in teaching organizations on university campuses are really foreign bodies. I love this reference to the fact that, when you set up an inter-disciplinary research organization on a campus, it's a little bit like putting a foreign organ in a human body. The minute you start one of these things on a campus, there are systemic rejection mechanisms that are engaged. And to keep them alive requires injecting the university with immunosuppressants. In this case, normally, money.

Now, what I'm trying to say here is that neither the NSF nor we in the university quite know how to make these things work. It is an experiment. I believe it to be a terribly important experiment. I think it needs time. I think the greatest barrier to the success of these programs is trying to establish evaluation criteria and make judgments on them before we quite know how to make them work.

The point I want to try to emphasize is that both the universities—and most universities believe that such organizations are important—and the NSF are both trying to learn how to make this program work. They're trying to learn without an established paradigm. That means there are going to be mistakes. It is a trial and error process. Error means that there will be some failures.

I guess I would plead with this Committee and with the whole community to give these organizations a chance, and not try to be what, all too frequently in this town, has become the norm: tough, blue-steel managers who can make tough decisions before there's been time enough to experiment and learn how these organizations can work.

I believe that what is going on with regard to the engineering research centers is perfectly characterized by one of my colleagues on the National Research Council Committee. He said the other day: we in the United States have almost no patience. Patience is critical when you're trying to build unique new organizations in universities. Yet, we in the United States have an almost chemical need to pull up the flowers and make sure that the roots are healthy.

There's a certain amount of pulling up these flowers too early. $33 million is a piddling amount of money. If we subjected physics

to the same kind of investigation for every $33 million that these organizations are being subjected to, I think the physics community would be in deep trouble.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you very much, Dr. Kash. Those are analogies that will stick to the ribs, and I appreciate them. Let's turn to Dr. Breuder.

[The prepared statement of Dr. Kash follows:]

TESTIMONY BEFORE

COMMITTEE ON SPACE, SCIENCE, AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

March 24, 1988

by

Don E. Kash

George Lynn Cross Research Professor

University of Oklahoma

The Engineering Research Centers

Mr. Chairman, Members of the Committee:

I'm pleased to have this opportunity to discuss the Engineering Research Centers. In my opening statement I want to emphasize two points. First, the Engineering Research Centers have been oversold. Second, the Engineering Research Centers are being overevaluated.

The Engineering Research Center Program was created as a response to the nation's competitiveness problem. While, over the long run, they can make a significant

contribution to the nation's competitiveness, that will only occur if a large number of other things change. The nation's competitiveness problem is heavily a result of our inability to rapidly move ideas into the marketplace. The critically important problem of rapid innovation requires improvement at a number of points. We must improve our capability for rapidly developing prototypes. With rare exceptions, the Engineering Research Centers will not do this. We must rapidly move prototypes into efficient, quality, low-cost, large-scale production. The Engineering Research Centers will play a minor role here. We must develop a capability to move new products rapidly into the world market. That requires vigorous, continuous world marketing systems. The ERCs have no role here.

For these things to occur broader changes are necessary. The American educational system must be significantly improved. Government-private sector cooperation must increase. Labor-management cooperation must increase. The American financial system must become something other than a Las Vegas gambling table. Americans must learn to save more. Americans must consume less.

The idea behind the Engineering Research Centers is sound. There is a compelling need on university campuses to more effectively tap the expertise in the disciplines, integrate that expertise, and link it to commercial needs. The Engineering Research Centers respond to a real need and, over the long term, can make a valuable contribution. The idea that a program which presently costs $33 million,

located on university campuses should be seen as the answer or even a major part of the answer to the nation's competitiveness problems is simply preposterous on its face.

When the Engineering Research Centers and the Science Technology Centers are identified as a major component of the national government's response to the competitiveness problem, one can only shiver. That is a load they cannot carry.

The Engineering Research Center Program is three years old. The first six centers have just gone through an initial NSF review. The General Accounting Office is studying the program. This Committee is holding hearings. The National Science Board required an evaluation before it decided what to do on new centers. I'm regularly called by the press to get an evaluation of the centers. I sometimes wonder how the centers get anything done, they spend so much time responding to requests about what they're doing and about how well they've done it.

Free-standing interdisciplinary research-teaching organizations with an applied focus are not wonderously compatible with America's research universities. Such organizations in many universities are appropriately seen as having the characteristics of a foreign organ implanted into a human body. The minute they are created systemic rejection mechanisms are engaged and their survival and prospering requires that the institution be continuously injected with immunosuppressants.

The Engineering Research Centers are needed. They are also experiments. Put simply, no one knows how to make them a success. They are in a trial-and-error phase.

In the context of the university, three years is a short time for an organizational experiment. The hiring cycles of universities go on the academic year basis. Thus, if you get a grant, it may be a year later before you get new people in place. If you're going to carry out research and teaching, there is a substantial lead time before anything happens, approving a new course requires a year. Put simply, three years is too short a time for meaningful evaluation. There's a strong tendency within all large organizations and certainly in government to want to establish clear-cut evaluation criteria. That's a wonderful thing to do if you know how to define those criteria, but, establishing evaluation criteria in the absence of reference points which tell you what is necessary for success is a formula that can only lead to problems.

Let me note in this connection that I do not disagree that there is one kind of evaluation that can occur. After three years you can evaluate whether the centers are trying to do what they said they were going to do.

Beyond that, however, three years is too short. That is, if you ask, "Are they making a substantive contribution?" you simply cannot know that in three years.

The people in the Natonal Science Foundation who are running this program are trying mightily to assure that

the program achieves its objectives. They are, I believe, doing a good job. Unfortunately, they operate under continuous pressure to evaluate. Early evidence suggests, not surprisingly, that some of the centers are doing better than others in achieving what they have defined as their objectives.

Let me conclude by repeating a comment that one of my colleagues on the Cross-disciplinary Engineering Research Committee of the National Research Council made the other day in a telephone conversation. "We in the United States have almost no patience. Patience is critical when you're trying to build unique new organizations in universities, yet we in the United States have this almost chemical need to pull up the flowers to see if the roots are healthy."

At the present time this tendency may be the greatest danger facing the Engineering Research Centers.

I thank you for the opportunity to make this statement.

Dr. BREUDER. Good morning, Mr. Chairman, and members of the Subcommittee. Thank you for the opportunity to testify on the reauthorization of the National Science Foundation in the Walgren bill, H.R. 2134, which the nation's community colleges wholeheartedly support.

Our timing is good. For the past three months my colleagues at the Williamsport Area Community College and I have been working on little else than technology transfer. In the process, we have arrived at a number of judgments on this and associated issues. These determinations are articulated in detail in my written statement, but, with the consent of the Subcommittee, let me depart from that printed text and summarize the highlights.

Mr. Chairman, I'm sure you are aware that our college has been working closely with the National Science Foundation for some six months to develop a prototype technology transfer center at the Williamsport Area Community College. As a Pennsylvanian, you know that our Commonwealth recently implemented law providing for the establishment of industrial resource centers, very similar to the centers envisioned in the imaginative legislation you moved through this House of Congress four years ago.

One week from today we deliver to Governor Casey a joint application from Penn State University and our college for a $2 million grant to establish such a center on the Williamsport campus. I share this information so that you understand that my views were forged in the trenches, not in some lofty ivory tower. I speak from the experience of a practitioner and leave the theorizing to others.

Last fall our college dedicated a $21 million advanced technology and health sciences facility. We equipped that facility with hands-on laboratories to offer technician-level training in such advanced technology fields as fiber optics, laser technology, and telecommunications. We developed a state-of-the-art automated manufacturing facility, supporting programs in computer-assisted drafting and design, computerized numerical control, and robotics.

We are told by knowledgeable representatives of industry that our new sophisticated facilities and advanced tech programs are equal or superior in design and implementation to any college in the country providing real instruction in the new technologies. This instruction in advanced technology is essential to efficient manufacturing.

You would, however, be alarmed and appalled to learn of the enormous difficulty we had in putting that capability in place. We stood virtually alone in our effort to determine what equipment to buy, how to effectively integrate and link that equipment, and what curricula to develop to best meet the present and emerging human resource needs of our regional enterprises.

Our area industries, the presumed primary beneficiaries of these new technologies, were simply unable to tell us what we needed to do and to help them make their factories more productive and efficient. Virtually no one could project for us their specific needs as little as three years ahead.

Across America, many manufacturers are in a fight for survival. In Pennsylvania alone, manufacturing employment has declined by 225,000 jobs between 1975 and 1985. If that trend continues, an ad-

ditional net loss of 90,000 jobs, or 850 firms, can be expected in the next decade.

In our perspective, the root of the problem is not the lack of cutting edge industrial research. The best of America's graduate research institutions, as exemplified by the National Science Foundation's network of engineering research centers, continue to expand the frontiers of manufacturing technologies each year.

Their problem is on the factory floor. Except for that which occurs in-house among many of America's larger companies, we do not have effective technology transfer in this country. Transfer, when it occurs at all, happens slowly, inefficiently, and unevenly.

In our written report, we discuss a number of the reasons technology transfer is not presently occurring, such as ignorance, lack of vision or appreciation of its benefits, deficient organizational mechanisms, the lack of a policy and commitment, and, in particular, the absence of funding and other incentives.

What we do find is this: our Nation does a wonderful job in inventing and developing technologies essential to high productivity. We have the largest, most pervasive, and, many would argue, the best system for the delivery of technical education in the world. What is lacking is conscious planning and critical linkage that moves new, proven, appropriate technologies from research and development, through training institutions, onto the factory floor.

Let me explain it this way. It's as if America is a factory producing, than merely warehousing, some wonderful new product. A product that would permit quantum improvements in the nation's ability to compete. America has developed its products, tested and proved them, but is keeping its new products a secret from those who need them.

This American technology factory must market its products and must explain the application and the advantage of these products to the manufacturers who require them. Once potential users understand the importance of these products, the American technology factory must distribute these products in an effective and timely manner into the field.

And, finally, this American technology factory needs to provide customer support which trains users, helps them navigate the maze of options facing them, solves their problems, and modifies their product to fit particular requirements. A company which merely fills its warehouse will not survive. A nation which develops new technology, but neither rapidly distributes this technology to users nor supports these users as they change their ways, will also not survive in an increasingly competitive marketplace.

In Williamsport, Pennsylvania, we have joined with the National Science Foundation to find a way of successfully meeting this challenge. Our approach is to focus on the specific production needs of individual manufacturers. We believe our community colleges can be the technological proving ground through which the industrial and research communities can meet and formulate relevant and practical solutions to specific, immediate manufacturing production problems.

We intend to offer relief to the manufacturer faced with outdated design and production capabilities, and besieged by the conflicting claims of a multitude of vendors and quick-fix consultants

promising that, with a robot and a computer, they can enter the modern industrial age. Real computer-integrated manufacturing is not that simple.

Our programs and services will focus on the difficult issues, product and process counseling and referral, hands-on training experiences, automated manufacturing demonstration, and production process prototyping that will enable a company to test and prove custom-made software and hardware without bringing their production line to a halt. We hear what the industrial community is asking for. It is our objective to provide it.

We believe our approach has national implications. Our symbiotic relationship with the National Science Foundation and our university research partners represents the kind of resource pooling that is absolutely essential if we are to revitalize American industry. We also believe that our approach will not succeed unless the colleges and their client industries get financial assistance.

I say from experience as recent as yesterday that, unless we can substantially underwrite the costs for prospective industrial participants, we will not reach the very ones who most need our help: those on the margin, lacking the resources to make it on their own, the smaller riskier companies. The same companies, incidentally, all the research tells us must succeed if the United States is to prosper in the face of a growing international competition.

The model we offer in Williamsport can be replicated throughout the existing network of more than 1,220 two-year colleges working through the partnership envisioned in your bill, Mr. Chairman. Located in large metropolitan centers and grassroots communities, the vast majority of these colleges already have substantial and successful experience in working directly with industry in delivering the customized training needed to upgrade today's work force.

Community colleges are proficient and positioned to expedite introduction of new technologies for tomorrow. It is time Congress joined states like Pennsylvania in helping to provide resources critical to those institutions who are willing and able to deliver the goods to American industry where it really counts: at home, on the factory floor.

Recently, Harold A. Pauling, vice chairman of the board of the Ford Motor Company, observed: the real competitive edge we must develop is the American work force. Mr. Chairman, members of the Committee, America does not have a hardware problem. We have a human resources problem.

Tomorrow's future is being determined today. Rapid, chaotic, unprecedented technological change will not permit us to waste more time or make additional mistakes. The time to act is now, and the opportunity to act is here in H.R. 2134.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you very much, Dr. Breuder. We appreciate that support for that particular aspect, and will come back and talk a little bit about the broader area after we finish the panel. We'll turn to Dr. Dean.

[The prepared statement of Dr. Breuder follows:]

Testimony

on

The National Science Foundation Reauthorization

and H.R. 2134

on behalf of

the Joint Commission on Federal Relations
of the American Association of Community and Junior Colleges
and the Association of Community College Trustees

by

Robert L. Breuder, President
Williamsport Area Community College
Williamsport, Pennsylvania

Subcommittee on Science, Research and Technology
The Honorable Doug Walgren, Chair
Committee on Science, Space and Technology
U.S. House of Representatives

March 24, 1988

TECHNICAL EDUCATION: THE CASE WAS NEVER STRONGER

Mr. Chairman and distinguished Subcommittee members:

I am pleased to be here today to talk about reauthorization of the National Science Foundation and related legislation H.R. 2134, commonly called the Walgren Bill (1).

The perspective I bring to this and that I want to share with you focuses on technology transfer. It's timely that I should be here today.

Mr. Chairman, I am sure you are aware that at the urging of Senator John Heinz our College has been working closely with the National Science Foundation for some six months to develop a prototype Technology Transfer Center at The Williamsport Area Community College, the first such Center to be established anywhere under the aegis of the National Science Foundation. As a Pennsylvanian, you are also aware that our Commonwealth recently implemented law providing for the establishment of Industrial Resource Centers whose purposes are very similar to that envisioned in the imaginative legislation you moved through this house of Congress four years ago. A week from today we deliver to Governor Casey a joint application from Penn State University and The Williamsport Area Community College for a $2 million grant from the state to establish such a Center on our campus. I share this information so you understand that my views were forged in the trenches, not from some lofty ivory tower. I speak to you as president of an institution whose tradition of service to business and industry is

traceable all the way back to 1914, the year of our inception as a technical training school.

Since the term technology transfer has come into such widespread use during the past eight to ten years and definitions vary, let me first give you my working definition. Technology transfer in its most basic sense is precisely what the term implies. That is, it is the transfer of techrology. It is a phenomenon which originates with the development of new technology in a variety of research settings, in universities and elsewhere, and culminates with the transfer of the technological breakthroughs achieved in these research settings into active integration in industrial operations on the factory floor. Ideally, this transfer occurs quickly, efficiently and pervasively to all manufacturers and others who might benefit.

In the best of worlds, word of new, important technological developments and the applicability of those developments would be rapidly articulated to all prospective companies, industries or other beneficiaries. Mechanisms would be provided to facilitate rapid diffusion of those technologies to appropriate users, who would be able to quickly integrate or adapt those technologies to maximum advantage.

Mr. Chairman, members of the Subcommittee, we do not have effective technology transfer in this country as we define technology transfer. Transfer--when it occurs at all--happens slowly, inefficiently and unevenly. Nor, in the absence of the sort of bold, national commitment entailed in Representative Walgren's legislation, are we likely to see things get any better. As the Statement of Findings of Representative Walgren's bill reads:

> The United States has no competitiveness strategy to develop and maintain the technically trained workforce needed for self-sufficiency in strategic advanced-technology fields, for the improvement of productivity of the Nation's industries, for the strengthening of our industries in competitive international markets, and for the reindustrialization of declining industries.

What are the problems we face and what has to be done about them? In its edition of May 9, 1987, the Financial Times of London editorialized (2):

> Can America make it? The huge trade imbalance, a sliding currency, falling real wages and a dismal productivity record. A decade ago, these were the hallmarks of a struggling British economy. Today they characterize an American economy which is struggling...against fierce competition from the Far East.

This touches on some, but not all, of the problems. Volatile investment markets, a change from being the greatest creditor nation to the greatest debtor nation in the world, enormous budget deficits, and rapid technological change are also among the many problems we face. And the list certainly doesn't end there.

Mr. Chairman, you know better than I the problems we face. I am here today to talk about solutions, or at least one solution. I am here to express the wholehearted support of the community colleges for reauthorization of the National Science Foundation, and for passage of the Walgren Bill, H.R. 2134. Both of these actions will constitute practical and effective attacks on a significant class of problems without the need to create massive new structures or support systems. Both will build on proven performance of existing assets: the National Science Foundation, especially through its tremendously successful Engineering Resource Centers

program, and the nation's 1,220 community colleges.

I believe a realistic financial investment such as that described in the Walgren Bill will bring together the resources of the National Science Foundation and the nation's community college system, through the partnerships proposed by the Walgren Bill, in an effort which will be a springboard for a turnaround in American manufacturing productivity and competitive ability. This will directly and effectively address key deficiencies, and help return America to an unchallenged leadership position in the marketplace of nations. The nation's existing community colleges have already demonstrated an understanding of and commitment to solving the serious manufacturing problems we face and they stand ready to work with you in this most important undertaking. The community college system is a pervasive network of proven resources already in place across our country, in locations ranging from large metropolitan areas and industry centers to the relatively rural environments such as ours in central Pennsylvania.

Substantially improving American manufacturing competitiveness through strengthened technology transfer requires coordinated progress on several fronts. Firstly, the nation must vigorously support the research efforts needed for technological breakthroughs. National Science Foundation support for Engineering Research Centers is critical to continue current developments such as artificial intelligence and machine vision systems and to begin yet unimagined future breakthroughs which will set a foundation for technical competitiveness. Secondly, the nation must more

effectively disseminate the products of past technological breakthroughs to potential users. Computer Numerical Control (CNC) machining, Computer Assisted Design (CAD), Programmable Logical Control (PLC), Statistical Process Control, and Material Requirements Planning (MRP), to name but a few, are existing technological solutions now well beyond the research phase which have yet to be implemented pervasively in industry. It is often eight to ten years before a proven breakthrough becomes established practice within industry. To have resources available and not use them is tragic. Thirdly, the nation must establish clearer, better linkage between on-going research and effective dissemination. Systematic programs must be established which more efficiently translate theoretical research into applied research aimed at solutions to manufacturing needs. Those programs must provide organized education and training for those expected to implement change on the shop floor itself.

An analogy can clarify this challenge and related opportunity. America is like a factory which is producing marvelous new products and storing these products in a warehouse. In our case, the products are new technologies, the CNC, CAD, PLC and MRP already mentioned. However, this American factory is all too often stopping its efforts at the warehouse. America has developed its products, tested and proved them, but is keeping them a secret from those who need them. This American factory needs to market its products, needs to explain the application and advantages of these products to the manufacturers who need them. Then once potential users understand the importance of these products, the American technology factory needs to distribute these products in an effective and timely

manner into the field. And finally, this American technology factory needs to provide customer support which trains users, helps them navigate the maze of options facing them, solves their problems, and modifies the product to fit particular needs. A company which merely fills its warehouse will not survive. A nation which develops new technology but neither rapidly distributes this technology to users nor supports these users as they change their ways will also not survive in an increasingly competitive world.

Fortunately, broadened support through the National Science Foundation, related initiatives like Representative Walgren's H.R. 2134, and the existing community college network offer effective means of responding to this challenge.

BACKGROUND

Our economic woes derive directly from the dismal productivity record and the continued decline in industrial competitiveness experienced during the past decade. We face the end of an era in manufacturing superiority.

One example is found in the recent Productivity Brief issued by the American Productivity Center (3). This Brief reports on the results of an in-depth study of Pennsylvania manufacturing firms carried out by Jacques Koppel, an economic development consultant experienced in international trade.

Koppel's study examined three industries in Pennsylvania: machine tools and tool and die shops, electronics components, and medical devices. The study was intended to determine the degree of use of advanced manufacturing technology in these three industry groups.

The results as reported by Koppel are startling:

* While 73 percent of the manufacturers use some form of computer for front office, administrative or accounting functions, use of advanced technology on the factory floor is far more modest. For example, the 90 firms studied together possess only two robots, two lasers, and one piece of equipment with machine vision.

* Only approximately 10 percent of the companies visited had any type of plan, strategy or objectives for the introduction of computers or other forms of technologies into their company.

* In one company, a $90,000 robot sat idle for most of two years because the equipment it was supposed to load was 25 years old and kept breaking down.

The following table provided by Koppel summarizes the degree of technology usage by industry identified by the 1985 study.

TECHNOLOGY USAGE BY INDUSTRY

Industry	Office Computer	NC/CNC	CAD	MRP/ MRPII	Robots/Lasers/ Machine Vision
Machine tools, tool & die	58%	66%	18%	4%	6%
Electronic components	96%	28%	16%	36%	8%
Medical devices	86%	13%	13%	26%	0%

Koppel cites many reasons for the failure of industries in Pennsylvania to incorporate existing, proven technologies, and focuses on education as a key ingredient. Koppel states in part "Even for simple stand-alone CNC machines, there appears to be a gap between what vendors are selling and what users can readily adopt. Distributors of this equipment indicate that firms have difficulties using these machines because the operators assigned to them do not have the basic mathematical skills required. This is particularly the case in small and medium-size companies." He continues "Although the acquisition of new technologies is a capital investment decision and the financing can often be a problem, the major reasons companies do not use advanced manufacturing technologies is because they do not understand them, find them too confusing, and are intimidated by them." (Underlining mine)

Paradoxically, a large number of small and medium-size manufacturers see themselves as already using advanced manufacturing and state-of-the-art technologies. This issue developed as an offshoot of Koppel's study. The largest number of companies that turned down the initial offer to be part of the project did so because they indicated they had all the technology they required or because their technologies were proprietary. Ironically, these same companies showed some of the lowest levels of technology usage, indicating the severity of the gap in awareness and education which exists. Koppel indicated that for many companies, the acquisition of a PC for the front office and accounting functions was considered a quantum leap into the age of technology, especially for small and medium-size firms which are preoccupied with the daily problems of getting their product out the door.

The centrality of education in technology isn't just my viewpoint; others also recognize education's pivotal role. In Tom Peters' new book Thriving on Chaos (2), Peters says we don't have to look far for examples of the accelerating American decline (pp.4-5):

1. Our average business productivity grew at 3 percent a year from 1950 to 1965. From 1965 to 1973, the rate was 2 percent; and since 1973, it's barely crept along at 1 percent. Manufacturing productivity looks worse. It grew at 2.5 percent a year from 1950 to 1985; that contrasts with Japan at 8.4 percent, Germany and Italy at 5.5 percent, France at 5.3 percent, Canada at 3.5 percent--and much-maligned Britain at 3.1 percent. (Underlining mine)

2. U.S. per capita GNP, called by some the truest measure of a nation's international economic standing, slipped below Japan's in 1986; it also trails the per capita GNP of such European nations as West Germany, Switzerland, Sweden, and Denmark.

3. The average wage for a 25-34-year-old white male declined 26 percent from 1973 to 1983 in constant dollars; the comparable figure for 35-44-year-olds was little better, a decline of 14 percent. This figure is more useful to look at than others. Given the increase in work force participation by women, overall family income has slowly risen. But the economic fate of the individual white male remains the bellwether indicator of progress (or lack of it).

4. The national savings rate, long the lowest in the industrial world, continues to decline. Despite supply-side economic stimulants such as the 1981 tax cut, savings as a share of disposable personal income plummeted from 7.5 percent to 3.9 percent from 1981 to 1986. At year's end 1986, it stood at 2.8 percent. Only our dramatic shift as a nation from premier net lender to premier net borrower has kept investment afloat.

5. In 1986, 138 banks failed, the largest number in one year since the Great Depression; the pace in 1987 is ahead of 1986's. By contrast, 10 banks toppled in 1981.

6. Economists estimate that as many as 30 million people have been dislocated by the "restructuring" in manufacturing during the last decade. Since 1980, the Fortune 500 have shed a staggering 2.8 million jobs.

7. The plain truth is that every major manufacturing or service firm--from the Bank of America and Citicorp, to DuPont and General Motors, to IBM and Intel and the Hospital Corporation of America--is undergoing trauma.

Peters goes on to say that alarming as these indicators are, it is the chaos in trade that most reveals our poor performance and provides harsh industry-by-industry evidence of our decline. Peters draws to a basic and inescapable point that we are getting clobbered not because of the dollar's strength a few years ago or other economic uncertainties, but "primarily because of the generally poor quality of what we produce and a failure, as a result of questionable service and slow responsiveness, to make use of our onshore, close-to-the-world's-biggest-market advantage." (p.5)

Following further discussion of a number of dimensions of the manufacturing environment, Peters makes the key point that "quality and flexibility will be the hallmarks of a successful economy for the forseeable future" (p.14). This will be true for manufacturing and the service sector. He presents a picture of a successful firm of the 1990's and beyond as being (p.27):

* Flatter (having fewer layers of organization structure)
* Populated by more autonomous units (having fewer central staff second-guessers, more local authority to introduce and price products)
* Oriented toward differentiation, producing high value added goods and services, creating niche markets
* Quality-conscious
* Service-conscious
* More responsive
* Much faster at innovation
* A user of highly trained, flexible people as the principal means of adding value to products (Underlining mine)

It is this final characteristic, the need for a highly trained, flexible workforce as the principal means of adding value to our products and services, that I believe is the central factor in economic competitiveness.

EDUCATION IS THE KEY

Mr. Chairman, working to put in place a highly skilled, technically competent workforce committed to quality and consumer responsiveness is the key ingredient to address our economic problems. Increasingly, others are recognizing this too.

In an article on manufacturing management which appeared in Metalworking News, January 11, 1988 (4), Robert E. Harvey discusses the key role education plays in successful installation and operation of Computer Integrated Manufacturing (CIM) programming. As flexibility becomes an increasingly important factor in manufacturing operations, CIM technology is being investigated and implemented in a number of U.S. companies. Harvey reports that obviously many CIM projects have been highly successful, otherwise the whole concept would have been abandoned, but goes on to discuss findings of Kirk D. Zylstra, Manager of the Manufacturing Industry Group, Deloitte Haskins & Sells, a leading public accounting firm. These findings speak to the failures in installing CIM, and the reasons for failure.

Harvey and Zylstra both indicate that the human side of the manufacturing equation continues to be poorly addressed. He quotes Zylstra as follows:

> While unanticipated technological problems can be major factors in these less-than-success stories, frequently the leading culprit has been management's reluctance to appreciate fully the transitional and lasting impact of CIM on their personnel and organizational structure...

Harvey continues with the observations of Peter Unterweger, Research Associate with the United Autoworkers Research Department in Detroit:

> Knowledgeable observers report that, of the resources allocated to process innovation, machinery expenditures account for about 90 percent at General Motors, 75 percent at Ford, and 65 percent at Chrysler, with the balances going to human resource development.
>
> Interestingly, the problems companies have with new technologies appear to be directly related to the proportion spent on hardware. The same observers indicate that a more sensible allocation of funds would be 80 percent on human resources and only 20 percent on hardware. (Underlining mine)

Stressing education, Harvey goes on to make a number of other important points:

* Education at the most basic level is job training, how to operate equipment in new CIM or JIT (just-in-time) environments. Beyond basic training is the need to educate employees about broad changes occurring company-wide. Worker attitudes and mindsets as well as jobs must be upgraded.

* Quoting Zylstra "Technology plans should parallel human issues. Two plans should be developed. I'd rather have one plan but when companies have one plan, it typically becomes a technological one. The idea is to have the human and educational issues pace technology implementation."

* Training in the future will be more comprehensive, more varied, and more ongoing than in the past...in fact, training in tomorrow's factory, geared to take full advantage of the intelligence of the shop floor worker, will take up increasing amounts of time and effort. And the companies with the best trained workforce, not necessarily the newest technology, will be

on top. Firms that continue to view education as an afterthought and don't address educational issues until problems arise will fall by the wayside.

Harvey's article presents the following chart developed by Zylstra which characterizes education's integral role in bringing about manufacturing change:

EDUCATION HELPS ADVANCE
ORGANIZATION CHANGES FOR CIM

Organization Change	Education Role in Change
*Performance Measures	*Provide understanding of relationship between performance measures and profit/strategy *Communicate methods for improving performance *Provide forums for problem identification and resolution
*Wider Job Responsibilities	*Enhance personnel flexibility with skills development *Build confidence to facilitate handling varied situations
*Compressed Organization Structure	*Improve teamwork attitudes *Breakdown departmental walls/ barriers *Develop project management skills
*Higher Technical Skills Requirements	*Provide technical training *Reinforce technical training with applications
*Information Systems Dominance	*Improve understanding of interrelationships with conceptual/generic education *Enhance confidence with hands-on and pilot training

Source: Kirk D. Zylstra, Deloitte Haskins & Sells

The key role education plays is again emphasized in the first report of the MIT Commission on Industrial Productivity (5). This Commission, appointed in December, 1986 by MIT President Paul E. Gray, included 18 MIT scientists, engineers, political scientists and economists, including Robert Solow, winner of the Nobel Prize in economics. The MIT Interim Report listed what the Commission identified as the five principal causes of the decline in American productivity, as noted in the following quotes by Michael L. Dertouzos, Director of the Laboratory for Computer Science at MIT, and Chairman of the Commission on Industrial Productivity:

* Excessive attention to activities and investments that are profitable in the short-run. America invented the transistor radio, color television, and the video-cassette recorder. American businesses quickly lost interest in producing them, however, and lost those markets to Japan.

* Parochial attitudes that lead American businesses to pay insufficient attention to foreign competitors. For example, in the Machine Tool industry, American firms tried to backlog orders rather than aggressively deliver products on time. Japanese firms, by contrast, promised quicker delivery and captured much of the market.

* A lack of cooperation within firms, among competing firms and between firms and suppliers. The worker is viewed as a cost factor to be minimized, rather than as a evolving human resource that has to be educated, motivated.

* Failures in applying technology to make simple, reliable, high quality products. In the case of VCR's, the Americans who invented them couldn't develop production lines that would meet the close tolerances necessary to produce them and would do so at an acceptable cost.

THE SOLUTION

Mr. Chairman, all of the studies and reports summarized above identify the central role technical education plays in manufacturing competitiveness and the effective introduction of advanced manufacturing techniques on the factory floor. And therein lies the solution, the foundation on which to restore America's competitiveness.

The technical education I'm talking about must be comprehensive. It must be immediate, intensive and effective, and it must, above all, be practical. This education must impact every organizational level. Managers must have a solid working knowledge of the new technologies their plants can use, and must understand both the choices and benefits which can be derived from their application as well as the problems which can be expected in introducing them. This comprehensive educational process must include engineers, product designers, supervisors, shop foremen and ultimately the line workers themselves.

The confusion which exists today about many of these new technologies can only be dissipated through comprehensive and continuing training. The intimidation factor, which many experience, must likewise be addressed through education. Industries must recognize that the new dynamics of marketplace survival require strong emphasis on quality and flexibility. The state-of-the-art technologies which exist today and the newer technologies which will emerge tomorrow, mastered through training, are the foundation that will restore American competitiveness.

Ninety-eight percent of the nation's community colleges recognize the importance of vocational/technical training and have this type of training already in place on their campuses. The vast majority of these colleges already have substantial and successful experience working directly with business and industry in designing and delivering the customized training needed to upgrade today's workforce. Community colleges are positioned to expedite introduction of new technologies for tomorrow.

An aggressive effort to enhance technology transfer should make National Science Foundation resources available to community colleges for improvement of their capacities to:

* Develop new training programs for business and industry, especially those concentrating in promising advanced technology areas such as Flexible Manufacturing and Computer Integrated Manufacturing (CIM).

* Provide support for equipping laboratories with state-of-the-art equipment.

* Provide support for staff development. While our community college staff already comprise a substantial bank of expertise, the pace of change is not going to slacken. We must, as industry must, continue to invest heavily in our central and most critical resource--the human resource.

* Conduct specific company projects and intensive applications with industry, serving as demonstration sites or proving grounds for technology application.

* Conduct technology assessments for individual industries, working directly with plant staff to design practical technology strategies, then follow-up with training and other technical support activities to solve applications problems and to insure effective choice and implementation.

* Sponsor workshops, institutes, seminars and conferences designed to raise the level of consciousness about the many proven technologies already available, but not widely used because of lack of understanding or fear of the technology.

There is abundant technology available to address the issues of quality and manufacturing flexibility. Examples, again, include Computer Assisted Design (CAD), Flexible Manufacturing, Numerically Controlled and Computer Numerically Controlled (NC/CNC) equipment, Program Logic Control (PLC) and other technologies with proven applicability and effectiveness in the manufacturing environment. The fact that these technologies have not been transferred successfully into widespread application on the manufacturing floor, especially for small and mid-size firms, is a result of several factors. These factors include a lack of basic understanding concerning the technology, fear or intimidation about its use, lack of appreciation of the benefits which will accrue from its use, lack of vision, insufficient internal resources to complete a technology assessment and produce a technology strategy, and cost.

We must go beyond an investment in the hard technologies. We must invest heavily in our human resources, providing education and training to go hand-in-hand with the infusion of hard technologies in manufacturing. H.R. 2134 would directly and effectively address the educational needs I have defined. This bill would establish a national advanced technician training program utilizing the resources of the nation's two-year colleges to expand the pool of skilled technicians in strategic advanced technology fields. This same bill could also be the foundation upon which a massive national training effort could be developed corresponding to the ERC program through which projects could be designed hand-in-hand with manufacturing industries. This strategy would enable those industries to more effectively address the practical problems which impede their ability to compete.

As I have noted previously, the response which is required must be immediate, it must be intensive, and it must be effective. The response must be immediate because not a single day goes by that we do not see further evidence of America's declining industrial position. The Walgren bill provides for an immediate response. It builds on an existing base with a proven track record in working directly and effectively with American manufacturing industry.

The Walgren bill provides an intensive response. The existing network of two-year colleges is a system already operating in or within a short distance of virtually every manufacturing industry in the country. Community colleges have worked with companies of all sizes--from 15 to 50,000 employees. We have worked with all types industries, from lumber to machining, from textiles to electronics, from mining to aerospace. We have worked with domestic as well as international firms. We have already been doing the job. We are already fully committed to working within our communities and regions to promote and achieve true economic development.

Above all, the plan and process with which we move forward must be practical! We cannot load the environment with well-intended but burdensome restrictions. Our government will make a serious mistake if we impose unworkable limitations, such as unrealistic expectations about private sector support levels and monumental paperwork requirements. You must not be too prescriptive in the guidelines and regulations. We know what works--this doesn't need attention. What's needed is the resources to make it operational.

The continuing rapid decline in our economic position in the world marketplace, the massive financial difficulties we face, the rapid and chaotic changes of the past few years--and changes which will continue in the future--do not allow for mistakes. The two-year college system in our nation has demonstrated its ability to be effective. What is needed now are the financial resources to expand what community colleges have been doing--to carry this to every industry in every city across this country.

Returning once again to quote Kirk D. Zylstra of Deloitte Haskins & Sells:

> Technology plans should parallel human issues. Two plans should be developed. I'd rather have one plan but when companies have one plan, it typically becomes a technological one. The idea is to have the human and educational issues pace technology implementation.

My own institution, The Williamsport Area Community College, is a classic example of the commitment which has been made by a number of leading community colleges across the nation in investing in advanced technology programs. For example, during the last four years we have invested $21 million in the construction of an Advanced Technology and Health Sciences Center, dedicated on October 2, 1987. Laboratory facilities included in this building provide for extensive hands-on training in the areas of Automated Manufacturing, Robotics, Laser Technology, Fiber Optics, Computer Peripheral Repair, Telecommunications and a number of other state-of-the-art technological areas. In fact, the College offers over 60 different vocational/technical programs of study, with over 90 percent of our full-time students enrolled in vocational/

technical programs. The College's placement rate among graduates available for employment annually ranges from 93-97 percent.

Designing and delivering customized job training programs for business and industry is a College priority. During the past four years alone we have offered seminars in 47 different subject areas, enrolling over 977 individuals, and developed and delivered 240 courses to 89 clients through which over 4,100 individuals have received direct hands-on training, much of this being in advanced technology fields. We have established an effective symbiotic relationship demonstrated by the fact that business and industry is our greatest ally in northcentral Pennsylvania.

Mr. Chairman, I want to express to you my sincere appreciation for the opportunity of appearing before you today. I hope I have brought a message of substance and a message of impact, and leave you with a clear understanding that the case was never stronger for the need for technical education to overcome our problems and to support an American manufacturing resurgence. Every day I work closely with the Chief Executive Officers and planners of the manufacturing industries in northcentral Pennsylvania. The message I bring today comes from those partnerships. They understand the need, they understand the tremendous knowledge base which exists in our College, and they want our help. In fact, they insist on our help and it is frustrating to them and to me when I am able to provide this only in limited degree because in fact the financial resources do not now exist to permit me to go much beyond delivering education to those students whose tuition is paying for our product.

Mr. Chairman, thanks to you and this Subcommittee, the Walgren bill swept through the House four years ago as part of the Emergency Mathematics and Science Education Act, on a floor vote of 348-54. Unfortunately, that Act died for lack of approval by the Senate. We look to this Committee to again approve H.R. 2134 as part of the NSF Reauthorization. The nation's community, technical and junior colleges thank you again for your vision and leadership, and for this opportunity to be heard. We want to play an even greater role in strengthening the economic foundation of our great nation.

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Dr. DEAN. Thank you, Mr. Chairman. I notice an interesting thing here in our panel. I come from an exceedingly small company. It has two employees, while Dr. Patel comes from a very large company. I don't know how many employees. But you're going to hear from industry from both ends of the spectrum.

My company is focused on developing innovative manufacturing technology equipment for the biotechnology industry. And, as you know, this industry started about 1970. It's growing very, very rapidly, and promises to be a very important competitive asset for this nation.

I want to talk today about one of the engineering research centers, the one at MIT, which was an early one. It's called the Biotechnology Process Engineering Center, and its objective is to develop basic knowledge and to train engineers for the manufacturing aspects of the biotechnology industry.

Now, this biotechnology industry has arisen since 1970 from the science called genetic engineering. This new technology enables man to force living cells to express particular biochemicals, and specifically proteins of great potency for medicine and agriculture. Such new medical proteins as human insulin, growth hormones, vaccines, and tissue plasminogen activator promise to control some of the most damaging diseases affecting man and his economic animals.

While genetic engineering as used to discover and express new molecules of promise has been largely American accomplishments, the commercial manufacture of these new drugs may be realized to a large extent in foreign countries. This is, unless a strong and quick effort is made in the United States to improve manufacturing technology and practice.

Today the new U.S. biopharmaceutical industry has, in general, a weak capability for commercial manufacture of its own products. It is widely recognized that this industry needs major advances in production technology and equipment for a complex of reasons which I will not elucidate here.

That nation which exploits such advantages in a practical way will have a strong cost-competitive position in biopharmaceuticals. Today U.S. suppliers of process equipment and systems for manufacturing biopharmaceuticals are weak compared to their European and Japanese competitors. The established U.S. suppliers are not developing vigorously their technology, their products, and their services.

Fortunately, small entrepreneurial ventures are springing up to grasp this market opportunity. But their course, while always innovative, is hazardous and their impact will be small in scale for a long time.

A large part of the biopharmaceutical industry's difficulty is a paucity of manufacturing systems engineers trained in biotechnology. A. E. Humphrey of Lehigh University was quoted in The New York Times as stating that the U.S. was then producing in 1985 only one-third of the biochemical process engineers needed by this new industry.

MIT created, with NSF, support the bioprocess engineering center with the intention of making a major contribution to resolving this need for manufacturing process engineers and to strength-

en the technology base for improving the manufacturing capability of the U.S. biotechnology industry.

Now I'll give my opinion of how successful this attempt has been. The MIT engineering research center has generated a large and strong educational community of undergraduate and graduate students, of industrial personnel in temporary residency, of workshop participants from industry, and from academia.

At MIT there are over 200 people regularly involved with the BPEC. It graduates about six Ph.D.s, three master's students, and about 90 bachelor biochemical engineers and biologists per year. This compares to about a 100 Ph.D. and master's level biochemical engineers in the entire U.S. every year.

In 1987 there were about 20 industrial personnel in residency at the BPEC for an average term of three months each. Over 700 students are enrolled each year in 25 biochemical engineering and related courses of instruction taught by the BPEC faculty. In addition, over 600 industrial personnel attend annually a series of workshops, short courses, and symposia sponsored by BPEC at MIT and also at industrial sites.

There are 13 members of the MIT and Harvard faculties involved with this center, averaging about 25 percent of their full-time effort in research sponsored by the center. And that's in addition to their teaching duties. These faculty members are drawn from the departments of chemical engineering, biology, applied biological sciences, electrical engineering, and computer sciences.

In my opinion, the scientific training of these BPEC students is very high in quality, and they must be skilled in all the usual disciplines of the chemical engineer. And, in addition, they must master considerable biological science. So, it's a tough program.

Now, what about its impact on the industry? Of course, again, I echo what Dr. Kash said. The center is only three years old. It's pretty early to measure the impact, but I think we can see some positive benefits.

The indirect impact, and, I think, the most significant impact, is by means of the graduates from this center, who not only will do the work of the industry but they are bringing heightened process science and technology skills and knowledge that the industry needs.

The direct transfer of new knowledge to participants from industry is strong and important. The BPEC has 53 industrial corporate members, paying member of its consortium, who maintain close ties with frequent visits. And the center is working aggressively now to strengthen this transfer flux.

The direct effect of new knowledge from the students' research is hard to evaluate. Student thesis research, which is the large part of the Center's research activity, is often a great educational utility, but not very often of direct practical use to industry.

However, the fundamental knowledge which is generated is, in the long run, a great utility, if it is intelligently used by the industry. And this exploitation is the weak spot in American industry, but I think the transfer will be enhanced by employment of such engineers as come out of this Center.

I also want to make few comments on how I think basic improvements can be made in the Engineering Research Center program.

There are basic weaknesses in U.S. engineering which the MIT-BPEC shares with almost all other academic institutions. The principle one is the lack of emphasis in undergraduate and graduate engineering education on innovation and design.

The job of engineers is to create things and systems of things. That is, tools for man to do his work. The way engineer creates new things is by invention, design and development. And that process is, today, called innovation.

Unfortunately, U.S. educational institutions have not emphasized innovation for several decades. Rather, engineering educators have focused on applied science and mathematics.

They are devoted to analysis rather than to the synthesis of real things. Most engineering educators have never had responsible charge of engineering project in industry.

They are focused more upon the generation of new knowledge, than upon the creation of practical tools for man. This weakness has been most glaring in manufacturing engineering of all kinds and is, in my opinion, one of the prime causes of the U.S. weakness in product quality and factory efficiency.

The new bio-technology industry needs manufacturing engineers to improve its processes and equipment. In my opinion, the universities, and particulary MIT's ERC, should more emphasize systems engineering, design, and the management of innovation.

Because most comtemporary academics are disinterested in these subjects, a determined effort should be made to recruit experienced senior faculty from industry for such teaching and thesis supervision.

This is the practice in many foreign countries, especially in Germany, which explains in part the quality of German products and the efficiency of her manufacturing.

I recommend that NSF put special emphasis in funding ERC's on the education of engineers at all levels, while well prepared for product and process innovation in highly competitive industries.

Thank you.

[The prepared statement of Dr. Dean follows:]

Corrected 3/24 KCDK

SYNOSYS CORPORATION
PROTEIN PURIFICATION SYSTEMS

March 24, 1988

Testimony of Dr. Robert C. Dean, Jr. to The U.S. House of Representatives Sub Committee on Science, Research and Technology regarding the Engineering Research Centers (ERC's) funded by the National Science Foundation (NSF).

Dr. Dean is the Chairman and a founder of the Synosys Corporation, Cambridge, Massachusetts, a new venture devoted to the innovation, production and marketing of manufacturing-process equipment and consumables for the biopharmaceutical industry. He is also Professor of Engineering (adjunct) of the Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire; Director of the American Society of Mechanical Engineers' Bioprocess Engineering Program; a member of the Massachusetts Institute of Technology's (MIT) Biotechnology Process Engineering Center's (BPEC) Industrial Advisory Board; a member of the National Academy of Engineering, and the founder of four other successful companies.

This testimony concerns the effectiveness of the NSF's ERC's at increasing the competitiveness of American industry. In particular, this testimony examines one of the earliest ERC's -- MIT's Biotechnology Process Engineering Center, directed by Daniel I.C. Wang, Professor of Chemical Engineering. This ERC was created in 1985. MIT has proposed recently to the NSF for continued funding, so an assessment of the Center's achievements has been made recently by the NSF. The writer was not an assessor, but has been closely associated with MIT's BPEC, and its Director. The writer's business partner, Dr. Noubar Afeyan, is a recent Ph.D. graduate of the Center.

THE SCOPE OF THE MIT ERC

This Center focuses on the biotechnology industry which has arisen since 1970 from genetic engineering. This new technology enables Man to force living cells to express particular biochemicals, and specifically, proteins of great potency for medicine and agriculture. Such new medical proteins as human insulin, growth hormones, vaccines and tissue plasminogen activator, promise to control some of the most damaging diseases affecting Man and his economic animals.

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THE PROBLEM

While genetic engineering and its use to discover and express new molecules of great promise have been largely American accomplishments, the commercial manufacture of these new drugs may be realized to a large extent in foreign countries. This is unless a strong and quick effort is made in the US to improve manufacturing technology and practice. Today the new US biopharmaceutical industry has in general a weak capability for commercial manufacture of its protein products. It is widely recognized that this industry needs major advances in production technology and equipment for a complex of reason which I will not elucidate here. That nation which exploits such advances in a practical way will have a strong cost-competitive position in biopharmaceuticals. Today, US suppliers of process equipment and systems for manufacturing biopharmaceuticals are weak compared to their European and Japanese competitors. The established US suppliers are not developing vigorously their technology, products and services. Fortunately, small ~~new~~ entrepreneurial ventures are springing up to grasp this market opportunity and to try to meet his need. But their course, while innovative, is hazardous and their impact will be small in scale for a long time.

A large part of the biopharmaceutical industry's difficulty is a paucity of manufacturing-systems engineers trained in biotechnology. A.E. Humphrey of Lehigh University was quoted in the New York Times (April 24, 1985 in Careers by Elizabeth M. Fowler) as stating that the US was then producing only one third of the biochemical-process engineers needed by the new biotechnology industry. MIT created, with NSF's support, the BPEC with the intention of making a major contribution to resolving this need for manufacturing-process engineers and to strengthen the technology base for improving the manufacturing capability of the US biotechnology industry. Here I shall give you my opinion of how successful this attempt has been.

EDUCATIONAL PERFORMANCE

The MIT BPEC ERC has generated a strong and large educational community of undergraduate and graduate students, of industrial personnel in temporary residency at the BPEC and of workshop participants from industry and academia. Over 200 persons within MIT are involved regularly with the BPEC. It graduates about six (6) Ph.D., three (3) Masters, and about 90 Bachelor biochemical engineers and biologists affiliated with the BPEC per year. This compares to about 100 Ph.D and Masters-level biochemical engineering graduates ~~of all degrees~~ in the US each year. In 1987, there were about twenty (20) industrial personnel in residence at the BPEC at various times for an average term of three months. Over 700 students are enrolled each year in the 25 biochemical engineering and related courses of instruction taught by BPEC faculty. In addition, over 600 industrial personnel attend annually a series of workshops, short courses and symposia sponsored by the BPEC at MIT and at industrial sites. There are thirteen (13) members of the MIT and Harvard faculty involved with the BPEC, averaging about 25% of their full-time efforts for research sponsored by the BPEC in addition to their

teaching duties. These faculty members are drawn from the Departments of Chemical Engineering, Biology, Applied Biological Sciences, Electrical Engineering and Computer Sciences.

The scientific training of BPEC students is very high in quality. They must be skilled in all the usual disciplines of the chemical engineer and, in addition, master considerable biological science.

IMPACT ON US BIOTECHNOLOGY INDUSTRY

The indirect, and most significant impact is by means of the BPEC's graduate, who not only will do the work of the industry, but are bringing heightened process science and technology skills and knowledge that the industry needs. The direct transfer of new knowledge to participants from industry is strong and important. The BPEC has 53 industrial members of its consortium who maintain close ties with frequent visits. The Center is working aggressively to strengthen this transfer flux.

The direct impact of new knowledge from BPEC research is harder to evaluate. Student thesis research, which is the largest part of the BPEC's research activity, is often of great educational utility, but not often of direct practical use to industry. However, the fundamental knowledge which is generated is, in the long run, of great utility if intelligently used by the industry. It is this exploitation which has been weak in US industry, but which should be enhanced by employment of the well-trained engineers from the BPEC.

POSSIBLE IMPROVEMENTS IN THE MIT ERC

There is a basic weakness in US engineering education which the MIT BPEC shares with almost every other institution. That is the lack of emphasis in undergraduate and graduate education on innovation and design. The job of engineers is to create things and systems of things; that is, tools for Man to do his work. The way an engineer creates new things is by invention, design and development -- a process called "innovation". Unfortunately, US educational institutions have not emphasized innovation for several decades. Rather, engineering educators have focused on applied science and mathematics devoted to analysis, rather than to the synthesis of real things. Most engineering educators have never had responsible charge of an engineering project in industry. They are focused more upon the generation of new knowledge than upon the creation of practical tools for Man. This weakness has been most glaring in manufacturing engineering of all kinds and is, in my opinion, one of the prime causes of the US's weakness in product quality and factory efficiency.

The new biotechnology industry needs manufacturing engineers to improve its process and equipment. In my opinion, the universities, and particularly, MIT BPEC ERC, should more emphasize systems engineering, design and the management of innovation. Because most contemporary

academics are disinterested in these subjects, a determined effort should be made to recruit experienced senior faculty from industry for such teaching and thesis supervision. This is the practice in some foreign countries, especially Germany, which explains in part the quality of German products and the efficiency of their manufacturing. I recommend that NSF put special emphasis, in funding ERC's, on the education of engineers at all levels who are well prepared for product and process innovation in highly-competitive industries.

Mr. WALGREN. Thank you, Dr. Dean.

Dr. Patel.

Dr. PATEL. Thank you, Chairman Walgren and members of the Committee. It's a pleasure to be here to testify on the very important matter of support of engineering education on our university campuses.

We cannot deal with ERC's or engineering research centers alone. I think we have to deal with them in the totality of the educational process on our campuses.

The role of universities, as has been pointed out several times this morning, is to educate young people for a variety of important functions in our society, including those in universities, industry, and government.

I speak from the position of an employer of such individuals, and so my view is different, and would be different, from the view that may come from academic institutions.

To prepare a young individual for making innovations in industry requires more than just education in traditional subjects. It does require knowledge about engineering and it requires knowledge about synthesis. It also requires knowledge about a very broad variety of subjects which cannot be lumped into any one specific discipline.

NSF has done a marvelous job over these years in supporting scientific disciplines, physics, chemistry, and others, that they have done using a very successful formula of supporting individual principal investigators, PI's. The funding is primarily based on meritocracy.

It's based on a fundamental belief that one first-rate scientist is better than two second-rate ones. Unfortunately, engineering doesn't quite fall into the same neatly defined box.

Engineering is a cross-disciplinary activity. It does require interaction with different kinds of individuals, different types of individuals, individuals with different backgrounds.

But that does not mean that one should get away from the traditional belief that the best work comes from best people.

One of the requirements of ERC's is that they contribute towards improving our international status in competitive industries.

If that's the case, then one has to ask the question, what do we mean by competitiveness, and as has been pointed out, innovation is a very important part of being competitive.

Innovation is not just research, it is not just development, it includes engineering, it includes system design, and it also includes eventual conversion of all of that into products and services at a competitive price and would quality.

All of these 5 or 6 quantities make up innovation. Universities can contribute very effectively to this process of contribution by training individuals who have a broad view of what innovation is.

Universities, in all of this, are going to supply the manpower. I doubt it very much if the specific research or engineering developments, discoveries, innovations, that come from universities that—I doubt if these will become very important in the final run. It's the people that will make the difference.

Why do I say it's the people? Because, in industry, the life cycle of a product has become increasingly short. On a university scale a

Ph.D. may take four or five years, a master's degree may take two years, or more. Product life cycles are shorter, very often shorter than this time scale, and therefore, it's not very likely that universities, ERC's, will contribute specifically to products; they can contribute towards how the products are made; in other words, the fundamental basis by which product design, product manufacture, understanding of what goes behind the products can be carried out.

The company that I work for, AT&T Laboratories, has involvement with a number of ERC's. A major involvement is with the Columbia University's Center for Telecommunications Research.

Here we find that we have been able to influence the university in redesigning some of the courses which, in the long run, clearly would be very helpful to my industry and other similar industries.

But, if one asks the question has this involvement made the technical interactions stronger than what they would have been otherwise, the answer is no.

Why is the answer no? It is because technical interactions are based primarily on the quality of individuals.

Just because there is a center, that does not necessarily imply that there are the right kinds of individuals who can contribute to the very difficult problems of process engineering as you heard a little while ago, process design, processing science, and so on.

Coming back to the question of funding of ERC's, it is a departure from the traditional mode that has been used by NSF all these years. And the traditional model has been reasonably successful, I would say it has been very successful.

There are several concerns here with this new mode of supporting engineering, or supporting activities, on university campuses.

One of my concerns is that centers are associated with places, and they have a tendency to take on a life of their own.

Rarely you will find an individual PI, principal investigator, being supported beyond the point where that individual contributes meaningfully to science and engineering.

I doubt if we have a sufficient matrix designed or implemented that will allow us to shut down an ERC. I agree it is too soon to think about those issues, but if we don't think about them today, it may be too late five years from now.

Let me turn to the question of how do the ERC's fit into the total educational process. Support of engineering by NSF is an excellent idea.

Unfortunately, it ought not to be done at the expense of other responsibilities of the NSF. One of the things that has happened in the last six months is that the traditional disciplines supported by NSF are being shortchanged, not necessarily because of funding of ERC's, but as a result of the general non-expansion of the NSF budget.

One of the things that has happened is the reduction in the support of condensed matter physics, solid state physics.

This is the part of physics' activity that has produced the largest number of employees that industries like AT&T employ people who have a broad view of what solid state physics is. They eventually become part of the solid state engineering community and have, in fact, contributed a lot.

If, at this time, they begin to cut back on these kind of activities, I dare say that in five years or ten years from now, we would have some real problems.

Yes, we have problems in converting our science into engineering, and our engineering into products. We are behind compared to many other nations. But, if in trying to catch up there, we fall behind in the fundamental generation of new ideas, ten years from now we'll neither have the new knowledge, nor will we have caught up with our competitors, and that would be a far worse situation to be in.

The message here is that we need a balanced approach towards what makes industrial competitiveness. It is not just engineering, it is a total process of innovation, research, engineering, product design, systems design, and finally, making the products services that the customer wants at a price that he or she can afford and at a quality which is the best.

Let me just make one final comment that has to do with how we can improve the present situation.

I believe it's necessary that some mechanism be found to make industries more active partners in this industry-university relationship that is being established.

The present mode requires industry to pay money to become part of it. That's a funny way of enticing industry to become part of the venture.

Granted that industry has to put something in, but the present mode just requires our industry to throw the money into the pot without having any direct input into what specific activities may be important.

I may be exaggerating the case a little bit, but the key point here is that as long as the ERC's are physically located on university campuses, they will be driven by the forces that drive all of the activities on university campuses. These are going to be discipline driven; these are going to be driven by the time scales that require four years for an undergraduate to get a degree, two years for a masters individual to get a degree, and four or five years for PhD.

If one wants to get away from those time scales, and make that technology transfer easier, generation of new product ideas, new technologies, a campus is not the right place.

Technology transfer is a hard thing to do even in a single institution, an institution which does all of its research, all of its development, all of its engineering.

If you put a break between the place where the knowledge is generated, engineering designs that are made, and the place where it is going to be used, the whole process will slow down even further.

So, we need to rethink the question of what we mean by technology transfer and ask the question about what are the important features of universities, how to take the best advantage of that and how to marry what universities do best with what the industry does best.

Mr. Chairman, my view is that we need to have a mixed process here of funding engineering on campuses. Engineering research centers are a good experiment, should be continued until the time we find out what's happening here. But, at the same time, we have

to remember that it is the best people who do the best work. It is not a physical location, it is not a geographical place.

There is a general belief amongst my colleagues, both in science and engineering, that in setting up of ERC's we have departed from going after the best people.

If that's the case, five or ten years down the line, we'll have some real problems. Here I offer a different way of further expanding the engineering funding by the National Science Foundation and that can be done by funding groups rather than specific centers.

Unlike the funding of physics or chemistry where funding is done or is provided to individual principal investigators, I dare say that it should be possible to provide funding for individuals who are in engineering disciplines, as groups without creating the specific center, which may take a life of its own.

We have a tremendous challenge, and we have lots of promises. I think what we need to do is to put together proper mechanisms so that things get done right.

Thank you very much.

[The prepared statement of Dr. Patel follows:]

C. K. N. Patel

Executive Director

Research, Materials Science, Enginering, and Academic Affairs

AT&T Bell Laboratories

Testimony Before the Subcommittee on

Science, Research, and Technology

U.S. House of Representatives

Hearings on FY 1989 NSF Authorization

Chairman Walgren and Members of the Subcommittee: I am pleased to have the opportunity to contribute to these hearings dealing with a subject which is of tremendous importance to the scientific and technological health of our Nation. While your letter asks me to address the issues associated with the NSF Engineering Research Centers (ERCs), we cannot deal with ERCs alone when we address the issues of industrial competitiveness. We must deal with all aspects of the process of education and research on our university campuses, especially as they are guided and aided by the activities of the National Science Foundation.

Accordingly, I will focus these remarks on my company's involvement and experience with the ERCs, and I will try to put this in perspective within the totality of the role of our educational institutions in assuring a strong industrial base in the U.S.

Our universities have been remarkably successful in fulfilling their fundamental charter of providing the highest quality education to our young people. It is this continuing influx of superbly educated and trained individuals that has made the engine of industrial enterprise function as well as it has in the last three decades. As a necessary and important corollary to high quality education, our university campuses have carried out forefront research in many disciplines. Without these research activities, the educational function of universities would be seriously impaired, especially in the physical sciences. In the last three decades, the National Science Foundation has done a remarkable job in the care and feeding of these activities. As a result the societal needs for manpower educated and trained in scientific and technological subjects have been reasonably fulfilled. Along with this also have come important fundamental scientific findings which often form the bases of technology that are developed by industrial institutions. However, the most important direct impact of the universities on our industrial strength has been due to their primary end product, i.e., students, and only secondarily due to their research results.

The successful formula employed by NSF in fulfilling its charter of education and research on the campuses has at its core the belief that the outstanding people are the most likely contributors of conceptual insights to keep the U.S. at the forefront of science. This has led to a funding mechanism which is strongly based in meritocracy and has resulted in the funding of individual faculty members. This is very reasonable in the fundamental sciences where

real advances arise from insights gained by an individual rather than from collective thought. The importance of individual creativity in fundamental research activities leads me to conclude that one first-rate scientist is far better than two second-rate scientists. The funding of individuals with a peer review process has assured, by and large, that political, philosophical and other factors do not contaminate the evaluation of what is good, better, and best. We have very few examples of "Lysenko" in the strictly maritocracy-based system which NAS has followed all these years in supporting of fundamental scientific education and research on our university campuses. NSF deserves the gratitude of our Nation for doing this job exceedingly well.

But how well should or does this successful model of funding fundamental science apply to the more recent foray of NSF in funding engineering research? Let me state at the outset that once more NSF has made an excellent decision through which NSF has begun to fund engineering research on U.S. campuses. The general funding model chosen for support of engineering research is, however, very different from that practiced in support of fundamental science. The funding to a large extent has taken the form of establishing Engineering Research Centers which look for the collective strength of individuals from a variety of disciplines to address challenging problems in the area of engineering. These cross-disciplinary research activities are expected "...to enhance the Nation's economic competitiveness by strengthening university/industry coupling in research and education." An infusion of knowledge from several disciplines and viewpoints is believed likely to increase the probability of

innovative and industrially relevant research. Just so we can address a common theme, I reproduce here a statement regarding ERCs (taken from a NSF document), "ERCs are designed to have a broad impact on academic engineering research and education. These centers expose students and faculty to an active dialogue with industry. Industrial collaboration is achieved through advisory bodies, joint projects, and joint educational activities. Emphasis is placed on developing strategic goals which will lead to new developments and an improved understanding of the integration and management of engineering systems." This is a laudable goal, and I will examine some of the consequences.

While it is generally agreed that science and engineering are both important ingredients in our Nation's international competitiveness, it is also a fact that engineering activities often have a much shorter time lapse till payoff. Also engineering research activities, no matter how well done, do not by themselves lead to industrial innovation. Technology transfer is a difficult task even when research, engineering, and manufacturing are done under a single industrial "roof"; but the problems become much more difficult when research and engineering are done in one institution and the industrial exploitation of their advances are done by another institution. In such a situation, national boundaries provide no specific competitive advantage to local industries. A close working relationship such as that envisioned in the Cross-Disciplinary Research (CDR) programs and ERCs of NSF clearly can help if the industrial partners have a serious stake in the enterprise. Industry, for it to become and

remain internationally competitive, needs properly educated human resources and a rapid conversion of ideas from research, to engineering demonstrations, to final products. The rapid engineering demonstrations leading to final products are best carried out in one and the same institution because of the close connection between what and how something is being engineered and why it is being engineered. Thus, the ERCs can be very important in the human resources part of the equation, but except for some unique situations, ERCs are unlikely to directly aid in the industrial innovation process.

Since the life cycles of many competitive products are on the order of two years, industry needs people who have a broad generic education which allows engineers to move ahead as technology evolves. Even in engineering, the role of university based research should be to seek conceptual advances which are broadly applicable to a variety of problems. Too close a coupling between ERCs and industry to assure that the research is focused on current and projected industry needs can make for a poor educational environment for graduate studies, where a PhD program may take as many as four years of intensive research. Collaboration with industry, where often the time horizon is very short, is likely to make engineering research at universities a "job shop" type of activity. Such activities do not fit well into graduate education.

ERCs represent collective activity as contrasted with the individual PI (principal investigator) funding in other areas of scientific investigations. Admittedly there may be sound reasons for following the path of ERC versus

extending the individual PI funding to engineering the same way it has been done in fundamental sciences. The strongest two arguments are that engineering is often a multidisciplinary activity and that engineering, as opposed to fundamental research, often requires expensive facilities which can only be afforded by a group effort. Both of these are at least partially correct.

My own experience with an ERC is limited to the Center for Telecommunications Research (CTR) at Columbia University. Our involvement began early in the proposal stage and now has culminated in our membership in the CTR Affiliates Program for an considerable yearly fee. Nonetheless, the primary driving force for our interactions has been the close technical relationships that had existed between a number of faculty members at Columbia in the relevant disciplines and a number of scientists and engineers at Bell Labs. Undoubtedly, the creation of the CTR provided a focus to strengthen these relationships. Perhaps as a direct result of the CTR, we have a number of individuals who are taking specific educational courses at Columbia. Research relationships which are generally based on mutual technical competence and needs have neither suffered nor become exceedingly strong, say strengthening by a factor of 10. But the positive aspects have come because absolutely first-rate people at Columbia were instrumental in setting up the CTR and first-rate people from industry are attracted to those at university. This is consistent with a wise observation "Where do you find excellent people? In the company of other excellent people, of course." Through our membership in the CTR we have had an influence in designing courses to

meet specific and urgent needs of industries like ours. It is too soon to comment on the success of the CTR in promoting industrial innovation in our or other industries that might improve the nation's competitive posture in the world.

In spite of the one relatively successful ERC of which I am aware and others that may be equally successful, I am concerned by the radical departure from the traditional funding mechanisms employed for the highly successful science programs. What characterized the individual funding of PIs was their track record. Along with this was the promise based on the track record and the quality of the proposed research activities. When one moves away from funding of individual PIs to funding of institutions through creation of ERCs, the burden of excellence shifts from people to the proposal. And yet in the end it's the people who must end up delivering the promised results. Therefore, there is a continuing need to examine the strengths of individuals as one of the principal criteria for the award of ERCs. This has not always been very evident. Since people do the work and not places, there can be serious long term harm to the credibility of the engineering profession.

Again, large grants, and especially those which get associated with places rather than people, can be subject to pressures other than technical ones. An apocryphal story will suffice. Some time ago I received, from a colleague of mine, a copy of a proposal for an ERC that he wanted me to look over and see if Bell Labs would write a supporting letter. After reading the proposal, I told my friend that I did not believe the proposal was a particularly strong one. His

response floored me: "We are quite sure that we will get the ERC since our state does not have one yet."

Yet another of my concerns about ERCs arises from the possibility that such institutions will take on lives of their own even after the real usefulness is no longer apparent. We do not have a long enough database to worry about it, but this is something that should be planned for ahead of time.

Finally, it is important to put ERCs in the context of the total educational and research role of NSF. I mentioned earlier that I support NSF's desire to become a supporter of engineering education and research activities the way it has carried out similar functions in science. However, NSF would be remiss to build up such an activity at the expense of what is regarded by everyone worldwide to be a truly successful enterprise of outstanding scientific research and education on our campuses. I am speaking of the distortion of funding that is occurring now because of the tight budget situation at NSF. Specifically, I am concerned about the budget cut that a number of outstanding solid-state physicists are experiencing around this country in 1988. These are real reductions in current dollars. When the cuts affect the leading scientists in this community, the whole nation should begin to worry because these "small science" activities produce the largest number of well-trained scientists that fuel the technological enterprise in the industry. (I have attached letters from three of my colleagues who go into greater detail on these issues.) Such a reduction is disastrous. It is so because our off-shore competitors are increasing their

support of those disciplines which generate the resourses that feed the industries important in international competiveness. Yes, we are behind some nations in our ability to convert our science into products, but if we follow the present path we will not have the science either!

A discussion of educational and research activities designed to improve our Nation's international competitivenes cannot be complete without a few comments on what might be done to address this issue. Supporting engineering education activities on university campuses assures an increasing flow of educated manpower. However, to impact the issue of international competitiveness one must look at what makes for industrial innovation. Industrial innovation requires "hand-in-glove" working and thinking relationships between marketing, manufacturing, engineering, and research activities. Successful industries are good at making all of these play together harmoniously. But it would be unwise to assume that setting up ERCs (and the future Science and Technology Centers, STCs) to do engineering will naturally attract industries to marry their needs with the promises of a specific ERC. By necessity campus based research activities have a strong educational component. As such, these activities are often incompatible with the engineering needs of industry whose desire is to manufacture and market products. If we as a nation want our universities to do a better job of educating and training young people in the areas of manufacturing, and processing science and engineering, a mechanism other than the ERCs needs to be invented. As a first step NSF should seriously consider the funding of

engineering science in the same way it does the funding of fundamental science. Second, incentives should be provided to industries to participate more fully in the R&D enterprise of the Nation - a large part of which is on campuses. Such an incentive can take the form of funding of ERC-type activities where a specific industry and a specific set of individuals from universities are joint partners in promoting a specific technology. The current scheme of ERCs which require them to coopt industries as paying partners is not working as well as it should. Industries join the Industrial Affiliates Programs of ERCs not because they expect any substantive returns that may help innovation but because of their enlightened self-interest in keeping educational institutions strong. A recent meeting of the Corporate Affiliates of the American Institute of Physics was devoted to discussion of the usefulness and desirability of STCs as currently envisioned. The industrial representatives were, at best, lukewarm to the proposed STCs. Many of us would rather support specific individuals than throw our money into the general pot.

Let me close by summarizing my views. Support of engineering education and research on the university campuses by the NSF is an excellent idea and needs to be expanded. Even the ERC as a concept is valuable, but I do not believe the current mechanism of funding will get the biggest bang from the buck for our Nation. We need to develop a parallel mechanism of funding engineering research at the individual PI level also. Finally, although I have not specifically addressed the issues of big science vs small science, I do not believe that bigger is necessarily better.

Appendix to Dr. Pate's testimony

February 16, 1988

As you are undoubtedly aware, a great explosion of activity has occurred in the field of high temperature superconductivity. You are probably also aware that American scientists and most especially, physicists in American universities, are playing a leading role in elucidating the basic mechanisms responsible for this wondrous phenomenon. The current administration has publically expressed its desire to support strongly science and technology in this area. Unfortunately, exactly the opposite has occurred. Leading university researchers in this field and indeed in solid state physics as a whole have had their budgets severely cut for 1988. This will not only inhibit U.S. leadership in this field, but, equally importantly, it will seriously limit the entry of new graduate students and postdoctoral fellows into this field. We are certain that this is not what Congress has intended. It has, nevertheless, happened.

During the period Jan. 17 to Jan. 23, 1988, 65 leading physicists from around the world gathered in Aspen Colorado to assess our current understanding of high temperature superconductivity. Simultaneously, the U.S. physicists addressed the issue of the funding crisis in solid state physics. From these discussions there emerged the enclosed statement which was unanimously endorsed by all American participants there, who represent a broad cross section of leading university, industrial and government laboratories in the United States.

We urge you to use your considerable influence to correct this situation. We are anxious to co-operate in any way possible.

Sincerely yours,

Robert J. Birgeneau
Head, Atomic, Condensed Matter and Plasma Physics, MIT

David Pines
Professor of Physics, University of Illinois

SEP 22 '88 14:05

January 22, 1988

During the week of January 17, 1988, sixty-five research scientists from leading university, industrial and government laboratories convened at the Aspen Center for Physics to discuss the latest ideas and discoveries in high temperature superconductivity - a field of immense potential for technology as well as profound intellectual challenge. We also considered - informally but intensely - the present status and trends of Federal support for university research in the field of condensed matter physics in general and superconductivity in particular. These discussions focussed on the growing crisis in this area and culminated in the present statement, which is endorsed by all U. S. participants in the meeting.

Condensed matter physics is concerned with the structure and behavior of materials. Since World War II, United States preeminence in condensed matter physics has been the basis for a host of technologies which we now take for granted. The transistor and the age of microelectronics and computers which it ushered in, the semiconductor laser and the optical fiber which have revolutionized communications, and magnetic resonance imaging are but a few examples of the fruits of relatively recent research in condensed matter physics. The discoveries of the past year in high temperature superconductivity have both spawned the promise of yet another technological revolution and stimulated increased interest in condensed matter physics and related fields of science.

Unfortunately, this increased interest and enthusiasm is being met with decreased funding from the National Science Foundation. In particular, individual university researchers supported by the Condensed Matter Sciences Section of NSF have almost all suffered funding cuts of between 6% and 12% for the current fiscal year. For lack of funds, promising young students must be turned away and creative young faculty are frustrated at the beginning of their research careers. In the longer term, the pool of scientific and technical talent needed if this country is to be competitive in the increasingly technological international arena will be significantly diminished. Thus, at a time when U. S. competitiveness in technology is of extreme concern, support for university research in the scientific field upon which such technology depends is rapidly falling behind the country's needs, and more importantly, behind the efforts of other industrial nations.

Steps must be taken now to reverse the increasing shortfall in Federal funding for condensed matter physics in universities. The "Brinkman Report" of the National Academy of Sciences documented the need to double such university research support over a five year period. Yet experience over the past two years and plans for the coming years indicate a diminution of support in real terms for condensed matter physics. This trend must be reversed in the coming fiscal year if this country is to have any realistic hope of maintaining technological competitiveness in the coming decade.

We have prepared this statement to draw attention to this serious situation and we are ready to provide additional advice, information or suggestions. Science, technology and the nation's economic health are closely related. We want to see the U. S. optimize these relationships for the good of all. We believe that investment in university research in condensed matter physics will pay off handsomely in the future as it has in the past.

Biography of Dr. C. K. N. Patel

Dr. C. K. N. Patel is Executive Director, Research, Materials Science, Engineering and Academic Affairs Division at AT&T Bell Laboratories, Murray Hill, New Jersey. He joined Bell Laboratories in 1961 where he has made numerous seminal contributions in the field of high power lasers, nonlinear optics, molecular spectroscopy, pollution detection, and laser surgery. He became Head of the Infrared Physics and Research Department in 1967, and in 1970 he assumed the position of Director of the Electronics Research Laboratory. In 1976 he became Director of the Physical Research Laboratory, and in 1981 he became Executive Director, Research, Physics and Academic Affairs Division. He assumed his current position in 1987. Since his election in 1979, he has served as a member of the Board of Trustees of the Aerospace Corporation, El Segundo, California. In 1986, he was elected to the Board of Directors of the Newport Corporation, Fountain Valley, California.

Dr. Patel is a member of the National Academy of Sciences and the National Academy of Engineering.

Mr. WALGREN. Thank you, Dr. Patel, for those perspectives. What seems to be emerging, certainly, is a very long view of the contribution that these centers can provide, the engineering centers, and unless specific contributions certainly in terms of a product anyway, but rather changes in courses, changes in training, changes in development of the focus of these engineers.

I guess the question is, we have 14 of these centers now. We're saying three years is too short a time to measure them. We don't have the measurement capabilities. $33 million is a piddling amount, when measured against other expenditures in the Federal Government and even other expenditures in science, and yet we are seeing other areas of NSF short changed—the fundamental disciplines, because of the demand for money elsewhere in large products and the like.

Under those circumstances, how quick should we be to expand the centers' concept? We're being asked to up front fund now 30 more centers—15 more centers—for $30 million a year, for five years, and yet three years into this program we have—we're coming away with the feeling that our best contribution was rather systemic at best, and we're not seeing concrete examples of models that we really want to just replicate because it was done this way and it had a real result.

How quick should we be to up front fund, with no ability to pull back, at least from a Congressional standpoint, 15 more centers in the science and technology area. Dr. Kash?

Dr. KASH. Mr. Chairman, I, unless something has occurred that I'm not acquainted with, there is a distinction which I think is terribly important here.

The up front funding, as I understand it in the proposal, is for what are called science technology centers. That is, that's $150 million chunk in the Administration's budget for next year.

The science technology centers are rather different animals than the engineering research centers, at least they appear rather different to me in terms of the National Science Foundation's request for proposals.

One of the things is that they do not require specific linkages with industry. They also don't really have to be cross-disciplinary. So, that's a different program.

I would make two comments on this. First, I want to mildly disagree with my colleague, Dr. Patel. He and I have disagreed once or twice previously.

The National Science Foundation, in managing this program, really has sought to get cooperation between industry and the centers, not just get money, and I think that that's been a point that's been emphasized repeatedly.

The second thing that is important is that if it is essential to have inter-disciplinary organizations on campuses, it's really quite important to have a number of these institutions, 14 is not enough, located in different parts of the country because they become a network of their own of a different kind.

I think it not unreasonable to make some analogies with the Ag schools. Fourteen is not enough, in my judgment. $33 million, after four years for engineering research centers is pretty small. I'm a

little puzzled by the National Science Foundation's eagerness to put a $150 million in the first year in science technology centers.

There's a difference here. It seems to me the engineers are getting one-fifth after four years of what the Foundation wishes to put primarily into the sciences in the first year, these different programs.

Mr. WALGREN. Dr. Patel.

Dr. PATEL. The science and technology centers are, in fact, different from engineering research centers. They have much less by the way of what is traditionally called engineering education.

One of the important features of science and technology centers is for them to become an important pipeline, important generator of new products, new processes. In my view—and that has nothing to do with how much they are going to cost.

In my view, creating science and technology centers is yet going to be another way by which we are going to offer our competitors, international competitors, something else on a platter because we haven't talked about the question of interface between a university-related technology center such as STC, and what it takes, what is required to convert those findings into competitive products.

Therefore, whether they cost $5 million or $150 million I think it's a bad idea. Six months ago, under the auspices of American Institution of Physics, which has a corporate associates program, we discussed with Mr. Bloch the issues associated with science and technology centers.

There was an overwhelming lack of support on the part of the industry representatives of what STC would do for their industries in terms of providing them with a better stance from which they can compete with the foreign competition.

I don't believe the STC concept has been thought well enough. Apart from the fact that it appears to be a much larger program compared to what ERC's are today, I don't believe that is the right way of getting into, or addressing the issue of competitiveness.

Mr. WALGREN. Let me ask Dr. Breuder. I was struck by your statement that when you tried to develop the idea of a technology transfer program from a local community college level, that there was no model, no projections, no way to know what to do. My question is with the National Science Foundation experimenting with these engineering research centers, we know that they are going, or the future is always projected in the terms of flexible manufacturing and the like.

Is there a way that you can see to tie a community college training course to new technologies in manufacturing that you indicated could be replicated? It seems awfully wrong for you to be out there all on your own trying to do it through what is, at this point, a state program I gather, the Industrial Resource Center. But, you're trying to invent it out of whole cloth with just the resources in your own community.

What would you like to see the NSF do that would help a community college get into the training business?

Dr. BREUDER. Mr. Chairman, I think that's a very appropriate question and let me try to answer it from, again, a personal perspective with some sensitivity to what's happening nationally.

It takes a great deal of courage for a community college in this country to move into the advanced or emerging technologies. Costs considerations alone make that a calculated risk in many cases because no segment of higher education today feels that it receives enough money, whatever those sources of money might be.

And, here in Williamsport, Pennsylvania, a small rural community, the home of a community college, not unlike what we find all across this country, where there are some 1,220 of them. Back four or five years ago, we had some difficulties in our own institution in terms of defining what ought to be our primary focus, what ought to be our curriculum portfolio, what are the kinds of services that we should be offering our community, not only the immediate community, but the extended community in the state as a whole.

We had to make some serious decisions relative to what we were offering and where we were going to go. And, we decided, based upon all that we had learned and read, that we ought to be moving along in what was then called high tech, now advanced tech, but the nomenclature is really irrelevant.

We met with industrialists from throughout our state and asked for their guidance and their direction. Everything from purchasing equipment to talking about software application, to designing facilities, only to find out that we got very little return from those people because they themselves couldn't give us a clear definition.

Let me pare out one of those for example. GTE has a plant in our community. It's a substantial plant, if you will. And, as we talk to them about fiber optics, they were telling me at that particular point in time in 1984, that if I could produce 30 fiber optic technicians tomorrow, they would hire them all and they would hire them at salaries of $25 to $40 thousand a year.

I didn't have that ability to train those people so we worked with GTE to produce that product hand in hand. What I see the National Science Foundation doing is providing some monies to institutions like community college, whereby they can strengthen that partnership with business and industry, to work with those industries in taking existing employees, if you will, retraining those people as the fields in which they're now working are changing, people who have been laid off because the marketplace has shifted, they're on the unemployment roles, but they're still viable members of the community, to retrain those people, to put them back into the labor force and let them be contributors again to the economy.

But then, to train people who are coming out of high school or out of the military or other places, who are looking for fields in which they can invest a portion of time, two years of four years, and develop that all important marketable skill.

People today want to go to school with the understanding that when they come out, there's job opportunities for them and there's an ability to go ahead and satisfy their personal needs as well as their professional aims.

For us, the National Science Foundation, to help not only move technology from the states which sit 40 miles away from us, from Bucknell University, into let's say, a GTE or a Textron Corporation. But, these people need our help in terms of being able to configure themselves in a way to receive all of that.

Mr. WALGREN. Well, there must be a—if the National Science Foundation is involved in developing these technologies through Engineering Research Centers and the like, there must be a clear educational component that would be able to be tied into those skills that obviously people are going to need if they're to be functioning in a technological society.

Let me recognize the gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman. I appreciate the contribution which all of the panelists have made. I think it is healthy for us to look realistically at the ERC's and the science and technology centers and trying to avoid the attitude that they may be some sort of a panacea. Obviously, they're not.

I somewhat prefer the perspective of Dr. Kash who puts them in perspective in comparison with the needs to improve education, industry/government cooperation, make some modest revisions like completely overhauling the U.S. financial system to keep it from becoming a gambling casino, and to encourage more savings and less consumption on the part of the American people.

Dr. Patel, I find that your emphasis is upon the importance of individual investigator research, while it's important, I think, neglects certain realities and I don't want to be carping, but I'm going to ask you a question or two.

Do you think that the state of research in solid state physics is more threatened by the funding of $50 to $100 million a year for the centers than it is from the $500 million a year from the superconducting supercollider?

Dr. PATEL. Mr. Brown, I did not mean to imply that the funding of individual PI's in solid state physics is threatened or that these people are being short changed by the funding of ERC's. That was not the implication.

The implication here is that any time you create a new program, you have to give up something, unless there is an ever expanding budget. If the budget is not expanding, it's got to come from somewhere else.

Yes, we have to make our priorities. Let's know ahead of time of what we are giving up and what we are getting in return.

Cutting the funding of individuals such as Phil Anderson by 20 percent, doesn't make sense, which is exactly what has happened, and he is not the only one in this category.

The question of superconducting supercollider—it's not here yet, so I can't really comment on what it is going to do to solid state physics, but a simple calculation tells you that even if the superconducting supercollider can be built out of brand new money, a $5 or $6 billion or whatever it is, it's a known fact that you need roughly 10 percent of the start up money as money each year to run the institution.

That amounts to about $500 million a year. That far exceeds the total support of fundamental science in this country today. Draw your own conclusions of what that will mean.

We have to put things into perspective; we have to generate our own priorities. Priorities that take into account, not only the need to further science, but also need to generate engineering technology and everything else that will support the science in the long run.

Mr. BROWN. Well, your point is absolutely correct. If we could fund the superconducting supercollider, it would take roughly $500 million a year, $300 to $500 million a year, after it's constructed to operate it.

The science and technology centers, we are thinking in terms of a five year program of $75 million, not per year, but a total.

They are not even comparable in terms of what they do, in terms of a threat to the existing NSF budget for disciplinary research, which I agree with you, is flat and needs to be increased. But, it is not going to be increased by reducing the science and technology centers, allowing the superconductor supercollider to go ahead.

I'm also a little bit at a loss to understand your perspective with regard to the preeminence of individual investigator processes in science itself. What you call science, which incidentally—you use the term "science" in what I have always thought of as rather elitist way. You define it carefully to exclude things like engineering and other things which are equally important to society.

But, having just returned from a visit to Cern, I found that they have several hundred scientists working over there. They're individual investigators, but they're working in teams, and I find that throughout what you call "science" including astronomy, high energy physics, bio-technology, is a going tendency to work in an inter-disciplinary manner with rather large teams of scientists working.

I know you recognize that, but your statement seemed to imply some ideal of the individual scientist in the laboratory with two or three great graduate students, but using all of the vehicles of modern knowledge, and that's not the reality today. You don't have it your own labs, as a matter of fact.

Dr. PATEL. Let me just make one comment. I did not imply that groups of individuals are not necessary as the technology evolves.

They are, indeed, necessary. But, these groups are not permanent. These groups form because the individual members of the group have something to contribute to the overall effort.

Yes, in my own laboratory, there are group activities but the group activities do not come about because somebody from the top says thou shall form a group to do such and such thing.

Groups form because a certain job has to be done; a certain activity has to be carried out. And, people seek out other help, other missing pieces or links that are absolutely necessary.

High energy particle physics is a very different kind of activity compared to even the engineering activities that we talk about. We do not have a few hundred people working on single research or engineering on projects campuses.

Heretofore, much of what we see as the best products of universities, are the best students. They'll come from small groups rather than large groups. They may have come from inter-disciplinary efforts, but these are essentially very small groups of PI's.

Mr. BROWN. Well, I am deliberately accentuating some of the differences between us. I hope you'll appreciate that. But, I do want to make one further point, and I'll ask—let me make this, Dr. Kash, and then I'll ask you to comment on it.

The real problem in our society today is not the ability to innovate new products. We've been pretty good at it. I agree with you

that this is not a realistic objective for Engineering Research Centers.

Where we really have fallen down is that we have a system which does not emphasize quality, it does not emphasize economy, it does emphasize better process design, manufacturing flexibility, full cycle designs, so that we treat the product from its inception as raw materials to its effect on the environment from the missions.

We have failed to cultivate a generation of engineers who look at the total processes of engineering in order to achieve ultimate value to the society.

The Japanese have defeated us in competition globally because they have, with the help of Deming and others who have gone over there and given them American know-how, which he says American managers were too stupid to undertake on their own.

Why can't we look on the Engineering Research Centers as a way of inculcating the ideals for a complete revamping of the U.S. attitude toward to the processes of creating material products in this society.

Not generating an individual new product, just the market testing of which, as we see in the case of things like an Edsel, they require several years, then still be complete flops.

We do not want students to get involved in that. We do want them to get involved in what is a fundamentally different understanding of the processes of manufacturing, however. Comment?

Dr. PATEL. Yes, we can, but it's more than we can. I think we have to. If we do not revamp our educational system as far as engineering is concerned, there isn't much hope left.

Let me cite you one example of what I see as just the tip of the iceberg. Our best engineering schools, Cornell's, MIT's, Stanford's, and so on, they generate a large number of engineering graduates each year.

We ask the question how many of these end up in manufacturing-related activities. Very, very small number. It is because, heretofore, manufacturing is not considered to be an honorable profession for a graduate of these schools.

I think that is a mistake. If funding of engineering education by NSF, either through ERC's or some other mechanism, allows us to change that mindset, NSF would have done a tremendous service to this nation.

Mr. WALGREN. Dr. Kash, I'm sorry I didn't let you comment before.

Dr. KASH. You saw I was eager to comment on this. I would like to make two comments.

First, it strikes me that the United States continues to, by every measure I can see, do very well with a small elite group of scientists and engineers that has somehow or other, this percolates high class stars to the top. And, it continues to do that and it hasn't helped much in international trade.

I'm taken by this comment that we're getting beaten by the quality of the next 70 percent, not the top two percent.

Modern technology and modern innovation is an organizational product, and engineers are organization men. Technology is too complex today to be invented and innovated by individuals.

Now, there is concern about the Engineering Research Centers becoming organizations in universities that are established and go on and don't change and don't perform. And, given these very conservative institutions, which I love, I'm a part of, and I don't want you folks in Washington touching them—nonetheless, it is precisely in this area of the universities learning how to put together research and teaching groups which are responsive to changing needs and intellectual development that we desperately need.

We need it for society's reasons, but we need it in the universities. And, I must tell you we won't do it by ourselves.

Those of us who are in universities like to propose radical changes, such as a total change in the U.S. financial system, or other people.

We have a hell of a time making any changes for ourselves. Now, the Engineering Research Centers are terribly important, precisely because they are a lever to help us learn how to experiment to do something which is, in fact, essential to pushing the frontiers of science and technology as well as developing competitive capabilities.

And, I just get absolutely frustrated by this notion that in a time when these terribly important changes are needed, people run up red flags that $33 million going into Engineering Research Centers are threatening all the future Einstein's and Lone Rangers, which would come out of this system if they only had $50 thousand.

Unfortunately, the university today is full of people like me. The problem with me is that I'm no Einstein. I wish I were. The fact of the matter is we've got to learn how, in the universities, to deal with what is a changed economic technological/scientific environment, and that is an environment where you just have to have groups and teams to do the work, and they've got to be from different disciplines, and we in the universities have got to learn how to organize and be flexible, and we're not going to do if we don't have some help. And, the kind of help you can provide here in Washington is money.

Because, although we're pure and virtueless, if you can support virtue with money, we tend to change more rapidly.

Thank you.

Mr. BROWN. Well, I think you have made some very good points there. I will end my participation at this point, although I would like to continue the discussion.

Mr. WALGREN. Next the gentleman from Illinois, Mr. Bruce.

Mr. BRUCE. I have no questions. I was intrigued by the questions by Mr. Brown.

Mr. WALGREN. I feel constrained. We ought to move along because we've got so many more witnesses. The gentleman from New York, Mr. Hochbrueckner.

Mr. HOCHBRUECKNER. Mr. Chairman, I just thought I'd ask a couple quick questions.

Dr. Kash, based on your presentation, did you in particular have an especially bad time with the NSF review or is it colleagues in the other programs that had an especially tough time, because you seem to be very negative about how the program, after a mere three years, was treated? You know, obviously we have to have the accountability, but certainly we don't want to waste your time,

spending all your time, telling what you're doing rather than doing.

Dr. KASH. I don't have a tough time except that this is a $33 billion program which, because it's new, is the focus of a great deal of attention.

And my plea is to simply say that if you are trying to learn how to do something new, you must give it a little time, and more importantly, this is a process or organization change which requires trial and error.

That is, it's going to stumble as it goes along. My plea is just that we get away from this terrible need to make judgments over very short periods of time. It's not anything that's negative specifically, except that—I've served on this committee which has sought to advise in this and I'm just appalled at the number of telephone calls I get asking me about the performance of these centers.

I keep saying it's too early. I'm prepared, given a little bit of time, to make very tough judgments and I think NSF is—if its got a center that isn't trying to do what it said it was going to try to do, it ought to kill it.

But, if you ask the question of can you measure whether they have contributed to competitiveness at the end of three years is just flat footedly isn't possible. And that's the point I want to make.

Mr. HOCHBRUECKNER. Thank you. Dr. Breuder, you had, of course, came out very strongly in support of the Chairman's bill, H.R. 2134, and as you know it has a lot of support here, and I think we all appreciate the fact that you would express support for it.

Can you just give us a quick example as to how you at Williamsport have been able to accomplish this transfer of technology? Are there any particular examples that you can cite in your own case?

Dr. BREUDER. We have, for example, been working with a company like QRP, Quick Release Pins, that relocated from New Jersey to Williamsport, PA.

They're a tool and dye manufacturing plant that was not automated when it arrived on the scene in Williamsport, Pennsylvania. We began a collaborative relationship with them, have taken them into our new facility, given them the opportunity to test product design, delivery of those products, work with us in systems development, software procurement, help them put systems on-line in our flexible manufacturing facility before they make that move within their own plant, because they're not yet large enough to be able to make that capital investment only to have it fail in the final analysis. So, we could work hand in hand with them.

We wrote various grants, got various subsidies, if you will, to field test to provide the practical applications portion of this equation, which I think is so desperately missing.

Then we provided the start up training for their people, and as the technology changes, we will retrain their workforce to match whatever their product line might be.

Mr. HOCHBRUECKNER. Dr. Patel, when we talk about this transfer of technology, one of the important programs that we have been promoting in-house around the Administration, but I think they are now supporting, is a program on x-ray lithography, which probably is an excellent example of what we're trying to accomplish in

terms of we have Brookhaven National Laboratory working on an x-ray source, the more portable synchrotron; we have IBM involved with the x-ray lithography manufacturing techniques. We have the University of Wisconsin involved, since they have a synchrotron with available port time.

Oddly enough, in all of this process, I've talked to many, many companies, but I've never heard anything from AT&T in terms of their interest in x-ray lithography as the technique for producing the next generation of computer chips, and I think as most people know today's technology—we are talking about one and a quarter micron element sizes in VSIC-1, but certainly with x-ray lithography a technique that can take us down to a quarter of a micron and allow us to have 64 million bits on this little piece of silicon as opposed to a million under today's technology. I just haven't heard anything from AT&T yet.

Could you tell me if AT&T has any interest in x-ray lithography?

Dr. PATEL. Yes. AT&T does have interest in ultra-fine line lithography, whether you call it x-ray lithography or give it some other name.

We are progressing from 1.5 which is the chip that you holding down, to eighth-tenths of a micron in about two years and then farther down.

The important question to ask is what are the crucial issues that need to be resolved before one can get to a quarter of a micron lithography. The important issue is not the synchrotron. The important issue is not the source of x-rays. I think generally it is agreed that that source of x-rays exists, either by the synchrotron or by using laser produced plasmas. Today there are a number of ways by which one can generate high intensity x-rays. The real problems lie elsewhere.

The real problems are in masks that you need to make the chips; and the photo-resists. These are very important issues and have not been addressed sufficiently. We at AT&T have been focusing our attention in taking care of these issues as best as we can before we stand up and say yes, we are all for x-ray lithography.

Fine line lithography will come. The line width shrinks by a factor of two every two years is a known fact and there is nothing that we know that is going to change that.

However, if you have a source of x-ray you need masks, you need photo resist and you need some mechanism by which you can write these fine masks so that you can replicate them. In this country, we do not have a supplier of electron beam writing machines—which is how one writes the mask in the first place—that will give you the .25-micron masks that you need. We just do not have that capability in this country. There is not one on blueprint, either. And I suspect what is going to happen three or five years down the line is that we'll be forced to buy a non-U.S. machine to write the fundamental mask which you may be replicating.

Mr. HOCHBRUECKNER. Well, Doctor, that's why we put $26 million into x-ray lithography and we have $35 million in so far this year, to do just that. So I would hope that AT&T would get in the game, too. We'd love to have you.

Dr. PATEL. Yes, sir. I think the point is that we are trying to address issues other than which are normally called x-ray lithogra-

phy; we are trying to address the issues of masks, photo resist and the electron beam writers.

Mr. HOCHBRUECKNER. Thank you, Mr. Chairman.

Mr. WALGREN. The gentleman from Louisiana, Mr. Hayes.

Mr. HAYES. No question, Mr. Chairman.

Mr. WALGREN. The gentleman from Pennsylvania, Mr. Ritter.

Mr. RITTER. Thank you, Mr. Chairman. I want to thank our witnesses for their excellent testimony. I've been reading it here and I regret not being here for the full hearing.

In looking at the NSF budget numbers, there's a $330 million increase projected, which amounts to about 19 percent. Last year, the request was for some 17 percent; we ended up with 5 percent. I think the bottom line here is that we're not going to get, in this budget climate, 19 percent, and so we won't get $330 million so we probably won't have $150 million to spend on centers. And then let's say we do have $150 million, let's say we get half of the 19 percent—should we essentially flat fund as is the request for the mathematical and physical sciences group and put all the money into centers, or should we diverge and give some of the solid state and materials sciences that are so crucial to the electronics and hopefully the new photonics revolution a little more attention? I'd just like to get some responses from our panelists.

Dr. BREUDER. Mr. Ritter, I'm probably the least capable of responding to that question with direct substance but let me try to in my own way if I can. I'm not that familiar with exactly what's entailed in the Science and Technology Center portion of the NSF budget, but I can assure you before the week is out I will be.

What I do know from a purely practical point of view is there is something fundamentally wrong in this country, and let me back up with that for a moment. It seems to me that if our agenda is to become more competitive in the international marketplace, to become more competitive in the domestic marketplace, if you will, to breathe new life and vigor into business and industry in this country so that our economy can be better than it was yesterday and vastly improved over years and years ago, then we need to do some things, in my mind.

I live in Pennsylvania now and I get tired of reading about the description of the Northeast as being laden with smokestack industries which so typify, if you will, what business and industry was like 10, 15, 20, 30 years ago; companies which haven't changed technologically within, they haven't improved their physical plant. It also suggests they haven't done anything with their people. And it's unfortunate, as you and I know, that increasingly more and more companies in our state—and I don't think it's endemic to Pennsylvania, by the way—are going Chapter 11, or in some cases they're simply relocating and leaving the state in its entirety.

If you meld that with the fact that we now have one of the largest out-migrations of youth in the country and——

Mr. RITTER. Could you try to—I come from Pennsylvania, too, and I'm very sensitive to what you're talking about and I think the ideas that you're putting forth to gain a greater handle on advanced manufacturing to small and medium-sized business is absolutely essential and I commend the Governor for his new program to foster that.

But I think we're dealing with a specific question here that's going to touch on NSF priorities, and I'm not sure NSF is going to be able to get into the kind of things that are awfully, awfully important, and the Chairman and I have collaborated over the years on trying to sell manufacturing to the system, which has ignored it. I sympathize with your frustration but I'm not sure where what you're saying fits into the question that I asked.

Dr. BREUDER. If you'll just give ten seconds here I'll take you right there. We have a substantial out-migration in the state of youth; we have a heavy retired population and there's nothing wrong with retired people. We have the third highest concentration in the country. Putting all of that aside, there are millions and millions of dollars every year being injected into higher education, and certainly our state has some of the finest university research centers in the country with Carnegie-Mellon, Pitt and Temple and all of those institutions.

Mr. RITTER. And Lehigh, I might add. [Laughter.]

Dr. BREUDER. And Lehigh. And I submit to you that something is wrong someplace with all those fertile, ingenious, creative ideas that are coming forth from those institutions; they are simply not getting out into the business and industry people of our state. Hence the problems that we're experiencing; that technology is not being transferred out, we are not providing the human resources——

Mr. RITTER. You know, the gentleman is not answering my question, Mr. Chairman. But I do want to make the point that he is absolutely correct. I mean, I do understand exactly.

NBS, by the way, we have drafted legislation to try to turn this thing around to have a focus in the federal government which cares about manufacturing, which cares about the kind of things you're doing. NBS now has a small program that's going to try to use its advanced manufacturing research facility to work with places in Pennsylvania perhaps.

And you're absolutely right, you're on target. I'm not sure NSF is going to make the jump to where Jacques Coppel and some people in Pennsylvania and Ben Franklin and yourself are working—it may be that it's much better addressed at the state level.

I'd like to get Dr. Patel's comment on this because I think it gets down to what we've been trying to talk about in the last bunch of hearings here. It's priorities, every day, priorities come up, priorities. Somebody mentioned the superconducting supercollider—you know, what's the priority between $150 million in Science and Technology Centers, between the mathematical and physical sciences, between SSE——

But if NSF was constrained to 5 or 6 percent, then where should we be on S&T Centers versus solid state, materials, ceramics, this sort of stuff?

Dr. PATEL. I think if our long-term goal is to regain international competitiveness there are two issues we ought to address. One asks the question, what makes for international competitiveness? One is hardware, the other is software. I'll leave the software aside for the time being.

Talk about hardware—everything is made from something. So materials science and engineering is at the fundamental root of our

being able to be competitive. Materials science and engineering includes processing, not only sciences but also engineering. That's where engineering research centers can and do, in fact, provide a very useful—can play a useful role in the scheme of things.

But in all of this, what we will need more than anything else are the appropriately trained people in these activities, as well as in the disciplines which underlie many of these activities, which does include all of mathematical and physical sciences.

From my understanding of what S&T Centers are supposed to do, if I'm given a choice of spending that or making sure that I have the fundamental base of sciences and engineering properly built, I would much rather go with building up that base, making sure that I can provide that fundamental change in people's attitudes on campuses that makes it possible for them to consider manufacturing an honorable profession. Rather than go toward S&T Centers which in fact intend to take the science and engineering activities a lot more toward demonstration, which eventually would have to be picked up by the industry. I would much rather not do it.

Mr. RITTER. Are you saying that the Engineering Research Centers deserve, in your opinion, a higher priority than the S&T Centers, and that there is more to be gained to change the mindset and mentality toward manufacturing out of the ERC than there is out of the S&T Centers?

Dr. PATEL. From what I know of S&T Centers today, whatever I have read about it, I'm led to believe that ERC's is a better direction to go into. I have reservations with ERC's, but those are nothing to do with when we compare——

Mr. RITTER. I might add that the reports of the National Academy of Sciences and the National Academy of Engineering that preceded the Engineering Research Center and preceded the initiation, the onset of S&T Centers, are somewhat different in that there's a far more significant effort that seems to have gone into the underpinnings, the intellectual, substantive underpinnings of the ERC's than the Science and Technology Centers.

You have commented in the past about priorities. You know, where do we go? You've made the comment that manufacturing is not a significant enough part of the federal regime, the R&D regime. Everybody has made that comment here. But no one seems to provide the way out. Is this something that really has to be an industry thing? Is there more that we could do? Dr. Dean, you've been noticeably silent.

Dr. DEAN. Well, I think the problem here is deeper than just manufacturing. I think this country has a difficulty in educating engineers, period, and the problem is that the people that do the education are not engineers and they don't have engineering experience.

Mr. RITTER. But the way, did you read in ASEE Magazine the Byron Pipes, University of Delaware, Dean of Engineering, or was it Technology Review—his comments on the flaws in engineering education, the deep flaws in engineering education in America? I can't comment on it, but he said the direct result of this was manufacturing competitiveness problems in the global economy.

But I'm sorry, please.

Dr. DEAN. And it's product design, too; it's not only how you make it but it's what you make.

Mr. RITTER. Because there's nobody teaching this, virtually.

Dr. DEAN. In general, no. And somehow this country has got to learn to educate engineers. I suggested in my testimony that we must bring engineers back from industry, experienced engineers, and somehow use them in the educational process. And I think the ERC's, the NSF should insist that there be a strong involvement of people from outside if they're going to teach engineering.

Mr. RITTER. I don't think there's any requirement in the ERC—and Dr. Kash can comment on this—for having design processing people come in and actually teach. They will collaborate in the work but necessarily teach. Could we just ask Dr. Kash to comment on the S&T versus ERC question?

Dr. KASH. Let me respond to your last comment, then I want to go to your first question. The NSF cannot require universities to bring in industry people to do what my colleague, Dr. Dean, suggests. That is, no university would accept that; in fact, we'd all write letters to Science Magazine and come in here and insist that you slap NSF's hands for interfering in our business.

The fact is that NSF, in this Engineering Research Center program, really tries to encourage that. But if you tried to put that in any kind of writing, we'd mobilize and attack the town.

Mr. RITTER. You know the irony here, though, Dr. Kash, is that the universities have followed the federal R&D economy to the point where the personnel composition of universities is in a sense reflective not of the private sector but—and the R&D program and the technology advanced program in the private sector—it's much more reflective of what the federal government has been asking for, looking for and paying for over the last two and a half decades. Isn't that true?

Dr. KASH. I think that's quite correct, although it's a very complex process, because if you look at NSF a lot of the definitions obviously come out of the academic community.

But I want to go back to your first question where you asked a very specific one and you wanted an answer about priorities.

Given a 5 percent increase in the NFS budget, where should it go? It should go to the Engineering Research Center programs, to let that program go through to a 25 center level, and be a real experiment. The dollars are not large. We shouldn't launch a science technology program on top of that, and if you are going to make a difference with these Engineering Research Centers, you've got to put enough money into those centers so that they have some catalytic—that's not a good word, I'm told by chemical engineers—so they have some capacity to concentrate enough talent to have an impact. And it is not true that these centers can't be killed.

In fact, it's my understanding that that's implicit in two of them, already. The nice thing about this money is that the way you kill them is you just don't give them new money, and being a recipient of federal money, I know how damned easy it is to do that.

My point is that you've got a program here which is trying to change engineering. Everybody agrees that there are some changes needed if academic engineering is going to contribute to competitiveness. I believe changes are needed within the university itself.

Don't short-change this program. Give it a chance. Come back and look at it a few years down the road, and if you're not happy, kill it. But my god, don't starve it to death before it's ever had a chance to try, and don't launch some new program which is going to fail because it's never going to have enough resources to be tried meaningfully, anyway.

The priorities are that's where you put your money.

Mr. RITTER. Mr. Chairman, I thank you for your indulgence. I will say that I agree with you, the supercomputer centers are going to say the same thing. The basic sciences that Dr. Patel is talking about are the guts of our next revolution in electronics and in photonics. So this becomes nut-crunching time.

I think, if you look around the federal budget in science, there's a $500 million initiative in clean coal, there's what's going to be $100 million this year, but $500 million a year superconduct supercollider. Unless we start setting better priorities, unless people like yourselves can bring us the kind of information that Dr. Breuder is so concerned about, and Dr. Pean and Dr. Patel are so concerned about, we'll go on making the priorities here on a purely political basis, and the science community will be frozen out of that decision.

Thank you, Mr. Chairman.

Mr. WALGREN. I thank the gentleman. And I wish there were more time, but we have to consider these things as sort of opening, or at least conversations that can be followed up on, and we appreciate each one of you being a resource to us on the committee, and look forward to future contact with you.

Thank you very much.

Let's turn to the second panel now on the supercomputer centers. Dr. Clifford Rhoades, the Deputy Division Leader for Computational Physics at Lawrence Livermore Laboratory; Dr. Ken Wilson, Professor of Physical Science at Cornell University; and Dr. Fred Weingarten, the Program Manager for Communications and Information Technologies at the Office of Technology Assessment.

Gentlemen, welcome to the committee. We appreciate your patience, and written statements will be made part of the record, as I said, and please feel free to focus and underscore particular points that you'd like to highlight in the record.

Let's start in the order in which I introduced you to the record, with Dr. Rhoades.

STATEMENTS OF DR. CLIFFORD E. RHOADES, JR., DEPUTY DIVISION LEADER OF COMPUTATIONAL PHYSICS, LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CA; DR. KENNETH G. WILSON, JAMES A. WEEKS PROFESSOR OF PHYSICAL SCIENCE, CORNELL UNIVERSITY, ITHACA, NY; AND DR. FRED W. WEINGARTEN, PROGRAM MANAGER, COMMUNICATIONS AND INFORMATION TECHNOLOGIES, OFFICE OF TECHNOLOGY ASSESSMENT, WASHINGTON, DC

Dr. RHOADES. Mr. Chairman, ladies and gentlemen, thank you very much for this opportunity to come by and speak to you today.

I would like to speak informally from the hard copies of some transparencies that you have in my written material. You will find them after page 8, and it may be useful to follow along from those viewgraph materials.

My primary purpose here today is to be a "fair witness" to the peer review process that NSF asked a number of people to go through concerning the National Supercomputer Centers. And I start off by commenting that in 1987, the peer review process found the National Supercomputer Centers to be very healthy indeed.

I'd like to talk a little bit about the review teams. There were five such teams. Each team was different in membership, but all charged with the same charter to review the centers. Each had six to eight members, plus three advisors and observers from the National Science Foundation, including the program manager, Dr. Paul Rotar, whose background includes being responsible for the supercomputing systems at the National Center for Atmospheric Research.

I have given you the names of the chairmen, since they had to take ultimate responsibility for the reports. Their credentials include: for Dr. Patterson, he's currently in private business as president of Mesa Archival Systems, Incorporated; but previous to that he was president of Cray Laboratories, Incorporated, and for six years prior to that, was responsible for the computing division at the National Center for Atmospheric Research in Boulder, Colorado.

Francis Balint is the deputy chief of the Automation Division for the National Weather Service.

Vic Peterson is the Director of Aerophysics of the NASA Ames Research Center, and in that guise he has the responsibility for two major supercomputing centers, the central supercomputer center for Ames itself, and the National Aerodynamic Simulation Facility.

Dr. Wheeler is Professor of Astronomy, University of Texas at Austin.

My biography is attached as No. 6, but in addition to being a working scientist from time to time, I have been responsible for the operation of two supercomputing centers, one for NASA and the other for the Air Force.

The evaluation criteria I have included as Attachment 2 to this particular report, but let me emphasize the whole issue, that the centers are enabling technologies for the university researchers to do research. The centers don't directly do research themselves, yet the scientific impact of the work done at the centers is the primary thing that the review panels are concerned with; that is, how effective is the center in advancing science and engineering.

There are other issues, like how can the users receive useful and timely consulting support, and the issues of how the supercomputing systems themselves work. Are they reliable? Can they be accessed? What progress is being made in enhancing them and, of course, the usual issues of management, including the ability to administer all of the accounts and to outreach to industry and the users.

Now if you'd turn to the next page, I summarize all of the ratings for all five centers. They range between very good and excel-

lent. I chose here some phrases out of the reports of the various teams.

As you can see, they range from an excellent job of meeting NSF goals to one, the lower comment to the effect that the support of science is excellent. I think that it's a great tribute to the enthusiasm and the dedication of center directors and the many members of their staffs to have achieved such goals.

I consider this a very remarkable achievement. Having had the opportunity to sit on all five panels, I would say that if those panels came and visited the supercomputing centers that I was responsible for, I would not have been able to get a "very good rating", at least not on the first pass, given the criteria.

So they were very effective in assessing the contributions that the centers have been able to make.

Now the second activity concerns the program plan review panel, which is on the following attachment. Since these centers have an aggregate total of approximately $40 million in expenditures, the budget was reviewed in quite great detail, and I suspect that center directors would have rather preferred a visit from the IRS than from us, because we did have to get into a great many details.

I have listed the members of that particular panel with their permission. I have talked already about the first three members. The other three, Mr. Fred Shaffer is the head of the Advanced Scientific Computing Facility at Goddard Space Flight Center. Norm Morse is the head of C Division at Los Alamos National Laboratory, and he has been responsible along with a couple of other people, for the renaissance of computational science that's been going on there, and has at his disposal more people than the total centers program has, and almost twice as much money.

Bill Baumer is program officer for the National Center for Engineering Earthquake Research at the State University of New York in Buffalo.

I mentioned the meetings that were held, both in Washington and each center. The week that I have described, in the middle, was rather a vigorous week, because it involved seeing all five centers in one whole week.

The panel's purpose, of course, was to look very hard at all the numbers to ensure that this amount of money was being properly spent and to understand what could happen in the event of reductions, and where increases should be given, and to assess what amount of funding is really required for this particular program.

Now that all occurred, as I said, at the end of fiscal year 1987. Now, unfortunately, the project that the centers program was able to be given was quite low and, as a result, in 1988, the National Supercomputing Centers are, in my view, in crisis. And the reason is contained on the very next viewgraph.

The fact is that the funding in 1988 is something like 14 to 15 percent below the cooperative agreement level. Now the cooperative agreement level should be viewed as essentially minimum funding, because when you are trying to project what it would cost to develop a program, there are always things that one winds up forgetting.

But the short term problems that this funding cut has caused, I've given as three here. The first is, the poor user access to the facilities.

The National Supercomputing Centers are different from other centers in the sense that they support a national community; that is, they support small researchers, individual researchers throughout the United States, something like 6,000 of them, with access to these centers at the moment, as well as large scale science or larger scale science.

But in order to be able to do that, means that the users have to be able to communicate, either through the telephone or through the NSFNET backbone.

Unfortunately, the funding cut has hit this area very hard because of the fact that the networking facilities are not up to full capability to handle the workload.

The short term problems also include, the lowered staff morale and reduced staff size.

And finally, I come to what I call the longer term problems. If by saturating these facilities, we turn off a whole generation of students and researchers, we are going to profoundly change the way people do business. And for these centers to be successful requires, in my view, a cooperation between the universities, the federal government, and the states, as well as industry. But these reductions or shortfalls will create doubt in the minds of the university, industry and state partners as to the commitment of the federal government.

In the following page, I have graphically illustrated the shortfall in the centers' budget. For fiscal year 1985 you can see there was none, but in 1986, 1987 and 1988, there was quite a bit.

Finally, we come to my recommendations as to steps that should be taken to ensure the viability of these supercomputing centers.

First, I think that the centers need to be funded at cooperative agreement levels that are provided by the NSF's budget request. It would be a shame if the centers weren't adequately funded to enable them to fulfill the promise that they have. This lowered funding has, as I said earlier, the potential for seizing defeat from the jaws of victory.

I also suggest that, in order to allow new and additional facilities, it would be useful to provide dollar for dollar matching for new non-NSF funding, up to about $75 million a year. This would permit the centers to regain the leading edge of technology and also to provide additional leverage of the federal money.

Finally, because we're in the middle of the third year of five-year agreements for most of the centers, the shortfall has resulted in taking the morale and the sail out of the program. I would suggest that the centers' agreements be extended for an additional five years in order to have them have the opportunity to fulfill the vision that resulted in their creation in the first place.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Rhoades follows:]

Prepared Statement of

Dr. Clifford E. Rhoades, Jr.
Deputy Division Leader
Computational Physics Division
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Lawrence Livermore National Laboratory

to the
Subcommittee on Science, Research, and Technology
Committee on Science, Space, and Technology
U.S. House of Representatives
2318 Rayburn House Office Building
9:30 am, March 24, 1988

"An Assessment of the National Supercomputer Centers
and Recommendations for the Future"

INTRODUCTION

The Committee on Science and Technology has heard over the last five or six years from a number of distinguished scientists on the role that very high performance computing plays in scientific investigation and in improving our Nation's competitive advantage. In addition, there have been a number of reports written on the topic. These include:

(1) "Prospects for Computational Physics," sponsored by NSF, William H. Press, Chairman, March 15, 1981.

(2) "Report of the Panel on Large Scale Computing in Science and Engineering," sponsored by DOD and NSF in cooperation with DOE and NASA, Peter D. Lax, Chairman, December 26, 1982.

(3) "A National Computing Environment for Academic Research," NSF staff study prepared under he direction of Marcel Bardon, Kent K. Curtis, Chairman, July 1983.

(4) "A National Computing Initiative - The Agenda for Leadership," report of the Panel on Research Issues in Large-scale Computational Science and Engineering, sponsored by NSF and DOE, Harold J. Raveché, October 1987.

Rather than repeat the substance of these reports, I have attached the recent report by Dean Raveché to my testimony. It projects that new resources totaling $1.5 billion will be required over the next five years.

Before discussing the NSF National Supercomputer Center, there are two points which need to be made. The central thrust of these reports, namely that very high speed computing is important for the advancement of science and engineering, that to meet grand challenges in areas of strategic national importance requires exploitation of leading-edge computational technology, and that our Nation's future economic standing in the world may well depend on our commitment to exploiting the power of computational science is correct. However, while this view is held by the leading lights of the academic, government, and industrial communities, it is not universally held. One has only to pick up the popular scientific press to see critical remarks. Further, the degree of understanding and commitment is limited even where the vision is nominally accepted.

Computational science, as the third mode of scientific investigation along with theory and experiment or observation, is relatively new, dating back no more than forty years to the seminal work of John von Neumann. While it has made significant contributions in several disciplines, such as meteorology, aerodynamics, and nuclear science and engineering, it is still a long way from general, universal acceptance in the scientific community. Even in nuclear fusion, where the National Magnetic Fusion Energy Computer Center under the leadership of Professor John Killeen and Dr. Hans Bruijnes has been of great influence, the acceptance of computational science has been uneven.

Progress in Inertial Confinement Fusion, or Laser Fusion, as it is sometimes called, has been advanced enormously by the computer code (or computer program) LASNEX developed at the Lawrence Livermore National Laboratory by George Zimmerman, while no similarly capable tool has been developed for Magnetic Mirror Fusion. It is interesting

to note that in the last few years vigorous effort was underway to build a Magnetic Mirror Fusion LASNEX, but the Magnetic Mirror Fusion Program was mothballed before the code could be completed.

In my view, the efforts of the Congress and the Executive to embrace computational science and to establish the National Supercomputer Centers are indeed visionary. They reflect great credit and insight on all the participating parties.

EVALUATION OF THE CENTERS

Now, let me turn to the National Supercomputer Centers, sponsored by the National Science Foundation (NSF).

As part of NSF's responsibilities to review the technical and scientific efforts of the five National Supercomputer Centers, the NSF commissioned five review teams to evaluate their scientific impact, user services and training, systems and software, and management. The methods used to conduct the evaluation included telephone interviews with major users and presentations by center management at a two day on site visit. These interviews, presentations, and questions and answers during the visits formed the basis of the review teams reports.

While the evaluations are necessarily subjective, each team seriously accepted its obligation to provide a peer-level review. The same criteria were used in all five cases.

In 1986, a similar peer review process uncovered a number of concerns. While this should not be surprising in view of the embryonic state of the centers' program in 1986, it should make clear that the review panels were fully prepared to review critically the performance of any centers.

The John von Neumann Center was reviewed March 12-13, 1987 under the chairmanship of Dr. G. Stuart Patterson. The Pittsburgh Supercomputer Center was reviewed June 8-9, 1987 under the chairmanship of Mr. Francis Balint. The National Center for Supercomputing Applications at the University of Illinois was reviewed June 25-26, 1987 under the chairmanship of Mr. Victor Peterson. The San Diego Supercomputer Center was reviewed July 1-2, 1987 under the chairmanship of Dr. J. Craig Wheeler. The Cornell National Supercomputer Facility was reviewed July 23-24, 1987 under my chairmanship. In addition, I was a member of the other four 1987 review teams.

I am sure that the National Supercomputer Center directors, in their statements which follow, will provide some objective measures of center performance, such as the number of papers published, talks given and funds raised from sources outside the National Science Foundation. It would be fair to say that the number of papers published is impressive and the quality such that all the center directors are justly proud.

Nearly 6000 university faculty, post doctoral, graduate and undergraduate students, and industrial researchers have received accounts at the centers during he past 2 years. These individuals have come from over 200 institutions, and have been involved in more than 2000 research projects.

Overall, the review teams were very favorably impressed during their site visits. Each center was rated at least very good. The ratings are from those normally used by the NSF, namely "excellent," the highest rating, "very good," "good," "fair," and "poor," the lowest rating. Perhaps it is better to let the review teams speak for themselves. Consequently, in the following five paragraphs, I have selected a few relevant remarks from the reports of the review teams.

Cornell National Supercomputer Facility (CNSF)

"The Cornell National Supercomputer Facility (Theory Center) has become an effective national center with considerable breadth and depth. It is unique in its efforts to implement parallelism both in interactions with its user community and its vendors. Operationally, this center is very good and its support of science is excellent. With the expected renewal of the center in FY 88 and proper long-range funding, it should continue to make outstanding contributions to science."

John von Neumann Center (JvNC)

"The John von Neumann Center has an effective management structure. Its user services are functioning very well. The committee's survey indicated a high level of satisfaction with the quality of help they have received and the responsiveness of the JvNC user services staff. The Cyber-205s are running productively with a rapidly growing user base. Research conducted at JvNC involves a broad range of science and engineering disciplines and multidisciplinary projects. It is also clear that a large number of graduate students are conducting their Ph.D. research using the Center's resources."

National Center for Supercomputing Applications (NCSA)

"The NCSA has done an excellent job of meeting the NSF and NCSA goals for providing supercomputer resources to the academic scientific and engineering community. The facility is at the cutting edge of technology; the scientific visualization program is especially advanced. The environment for fostering interdisciplinary approaches to engineering and scientific research is very good. The widespread Academic Affiliates program, the visitors program, and the emerging Industrial Partners program serve to broaden the influence of the NCSA and advanced computing in general. Now that the transition to full operation has been successfully completed, special attention must be paid to maintaining the excellence while planning for future expansion."

Pittsburgh Supercomputing Center (PSC)

"The PSC is a cost-effective and productive organization, making excellent progress toward the goals of the NSF Centers program as outlined in the Charge to the review team. Given that this center is in the early stages of its lifetime, its overall performance ranges between very good and excellent. There is much opportunity for continued growth if adequate funding from all sources is provided."

San Diego Supercomputer Center (SDSC)

"The San Diego Supercomputer Center has made rapid progress in attaining its initial goal of providing high-quality, well-documented service to the research community. This is due in great part to excellent management and user services. The scientific productivity has been very good as have been the efforts to evolve the operating system and the distributed interactive capabilities. In the future, attention must be given to expanded graphics capabilities and to operations in a saturated environment. The SDSC has been cost-effective in utilizing its funds from the NSF and other sources, and could be expected to make good use of future resources to expand the service."

CONCERNS

The National Supercomputer Research Centers need to be thought of as global entities, running from the individual, often remote, scientist or engineer to the supercomputer hardware itself. This global system has many components. They have to be functioning fairly well for the centers to be very good. They have to be functioning very well for the centers to be excellent.

The major technical issue that appeared in several of the reviews concerned networking and communications. Again, let me quote from two recent review team reports.

> *"NSF and SDSC have succeeded in providing high-quality communications at the Remote User Access Centers (RUAC) sites according to both the Team's and the SDSC's user surveys. This service should not be degraded because of tight budgets. The RUACs should continue to be funded by the NSF until the NSFnet can provide an equivalent or higher level of service."*

> *"NSF should facilitate the connections between individual researchers and the supercomputer centers. For example, NSF should speed the funding of nodes/gateways that are vitally needed and insure reliable effective network monitoring.*

> *"In the transition from 800 numbers (Wide Area Telephone Service) to full network access, NSF should insure that the quality of service to the supercomputer user is not degraded."*

The figure on the next page presents the Centers cooperative agreement funding levels for FY 1985 to FY 1990. To arrive at FY 1989 and FY 1990 cooperative agreement levels, I have extended at level effort those agreements which are set to expire. Also, the cooperative agreement levels in FY 1987 and FY 1988 do not include about $.8 million in networking funding.

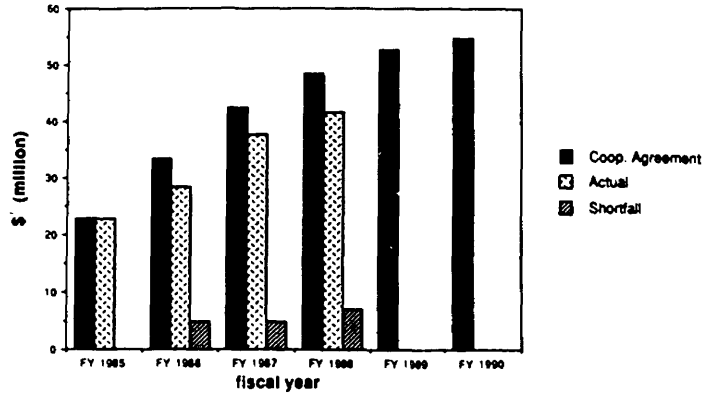
In FY 1988, funding levels are between 14 and 15 percent below the cooperative agreement levels. In FY 1987, most of the cuts were absorbed by delays in equipment installations. With FY 1988, about half the cut could be absorbed by a delay in equipment delivery. The rest will have to be achieved through staff attrition, returning already delivered equipment, and discontinuing communications access.

It should be emphasized that since so many costs are fixed by a mortgage on the equipment it is extremely difficult for the centers to absorb these cuts. It is like moving to Washington, buying a new house and then having your salary cut by 15 percent. It means that half your take home pay has to absorb the cut or you have to sell your home and move into a smaller one. The centers basically do not have this latter option, for there is no such thing as a smaller supercomputer.

The problems that result from reduced funding levels can be divided into two categories: short-term and long-term.

In the short-term, many users will experience poorer access. This results from discontinuing Wide Area Telephone Service (WATS) before the NSFNet and Internet are capable of handling the communications workload. NSF program managers in all

NSF Centers Budget



disciplines can expect many unhappy letters from principal investigators. It would not be surprising for such letters to be sent to the Congress as well. These letters are not likely to be reasoned for it is difficult for users to know where or even what their problems are – they only know they cannot compute! The national character of the centers will erode because local access will be far easier than remote. Unlike most "big science" facilities such as accelerators or telescopes, supercomputer Centers support "little science" throughout the nation. Naturally, a year of poor service will undermine the political support for the centers at the working scientist level.

Even local scientist and engineers, particularly new researchers and students will suffer from reduced staff levels and poorer staff morale. Supercomputing is not a mature science so that new people have to interact with a consulting staff. Even today's supercomputers are not powerful enough to solve problems which the researchers are going to tackle. Thus, it is not unusual to break the system one way or the other. Consultants help the researchers around such problems.

Because disk, mass storage, and other support equipment will have to be returned to the vendor, the remaining storage capabilities will be saturated. In 1987, all the centers showed growth patterns which indicated that the centers' processing power would be saturated before the end of 1987 if not sooner. Consequently, in 1988, even with a reduction in the rate of increase of the number of users due to poor access, the centers will be saturated with work. In the reduced funding environment, it is difficult for the centers to plan any major upgrades. None of the centers include the latest

supercomputers, namely Cray Y-MP/832, Cray-2/Cray-3 or ETA-10, although the John von Neumann center is to start ETA-10 acceptance in April 1988. With the exception of JvNC, no center has more than one supercomputer installed at the present time. There are economies of scale that derive from adding a second supercomputer. To add a second supercomputer to an operational facility is a fairly low marginal cost; funds must be found for the second machine and the incremental staff needed to run it, but these costs are a fraction of the costs required to start the center in the first place.

The long-term problems for the National Supercomputer Centers due to the reduced budgets are twofold. As researchers and students find that they have great difficulty gaining access to the centers and even greater difficulty computing, they will become disillusioned and will adopt other research methods. New work and new ideas particularly suffer in such an environment. As a result, we could lose a whole generation of students.

Rapid transfer of new computational technologies into the private sector will have a major impact on the competitiveness of American industry. The national centers were conceived as nuclei for a new type of partnership between the Federal government, the universities, the states and industry to assure that new technologies can be developed and applied to American industries in time to allow us to remain economically competitive in the global marketplace. Just at the moment when this vision is about to come to fruition, the centers face large budget cuts. We have to remember that they were already highly leveraged and such cuts can only serve to raise great doubt in the minds of the university, state, and industrial partners as to the seriousness of the Federal commitment. Without the core NSF funding, this partnership cannot be fostered. With it, it can!

RECOMMENDATIONS

My recommendations are threefold. The funding levels agreed to by the National Science Foundation and the various national centers should be viewed as the minimum funding necessary to allow the centers to successful. Consequently, I urge the Congress to fund the centers at the Cooperative Agreement levels as provided in NSF's budget request. It would be a tremendous waste of funds already invested if the centers were starved for the necessary funds to carry out their missions.

Because the centers program has been short-changed in FY 1987 and 1988, I believe that additional incentives should be provided in FY 1989 and in the out years to enable the Centers to regain and maintain the leading edge. The incentives would take the form of dollar for dollar federal matching of new funds provided by industry, state, and university. By new funds, I mean additional funding not already included in the cooperative agreement.

Also, I suggest that the existing Centers' agreements be extended for another five years at current core-funding levels. This will allow the time needed to recover from the shortfalls and to restore confidence in the program.

Finally, in all this, we must be mindful that the Centers do not operate in a vacuum. Funding for networking and for the intellectual programs which arise because of the centers must also be found.

CONCLUSION

The Centers are poised to be at the forefront in the development of computational science. The NSF National Supercomputer Centers are already providing supercomputer cycles to university researchers, training new users, and developing new application software.

FY 1988 funding levels have created a crisis, of finance and of confidence. If FY 1989 funding is at the level requested by NSF, if incentives are provided and if the program is extended, I am confident the centers can fulfill the vision which helped to create them.

COPIES OF TRANSPARENCIES

USED DURING

ORAL TESTIMONY

In 1987, Peer Review found National Supercomputer Centers healthy.

Five review teams (6-8 members)

JVNC	Princeton	Dr. G. Stuart Patterson
PSC	Pittsburgh	Mr. Francis Balint
NCSA	Illinois	Mr. Victor Peterson
SDSC	San Diego	Dr. J. Craig Wheeler
CNSF	Cornell	Dr. Clifford E. Rhoades, Jr.

Criteria

Scientific Impact:	How effective is the center in advancing science and engineering?
User Services:	Do researchers receive useful and timely consulting support?
Systems:	reliability, accessibility, enhancements
Management:	staff mix, user administration, outreach

All centers rated between very good and excellent.

- excellent job of meeting NSF goals
- environment for fostering scientific research is very good
- excellent management and user services
- scientific productivity is very good
- operationally very good
- support of science is excellent

National Supercomputer Centers' budgets were reviewed in detail.



The program plan review panel:

Dr. Clifford E. Rhoades, Jr. (chairman)
Mr. Francis Balint
Dr. G. Stuart Patterson
Mr. Fred Shaffer
Mr. Norman Morse
Dr. William Baumer

The meetings:

20-21 August 1987 in Washington
14-18 September 1987 at each center
25 September 1987 in Washington

In 1988, the National Supercomputer Centers are in crisis.

The reason:

- NSF FY 1988 funding is 14-15% below Cooperative Agreement level

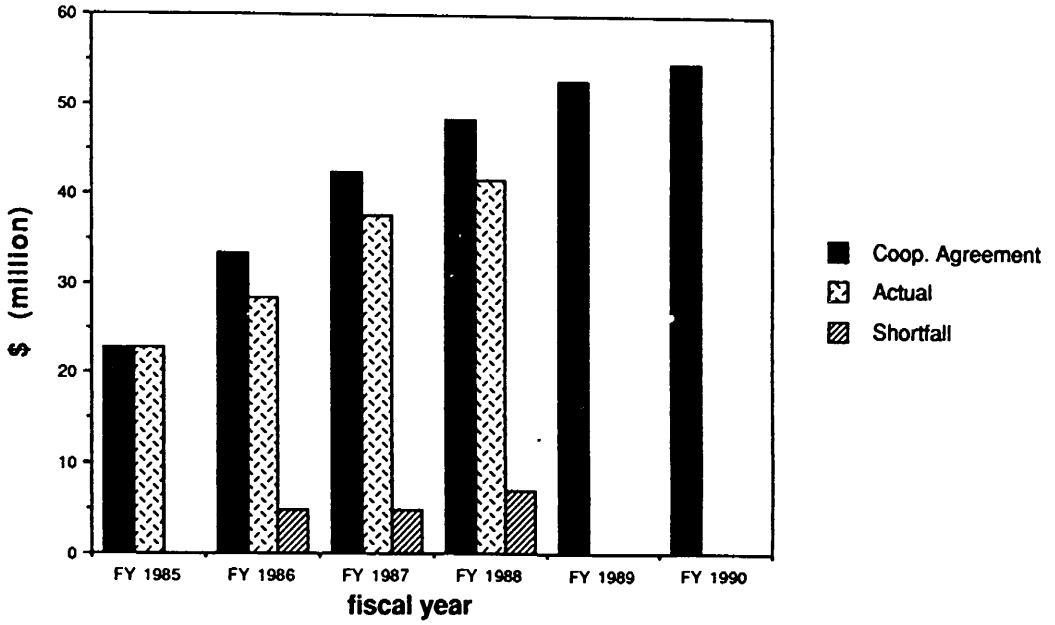
The short-term problems:

- poor user access (communications and networking)
- lower staff morale and reduced staff size
- saturated computing facilities (disk, CPU)

The long-term problems:

- "turning off" researchers and students
- university, state, and industry will doubt commitment of Federal Government

NSF Centers Budget



Recommendations to insure viability of the National Supercomputer Centers:



- Fund the Centers at the Cooperative Agreement levels per NSF's budget request.
- Provide dollar-for-dollar matching for new non-Federal funding (up to $ 75 million/year) to permit the Centers to regain the leading edge.
- Extend Centers' agreements for an additional 5 years.

Attachment 1: 1987 Supercomputer Center Site Review Charge to the Review Team for the National Science Foundation's national advanced computing centers.

Attachment 2: Evaluation Criteria for 1987 Site Review

Attachment 3: Telephone Survey Form

Attachment 4: Cornell Theory Center - NSF Site Review Agenda

Attachment 5: Memo from Paul Rotar re Program Plan Review Panel activities and responsibilities

Attachment 6: Biographical Sketch of Clifford E. Rhoades, Jr.

Attachment 1

1987 SUPERCOMPUTER CENTER SITE REVIEW
CHARGE TO THE REVIEW TEAM

In 1985-86, the National Science Foundation established five national advanced computing centers, with the following goals:

- To create a research environment of high quality for a variety of scientific and engineering disciplines,
- To acquire, install, operate, maintain and provide access to a supercomputer system configured with appropriate hardware and software,
- To encourage computational research which cuts across the boundaries of scientific and engineering disciplines,
- To encourage collaboration among researchers in academia, industry and government,
- To broaden the research community's awareness and involvement in computational methods of research.

As a 1987 review team member, you are requested to evaluate the center's progress during the last year and its plans for the near future. The evaluation will cover: scientific impact, user services and training, systems and software, and management.

Prior to the site visit each team member will contact four researchers who have been allocated resources at the center. The product of the 1987 review will be a report to be drafted by the team members during the closed session at the end of the visit. The chairman will guide discussion during this session and make writing assignments for a draft report to be completed on site. NSF will assist the Chairman in the preparation of the final report. The report should include:

- An introduction pointing out key accomplishments,
- Comments on each of the four evaluation criteria,
- Recommendations to the center for meeting the national research community's needs,
- Recommendations to the NSF for management and oversight,
- A closing statement to draw conclusions

Attachment 2

Evaluation Criteria
for 1987 Site Review

SCIENTIFIC IMPACT

- How effective is the center in advancing science and engineering? Are there citations of scientific results which have been or may be published?
- How are students involved in the center?
- To what extent is the center organized to foster computational research?
- Does the center's peer review board represent an appropriate cross section of disciplines and institutions?
- How effective is the peer review board in allocating resources to the best research projects?

USER SERVICES

- Does the center offer the right variety and quality of software, databases and application packages?
- Have researchers been receiving adequate, useful, and timely consulting support?
- Is the user training offered by the center adequate in terms of availability, variety, quality and outreach efforts?
- How adequate is the documentation available to users, both on-line and off-line?

SUPERCOMPUTER SYSTEM

- Has the supercomputer and related hardware been reliable?
- Have upgrades and enhancements been installed with a minimum disruption of service to users?
- Has the center served its remote users well? Are internal and external network efforts appropriate?
- What have the center's efforts been in the area of operating systems? Are plans for enhancements/UNIX development in place?
- Is coordination with other similar supercomputer sites adequate?

MANAGEMENT

- Is the staffing mix and quantity adequate? What are the plans for additional hiring?
- Are the various components of the center (consortium sites; facility management subcontractor, user services, research institutes, etc.) working well together?
- How effective is the center's administrative interface with its users? Are user accounting procedures adequate?
- What are the center's plans and accomplishments for communication with the research community in the areas of workshops, seminars, newsletters, visitor programs etc.?

Attachment 3

Telephone Survey Form

Name: Phone:

Institution: Discipline:

1. What kind of research are you performing? (e.g., finite element solutions of Navier-Stokes equations, Monte Carlo Quantum Chromodynamics, etc.) What is the impact of your computer codes on the system? (e.g., processor intensive, high input/output, large disk space, etc.)

2. Rate effectiveness of remote communications. E VG G F P
   Hardware. E VG G F P
   Software. E VG G F P
   System Operations E VG G F P
   Comments:

3. Rate the availability, responsiveness, and quality of consulting support. E VG G F P
   Comments:

4. Rate the availibility and quality of training and documentation. E VG G F P
   Comments:

5. Rate the administrative procedures e.g., accounting information. E VG G F P
   Comments:

6. Rate the availability and quality of software e.g., tools, editors, graphics, application packages, libraries.
   E VG G F P
   Comments:

Attachment 4



CORNELL THEORY CENTER
Center for Theory and Simulation in Science and Engineering ■ Cornell University
265 Olin Hall ■ Ithaca, NY 14853-5201 ■ 607/255-8686

NSF SITE REVIEW AGENDA
JULY 23-24, 1987
CLARK HALL, 7TH FLOOR, ROOM 701

THURSDAY, JULY 23

7.00 - 8:15 a.m.	Executive Session, Sheraton Inn (For Site Review Committee and NSF Representatives only)
8:30 a.m.	Welcome, University activities associated with Theory Center - Dr. Joseph Ballantyne, Vice President for Research and Advanced Studies
8:45 a.m.	Overview/Scientific Progress - Dr. Kenneth G. Wilson, Director, Theory Center
9:15 a.m.	Overview of CNSF Facility/Unique Capabilities- Dr. Larry Lee, Director, Cornell National Supercomputer Facility (CNSF) ■ Enhancements during the last year ■ Profile of User Community ■ Features of the CNSF
9:45 a.m.	Computation and Experimental Study of Laminar Flames - Dr. Mitchell Smooke, Department of Mechanical Engineering, Yale University
10.00 a.m.	Break
10:15 a.m.	Large-Scale Computing - Peter Siegel, CNSF Associate Director for Parallel, Vector, and Visualization Support ■ System Features and Utilization Statistics ■ Progress in Vectorization ■ Progress in Parallelization ■ Strategic User Program ■ UNIX

11:15 a.m.	Joint Activities in Parallel Processing - Dr. Kenneth Kennedy, Chairman of Computer Science Department, Rice University
11:30 a.m.	Protein Folding Problem - Dr. Harold Scheraga, Professor of Chemistry, Cornell University
11:45 a.m.	WORKING LUNCH - 701 Clark Hall ▪ IBM, Scientific Computing, and Cornell - Dr. Irving Wladawsky-Berger, Vice President, Engineering/Scientific Computing, IBM Data Systems Division ▪ University Support Activities - Dr. Kenneth King, Vice Provost for Computing and John Rudan, Assistant Vice Provost
1:15 p.m.	Relativistic Stellar Dynamics on the Computer: MOVIE II - Dr. Stuart Shapiro, Professor of Physics, Cornell University
1:30 p.m.	Visualization ▪ Introduction - Dr. Donald Greenberg, Director, Computer Graphics, Cornell University ▪ Central and Distributed Graphics Support - Judy Warren, Acting Manager of Graphics and Workstation Support ▪ Advanced Graphics Research - Donald Greenberg ▪ Presentations by: Dr. Gene Dykes, Senior Research, Associate Computer Graphic Program Thomas Tysinger, Ph.D Candidate, Mechanical & Aerospace Engineering Dr. John Abel, Professor, Civil & Environmental Engineering
2:30 p.m.	Break
2:45 p.m.	Overview of Center Staffing - Janice Abraham, Assistant Director for Finance, Theory Center
2:55 p.m.	Allocations Committee - Dr. Ravindra Sudan, Chairman, Allocations Committee; and Deputy Director, Theory Center
3:15 p.m.	Access/Networking - Alison Brown, Associate Director of Networking and Advanced Computing

3:45 p.m.	CNSF Outreach/Smart Nodes - Elizabeth Schermerhorn, CNSF Assistant Director for Outreach and User Support • Introduction to Smart Node Program • Smart Node Panel
4:15 p.m	User Support Programs
4:45 p.m	Perspective of Computer Policy Subcommittee - Dr. William Buzbee, Chairman, Theory Center Computer Policy Subcommittee; and Director of Scientific Computing Division, National Center for Atmospheric Research
5:00 p.m.	Supercomputer Graphics and Complex Analytic Dynamics - Professor John Hubbard, Math Department, Cornell University
5:15 p.m	Adjourn
5:30 p.m.	Reception - A.D. White House - opportunity to speak with Cornell CNSF users as well as Directors of other interdisciplinary research centers on campus
7:00 p.m.	Dinner - 701 Clark Hall - Ken King, Host ▪ Before Dinner Talk • James A. Cannavino, President of IBM Data Systems Division - IBM Large Systems and Cornell ▪ After Dinner Presentations • George O'Leary, President and Chief Operating Officer, FPS • Kenneth Wilson - Electronic Structures (subject to time availability) • Larry Brown, Associate Professor, Geological Sciences - Seismic Modeling

FRIDAY, JULY 24 (For Site Review Committee and NSF Representatives only)

7:30 a.m.	Breakfast at Sheraton
9.00 a.m.	Executive Session - 701 Clark Hall

REVISED 7/22/87
LM:JLM

Attachment 5

NATIONAL SCIENCE FOUNDATION
Division of Advanced Scientific Computing

MEMORANDUM

Date: June 17, 1987

To: Members of PPRP

From: Paul Rotar, Program Director for Centers

Subject: Program Plan Review Panel (PPRP)

This memorandum is to explain the details of the Program Plan Review Panel's activities and responsibilities.

The PPRP will meet once in August and once in September. It will assist with the difficult problem of equitably handling the FY88 center budgets and will provide advice on the best distribution of the available funds. By July 1, all of the centers will have submitted a program plan and budget for FY88 which will be mailed to PPRP members before the meeting. The budget levels will be consistent with each center's Cooperative Agreement with NSF. The centers should clearly flag any proposed FY88 items that go beyond the current cooperative agreements and any new projects which will have out-year implications. Each PPRP member will be asked to concentrate his efforts on one center as a "Primary Reader" but will also be encouraged to read all plans and budgets for comparison purposes. As Chairman, Cliff Rhoades will be familiar with all five Program Plans. The PPRP will compare budget requests and the capabilities of each center in light of the expected FY88 funding and will also discuss each center's budgetary tradeoffs with the center's management.

The first meeting of the PPRP will be on August 20-21 '87 here at NSF. On the first day each center director will be asked to make a 1 hour presentation on the center's FY88 program plan and budget. This will be followed by a half hour Q and A session by the panel members. On the second day, which will be closed to all except NSF staff, the PPRP members will compare the program plans, budgets, proposed FY88 items beyond the scope of the cooperative agreements, and the projections for use of the centers in FY88. They will estimate each center's ability to provide the necessary services based on the plan, budget, availability of funds (all sources) and service projection. From this estimate they will prepare a document recommending an appropriate funding level that supports each center adequately, and does as much as possible to keep all the centers at the leading edge of supercomputing technology, including staff, hardware, and software. The appropriate sections of these preliminary recommendations will be forwarded to each center shortly after the meeting.

It will be necessary to visit each center after this first meeting to clarify its position and to insure that the center's management understands the views of NSF and the PPRP. A subgroup of the PPRP consisting of the Program Director for Centers, The PPRP Chairman, and the primary reader will visit each center for one day on the following schedule:

CENTER	VISIT DATE	NSF ATTENDEES
CNSF	Sept 15	Paul Rotar, Cliff Rhoades, Norm Morse
JVNC	Sept 14	Paul Rotar, Cliff Rhoades, Fred Shaffer
NCSA	Sept 17	Paul Rotar, Cliff Rhoades, Fran Balint
PSC	Sept 16	Paul Rotar, Cliff Rhoades, Stu Patterson
SDSC	Sept 18	Paul Rotar, Cliff Rhoades, Bill Baumer

Please let me know if these dates are problems for you.

The PPRP will meet again at NSF on Sept. 25 to finalize the funding recommendations and the priorities needed to handle variations, both up and down, from the expected DASC centers funding level. This session will be closed to all except NSF staff. The results of this meeting will be communicated to the centers. The Program Director for Centers will consider the final findings of the PPRP and will present recommendations to the Centers' Subcommittee of the DASC Program Advisory Committee at the November meeting.

An additional responsibility of the PPRP at the Sept. 25 meeting will be to discuss and review a proposal from the San Diego Center to upgrade its supercomputer systems, including a building enhancement, additional labor, and a 3-year extension to the current SDSC/NSF Agreement. You will be provided a copy of this proposal at the end of the August 21 session, along with rating forms. All panel members should read and rate this proposal.

Attachment 6

CLIFFORD E. RHOADES, JR.

Clifford E. Rhoades, Jr. has been Deputy Division Leader of the Computational Physics Division at the University of California, Lawrence Livermore National Laboratory since November, 1985. Prior to his current duties Dr. Rhoades was Chief of the Computer Systems and Research Division at National Aeronautics and Space Administration-Ames Research Center where he was responsible for computer science research as well as the operation of the Central Computer Facility consisting of a CDC Cyber 205 and Cray X-MP. Prior to his assignment at Ames, he was Associate Division Leader of the Theoretical Physics Division at Livermore.

During the 1985-1986 period he served on the Theoretical and Computational Advisory Committee of Los Alamos National Laboratory. In 1987 Dr. Rhoades chaired both the Program Plan Review Panel and the Cornell Theory Center Review Panel for the National Science Foundation's Division of Advanced Scientific Computing .

Dr. Rhoades did his undergraduate work at Rensselaer and received his Ph.D. in physics from Princeton in 1971 under Prof. John A. Wheeler.

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3/88

Mr. BROWN [presiding]. Thank you, Dr. Rhoades.

Dr. Wilson.

Dr. WILSON. I would first of all like to say that I come from what has been referred to here as a scientific elite. I have many of the views of that elite. I still have some of them, but my period as Director of the supercomputing center at Cornel has been an enormous education for me personally in many of the issues that have discussed throughout the day here.

I detect a note of pessimism in the discussion which is not warranted. The best way to find that out is to try to buy a house anywhere near Boston. I don't think that if you are in Massachusetts, and you didn't see things that were happening in Detroit and Ohio and places like that, you'd wonder what all the fuss was about; where if you were to visit Digital Equipment Corporation and look at the development of their bottom line, you would again wonder what the fuss is about.

It seems to be clear that in Route 128 we have an example where the scientific elite of this country is breeding extraordinary economic development and the difficulty we have is we haven't learned how to export that experience to other parts of the country.

It is not that the scientific elite is in any way disconnected from economic development. It's just that we haven't learned how to spread that in a good geographical fashion.

In fact, I am in the process of moving from Ithaca, New York to the great state of Ohio because it's my sense that the commitment to try to achieve economic growth through science is higher in Ohio than almost any other part of the country at this point, and I want to be part of that process.

Let me come to the issues related to the supercomputer centers. First of all, I want to talk about the supercomputing centers mean in terms of science itself.

It is clear—my experience as a supercomputing director has strongly confirmed this—that the whole role of computation in science is creating a third mode of scientific activity.

We have some 6,000 scientists, many of whom are students working at the centers. They are building careers around the availability of supercomputing, and they are spending several years of their lives accumulating the skills that are necessary to use supercomputers effectively.

This is not something that you can walk up to, spend an hour doing a computation, and go back doing traditional type scientific research. It's just not possible.

In studying the scientific opportunity in supercomputing that is available across every discipline that the NSF studies and supports, it is clear that there is a long term scientific opportunity extending through centuries that is awesome.

In fact, in the earlier stages of my career working in more conventional areas of theoretical science, I had no realization that scientific developments were going to continue for centuries beyond the 20th Century.

But, what is happening is that with the help of instrumentation like supercomputers, scientists are starting to focus on the properties of systems as opposed to asking what systems are made of.

Systems might be a protein. How does an entire protein unfold to become biologically active, instead of asking what are the units out of which a protein is made?

To pursue the scientific opportunity requires different organizations, and to my mind, the science and technology centers, which will in large measure be modeled after centers which already exist, such as at Cornell where we already have over 20 centers that could qualify to be science and technology centers, will be one of the principal organization mechanisms by which the new scientific opportunity is pursued. Because systems are not typically studied by a single investigator with two graduate students.

I have become much more aware of the scientific opportunity. In fact, I have characterized them as a set of grand challenges which will not be solved in the next year or two. Some may not be solved even in this century.

But, in areas like the nature of the chemical bond, turbulence, and of course, outside the traditional scientific areas, we have the whole question of, for example, the global economy and understanding how it works.

I could give you a long list; but, I can tell you that there is going to be a growing scientific effort surrounding these areas, especially as instrumentation like supercomputers gets powerful enough so that we begin to see real breakthroughs in these problems, rather than just progress such as it typifies what's happening at the supercomputer centers today.

What I've also become aware of, especially in the industrial directions which have developed as a result of being director of the center, is we are going through a truly revolutionary period at this time.

One of the previous speakers alluded to the problem that none of the companies he dealt with had plans for three years down the road.

You can't plan in a revolution. It's not possible. In fact, you have to plan, in order to allow people to go in strange directions, and this is a period where entrepreneurship and people willing to push forward even with no plans is what this country depends on.

And, one of the things I like about Ohio State is that there is very much that spirit present at the university at this time.

Let me talk about the issue of disciplinary reach. What we found at Cornell, in the Cornell supercomputing center, we originally planned to have scientific programs part of the center's operation.

But, we found that the disciplinary reach of the supercomputers was so broad that we would narrow our focus too much if we built actual scientific programs in the center itself.

Instead, we have evolved to a mode of what I call a center of centers, where we help whole centers get formed to treat different problems, as I say, in the system—Centers which will have to develop and grow on their own. We just help them get started. For instance, there are eight proposals from Cornell to the science and technology center program, and most of them have interacted with us in some way, programs in new materials all the way to a program in economic and social sciences to study some of the economic and social impacts of technological advance.

When we get our building, which is going to get underway this summer, we would expect to use our space in the building to further help new programs get started, and then they would have to find their own space.

In our industrial outreach program that is part of the Theory Center, this has become an industrial outreach program on behalf of the entire university. It is not restricted to supercomputing because we figure any program in the university is going to use supercomputing some day.

Obviously from what I've said, I am a strong supporter of the science and technology center's program. I believe it is a principle mechanism of exploring the scientific opportunity that one can see related to supercomputing, and one of the special benefits of that program is, as has happened with the supercomputing program and has happened with the microelectronic centers programs, many of the people writing those science and technology proposals do not expect to be funded by NSF.

They simply need the legitimization of an NSF program so they can get other sources of funding for their projects. I repeat, many people who have submitted proposals to NSF do not expect to get funded, but to kill that NSF program would kill many alternative sources of funding for those proposals.

Let me come to competitiveness issues. Computers are clearly the engines of industrial progress. And, more powerful computers are going to be more powerful engines of industrial progress.

One of the big achievements of the NSF center's program has been the return of IBM to the supercomputer arena. And, I remind you that the announcement of IBM's entry in the supercomputer business, namely the 3090 with Vector boards, took place after IBM and Cornell formed a partnership to be an NSF center.

I can not speak for IBM, but I can speak for my own observations that that partnership put incredible pressure on IBM to announce that product.

Since that partnership was formed, IBM has gone well out of their way, both in terms of accelerating schedules for products and in terms of building new programs that were needed to support Cornell.

Cornell has a major software product in parallelism from IBM that was designed to Cornell's specifications, directly coming out of the Cornell program in its emphasis on parallelism. And, that product is now available in a preliminary fashion to other IBM customers and will become part of its mainstream parallel offer.

At the present time, IBM has designed an upgrade for Cornell from six processors, the 3090-600, to 12 processors. Again, as part of its mainframe product development efforts, its mainframes provide the basis for much of the production engineering work that takes place in the U.S., throughout U.S. industry.

The products that are being designed for Cornell become available to all IBM's commercial customers as part of a $10 billion product line.

It is extraordinary that a university has the kind of access that we have to that product development team. Extraordinary.

But, IBM is prepared to deliver its upgrade to Cornell some time this summer. The day that that is delivered is already being de-

layed because there has been no decision at NSF whether to support that upgrade.

We have this fantastic arrangement with IBM, but that arrangement is in severe danger at the present time because, in fact, even in the 1989 budget, if fully approved, there is no money designated for that upgrade.

It is incredible that OSTP is considering a $1.7 billion program to advance supercomputing and networking in the U.S. at the same time that less than $10 million is needed for this relationship with IBM to continue.

Let me talk about the relationship of the NSF centers to university computing, an exceedingly important area.

The National Center, and let me say that I'm speaking fully cognizant of the fact that at Ohio State, I will be involved with a fully state funded center. It is not a national center, does not even have Federal funding.

First of all, the NSF centers are critical to set the standard for the high end of computing for the entire university system.

We have an expert staff which is—there's no question that Ohio State will try to duplicate that staff, and my wife is already starting recruiting, but it will be very difficult to match the quality that we have at Cornell or the other centers.

We set the standard in terms of large memory. The IBM machine came in with 64 times the memory of the Cray-1; 64 times. Competitive with the Cray-2.

The systems that are being touted as minicomputers cannot reach that level of memory; mass storage. And, it was critical to the original plan that the centers would be frequently upgraded as the technology itself got upgraded. It's time to do it.

The centers play an extremely important role in providing training to the university community. And, that training is heavily valued by universities around the country, as we know from our interactions with over 40 universities that are in partnership with Cornell around the Cornell center.

We provide democratic, nationwide access that is not duplicable by university centers because it will not be democratic.

The NSF support of the five centers is irreplaceable in our dialogue with the vendors. The weight that the—the impact that we have in IBM, because we have the NSF behind us, is enormous and there is none of the 30 universities that have 3090's can have anything like to impact that we have in IBM because they don't have that rubric.

The evaluation for NSF for excellence, we're just as burdened as the engineering research centers are by those constant evaluations.

On the other hand, it is perfectly obvious that university computing centers, including Cornell, suffer severely because they do not go through that evaluation process.

It is absolutely vital that, at the top of the whole university computing system, you have centers that are evaluated, that are in competition, that have to maintain excellence.

The university centers can just fall in decay, and partly because there's nobody giving them that kind of evaluation.

The centers serve as a showcase to the world market of U.S. supercomputing projects. I mean, we have constant streams of visi-

tors from Austria, from Sweden, from England, from Italy, from France. You name it. Let's keep the showcase looking good. Given the current funding picture, I would be embarrassed to continue those shows beyond about six months from now.

Let me give you a couple of warnings. First of all, the National Science Foundation funded, or helped fund, university computing centers in the 1960s. That funding was dropped as one of the first responses to the difficult funding picture that developed in the 1970s. The computing centers have gone into decay. Not, of course, uniformly. There are always exceptions. But they fall behind technologically.

They have converted mostly to supporting administrative instructional computing, rather than research computing. One can go on and on. Let's not make the same mistake again of starting an excellent program and then dropping it.

Secondly, an even stronger warning. U.S. supercomputer technology stood stock still. It did not advance one iota between 1976 and 1984. The Cray-1 was the supercomputer, without competition, in 1976. Up until about 1983 or 1984, the Cray-1 was still the supercomputer, with essentially no competition. And that's what allowed Japan to get into the market. They were given eight years free and clear to build up their program.

Now we have competition. Cray has announced a whole succession of products to be coming out over the next two or three years. CDC through ETA Systems is trying to make a comeback. And IBM has entered the market. It has a strong product right now, especially in its memory system. And it has made moves, such as its support of Steve Chen's start-up company, to make it clear that it intends to be in the market for the long haul.

But the NSF centers are critical to maintaining the pressure for advances in U.S. technology, instead of just folding up our tents and starting to buy everything from Japan. Let's not let that happen again, that eight years of no advancement.

We can see the importance of the national centers, even though they compete with other universities, and the reaction of universities around the country to the program. The response and helpfulness of people at universities around the country to Cornell's program, of providing people who help consult on the Cornell system, for people on their campuses. We have over 40 consultants scattered around the country who are just helping people access Cornell.

That tells you how important Cornell is to those universities. I was astounded at the amount of support and help that we're getting from universities around the country, and the participation in our training programs, and assisting people to access our system and so forth.

Finally, let me talk to you about the relationship to the total NSF budget. We have over 6,000 users of the centers, from every discipline supported by the NSF. Many of them have NSF grants, mostly small grants of the kind that lots of people have been singing praises of. The supercomputer centers are engaged in small science, rather than big science, according to the traditional definition of the distinction.

Cutbacks in the total NSF budget mean cutbacks for our users. And cutbacks for our users means that we are less productive as centers. Do not take money from those users and put them into the centers, please.

There is discussion of scientific priorities. I am not going to sit here and say that you should take money from Phil Anderson to put into the centers program. That would be absurd. What I do say is that, first of all, the full budget request that NSF has asked for should be supported and that the centers have to take their lumps along with everybody else when you cut back from that full budget. There is no other way you can rationally do it.

But, if that full budget does get supported, then it is my belief that the centers are so extraordinarily successful that some money should be found so that, in particular, the most crucial upgrades can take place. And, as Dr. Rhodes has suggested, I think matching money is the right way to do it.

Furthermore, there needs to be planning beyond 1989 because upgrades, such as our upgrades, the 6 to 12 processors, has to be amortized over several years, and we have no indication from NSF that they are prepared to support the amortization beyond 1989.

On the total budget, let me remind you there are terrific stresses on that total budget that have developed over the last 20 years and that have simply not been taken care of in terms of budget increases for NSF.

Geographical distribution of the university base. Lots of people, good quality researchers, were trained in the 1960s at the small number of institutions that were functioning in the 1960s, and they now have become part of the research base all over the country, like at Ohio State. The NSF budget has not risen to support that geographical expansion of research, all the engineering programs which have developed in the last 20 years. It's a very important part of the NSF effort, but the budget hasn't increased to support that.

Huge increases in the cost of instrumentation. And, of course, that instrumentation is essential to the progress of science as well as to competitiveness.

And the demands on universities due to the growth of industrial R&D. How can we have essentially flat budgets for NSF and support the incredible growth in industrial R&D? It's not possible.

So, Mr. Chairman, I conclude by saying that I believe that the NSF centers program was a program of extraordinary risk and extraordinary opportunity when it started. I believe the risk has now gone. I think the success of the program is incredible. It's time to put more support into that program. And I believe that the centers program will have major impact on the future, not just the U.S. economy but the global economy, through the traditional route of extraordinary science leading to entirely new engineering professions and new engineering knowhow, which is what the engine of progress is built on.

Thank you.

[The prepared statement of Dr. Wilson follows:]

Prepared Statement of

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to the

Subcommittee on Science, Research, and Technology
Committee on Science, Space, and Technology
U.S. House of Representatives
2318 Rayburn House Office Building
9:30am, March 24, 1988

"Report from an NSF National Supercomputer Center Director"

In 1984 I was one of the strongest supporters of the plans for the NSF National Supercomputer Centers, testifying before Congress and participating in major panels on the subject. Since 1985, I have been the Director of the Cornell Theory Center which houses one of the five NSF National Supercomputer Centers, namely the Cornell National Supercomputer Facility. I have now resigned my position as Director, effective August 1 of 1988, in order to pursue my research and become a full-time supercomputer user. I will be based at the Ohio State University while my wife is Associate Director of the Ohio Supercomputer Center - a state-funded facility with no Federal support that will shortly house a Cray Y-MP. I am happy to have this opportunity to give my perspective on the state of the NSF National Centers three years after their establishment and at the end of my own term as a Center Director.

The NSF Supercomputer Centers have, I believe, become an extraordinary success, in certain respects astoundingly so. Their impact on science is, in fact, more revolutionary than I had understood when I was advocating them.

The users of the Centers come from virtually every discipline supported at the NSF, including mathematics; physics; chemistry; biology, all the engineering disciplines; economic and social sciences; and more. They recognize that effective supercomputer usage is not easy. The building of working software, the analysis of errors in numerical approximations, the speeding up of computer programs to run efficiently, and above all, the selection of problems and parameter sets that are worth computing are all challenging and time-consuming efforts. Many of the thousands of scientists using the Centers are building their own careers and training their students under the assumption of continued availability to them of supercomputing; they are devoting years of their lives to building the novel set of skills needed to use supercomputers effectively. At the same time these scientists are often engaged in conventional theoretical or experimental research; they often have NSF grants for funding of summer salaries, graduate student stipends, and instrumentation to support both their conventional research and their use of supercomputers.

The Centers required a year to two years for their initial buildup of staff and equipment, and the establishment of reliable remote access and consulting arrangements. It is astonishing how rapidly and effectively this buildup has occurred. In many respects the Centers already provide an accomplished professional operation; there are already many research results and published papers from users of the Centers as a consequence. The staff of the Centers is an extraordinarily talented mix of people who are dedicated to helping users achieve the most productive use of Centers' resources despite problems ranging from graphics to remote access. Users' problems are becoming increasingly complex as users go beyond simple logon procedures and start to challenge the full capabilities provided by supercomputers - in parallelization, vectorization, graphics displays, and more.

The frequent and heavily demanding reviews of the Centers by the NSF have been important in ensuring the Centers' high quality. However, the current budget cutbacks have put a very severe strain on the Centers' staff just to serve users' needs. It is important now that they be given some respite from the constant pressure to take time out from their workload in order to prove that services continue to be of high quality.

There are many examples from every one of the Centers of scientific achievements of the users, as you will learn in testimony from the Center Directors. I will focus on the overall impact of the supercomputer program on science. To me, one of the most startling features of the supercomputing program has been the vast extent of the scientific opportunity opened up by supercomputing, how difficult it is to pursue this opportunity, and how different the practice of research is on a supercomputer ("computational science") from either experimental or theoretical science. Truly, computational science is a third mode of science distinct from experimental or theoretical science, as illustrated by the challenges faced by all computational scientists, from software reliability to the building of accurate computer models of natural phenomena. None of these tasks are part of either experimental or theoretical science.

I like to characterize the scientific opportunities being opened up by supercomputers as a set of Grand Challenges which many of the Centers' users are pursuing. These Grand Challenges, when fully solved, will have the same impact on science and technology that the discovery of Newton's Laws of Mechanics or the discovery of the atom has had. However, it will take a sustained effort in both scientific research and supercomputer technology to achieve a full and fully reliable solution to any of the Grand Challenges. Anyone who claims these problems are already solved or are about to be solved is suffering from the unjustified optimism that is both necessary to sustain many computational scientists in their research and yet infuriates more traditional scientists who know that this immediate optimism is unfounded.

Some of the Grand Challenge areas that I have identified in research by users of the Centers include:

- The billion year life histories of astronomical objects such as planets, stars, galaxies, black holes, and the Universe itself.
- The folding of proteins, which provides the molecular basis for life itself.
- The nature of the chemical bond.
- Turbulence.
- The Global environment (the Sun, Air, Sea, Underground).

and challenges outside traditional scientific areas such as:

- Full computer-aided design, Engineering, and Manufacturing.

- The Global Economy.

There is not enough space for me to describe these challenges in detail; undoubtedly the Congress will be hearing more about Grand Challenges in future.

The Centers have truly spectacular interaction with industry; a prime example is Cornell's technology exchange with IBM's mainframe and supercomputer design group in Kingston, New York. This design group is responsible for the IBM 3090 mainframe line and its successors. These mainframes play a crucial role in many large production engineering groups throughout U.S. industry. In other industrial interactions, the National Center for Supercomputer Applications has million-dollar-a-year programs with Kodak, Motorola, Amoco, and Eli Lilly. Other Centers (including Cornell) have successes at lower levels.

About the time the NSF program started, supercomputing technology started to advance rapidly. This advance followed almost eight years (1976-1984) when the U.S. stood still with the Cray-1 while Japan made great strides in establishing supercomputing products from NEC, Fujitsu, and Hitachi. Now a succession of future advances from Cray have been announced: the Cray Y-MP, the Cray 3 and the Cray 4; ETA Systems has a hot machine with software a-building. All of these machines are likely to be heavily challenged by Japan. Meanwhile, IBM has reentered the supercomputer market with an industry-leading memory system: 64-times larger than the Cray-1, comparable in size and much easier to use than the solid state disk on the Cray X-MP, and competitive with the Cray 2 (which is not available at any NSF Center). Furthermore, IBM has been pursuing parallelism in large scale computation since the early eighties and now has what I consider to be industry-leading software for parallelism on display at Cornell. Very recently, IBM announced a plan to support Steve Chen's startup supercomputer company, Supercomputer Systems, Inc. The software in use at Cornell could prove critical to the success of Chen's machine.

The Centers have become a crucial resource for the training of students, especially those who will join the most technologically skilled part of the U.S. workforce. Many of the 6000 users of the Centers are students. Undergraduates gain access to the Centers, often as junior members of research teams; they are invaluable at handling tasks like computer graphics displays.

The Centers have established close ties, more effective than I expected, with many of the U.S. research universities. Often a local consultant helps users access several of the National Centers. The National Centers are recognized on many campuses as providing critically needed high-end supercomputing resources while a hierarchy of machines on campus, from PCs to mainframes, cover less demanding needs. The NSFNet is gradually establishing effective computer links between campus facilities and the National Centers; meanwhile, dial-up 800 numbers (currently being discontinued due to NSF budget cuts) have enabled reliable access to the Centers by users from every corner of the U.S.

The NSF Centers face a severe problem now despite their success. Namely, their development to full maturity as supercomputer centers is

being stunted by lack of adequate budgets. This problem has been present since about the second year of the program but became truly acute in 1988. The continued successful growth of the Centers has eclipsed current budget levels so that the budget cuts of the December Summit have had more severe effects that cuts of previous years. Even more demoralizing is the lack of any funding for supercomputer upgrades in the President's budget request in 1989.

The vision for the Centers in 1984 was that they would play a dual role in supercomputing. One role would be providing supercomputer access to scientists throughout the nation, helping the third mode of science to grow in importance. But I saw another, equally important, role for the Centers as an early market for new U.S. supercomputer technology - encouraging supercomputer manufacturers to be bolder in advancing their technology in order to meet the demands of the university users. The supercomputer Centers would demonstrate U.S. supercomputer technology to the world, would use their experience to advocate further technological advances, would help the manufacturers find and fix problems in hardware and software, and their user base would be a source of new software. In return for these services, it was my expectation that considerable cost-sharing would be available to the NSF Centers from the manufacturers. But this whole concept depended on the NSF Centers being among the very first customers for upgrades from the U.S. manufacturers of supercomputers.

By providing this early market, it was my hope that the terrible period 1976-1984, which saw NO ADVANCE in U.S. supercomputer technology and allowed Japan to catch up with us, would not be repeated. Meanwhile, it was also my hope that the Centers would ensure continuing access of U.S. university researchers to state-of-the-art supercomputing as this state-of-the-art advanced, and moreover that these advances would be more rapid as a consequence of this access.

Another purpose of the plan was to encourage universities in the U.S. to maintain their own scientific computing facilities (from PC's to mainframes, and in some cases, campus or state-wide supercomputers) close to the state-of-the-art, driven by demands from scientists familiar with the National Centers. The NSF supported campus-wide facilities in the 1960's but after this support was withdrawn, campus computing centers fell well behind technologically and often served mostly administrative and instructional needs rather than research needs.

Three years after the founding of the Centers, all these hopes have been realized. The Centers have state-of-the-art supercomputers, supercomputer technology in the U.S. has been advancing rapidly, major leverage of NSF funds has been achieved, and universities throughout the country have been upgrading their own facilities for scientific computing. But, for the Centers to continue their success, the overall plan has to be adhered to and it is now time for upgrades at the Centers. Cray Research starts deliveries of the Cray Y-MP in 1989 and the Cray 3 is on the horizon, yet to my knowledge, no plan exists to equip any Center with either a Y-MP or Cray 3. Princeton's upgrade to an ETA-10 is set. Cornell's need for an upgrade is most urgent; IBM is ready to supply Cornell with an upgrade from six processors to twelve processors sometime this summer. Unfortunately, NSF has not agreed to any cost-sharing plan for this upgrade and the

installation date has already been delayed as a result. Cornell's interaction with IBM has been the most successful of any of the Centers in both cost-sharing and technology transfer, but this interaction could wither if Cornell is not able to obtain IBM's top-of-the-line system and it is installed elsewhere instead.

Cornell and IBM formed a partnership, also including Floating Point Systems, to bid for an NSF Center even before IBM decided to reenter the supercomputer market. The partnership was committed to explore parallelism (multiple computing processors acting in parallel) as a route to greater computing power based on research inside IBM led by Enrico Clementi using Floating Point Systems equipment. Major cost-sharing was arranged for the partnership: for 1985-1988 the figures were

NSF	$21.9 million (just over 30% of the total)
IBM	$30.6 million
State of NY	$13.2 million
Cornell	$ 6.3 million

These figures include IBM's initial supercomputer - the 3090-400 with four vector boards, a complete set of peripherals, and full maintenance; this product was delivered to Cornell in October, 1986. As part of this plan, IBM has eight staff in residence at Cornell and there is a constant flow of people and information between Cornell and the numerically intensive computation group within IBM that is responsible for scientific and engineering computing based on the 3090 product line.

In June, 1987, IBM delivered to Cornell a major software package to support parallelism, designed to Cornell's specifications following a year of testing of previous software. This package was prepared by IBM's mainframe design group; following a period of testing at Cornell it is on its way to becoming a standard product offered by IBM and is already available on a limited basis.

In July of 1987, IBM upgraded the Cornell system to their new top-of-the-line, a 3090-600 with six vector features. IBM brought in the upgrade at no cost to the NSF; the estimated value of the upgrade was $7 million. NSF provided $200,000 in matching money (3% of the IBM contribution) for staff growth associated with the upgrade.

Experiments at Cornell in parallelism have shown an urgent need for more processors to obtain greater gains from parallelism. Cornell and IBM have agreed on a plan to increase the number of processors at Cornell from six to twelve. With encouragement from NSF, Cornell pressed IBM hard to meet an early delivery date for a second 3090-600 to be coupled to the existing 3090-600 thereby forming a twelve-processor system. IBM will be ready to deliver the second 600 sometime this summer. In fact, throughout the history of the partnership, IBM has repeatedly accelerated its internal development schedules to meet Cornell's needs. The result was always earlier availability of IBM's supercomputing products for the academic and commercial markets, not just for Cornell. Since IBM now has a large number of supercomputer systems installed world-wide, the interaction with Cornell has considerable leverage.

Unfortunately, following the December Budget Summit, all plans at NSF to encourage supercomputer upgrades, including at Cornell, vanished. There is no money in the proposed 1989 budget for NSF to support upgrades. There is currently no plan at NSF (known to me) to enable amortization of upgrades into the following years. IBM is likely to place its initial coupled 600 system elsewhere despite the critical role of Cornell in initiating the coupled system project. At the present time Cornell, from President Rhodes on down, is looking for a way to continue the extraordinary collaboration that has been established between Cornell, IBM, the State of New York, and the NSF; the coupled 600 project is essential to building on the previous successes of this collaboration.

Any signal of an ability from NSF to help Cornell's upgrade would be very welcome at this time.

The supercomputing collaboration at Cornell includes Floating Point Systems, the manufacturer of the first minisupercomputer and the only minisupercomputer in production at the time of the proposal to NSF. Five FPS-264's are currently part of Cornell's supercomputer facility and the rich software libraries available on the 264 are a major benefit to our users. Plans for upgrades on the FPS side are being developed but these are not targeted for implementation at Cornell in 1989.

The present 1989 budget levels proposed for the Centers would not be adequate even if there were no question of upgrades. In the case of Cornell, the proposed budget levels do not allow acquisition of a mass storage system or buildup of graphics display (visualization). Cornell also will not be able to provide full user support for the industry standard operating system (UNIX) availability of which has just been announced by IBM for the 3090 under strong pressure from both Cornell and NSF.

The Budget Summit and resulting cutbacks from the President's budget request for 1988 have had severe impacts on all of science, making it much more difficult for NSF to provide the needs of the Centers and their large user base. It is urgent for the Centers that the full budget for 1989 proposed by the President be enacted. Since users of the Centers come from all disciplines funded by the NSF and the users often have their own NSF grants, cutbacks in any area supported by the NSF reduce the ability of Centers' users to pursue their research. In particular, it would be of little value to the Centers to take funds away from users in order to fund the Center. It is also of little value to the Centers to receive funds transferred from scientific areas of very high priority (such as Nobel Prize winners engaged in research on high T_c superconductivity) because despite the great importance of the Centers, there is no justification (in my view) for giving them absolute priority over projects such as high T_c superconductivity. To attempt to do so would serious erode support for the Centers in the scientific community, support which is difficult to obtain in any case.

The NSF budget has received some major increases in the last eight years. Unfortunately, it remains under severe pressure because of very much larger increases in the responsibilities of the NSF over the last two decades without corresponding budget increases. First there were major

programs transferred to the NSF at the time of the Mansfield Amendment, such as the Materials Science Centers, the Arecibo Ionospheric Observatory, etc. Then there was the growth of support for graduate training and research programs in engineering, including key areas such as computer science and electrical engineering. Then there was the spectacular growth in the needs and costs of instrumentation, driven by continuing advances in instrumentation, the growth of an enormous industrial market for scientific instruments, and the growth in distributed computing (PC's, minicomputers, and superminicomputers). Then there was the geographical expansion of the base of research universities seeking NSF support, as high quality researchers trained in the sixties found jobs throughout the country. There was throughout this period the strong growth in industrial R & D expenditures, creating increasing needs both for highly skilled engineers and for new scientific discoveries of industrial importance.

The response at NSF to all these pressures has been a twenty-year rise in the quality cutoff for the acceptance of grant proposals which has now risen to the point, I believe, of absurdity. A young assistant professor with a long-term high risk research plan of Nobel Prize quality, similar to my own research plan in the sixties, has little chance of being funded today because any plan with risk is likely to get at least one "very good" instead of "excellent" from NSF reviewers, and just one "very good" can be devastating. It is also very difficult in the present funding climate to maintain the full range of diversity of research that is needed for the U.S. to be fully in contact with global research programs and to support unexpected breakthroughs or industrial needs. It is very difficult for the NSF to achieve fully adequate funding for the supercomputer Centers in the face of all the other funding pressures it experiences.

One regret that I have about the last three years is that major developments in massive parallel processing were not tied in with the Center's program. It is sad that none of the highly parallel machines now on the market are available to NSF researchers through the Centers program. Now that a billion dollar initiative in parallel processing and networking is being discussed at the level of the White House Science Advisor, I think it especially important that the strength of the NSF Centers be maintained (at far less cost than the Initiative) and that the Centers be given an opportunity to prepare the scientific community for the coming generation of highly parallel supercomputers.

There has been a concern that thousand processor systems will not be usable by a broad spectrum of scientists. Indeed, the tests to date of such systems (first in England in the early eighties on the four-thousand processor ICL DAP, and most recently at the Sandia Labs reported on in the March 28 issue of Time Magazine and elsewhere) have involved carefully chosen problems that are relatively easy to split into thousands of independent tasks. However, in a major supercomputer center with thousands of users, parallelism will bring major benefits with far less effort by users. The reason for this is that thousands of users generate thousands of separate jobs daily which currently pile up awaiting free processors. It would require over a hundred-processor system to ensure instant turnaround (which is what a supercomputer is for) to each user rather than a long wait. A thousand processor supercomputer would easily achieve full

utilization as long as the bulk of the users were able to use about ten processors per job, and experience at Cornell suggests that would not be very difficult to do.

In conclusion, I believe the Centers program has become a major success. I congratulate the Congress, the NSF, the Executive ranch and all the cost-sharing partners that have made the Centers possible. I salute the fantastically dedicated staff that brought about the success. I urge Congress to work with the NSF to ensure this success is not forestalled but continues despite budgetary problems.

Background:

1) The NSF Supercomputer Centers are a success.

2) UPGRADES are essential to build on this success.

3) The TIMING of the upgrades is critical - need to start in Fiscal 1989.

4) The FULL budget increase for the **entire** NSF is crucial.

The Problem:

The President's 1989 Budget provides NO MONEY for UPGRADES.

Success of the Centers:

Scientifically

- Over 6000 scientists BUILDING CAREERS around supercomputing.

- A **major fraction** of Centers' supercomputer users are STUDENTS.

- Progress is being made in GRAND CHALLENGE areas such as:

  Life History of Planets, Stars, Galaxies, Black Holes and the Universe

  The Nature of the Chemical Bond

  The Molecular Basis of Life

  Turbulence

  The Global Environment (the Sun, Air, Sea, Underground)

  Computer-aided Design, Engineering, and Manufacture

  The Global Economy.

Success of the Centers:

Technologically

- U.S. Supercomputer development is now advancing rapidly.

Speed:	1984-1988 (factor of five improvement)
	1976-1984 (no improvement)
Memory:	1984-1988 (factor of 64 improvement)

- The NSF Supercomputer Centers Program has had a major influence.

NSF Influence on the Technology is VITAL

An Example: The influence on IBM through Cornell

- Eight IBM staff in residence at Cornell.
- Daily interactions between Cornell and IBM's mainframe design group.
- Repeated speedups in IBM product development to meet Cornell needs.
- Major products designed at Cornell's request.

History

Aug. '84 IBM is **absent** from Supercomputer Market

IBM/Cornell form **Supercomputer Partnership** with Floating Point Systems

Feb. '85 **Cornell selected** as one of NSF Centers

Cost sharing ('85-'88):	IBM	$30.6 million
	NSF	$21.9 million
	Cornell	$ 6.3 million
	NY State	$13.2 million

Oct. '85 IBM (under pressure from NSF award), **announces** its first Supercomputer in 15 years.

Nov. '86 IBM's top-of-the-line 3090-400 SUPERCOMPUTER **installed** at Cornell, as planned.

Users **rejoice** in its INDUSTRY-LEADING Supercomputer MEMORY.

Jun. '87 At Cornell's request, IBM **Builds and Supplies** Industry-Leading Parallel Software Package to Cornell, preparatory to wider release.

Jul. '87 IBM provides upgrade to 3090-600

Cost sharing:	IBM	$7M
	NSF	$200K

Dec. '87 IBM **announces intent** to support Steve Chen's startup supercomputer company, and make IBM's parallel processing technology in test at Cornell, available to Chen.

Jun. '88 At Cornell's request, IBM **designed and will be ready to deliver** major upgrade:

6 processors -> 12 processors

Cost sharing:	IBM	under negotiation
	Cornell	" " "
	NY State	" " "
	NSF	NO cost sharing for upgrade in budgets 1988 or 1989

Likely IBM response to lack of NSF cost sharing:

Upgrade will be installed elsewhere;

Cornell (and NSF) involvement in IBM top-of-the-line supercomputing substantially diminished.

The Budget Increase for Entire NSF is Crucial

- **6000 Users** of Centers, from **every Directorate** of NSF

- Budget **squeeze reduces users' capability** to:
  - train students to use supercomputers
  - complete experiments related to supercomputer projects
  - spend their own time on research
  - acquire local facilities for access to supercomputers

- **More money for Centers alone is not enough**

THE PROBLEM:

- **Startling Success** of the Centers has taken NSF management by surprise

- Even in the President's budget request:
  - there is **no money for cost-sharing of upgrades** such as at Cornell
  - there is **not enough to support** critical **on-going needs** in

    Advanced Supercomputer Consulting

    Mass Storage

    Support of Industry Standard Software

    Advanced Visualization

- The Centers have **staff of extraordinary calibre** with a fanatic dedication to quality support of users

- I seek your **help** in **encouraging their continued success and devotion.**

Pushing Parallelism:

(Many Processors acting simultaneously)

Industry View: (*Both here and in Japan*)
Only a minority of users will achieve high levels of parallelism (>10 processors/job).

Industry Design Goal: A small number of processors, each as fast as possible.

Publicity: (*Special cases which use thousands of processors at once*)

- Sandia National Labs.
- Connection Machine

Reality: (*Parallelism at Cornell*)

Expensive Supercomputers have **large job queues** (30 to 50 jobs simultaneously await execution at Cornell).

30-50 processors needed to **provide rapid response** to our 1200 users, just for single processor jobs.

> 300 processors total are needed to **permit 10 processors per job**

Mr. BROWN. Your testimony is extremely valuable. I say that to every witness, but in your case it's most appropriate. I have a strong recollection of the important role you played in gaining support for the initiation of this program, and you may credit that as one of the great achievements of your professional career.

And after Dr. Weingarten, who is not quite as elite as you and will therefore not get as much time, I'm going to discuss with you something about elitism.

Dr. WILSON. Fine.

Mr. BROWN. Dr. Weingarten.

Dr. WEINGARTEN. Thank you, Mr. Chairman. I'll try to keep these comments very short in consideration of that. In fact, I'll just make some comments about my testimony, if I may.

In the first place, thank you for the opportunity to testify here. I should make the caveat that OTA has not studied the NSF budget submission and normally does not comment on budget matters of agencies of this kind.

Instead, our comments will be based on studies we have done on supercomputers and on information technology R&D, work dating back some years, in fact, preceding the National Centers Program.

To give a bit of context to this, for the last 30 years the revolution in information technology has been transforming the conduct of science in the United States. Some of that revolution has been invisible, particularly in the early years. But we've seen transformations in computer technology, which has provided new techniques, even new forms of research. Some people even talk about a third branch of research alongside theoretical research and experimental research. They talk about computational research.

More recently, we've seen electronic technology change scientific communications, challenge the operations of libraries, and even the publication and dissemination of scientific information. This Committee, science agencies, even the universities and research institutions themselves, have been wrestling for a long time with the implications of this change.

In the first place, all of these revolutions are combining. They are merging together, and they are forming a basic infrastructure for the conduct of science. It is not clear how, within traditional patterns of science funding, we should handle the programmatic issues in building and maintaining this kind of an infrastructure.

Now, we are discussing here a particular issue—the provision and maintenance of supercomputer centers. In some sense, that violates my point about the merging of technologies. But, in fact, the reality of political life is that we have to make specific decisions on specific programs. And so, I'm going to talk about that topic. But I think we should keep in mind the context of the broader implications of technology on scientific research.

When I say supercomputer, I'd like to be a traditionalist and keep the old fashioned definition of supercomputers, meaning the biggest machines available at any time. That definition has been slipping and sliding lately. I've even seen reference to personal supercomputers, minisupercomputers, big supercomputers. It begins to resemble olives.

Besides confusing, I think it's also possible then to define our way out of a problem. If we say the problem is scientific access to

supercomputers, we can define our way out of it by expanding the definition of supercomputers and saying it's been fixed. I don't think that's what the original Lax panel intended.

And so, I'd like to go back and revisit, just very briefly, the state of the debate when the supercomputer centers were formed. The panel chaired by Peter Lax of NYU talked about critical research in science, engineering, and technology that was undone due to the lack of access to computing capacity substantially greater than those currently available.

Now, there are two points. First, they weren't talking about Cray-1s. They were talking about machines hundreds or thousands of times faster than Cray-1s. And, second, they weren't talking about more science. They weren't talking about cheaper science. More science and cheaper science may, in fact, be important goals. But the Lax panel was talking about new science. And they referred to it as "critical science," extremely important for the future of our society, that scientists were not able to pursue because they didn't have access to these computing resources.

They proposed two responses. One was to provide researchers with access to the best available systems at any time. And, secondly, to push as fast as possible the state of the art in supercomputers. The National Centers Program was designed in part to respond to that. In fact, to serve both of those goals.

In the first place, they were to provide access by researchers to supercomputer capability through a program of aggressive and continual upgrading of hardware to stay at the leading edge. By a program of user support, including software development, consulting services, user training, and so on, they would develop supercomputer applications in scientific research. And, finally, the establishment of networks would provide access to these facilities around the country.

The second goal, advancing the state of the art, was addressed by these centers, in the first place, by providing test sites for the most advanced designs. Dr. Wilson has already referred to that as one of the benefits in the Cornell experiment. Second, the centers would continue the process of feedback from centers of expertise, a tradition that went back many years. The Los Alamos and Livermore installations have always been major drivers of supercomputer technology by their role as the most sophisticated users of this technology.

When we look at the situation now, the term I used in my testimony was "shrinking expectations", in terms of the numbers of centers. (In those days, people were talking about 10 to as many as 24 centers being established. We now have five.) And, as has been testified already, and I think will be discussed more in the next panel, the funding of those centers has continually fallen short, even of the commitments, much less of hopes and expectations.

At the same time, I think we can say that those goals remain valid. Not because OTA has done a recent analysis and decided that, but that they have been reaffirmed continually by the scientific community in recent years through other reports. I referred to them in my testimony, and they haven't been seriously challenged.

To the extent that Congress feels that those goals are still valid and wants to sustain the supercomputer centers, though, we feel

that there are two kinds of problems that need to be addressed. One is the need for long-term commitments, a clear expression of the charters for those centers. What is it they are to provide? How are they to operate. And long-term commitments that are met on the part of the Government to the support of those centers.

Without those kinds of commitments, basic support facilities like this simply can't operate. They are operating continually in a state of uncertainty. They can't invest in new hardware. They can't keep the best people. They can't develop new science, because scientists are not willing to invest the amount of time to get their work on the computer if they're not sure that the machine is going to be there.

The second cluster of issues, I think, are particularly difficult for NSF and perhaps for the other science agencies, because they are programmatic problems. Support of these kinds of infrastructure investments don't fit traditional patterns of science research, project by project, discipline by discipline. They cross disciplines.

Even within the computer directorate in the National Science Foundation, one sees a natural clash of interests between the desire to fund computer science research and the need to sustain facilities to support all areas of research. And I should point out as a computer scientist myself, that computer scientists are not major users of supercomputers. So, there's not a lot of self-interest there.

The problems also cross agencies. There's no natural lead agency for supercomputers. So, the Department of Energy, the Department of Defense, NASA, NOAA, all of these agencies are users and promoters of supercomputer use. They all have networks. They all have centers. And there's a particular problem in coordinating any programs with all of these efforts going on.

In conclusion, I'd simply like to point out that we have, particularly at this time, an opportunity and, probably, at the same time, a parallel problem. There is a new generation of hardware coming along, the Cray-YMP, the Cray-3, other systems. There's the IBM system that Dr. Wilson mentioned. And we have to decide whether or not to invest in those technologies and keep the centers at the leading edge of supercomputer capacity.

The original contracts are going to be up in a couple of years. The question now is the terms. Are they going to be renewed? On what terms are they going to be renewed? What new commitments might be made? Might new centers be established? Will the old centers be maintained? And there have been some management changes within the National Science Foundation in this area. There's a new assistant director about to join, new program and division directors, and so on.

So, it's an ideal opportunity for the Congress and for the Science Foundation to reevaluate and redefine its program goals and to, hopefully, arrive at a long-term commitment that establishes purposes and goals for these centers, and makes commitments that can be lived up to from year to year, so that it is not such an uncertain environment in which the centers have to operate.

Finally, all of this consideration needs to be done in light of the context I mentioned at the start of my testimony the developments in communications, the new developments in creation and dissemination and archiving of scientific information, and the problem of

building an information infrastructure, essentially for the U.S. research establishment. It's a very difficult problem. If there's any way in which OTA can continue to help, we'll be glad to.

Thank you.

[The prepared statement of Dr. Weingarten follows:]

TESTIMONY OF FRED W. WEINGARTEN
OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY
AND THE HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

REVIEW OF THE NSF NATIONAL SUPERCOMPUTER CENTERS

MARCH 24, 1988

Mr. Chairman, thank you for the opportunity to appear before your subcommittee about the National Science Foundation's (NSF) authorization bill, specifically that part related to its advanced scientific computing programs.

To start, I must note that OTA has not in any sense audited or otherwise evaluated in detail the NSF advanced computing programs, nor have we examined the FY 1989 budget requests of either the National Centers or NSF.

As a result, rather than focusing on specific FY89 budgets I will confine my remarks to strategic issues that underlie both the past and future of these programs. In OTA's view, these strategic questions are fundamental to this Committee's consideration of these programs and, in an important way, they underlie the decisions to be made in the more narrow arena of FY89 authorizations.

My comments are based on work done at OTA over the last five years on information technology research and development. One area we follow includes supercomputers and other advanced computational systems -- looking at Federal R&D policy, the growing Japanese competition, and the use of these machines for scientific research. In the course of our studies we have written about various Federal supercomputer programs, including programs of NSF.

The two publications most directly related are our report, Information Technology R&D, and a background paper Supercomputers: Government Plans and

Policies, but we have done other studies on long-term trends in computing, and R&D issues.

DIMINISHING EXPECTATIONS

As the NSF Advanced Computing program currently stands, uncertainties and conflicts between the Foundation and the National Supercomputer Centers are inevitable. Until the purposes and goals of the Government's supercomputer program are clarified and a long-term, achievable program plan for support of academic computing is agreed to by the Congress, the National Science Foundation, and the scientific community, these problems are likely to continue.

The last four years of the NSF Advanced Scientific Computing Program has been a period of steadily diminishing expectations -- to the point where the original program purposes, goals, and plans are, practically speaking, no longer operative. Many external factors, such as the availability of alternative computing resources, have also changed. Yet, a new program charter has not been formulated, approved by Congress, and explained to the scientific community.

In the meantime, the existing National Centers are trying to operate in accordance with contracts signed in an earlier and different era. Furthermore, in about two years (a very short time frame in terms of facility operations) the Centers will be facing the completion of their initial five-year contracts -- and the future intentions of the Government in terms of withdrawing, maintaining, or expanding support of those centers are very unclear.

BACKGROUND

Several years ago, a series of events combined to focus attention on supercomputers, a sector of the computing industry that had been considered to be a small, arcane, and not very important part of the much bigger computer industry.

Special Reports

In late 1982, the Panel on Large Scale Computing in Science and Engineering, chaired by Professor Peter Lax from NYU and composed of several other prominent researchers from a variety of scientific fields, said that "Large scale computing is a vital component of science, engineering, and modern technology," and issued three basic warnings:

1. "Important segments of the research and defense community lack effective access to supercomputers..."
2. "The capacity of today's supercomputers is several orders of magnitude too small for problems of current urgency in science, engineering and technology" and
3. "Nevertheless, the development of supercomputers, as now planned in the U.S., will yield only a small fraction of the capability and capacity thought to be technically achievable in this decade."

A particularly important point to note for our purposes here is the emphasis in the second statement on capabilities much greater than those now available.

The conclusions of this report triggered subsequent debate and further study on the part of NSF and the Departments of Energy and Defense -- the agencies that funded the Lax Panel's work. In 1983, NSF issued a report, commonly referred to as the Bardon-Curtis Report, that affirmed the findings of the Lax Panel, stating "There is an immediate need to make supercomputers more available to academic scientists and engineers."

New Japanese Computer Research Programs

In the early eighties, Japan announced two new, coordinated research programs. In 1981, the Supercomputer Project was initiated. This program was designed to achieve speed, not only through architectural innovation, but through faster device technology.

In 1982, the Fifth Generation Project was announced to world-wide public attention. This program was not focused on computational speed, per se, but on a machine designed specifically for artificial intelligence applications, incorporating radical new architectural and programming concepts.

Since Japanese industry had already successfully challenged the U.S. microelectronics industry, in part through such targeted programs, these challenges to the U.S. computer industry were not taken lightly by industry or by policy makers. Nor did the focus of both projects on the very large end of the computer spectrum go without notice.

New Japanese Computers on the Market

At about the same time that the Japanese research programs were announced, Hitachi and Fujitsu began to sell computers that appeared to be as powerful as -- possibly more powerful than -- the best U.S. machines. (The "power" of a supercomputer is not an exact measure. It depends on the nature of the problem and the design of the software to run it. So opinions can differ.)

In the earliest days, the U.S. computer industry was considered to be unchallenged. Now, times changed. And, while Japanese research projects seemed to be a future threat to the U.S. in the marketplace and, hence, a worry, the appearance of these two machines on the market was a shock.

Impact

That these events occurred in roughly the same time period served to focus the attention of computer experts, users, and the Government on the U.S. technological position in advanced computers. The result was to stimulate interest and build momentum behind Government programs. However, the problem was that they were separate, although related problems, and tended to mix objectives that, on occasion, conflict with one another. These objectives were to:

- Provide access for research use.
- Support research on computer architecture.
- Support the U.S. supercomputer industry.
- Support U.S. agency missions such as defense, energy, and space.

One Response was NSF Program

One response to this new Federal concern over supercomputers was the NSF Advanced Scientific Computing Program, a very ambitious effort intended to establish several supercomputer centers over the succeeding years, to build a network to provide researcher access to the centers, and to develop scientific use through training, software development, and so on. The program was originally intended to fund several centers -- as many as twenty-four were mentioned by NSF staff with estimates of its funding level at the end of five years ranging from $200 million to as much as $500 million. (The Bardon-Curtis report recommended 10 centers and a program budget of $110 million by FY 86.)

SITUATION NOW

Today's situation clearly falls substantially short of those original

proposals. Rather than ten to twenty-four centers, we have only five centers, apparently funded below even their originally contracted obligations. Of course, over the last few years some changes have occurred in the environment that could explain at least in part such declining program aspirations.

For instance, Mini-Supercomputers have appeared on the market. These computers possess some significant fraction of the speed of very large existing machines, yet cost much less. Some of them share the same architectural concepts of the full supercomputers, other are more experimental. Secondly, many universities, independent of the NSF centers, have installed or are planning to purchase supercomputers. In both cases, access by researchers to computer resources has increased. It is important to note, however, that these resources do not generally represent the leading edge of computing capability. The term, "supercomputer," as popularly used has been broadened to encompass a wide range of machines -- from large main frames equipped with vector processors to desk-top work stations -- that have unusual architecture specifically designed for high speed numerical computation.

nother important development, of course, has been severe budget pressure as NSF and, in turn, its grantees are asked to share in easing the Federal deficit. The Advanced Scientific Computing Program is not the only Government program required to scale back ambitious plans.

However, some conditions have not changed. For instance, the analysis of the Lax panel has not changed. The report's authors, recall, were most concerned about researcher's access to order-of-magnitude (at least) increases of computer speed. They discussed important unsolved and, with current hardware, unsolvable problems. No major changes have occurred either in science or in commercially available supercomputers to change that analysis,

assuming it was correct at the time.

Secondly, Japanese computer manufacturers continue to improve their offerings and are marketing impressive machines. These machines are fully competitive. Some computer center directors tell me that, if they had the money to buy a new machine today and no restrictions were placed on what they could buy, a Japanese machine would be their choice.

Finally, the importance of R&D in supporting economic growth in the U.S. and the world is undiminished. The economic stakes are very high in supporting the computational science, engineering, and technology that is typically done on the fastest machines available and competition is intense.

WHERE FROM HERE?

Given this new environment, what should the Government's role be in advanced research computing? Should it declare victory and close down the program as it once did to the computer facilities program? Mini-supercomputers and numerous full size supercomputers now available in university research centers might suggest such a course.

However, if the original analysis in the Lax report, mentioned earlier, together with that in the follow up NSF report, voluminous testimony to this Committee and even the recent FCCSET report to this Committee is correct, then there is still an important role for National Supercomputer Centers.

A 1987 report by the Panel of Research Issues in Large Scale Computational Science and Engineering (jointly supported by NSF and the Department of Energy) says:

> "... the U.S. research community must be able to exploit leading-edge computational technology. This requires, over the next few

> years, a thousand-fold increase in applied computational performance ... and action to ensure innovative applications of this extraordinarily powerful technology."

The role of the Centers would be (as it was originally) to provide scientific and engineering researchers with access to the best supercomputers available at any time. In this way, research is always being conducted at the leading edge of computational capability and the boundaries are continually pushed. By creating new techniques and exploring the most advanced new computer architectures, the Centers can help increase our basic understanding of computer performance, leading to the development of future generations of supercomputers (another of the original goals of the Centers Program).

To work effectively toward these goals, the Centers would need to continually improve their facilities, both in terms of new, more powerful machines and in terms of adding technical improvements to existing facilities as they become available. The report just cited urged the immediate upgrading of equipment in the National Centers.

To be effective, the Centers need long-term commitments from Government. Just ordering, installing, paying for, programming and tuning the hardware is a multiyear effort. To attract and train the best support staff possible is also requires a long term effort.

Finally, it will take many years to develop the type of scientific applications and analysis methods to take full advantage of state-of-the-art facilities. Scientists and engineers, in particular, will look for long-term stability and smooth transitions before they are willing to commit major research to the supercomputer. In their NSF report, Bardon and Curtis said:[1]

> "... it will take a strong sustained commitment to large scale computing by the Foundation to persuade scientists

to invest their time and effort, sometimes involving years, in preparing programs for supercomputers."

IMPLICATIONS FOR NSF AND CONGRESS

Strategic Plan and Commitment for the National Centers

If Congress wishes NSF, through some form of National Centers Program, to support intensively the use of leading-edge supercomputing facilities in research, then serious strategic planning must be undertaken as soon as possible. This plan is necessary if Congress wishes to eliminate the current uncertainty on the part of the Centers about their future, and to alleviate the contentiousness that now characterizes the relationship between NSF and the Centers.

Any plan that is to be agreed to by the Congress, the NSF, and the scientific community must specify at least the following: how many Centers will there be; what funding patterns the Centers could expect over the next several years; and how fast they should plan for upgrading their facilities. To the extent that such a plan may have existed four years ago at the start of the program, the technological, economic, and program changes that have taken place since then have clearly made it obsolete.

With such a plan in hand, provided it were adhered to, year to year funding considerations would be clearer and presumably less contentious. Furthermore, temporary on-year budget shortfalls could be more easily accommodated by temporary adjustments.

Maintaining an Information Infrastructure

Information technology is transforming the nature of much scientific and engineering research, and the Supercomputer issue is only one of a wide range

of issues that will be confronting the Congress and the scientific funding agencies over the next several decades. Computers of all sizes and forms are transforming the nature of data collection and analysis, experiment control, and modeling. Communications technology is tying scientific research and researchers in the U.S. and around the world more closely together. Electronic storage technology is changing the basic form in which scientific results and data are archived and accessed. And, desk-top and on-line publishing is changing the way scientists communicate the results of their work.

Scientific research is growing dependent on a complex, capital intensive infrastructure of technology and institutions to support these functions, which raises several implications for science funding. Funding, building, and managing very capital intensive services such as networks, on-line archives, and computation centers is a different type of programmatic challenge than the traditional research project mode that is most common for research support agencies such as NSF. Complicating the task is the fact that these facilities undergird all the disciplines and, hence, programs cut across the normal scientific discipline lines of most science agencies. Finally, no one agency is a natural lead agency for these infrastructures. They all share in using them and supporting them. Hence, interagency coordination of programs can be more complicated, yet also more necessary so that the facilities serve all needs.

M-. Chairman, this concludes my formal testimony. I will be glad to answer any questions the Committee might have, either here or later in writing.

Mr. WALGREN [presiding]. Well, thank you very much, to all.

Along the lines of this long-term commitment that we should make, what do you see in terms of dollar amounts a year that would be required? I suppose that changes with the charter. But, I would think the best charter would be to keep on the true leading edge of it, at least in a number of centers. What would it take to make that commitment per year?

Dr. WEINGARTEN. We haven't done an analysis in terms of exactly how many dollars. I think there are a couple of important considerations, though. One is that it's a function of how many centers are established, and it's very important that we don't establish more centers than we have funds to support.

Mr. WALGREN. How do you feel about the five now? Is that enough?

Dr. WEINGARTEN. I really haven't—I haven't done the kind of analysis that would allow me to answer. There are three things one ought to take into account. One is demand; one is the degree to which one wants to have a variety of different computers, different architectures available, because there is no such thing as a single supercomputer design. There are a variety of centers and a variety of ways those centers can evolve. So we may need multiple centers for that.

And second, the centers may specialize. There are several areas of science, several kinds of computing that require supercomputers, and it may well be that these centers are going to start to evolve in their own characteristic directions, and that also will dictate how many centers we need.

Mr. WALGREN. Can I ask the others where there is any rough estimate that you can make of the kind of commitment that you feel would be necessary to provide some service, quite broadly in the nation, that would be on the leading technological state?

Dr. RHOADES. Yes, Mr. Chairman. I think there are a couple of reports that have tried to address it. It depends on how broad your question is, but if we just confine ourselves to the supercomputing centers as entities in the infrastructure required and let the researchers talk to those, that the magnitude of the strategic effort that was discussed by Dean Raveche in the SIAM Report that was attached to my testimony specified something like $125 million a year just in that one aspect. He describes a much broader $1.5 billion effort, but the $125 million per year number is a reasonable number. I have given the number of like 75 million, because this represented the views of the program plan review panel review.

There's lots more that one can say. First of all, the number of centers, five, is not necessarily an ideal number for the reasons just previously given, but I should point out that none of them, with one exception, have more than one supercomputer; that there are certain economies of scale that you get if you have more than one, that makes it a little less expensive, than to establish a whole new center from the ground up.

I also think it's true that there's a huge pent-up demand. I pointed out in my written testimony that all the centers have reached saturation as of roughly last July; but, even with the situation that we have in which many people in the outlying areas, off the beaten path from the point of view of the NSFNET backbone, are finding

difficulty getting access to the centers, there's still so much demand that I suspect that all the centers are going to be saturated.

Mr. WALGREN. Dr. Wilson.

Dr. WILSON. I believe the total budgets of the centers have to roughly double, and that would put them on a par with NCAR which can give you a good reference point as to what a supercomputer center really needs in terms of a budget.

The amount of funding that NSF has to provide to achieve that doubling is—it's not that the NSF itself has to provide the doubling, but it has to provide a fair fraction of that, and I would say, you know, somewhere in the middle, between 50 and 100 million is where that program should sit.

I am opposed to building any more centers at this time. I think it is in the interest of everybody to bring the present centers to the strength where they can really be setting a standard for the whole university community, rather than trying to build more centers which will be just as underfunded as the present ones.

Mr. WALGREN. What would that cost? Doubling, I guess, would be for the whole, but if you say okay, we're going to stay with these, and we are going to do the right thing by these, what kind of new money are we talking about there?

Dr. WILSON. Well, as I said, I think you should target it somewhere sort of in the middle between the present level and a doubling of the NSF budget for those centers. I promised Erich Bloch I would not give you a number. [Laughter.]

Mr. WALGREN. Well, okay.

The Chair would like to recognize the gentleman from California, Mr. Brown.

Mr. BROWN. Mr. Chairman, in view of the time, I'm not going to pursue a lengthy line of questioning, but since Dr. Wilson did refer to the term "elite," identified himself as one of those, I wanted to make it clear that I think physics and society have to have elites. It is extremely necessary. But there is a problem some time even in physics when the elites refuse to recognize that a new paradigm is developing, and the progress of the science is sometimes delayed by the action of some elites who have a characteristic sometimes called hubris, which means they seek to mock the gods. And when that happens, you have some very deleterious effects.

Now I find that that characteristic exists even in politicians, as well as physicists, and it's to be condemned whenever it occurs. I'm not accusing you of being guilty of that sin, but it is something that we all need to be careful of from time to time. I hope you recognize that point.

Dr. WILSON. Well, if I may comment, clearly a lot of scientific progress has developed from young whippersnappers challenging the establishment or the elite. I think, however, it is very important to have that elite so that you have young whippersnappers trying to challenge it. [Laughter.]

Mr. BROWN. I yield back the balance of my time. [Laughter.]

Mr. WALGREN. The gentlelady from Maryland, Mrs. Morella.

Mrs. MORELLA. I am pleased to have such a distinguished panel before us, and I understand you are a Nobel Laureate, Dr. Wilson, and the rest of you have incredible credentials.

I am curious about a couple of points. To pick up on what Congressman Brown has said, if—and what you had said—if you suggested maybe we shouldn't launch out with trying to have more supercomputer centers, so that we don't diminish the quality of the five that we have, would you then say if there were not additional funding adequate enough, that the five should be reduced, so that you can have fewer that might do just what you want?

Dr. WEINGARTEN. Obviously I am not going to give you a direct answer to that question, but let me say I think the really important thing that has distinguished the centers is the ties between the center and the manufacturer. There is no question in my mind that if we had more manufacturers of supercomputers, that were really important, we would have to have more centers to build those ties.

Mrs. MORELLA. Another point. If the Japanese have excelled or exceeded us in their technology with regard to supercomputers, how do we fit in, other than trying to reach that point and go beyond? And is there any, you know, suggestion with regard to whether we should consider buying some of the Japanese supercomputers? What—I would like you to comment, any of you, on the—our relationship with the Japanese in terms of this particular supercomputer technology. Where should we go?

Dr. WILSON. Okay, let me make a couple of comments.

First of all, it is obviously a very delicate question whether there should be a national center with foreign technology, because of the whole way that these national centers interact with vendors and, for instance, in our interaction with IBM, we are obviously having a major role in how IBM develops its product line.

On the other hand, what I think is reprehensible is to block universities from getting Japanese equipment not in the national center basis, because the idea that we would not even have the ability to find out what the Japanese are doing in supercomputers is absurd. And if they're getting ahead of us, we'd better well know it, and we'd better well know it from first hand experience.

Mrs. MORELLA. Do they have any of ours? Have they got any——

Dr. WILSON. Yes. As a result of the trade negotiations, there are even more Cray supercomputers going into Japan than had otherwise been planned, which I find a bit strange, because computers are—I mean our aim is not to sell supercomputers. Our aim is to use supercomputers as an engine of engineering progress, and let's get supercomputers in to our manufacturers before we worry about getting them in to Japanese manufacturers.

Mrs. MORELLA. Did you want to comment on that?

Dr. WEINGARTEN. Yes. A couple of comments. In the first place, I don't know that U.S. supercomputer companies would concede the leadership to Japan. I think they would refer to the Japanese manufacturers as worthy competitors, and in some ways the machines seem superior, and in other ways, the U.S. is moving very quickly, too. So it is a tight competition. I don't think it's clear that anyone has achieved dominance in it.

Second, the question of whether centers should install Japanese systems or foreign systems in general, the trade issues aside, I'll refer back to my statement of two purposes of the centers.

One is to provide scientists with access to the best machines possible. If we get to the point where the best machine possible is a foreign system, then that is going to be a difficult decision to make, because not to buy that system would be to deny the scientists access to the best technology.

Second, if the centers are to study and understand and pursue the state of the art, to the extent that those foreign machines have a different architectural approach or are pushing the boundaries of supercomputing in different ways technologically, it is in our interest to understand that, to experiment with it, and to have some experience.

So from those two perspectives, I think we would worry about overly harsh restrictions on looking at foreign machines.

Mrs. MORELLA. They must find ours quite favorable, though, to be engaged in the purchase of them. And then I wonder about, just finally, Mr. Chairman, how do you relate to the universities that already have put in supercomputers? I think it was your testimony that I was reading here that indicated a number of universities have purchased or are planning to purchase supercomputers. Will they have any relationship, liaison, whatever, with the regional centers?

Dr. WILSON. Yes. There are 30 universities that have 3090 systems from IBM, and most of them have equipped them with supercomputer attachments. They're, of course, not fully utilized for scientific engineering research, they're mostly in computing centers where they handle instructional and administrative computing as well. But we have built a very strong liaison with those universities. Many of them are in what we call our smart node program. Many of them are participating in our training programs, because we are the lead IBM installation, and we have more experience with the supercomputer capabilities than the other universities have. They send people to us to be trained. They come to us to learn how to run an installation for scientific researchers. Anything that we do that helps IBM develop its product line is of benefit to all those 30 universities, and there's no other university that can get IBM to actually design a product the way we have gotten them to, because they don't have the clout.

Mrs. MORELLA. I am pleased to hear about that kind of liaison. I mean good endowment, maybe they can—another university could get involved, too. But the fact that you work with some of these same people to be trained.

Thank you.

Thank you, Mr. Chairman.

Mr. WALGREN. Thank you, Mrs. Morella.

Mr. Hayes.

Mr. HAYES. Sorry I came in a bit late.

One of the things that I was struck with as you were testifying, if we're looking at equipment that is technologically competitive in order to learn from it, what I conclude from that, that that would mean on the basis of going into a center rather than suddenly promoting equipment on several centers.

In other words, should several different supercomputer centers be motivated toward looking at the equipment that would become state of the art, or can you do that on the basis of having a center

that does that and not be talking about the wholesale change of equipment across the board?

Dr. WILSON. Let me answer it this way. I think Cornell has special clout by being the only NSF center with IBM equipment. That means that the whole NSF clout is focused through one center, and one center which is visible all the way up to the Board of Directors of IBM.

I don't think that NSF could have had that same clout if it had, for example, three centers with IBM equipment.

Mr. HAYES. Thank you.

Mr. WALGREN. Thank you, Mr. Hayes. Well, let me express our appreciation to all of you for being a resource to us. We do appreciate that and I hope we can sort our way through this area in a constructive fashion.

Thank you very much.

The second panel on supercomputing, the various people that are directly involved in the centers: Dr. Larry Smarr, the Director of the National Center for Supercomputing Applications at the University of Illinois; Dr. Sidney Karin, Director of the San Diego Supercomputer Center; Dr. Doyle Knight, the President of the John von Neumann National Supercomputer Center in Princeton, New Jersey; Larry Lee, the Director of the Cornell Supercomputer Center; and, Ralph Roskies, Director of the Pittsburgh Supercomputer Center. Dr. Roskies is accompanied by Dr. Mike Levine who is the Codirector of that Center.

We appreciate all of you being here and for your patience. As you can see, these proceedings get protracted, but we are glad you are here and would be very interested in hearing your experiences and guidance that you'd like to give to us.

As we've said before, written statements will become reproduced without and you can feel free to focus on points that you'd like to underscore.

Let's start with Dr. Smarr.

STATEMENTS OF DR. LARRY L. SMARR, DIRECTOR, NATIONAL CENTER FOR SUPERCONDUCTING APPLICATIONS, UNIVERSITY OF ILLINOIS; DR. SIDNEY KARIN, DIRECTOR, SAN DIEGO SUPERCOMPUTER CENTER; DR. DOYLE D. KNIGHT, PRESIDENT, JOHN VON NEUMANN NATIONAL SUPERCOMPUTER CENTER, PRINCETON, NJ; DR. LAWRENCE A. LEE, DIRECTOR, CORNELL NATIONAL SUPERCOMPUTER CENTER; DR. RALPH ROSKIES, CODIRECTOR, PITTSBURGH SUPERCOMPUTER CENTER, ACCOMPANIED BY DR. MICHAEL LEVINE, CODIRECTOR, PITTSBURGH SUPERCOMPUTER CENTER

Dr. SMARR. Thank you very much, Mr. Chairman. I think the Congress can be justly proud of the achievements of the supercomputer centers.

It's, I think, rare for a government program to come so far in such a short time and to create so much accomplishment for the national educational and technological agenda.

However, I think it's quite true, as Dr. Rhoades said, that this fiscal year, the decisions you make and the authorization bill coming up, are going to be the determining factor in whether we

can take the extremely exciting beginning of this program and translate it into long term benefit for the country.

I last testified to this committee three years ago, in June of 1985 in Florida. The center awards had just been made. I was a fresh graduate from being a theoretical physicist into being a center director, and it's been a very interesting period.

At that time, I had a staff of 16. I now have a staff of 120. I had one or two computers, I think PC-AT's at that point; we now have well over 200, including one supercomputer, two mini-supercomputers, an IBM mainframe and many personal computers, workstations, and networks in our interdisciplinary research center.

We had no users in the country and we're at the end of a 15 year supercomputer famine in which the Federal Government had neglected the universities in this critical area.

We now have over 2,000 users of our own center allocated through the National Science Foundation by peer review, and 125 universities.

The users we have just polled, and we have now a 335 page book, that is each page written by a different scientist, giving the achievements of the use of the machine in their area, in all areas of science and engineering, social sciences, and the humanities, and at the end there are over 500 publications that have come in just the two years since our center opened its door to the national community.

I think this an achievement that is rather unprecedented in my experience as a scientist. And, I think it's something you should be very proud of.

In terms of the funding of this program, the State of Illinois, the University of Illinois, and Cray Research, Incorporated, all joined the NSF in making major long term financial commitments to the center. In fact, of the five year cooperative agreement, fully 40 percent of the funding for our center of the cash, forget the donations and space and everything, that's on top of that, 40 percent was non-Federal funds from the beginning.

We used that core funding to build an aggressive program with industrial partners. I've talked personally, I've made over 100 presentations to corporations in the last year and a half. I've probably reached the vice presidents of research of between 200 and 300 corporations with this message of how they must transform their scientists and engineers into this new technology.

We have been very successful in this program. We now have four major industrial partners contributing a million dollars a year so that we have over a three year commitment. We have $3 million to $4 million from Eastman Kodak, Amoco, Eli Lilly & Co., and Motorola.

In the testimony, rather than my telling you whether it makes any difference to Eastman Kodak, I've actually included the transcript of the speech given to the Industrial Research Institute by Cliff Perry, who is the Director of the Computational Science Lab at Kodak Research Laboratories.

The Industrial Research Institute is the vice presidents of the corporations in our country, 250 or so, that control 85 percent of the R&D dollars in the corporate economy.

He is extremely enthusiastic about the Illinois program, which allows for on-site visits to the center. The corporation has its researchers actually live in our interdisciplinary research center. We've had some 90 industrial researchers come and participate in the last year in our center.

And Kodak talks about some four major projects, everything from film manufacture to plastic injection molding, that were done in the facility that could not have been done otherwise, even though Kodak has an enormous commitment of capital and current expenditures on computing infrastructure within one of the great research laboratories in corporate America, in Rochester.

The same story could be said about Amoco, Eli Lilly, and now Motorola. To give you an example, this is the brand new Eli Lilly 1987 annual report which came out just last month, and if you turn into the center portion, here is a photograph of the Lilly researchers in front of the supercomputer at the National Center for Supercomputing Applications.

So, the photographers came over and took this picture one week after the first Lilly person came in, and they're so proud of it that this has been sent all over the world now as an example of Lilly's commitment to high technology in the drug design area.

Motorola, last week, just had 20 of their top researchers from Florida, Phoenix, Texas, and Chicago come to our center to spend a full-day, non-disclosure session deciding which of their critical needs would be first to be on our facility.

So, this is a very, very real partnership between the Federal Government, the State Government, universities, and corporations, and I, of course, would add that computer manufacturers, IBM, Apple, Cray Research, Sun and so forth, are themselves very much a part of that because of their major donations which I did not include in that cash analysis.

Now, as a result of the extensive education and training that the centers are engaged in, and all the centers are engaged in this, we are producing an enormous growth of national demand that has already exceeded the capacity of the centers.

This map, for instance, following Page 8, is the academic affiliates of our national center. These are not the universities just using, there are 125 universities that have scientists accessing our center, but these are 60 more universities that have actually designated people to come to our center to get trained in full week long sessions of intensive training, and then go back and train yet more people at their universities on how to use the facility.

We've recognized something like 500 users at the universities that have been trained on-site in those universities by the people who have been trained and go back to the universities through the academic affiliate program.

Probably 1,000 of our 2,000 users are, themselves, graduate students and post docs, that is new users of supercomputers making new applications as part of the doctoral thesis or post graduate work.

Now, in addition, to this massive increase in the number of new users, the restoration of the National Trained Manpower Pool, in using advanced scientific computers, which for 15 years atrophied away, we're now well toward rebuilding that manpower pool which

is so critical both for basic research in universities and in, of course, applied research in industry.

But, that's only one of the three factors driving the need for more capacity. The other is that the national networking is still in a rather primitive state compared to what it will have to be to give the kind of excellent access one expects of a supercomputer.

That, as it gets better, will allow more of these users to try to access and run large jobs. Many of them simply can't today because of the access.

And the third thing, of course, is as scientists, your problem, the more you work on it, you then decide to get more ambitious and attack an even more complex problem which requires even more capacity.

So, on Page 11, what you can see is, versus time from when our center started, the demand of allocation which is the straight line that just rises and rises and rises. That's given to us by the NSF program officers. And, you can see the saturation of capacity which we've been in since last July, by the turnover in the line of what we can actually deliver to the community.

We have over 5,000 hours just in backlog now, and we have, of course, more industrial partners. At this point, we can not take any more industrial partners without additional capacity in our center, or else we would have to take away too much of a share of the university holders.

So, let me just go the recommendations of what I think Congress and the National Science Foundation need to do. I think the basic commitment to doubling the National Science Foundation budget over five years is just extremely critical to the future of this country.

I would not urge that supercomputer dollars be taken away from basic individual investigators. I was an individual investigator for many years. I am still trying to be besides running this center in general relativity. But, I think that, for instance, if an individual investigator does not have a grant big enough to buy local work stations, to have RA's for graduate students, they're not going to be able to take advantage of supercomputers. You need more local equipment, not less when you have this fire hydrant you can attach to across the country.

So, I think that's the underpinnings of everything else we do. I think that, in terms of the centers, we must have a predictable and stable funding with a five year horizon if possible.

I have been negotiating for 14 months with Cray Research on trying to bring more capacity in in the form of a Cray-2 supercomputer which we do not have in any of the national centers, and no American corporation has one of these advanced computers.

The first of these machines that is being sold to a corporation is to NTT in Japan. So, with our industrial program, this would have a tremendous exposure, and yet, because of the unfortunate results of the deficit reduction action in December on the NSF and the resulting action on the centers, it is extremely difficult to put together a five year financing plan for that $20 million supercomputer.

We don't know whether we're going to have an agreement beyond fiscal 1990. As a result, I have to pay an extra one and a half percent interest to Chase Manhattan for the risk factor that

the Federal Government won't extend the centers beyond 1990 so I can have an out clause so they can come and repossess the machine. And that's just not a sensible way to do business for this country.

And so, there are many other examples I could give you, but that's just a very real one I'm faced with right now.

I think that the Congress and the National Science Foundation must renew their commitment to maintaining the national centers at the leading edge of technology. That's so critical. And yet, we aren't doing that. We do not have upgrade plans in place that are financed that the Federal Government is backing.

We're just struggling to regain the cooperative agreement levels which simply allows to do what we started to do. There aren't upgrade dollars in the cooperative agreements.

So, I think, if the Congress wants us to stay at the leading edge, we can do it, and we can get very fast technology transfer into American industry, and we can train a new generation of scientists and engineers, but we must have the dollars to back that policy commitment.

I think new, obviously, we need some new supercomputing capacity in the centers right now. We've been saturated, I think San Diego's been saturated much longer than we have, and that means that we are turning away this new generation of trained users from our centers.

I fully support Cliff Rhoades' new idea of Federal matching funds for dollars raised beyond the cooperative agreement levels.

The last point—I'll just make one last point that it must be a balanced national program. I said this when I first testified to you in 1985. We must have a balance between the local work stations and personal computers and campus networks, then the national networks, to give access to the centers in the capacity of the centers.

You know, a national network is very much like a national river system. You start out with little streams all over the country, and they come together to bigger brooks, and those flow together until you finally get regional—the Ohio River, and the Missouri River—and those finally go into the Mississippi, which is gigantic.

In that increasing capacity, as this network goes from the individual's office to his department, to the campus, to the regional state networks, to finally the backbones, the trunk lines, the interstate highway system.

That should be our goal and we should let that tell us what we need to do to provide that kind of access. In many cases, dollars are coming from states and regions as well as the Federal Government, and also from the telecommunications industry to make that happen.

But, we need to make our requirement to give the best minds in this country, the best telecommunications access, to the best computers that our country manufactures. If we do that, and I think we're very close to in terms of the dollars we need, then we will provide a major engine for this economy well into the next century.

Thank you.

[The prepared statement of Dr. Smarr follows:]

TESTIMONY BEFORE

THE UNITED STATES
HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

March 24, 1988

2321 Rayburn Office Building

Submitted by

DR. LARRY L. SMARR, DIRECTOR

NATIONAL CENTER FOR SUPERCOMPUTING APPLICATIONS

155 Computing Application Building
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Champaign, Illinois 61820

Mr. Chairman and distinguished members of the House Subcommittee on Science, Research and Technology, I am grateful for the opportunity to testify today on the health of the National Science Foundation's Phase II Supercomputing Centers. My name is Dr. Larry Smarr, and I am Director of the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign.

The Congress can be proud of the achievements of the National Supercomputing Centers. It is rare that a new government program can come so far in so short a time, accomplishing so much for the national scientific, educational, and technological agenda. We stand today at an important crossroads for realizing the full promise of the investment made in this nation's future by the initiation of the centers program.

When I last testified to this committee in June, 1985, the center awards had just been made. In the thirty-three months since then, our center, the National Center for Supercomputing Applications (NCSA), has grown from a staff of 16, no computers, and no users to a staff of 120, over 200 computers, and 2000 remote users in 125 universities. Our users have produced over 500 scientific publications using the facility, in fields as varied as agriculture, chemistry, manufacturing, petroleum engineering, and weather prediction. Formal education and training courses in advanced computing have been provided to over 1000 researchers nationwide.

The State of Illinois, the University of Illinois, and Cray Research, Inc. all joined the National Science Foundation in making major long term financial commitments to our center in 1985. In fact, fully 40% of the funding for the five year Cooperative Agreement was from non-Federal sources.

Since then, NCSA has used this core funding to attract corporations such as Eastman Kodak Company, Amoco Corporation, Eli Lilly & Company, and Motorola to become partners with us in applying supercomputing to real-world problems confronting American industry. We have also received major donations and discounts from many of the major scientific computer and communications manufacturers such as Apple, IBM, AT&T, SUN, Alliant, DEC, Silicon Graphics, and others. We are now beginning to have input on new product design by these companies to better serve the emerging scientific and engineering computer marketplace.

The resulting NCSA partnership of government, university and corporations is a new model for exploiting other nationally critical technologies. We read a lot about the United States being unable to compete with Japan because the various sectors of their society seem to cooperate better than ours do. Yet here is a "home-grown" example of American team

spirit, focusing on one of the most critical technologies in the global battle for industrial competitiveness. The Japanese now manufacture their own supercomputers--the race is becoming head-to-head. However, I believe that if each party in the NCSA partnership renews their commitment, the United States will be able to remain preeminent in applying supercomputers to basic research and to our national industrial base.

The dream of a new kind of research -- Computational Science and Engineering -- has become reality. Major questions in basic and applied research have been attacked by users of our center, among them:

- What was the state of matter in the very early universe?
- Can electrons jump from one side of a protein molecule to the other?
- How do electrons flow in new types of Gallium Arsenide transistors?
- What is the electron structure of high temperature superconductors?
- How do metal bars fracture under stress?
- How does plastic flow into a metal manufacturing mold?
- How do tornadoes or downbursts form in severe thunderstorms?

The answers to these questions will have practical implications in the future. For instance, the list above will translate into new insights, respectively, for major government projects like the Superconducting Super Collider, for new industries such as biotechnology, for defense applications using ultrafast switches, for designing new superconducting materials, for increasing the margin for failure of critical metal parts in airplanes, for creating more durable plastic products, and for public safety by more reliable predictions of violent weather.

An entire new generation of students, faculty, and industrial researchers are being educated and trained in how to use the most advanced computers made in our country to solve problems at the frontiers of knowledge. By creating a new type of alliance between government, universities, and corporations, we have leveraged the federal investment and created a powerful new mechanism for technology transfer. The result is a strengthened national scientific infrastructure and increased international competitiveness.

In this testimony, I will review briefly the rapid progress we have made in setting up a true national center, containing a critical mass of minds and machines, for advanced scientific and engineering computing. Although we have achieved the immediate goals outlined for the program by Congress four years ago, the demand for these services which we have ignited is beginning to grow far beyond the capacity of our national networks and center's supercomputers. To allow the ever growing pool of newly trained users access to these tools and to give our American scientists a competitive edge, we must immediately upgrade these facilities to keep them at the leading edge of computer technology.

To do this requires a stable, predictable, and adequate Federal funding base. Assuming this, I believe there will be an enormous explosion of new applications using high performance computers in virtually every field of science and engineering. The continued close participation by American industry will guarantee a rapid transfer of these discoveries into economic benefits.

THE NCSA FACILITY

The central facility at the NCSA contains a four-processor CRAY X-MP system with an electronic "RAM disk" containing one billion bytes of storage. This supercomputer, manufactured by Cray Research, Inc., is about 1,000 times as fast and has about 1,000 times as much memory as a personal computer. In other words, a computer problem that would run in one hour on the CRAY would take over a month to run on a personal computer. Furthermore, the problem can be made enormously more complex, and therefore more realistic, on the supercomputer because of the large memory.

This supercomputer is coupled to a mass storage device which holds all the user's files. The one in our center is based on an IBM mainframe using the Los Alamos National Laboratory software Common File System. It currently contains 1.8 trillion bits of user data generated by the supercomputer since our center opened. In addition, we have several Digital Equipment Corporation superminicomputers as front ends to the CRAY. These act as "traffic cops" for the streams of data coming in and out of our center from hundreds of simultaneous users.

NCSA has placed a major emphasis on changing the way in which researchers use supercomputers. Because almost all remote users have personal computers or scientific workstations on their desktops, we have developed a strategy of coupling the CRAY closely to their personal computers. This allows them to work in the environment familiar from day-to-day use of their personal computer, but enables them to "reach through"

the personal computer to grab the extra speed of the distant supercomputer when they have the need.

To support our staff and visitors, we have networked together over 100 Apple Macintosh and 60 IBM personal computers in our center. In addition, we have over 65 scientific workstations manufactured by Sun, DEC, Raster Technologies, and Silicon Graphics on our internal Ethernet (10 megabits/sec) network. As our staff develops new software to make computing more convenient on these standard desktop machines, we can easily distribute it to our users to install on their local computers.

Since most desktop computers have excellent color screens available now, we have developed techniques to "visualize" on the screen in front of your eyes the results of the computations on the supercomputer. One color image of a complex flow of gas contains about one million numbers. The ability to switch from the individual number (Byte), as the basic unit of computing, to the color image (Megabyte), not only speeds up the human's ability to scan large amounts of data, but more importantly it intimately couples the human eye-brain system into the computer. We are much more capable of recognizing patterns and relationships in images than in pages of numbers. This is a critical breakthrough, since the goal of supercomputing is new insight, not number generation.

Personal computers are not powerful enough yet to show fully three-dimensional "movies" on your local screen, so we have pulled together an outstanding team of computer graphics professionals, who were previous employed by companies that produce TV commercials and special effects in films, and built around them a "Scientific Visualization Facility." This facility makes the computer tools and techniques, previously reserved for the advertising and Hollywood feature film industries, available to the university and corporate researchers of our country. Such tools will be indispensable for visualizing the simulations which will be performed on the upgraded supercomputers coming into the centers in the next few years.

Of course, none of these wonderful computers would be very useful to our remote scientists and engineers without a support staff to administer the program, consult on problems, keep the machines working, put up and write new software, document the system, operate the computers, and train new users. We have gathered together a dedicated team of first-rate professionals who believe that their job is to do whatever they can to enhance the ability of our users to create new knowledge by the use of high performance computing. The center's parking lot is often full on Saturday and, several times a week, staff members will stay up all night to help a researcher finish a project with a deadline. This commitment comes from sharing a common vision of the importance of our work for pushing back the frontiers of knowledge and helping create a better future for our country.

COMPUTATIONAL SCIENCE AND ENGINEERING

This facility has encouraged over two thousand scientists, engineers, social scientists, and humanists to obtain allocations of supercomputer time on our CRAY system as part of 750 projects. We recently surveyed our users to find out how many publications have resulted so far from their use of the facility. The partial results are contained in SCIENCE-The State of Knowing, our 335 page Annual Report to the National Science Foundation for 1987. There we list over 500 articles published by our users in an enormously wide range of journals, ranging from the Journal of Dairy Science to Physical Review Letters to the Journal of Geotechnical Engineering. This is just the beginning of the flood of new knowledge which the national supercomputing initiative is releasing.

The color images resulting from the computer visualization of these computations have been extremely popular with the national press. Hundreds of newspaper and magazine articles have reported on our center alone. Several major national television specials have used videotapes produced by our center. This has heightened the public's awareness of the critical importance of these technologies for the nation's future.

We have always believed that our center must be much more than a professionally run computer center. A great national scientific institute must arise built around this facility. Therefore, NCSA has created an Interdisciplinary Research Center (IRC) to bring together a powerful mixture of many of our best minds from academia and industry. We support world-class research scientists in the IRC to push their fields as far as our leading edge computers will allow. Computer artists and humanists are encouraged to form "Renaissance Teams" with scientists and computer professionals, so that the team can solve problems impossible for single investigators. A steady stream of national visitors enriches the "melting pot." Out of this critical mass come major software innovations which are distributed freely to the national community.

Another key reason for the success of our center is that it is located in the heart of a major research university. As a result, our supercomputer center has become a part of the lifeblood of the campus of the University of Illinois at Urbana-Champaign. Our center takes a portion of the State of Illinois cost-sharing dollars and returns them to academic departments on a competitive basis for fellowships to foster new applications in supercomputing. NCSA financially supports undergraduates, graduate students, postdoctoral fellows, professors, and visiting professors in areas as diverse as agricultural economics, chaos theory, elementary particles, history, petroleum engineering, urban and regional planning, and x-ray crystallography.

NCSA's goal is to become a hub for interdisciplinary research, providing a campus "watering hole" for researchers who might otherwise not know of each other's work because of departmental barriers. We also try to bring together students to work directly on original research projects. For instance, our campus is fortunate to have 400 extremely bright graduate students in computer science. NCSA has been able to help team many of them up with faculty or NCSA staff scientists and computer professionals to attack the new software problems generated on the frontiers of computational science.

Often these seed grants grow into ideas for national thrusts in new application areas. NCSA sponsors workshops to bring together many of the nation's leading experts to explore the possibilities of how our center could help nurture the development of these new fields. Examples in the last year ranged from the statistics of experimental design to symbolic manipulation in quantum gravity.

In addition, campus faculty involved may follow up by submitting individual or center grants to the NSF or other funding agencies in order to sustain this new activity. One recent successful example is the $400,000 NSF Biological Center grant for genome sequencing of bacteria awarded to our Microbiology Department. That was followed by a $1,000,000 (over five years) joint software development grant from the Amoco Corporation. NCSA is now planning with this center and its sponsors how to integrate the supercomputer and massive data bases into this pioneering wet laboratory work. The Biological Center is collaborating with many other researchers in universities across this country. Similar efforts on our campus coordinated with NCSA are underway in Proteins, Electron Device Simulation, and Integrated Global Economic Models.

To insure a rapid and effective transfer of these technologies into American industry, NCSA has designed an Industrial Partners program. Our goal is to form research partnerships with ten leading corporations whose research interests span the United States economy. By helping them solve problems with advanced computing, we directly enhance this country's productivity and industrial competitiveness. Each Partner has remote access to our supercomputer and sends many of its scientists, engineers, executives, and strategic planners to visit or work in our IRC. To date, four corporations have joined the program: Eastman Kodak Company, Amoco Corporation, Eli Lilly and Company, and Motorola. We have made presentations to several hundred others and expect to finish filling our Partners program in the next two years.

To illustrate the effectiveness of our corporate program in allowing industry to solve problems it could not attack without our center, I have included as an Appendix the invited talk Dr. Cliff Perry, Director of the Eastman Kodak Company Computational Sci-

ence Lab, gave at the Industrial Research Institute's annual meeting on October 25, 1987. I was asked to give the keynote speech on the "Computational Science Revolution and Its Impact on American Industry" at the same meeting. The IRI members are the Vice Presidents of Research of the 250 corporations in America that control some 85% of the corporate R & D in this country.

Dr. Perry's talk details how Kodak's partnership with NCSA has allowed its scientists and engineers to pursue "cost-effective research" with advanced computing technologies. He states that "NCSA offered what [Kodak] feels is the most attractive opportunity for us to explore and exploit supercomputing technology."

He discusses four examples of Kodak supercomputing projects made possible by the partnership with NCSA in the fields of chemical dye research, tolerance analysis in product design, image processing to improve film quality, and the manufacturing of film. Dr. Perry also showed a video of four other Kodak projects completed in the first year of its partnership with NCSA in the areas of heat conduction in optical laser disks, etching of silicon integrated circuits by ion bombardment, surface diffusion of hydrogen on catalytic materials, and plastic injection molding simulations.

This innovative program of closely coupling industrial needs with our center's expertise and advanced computational resources will serve as a new sparkplug for the American economy. I believe that a major reason for our failure to compete effectively in the international marketplace has been a decoupling over the last few decades of the three key subsystems in the United States economy: government, industry, and universities. The NCSA model for quickly getting new advances in knowledge or technology directly into the heart of our leading corporations could have a major positive impact on this nation's international competitiveness.

GROWTH OF NATIONAL DEMAND

The national supercomputer centers and the national network which connects them with the remote users is generating an unprecedented demand for access to advanced computing facilities. We all need to be very aware of this, because one of the major payoffs of the initial investment in the program will be a vastly increased national pool of trained manpower skilled in advanced scientific computing. I will review a number of the factors driving the demand and give some estimates for its growth rate. It is extremely important to encourage this growth of interest in applying high performance computing to new areas of research and application. A broadly based use of such technologies will form the underpinning of the United States economy in the 1990's.

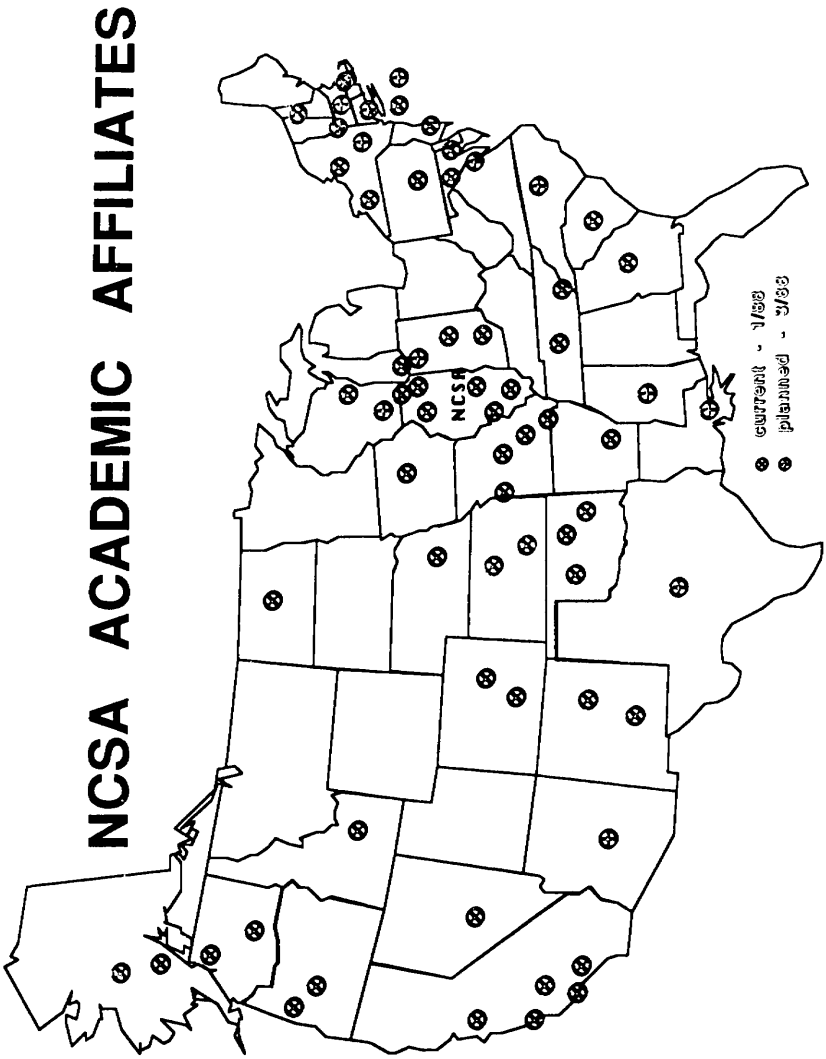
EDUCATION AND TRAINING

Training of new users has become a major focus for NCSA. This is the key to avoiding the trap of just giving the "old guys new toys." If computational science and engineering is to take its place alongside experimental and theoretical approaches, then we must greatly widen the number of researchers who are trained in these techniques.

The clearest indication that new users are taking advantage of the access provided by the centers is that over 1000 of the 2000 users allocated time on our CRAY are graduate students or postdoctoral fellows. They are getting "on-the-job training" by working closely with older faculty, in the traditional apprentice mode of training young scientists. These researchers are spread out throughout 125 institutions. They act as local models for other researchers to follow in obtaining access.

NCSA has designed an Academic Affiliates Program to provide resident on-site training for universities. Some sixty universities, small and large, have taken advantage of the program so far (see graph and table attached as next three pages). To join the program, a university must appoint one or more experienced computer professionals to act as an on-site resource person for NCSA. These trainees must come to NCSA for an intensive week of lectures and "hands-on" training. In the last twelve months, 120 trainees have gone through our program, with a number of them returning for advanced training courses. These graduates return to their own campuses, where they set up local training courses on supercomputing. We estimate that these remote courses have reached another 500 students and researchers. Finally, the Academic Affiliate institutions get a block of supercomputer time to divide up as small "starter grants" among their faculty and students to encourage more colleagues to try supercomputing. This "second generation" of remote users is just now starting to apply for followup large allocations of supercomputer time.

From the beginning, NCSA has had an active national visitors program. This allows researchers to come to our Interdisciplinary Research Center and "totally immerse" themselves in the atmosphere and resources of advanced computing. While at NCSA, the visitors work with advanced networked workstations and with a designated consultant. They can collaborate with our research scientists or campus faculty and take advantage of our Scientific Visualization Facility. In the last year, over 70 visitors from 44 institutions have come to NCSA. If you count all the days they have stayed, you find that NCSA has supported 1600 visitor-days in the last twelve months! Usually the visitors go back to their home institutions with a capability of attacking even more ambitious scientific challenges, which require ever larger blocks of supercomputer time than before they came, thus


NCSA ACADEMIC AFFILIATES
NCSA
planned - 1993
current - 1993

NCSA Academic Affiliates
As of March 1, 1988

Clemson University
C. J. Duckenfield
(803) 656-3692

Colorado State University
John Cooley
(303) 491-1575

Duke University
Shiangtai Tuan
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Eastern Illinois University
Dave Henard
(217) 581-3227

Gallaudet University
Donald V. Torr
(202) 651-5027

George Washington University
Thomas E. Moyer
(202) 944-6389

Georgia Institute of Technology
Eugene Galiano
(404) 894-4660

Harvard University
Lewis Law
(617) 495-2627

Illinois Institute of Technology
Patrick Feldner
(312) 567-5962

Indiana University
Robert Holden
(812) 335-9258

Kansas State University
Neil Erdwein
(913) 532-6311

New Mexico State University
Joseph R. Denk
(505) 646-3439

New York University
Jeff Bary
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North Dakota State University
Mark Gordon
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Northern Illinois University
Samnuan Duramad
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Janice Hanson
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Oregon Graduate Center
Jon Crowhurst
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Oregon State University
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Pennsylvania State University
Molly Mahaffy
(814) 865-4750

Rose-Hulman Institute of Technology
Bruce Danner
(812) 877-1511

Southeast Missouri State University
Anthony J. Duben
(314) 651-2785

Southern Illinois University-Carbondale
Charles Gibson
(618) 453-4361

Stanford University
Randy Melen
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State University of New York-Buffalo
Geraldine Sonesso
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Syracuse University
Wayne Fordyce
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Tufts University
Kanthi Yapa
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Beverly Valdez
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University of Alaska-Fairbanks
Mitchell Roth
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University of Arkansas
Bill Ashmore
(505) 575-2905

University of California-Irvine
Herbert W. Hamber
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University of California–Los Angeles
Vahe Peroomian
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Paul N. Lowe
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University of California–Santa Barbara
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University of Chicago
Eric Nelson
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University of Colorado
Neal Huriburt
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University of Delaware
Dean Nairn
(302) 451-1718

University of Idaho
John Finnie
(208) 885-7559

University of Illinois–Chicago
Steve Roy
(312) 996-2489

University of Iowa
Judy Brown
(319) 335-5552

University of Kansas
Michael Grobe
(913) 864-4965

University of Maryland
Jerry Michener
(301) 454-2943

University of Missouri–Columbia
Lew Davidson
(314) 882-5175

University of Missouri–Kansas City
Mike Fatino
(816) 276-1180

University of Missouri–Rolla
Meg Brady
(314) 341-4845

University of Missouri–St. Louis
Larry Westermeyer
(314) 553-6000

University of Nebraska
Darrell K. Fluehr
(402) 472-5663

University of Nevada–Las Vegas
James Williams
(702) 739-3557

University of New Hampshire
Elizabeth Rivet
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University of New Mexico
Art St. George
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University of Notre Dame
Clyde Dawson
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University of Oregon
Patrick Holleran
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University of Rochester
Richard Phillips
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University of Tennessee
Sue Smith
(615) 974-6721

University of Tulsa
Travis Tull
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University of Washington
Larry Gales
(206) 543-9700

University of Wisconsin–Madison
Wayne Shockley
(608) 262-3724

University of Wisconsin–Milwaukee
David Stack
(414) 229-4041

Vanderbilt University
Maria Perkins
(615) 322-7311

Washington State University
Victor Swan
(509) 335-0490

adding to the national demand. They also act as a local "model" for large scale computing to their colleagues and inspire them to apply to the NSF for supercomputer time at one of the centers.

The Industrial Partners typically find that it is advantageous to send their researchers to NCSA before using remote access. An industrial user will usually have an application code that runs on a smaller computer in the corporate laboratory, but it isn't optimized for a supercomputer and the user may not know the latest in workstation and visualization technology. After visiting and getting the application up in our advanced environment, the user can return home, clone any of the local equipment needed, and use our facility remotely. We have had over 90 individuals visit from Kodak, Amoco, and Lilly in the last year. In addition, our training staff have conducted courses at the industrial labs for about 150 researchers. Only Kodak, our first partner, has ramped up to major use of the CRAY. Amoco, Lilly, and Motorola will triple that demand in 1988. As we add the remaining six partners in our Program, the industrial demand will rise rapidly in 1989 and 1990. Although the NCSA Industrial Partners cover the cost of their cycles, their demand must be balanced with the academic demand on the same machines.

In addition to these special groups, NCSA holds a variety of general training sessions year round. The nationally competitive Summer Institute had 40 attendees. We have trained 200 remote users on their campuses in our Outreach Program. A number of more specialized NCSA workshops in advanced computing were attended by 200 more. Finally, our short training courses offered every two weeks have trained 150 in the last year.

Thus, altogether NCSA has trained over 800 users in the last twelve months. These researchers are now adding to the increasing demand for capacity at our center. Having made the commitment to training them, it is imperative that we follow through with the increased capacity to allow them to pursue their supercomputing science and engineering. If we do, then our center will become a powerful national force for creating a constantly enlarging pool of trained manpower in supercomputing science and technology, which is increasingly critical in the race for international competitiveness.

REMOTE ACCESS

It is important to note that most researchers in universities still have very poor access to the five NSF supercomputer centers. The problem starts on the campus of the researcher. We hear from many users who have been allocated time on our CRAY system and whose campus has a connection (an internet node) to the NSFnet, but whose university has not yet spent the money to hook up the user's research office to the campus internet

node. In a lot of cases, the user cannot even dial in by telephone modem (1200 bits/sec) from his office to the internet node.

Even if the researcher has a campus with a good local area network which connects to the NSFnet internet node on that campus, it is getting very difficult to use the NSFnet to get to an NSF supercomputer center. This is due to the low bandwidth of the current NSFnet Backbone (56,000 bits/sec) which connects the five centers, and to the increasing growth in demand for use of supercomputers.

Dr. David Mills, one of the principal NSFnet architects, has noted by electronic mail in December 1987 that "the [NSFnet] backbone has thus almost reached its design maximum drop rate... and should be considered fully loaded." His statistics indicate that "the typical [remote local area network] would appear to be unreachable almost one minute in ten." His conclusion is that "with traffic doubling at about 4.5 months and new [connections] doubling at about 5.1 months, there is no question that the [NSFnet] backbone will soon be completely swamped and performance will deteriorate severely..."

There will be no major relief until July 1988 at best, when the upgraded NSFnet is scheduled to come into existence. That network is much more sophisticated than the current Backbone and has T1 (1,500,000 bits/sec) links among 13 nodes. At that point the bottlenecks will shift back to the regional networks which feed into the NSFnet and to the local area networks on individual campuses.

The campus of the University of Illinois at Urbana-Champaign provides an object lesson in how good local area networks can make an enormous difference in a campus' demand for supercomputer time. Because of the importance which the campus places on computing in all disciplines, and the leadership of our Computing Services Office, there is at least 9600 bits/sec access to almost every office on campus. Most of the buildings are now being linked up by fiber optic supporting 10,000,000 or 80,000,000 bits/sec access. In addition, use of local dialup at 2400 bit/sec allows many faculty to continue computing at night and on weekends from their homes to campus.

As a result of the excellent local access, our campus probably has more users of a supercomputing center than any other in the United States. Even though our faculty have to go through exactly the same process of peer review by NSF program officers to get an allocation of supercomputer time as faculty at any other university, we have users in over fifty campus departments or units that now have allocations. Our campus usage illustrates just how deeply universities will become penetrated by supercomputer users as the national NSFnet, the regional networks, and the local area networks on campuses catch up to the

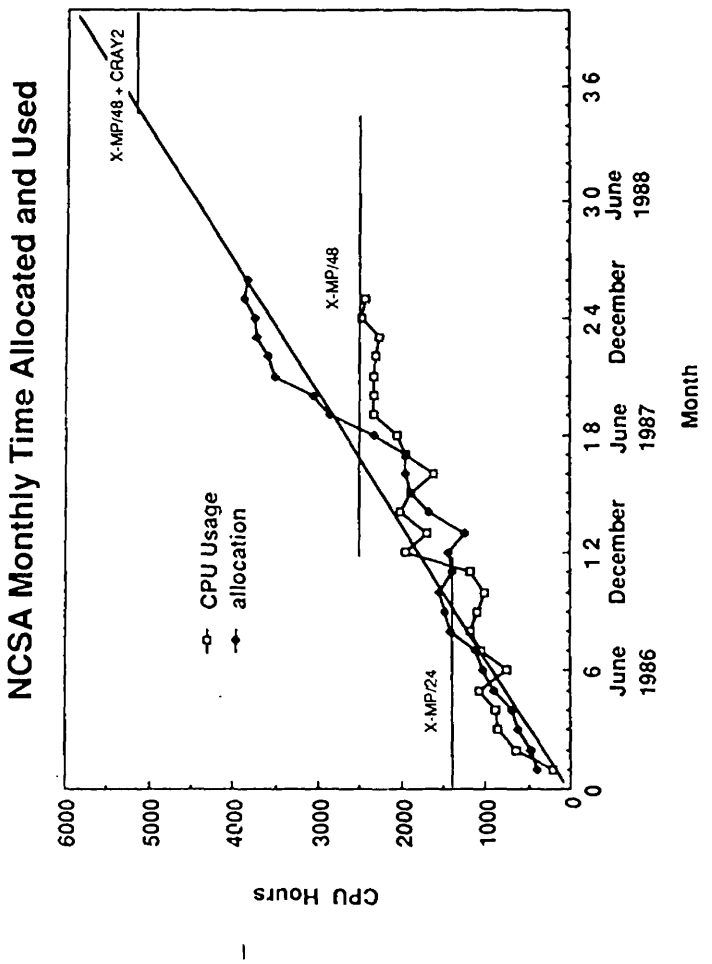
network at the University of Illinois at Urbana-Champaign. This translates into a phenomenal increase in demand for supercomputer cycles in the next few years.

Another consequence of widespread campus local area networks will be a need to accelerate the bandwidth capacity of the NSFnet. A typical network in a department linking researcher's offices will have a bandwidth of at least a megabit/sec. The campus trunk lines will therefore have to be about 100 megabits/sec, as all the departmental networks flow into them. This obviously implies a need for regional networks to have capacities near 1 gigabit/sec and the national trunk lines will need to be in the gigabyte/sec range. Just like small brooks flow into streams which in turn become part of regional river systems and which finally empty into the Mighty Mississippi, the architecture of the hierarchical national network must have adequate capacity at all levels.

DEMAND IS EXCEEDING SUPPLY

Our center has been open to the national community since January 1986. For the first eleven months we had a two-processor CRAY X-MP supercomputer. It was upgraded to four processors, doubling our capacity, in November 1987. For the last sixteen months our machine has become more and more heavily used. The national allocation process has been mainly through the NSF program officers, with little feedback as to whether the aggregate allocations sent to NCSA from all Divisions of the NSF exceeded our fixed supply of cycles. Until summer of 1987, our monthly supply of CRAY cycles exceeded the demand. The accompanying graph (see next page) shows dramatically how rapidly demand began to exceed supply starting in August 1987.

When too many users try simultaneously to obtain access to a computer, a characteristic "saturation" situation results. The time it takes for a job to execute gets longer and longer. The response time on editing files becomes very slow. Users can't get their interactive work done during the day, and large "overnight" jobs become "weekend" jobs. Users are forced to pay (in service units) a premium to get their computing done in a reasonable time. The users who can get onto the CRAY are frustrated because the slowness in turnaround begins to hinder the rate at which they can make progress in their research. The newly allocated users are told that they can't get access to the supercomputer until old users' allocations are used up. The net result is a lot of angry users and the beginning of a dangerous period of "turning off" potential users. If this is allowed to persist for much longer, permanent damage to the nation's scientific and economic future will occur, because users will feel that it is not worth the effort to pioneer new areas of computational science.


NCSA Monthly Time Allocated and Used
CPU Hours
6000
5000
4000
3000
2000
1000
0
CPU Usage
allocation
X-MP/48 + CRAY2
X-MP/48
X-MP/24
6 June 1986
12 December
18 June 1987
24 December
30 June 1988
36
Month

We presented a detailed proposal to accomplish this planned and predictable upgrade path to the National Science Foundation in August 1987 in response to its request for a FY88 Program Plan and a Long Range Plan. This Program Plan was reviewed by the Program Plan Review Panel, headed by Dr. Clifford Rhoades in September 1987. Comments from the Panel and from the users of our increasingly saturated CRAY X-MP system were quite favorable. To carry out the upgrades would require a supplemental allocation to our Cooperative Agreement in FY88 to cover machine room retrofits to accommodate the CRAY-2 system and a five year renewal of the Cooperative Agreement with renegotiated yearly amounts in the out years to cover the upgraded capacity. This complex upgrade plan was proceeding fairly smoothly until December 22, 1987.

NEED FOR STABLE AND PREDICTABLE FUNDING

Gripped in a Federal fiscal crisis caused by the growing Federal deficit, foreign trade deficit, and the shadow of the October 19 "Black Monday," the Congress passed and the President signed the Omnibus Continuing Resolution (P.L.100-202) and the Deficit Reduction Act (P.L. 100-203) three days before Christmas. The net result was that the National Science Foundation's requested increase in research for FY88 was slashed $182 million.

This resulted in fewer Federal dollars being available for the Centers than was hoped for by the Foundation. Although the Division of Advanced Scientific Computing did achieve an increase over FY87 funding levels, NCSA was cut $1 million from our Cooperative Agreement FY88 amount of $8.8 million. Even more difficult for us was that the resulting FY88 funding level of $7.8 million was $700,000 below the FY87 funding level for our center. This decrease of NSF funds from one fiscal year to the next sent a very negative signal to the other members of our cost-sharing partnership.

In response to these cuts, we immediately halted remodeling plans on our machine room and temporarily suspended negotiations with Cray Research, Inc. on an upgrade to a CRAY-2 supercomputer. We were forced by the fiscal constraints to effectively sever access to about 200 of our scientists nationally. NCSA was forced to postpone payments which we owed to some of our computer manufacturers. For a large fraction of the last two months our staff have spent their time figuring other ways to manage the reduced funding.

Our center and university have put an enormous amount of energy into persuading major corporations to join us as Industrial Partners. We have made over one hundred

At NCSA we already have a backlog of over 5000 hours of allocations which are being held in a queue. We will be unable to grant any new allocations in the second quarter of 1988. Yet as we have seen above, the policies of training and improving networks are creating major sources of new demand for allocation. It is clear that another doubling of our capacity is overdue.

UPGRADES

In summary, there are three independent forces driving demand for more supercomputing cycles at the national centers. First, each user gradually requires more cycles for a problem as he adds realism to the simulation (e.g., going from two to three spatial dimensions or adding magnetic fields to a fluid flow). Secondly, the national training programs are preparing many new users to attack problems with supercomputers. Thirdly, as national networking steadily improves, the ease of using remote supercomputers becomes greater, encouraging even more users.

This is why the demand for capacity at the national centers will continue to rise rapidly for the foreseeable future. While it is true that some of this load can be handled by the supercomputers being acquired by individual universities, the capabilities offered by the leading edge national centers will not be available elsewhere. These capabilities, such as gigabit/sec networking, advanced visualization facilities, and large teams of support computer professionals, become more necessary as the speed and memory of supercomputers increase. Furthermore, as the DOE laboratories such as Los Alamos National Laboratory or Lawrence Livermore National Laboratory discovered, there is an economy of scale to have several supercomputers in a national center to provide capacity. This is because the staff, peripherals, and buildings have already been paid for. Adding another supercomputer is a marginal expense compared to building a new center from scratch. The NSF centers have not yet taken advantage of this cost efficient manner for meeting the growing national demand.

Because our center's demand-doubling time was about twelve months, we began negotiating with supercomputer vendors for upgrades almost as soon as the last upgrade arrived. By summer 1987, NCSA had concluded that the best strategy was to pursue a dual upgrade path with Cray Research, Inc. This would bring in a large memory CRAY-2 supercomputer in the third to fourth quarter of 1988 to double the capacity of the existing CRAY X-MP system. The X-MP system would be upgraded in 1989, the CRAY-2 system in 1990, and so on. This would leave each machine in our center for two years, but by staggering the upgrade, would bring in a new machine each year. The rest of our facility -- wide area and internal networks, mass storage devices, front end machines, workstations, etc. -- would need to be upgraded simultaneously to keep the overall system in balance.

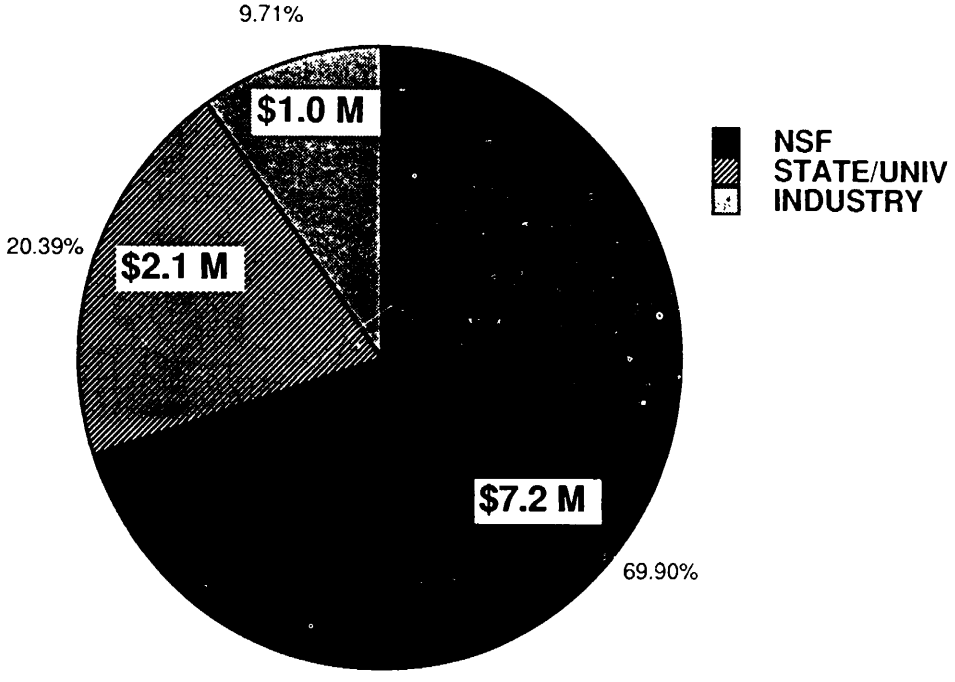
presentations to corporations in the last two years. I have addressed high level executives of several hundred corporations on the urgency of incorporating supercomputing in their research, development, and manufacturing divisions. By the time of the FY88 budget decisions, four corporations had each committed at least $3 million over at least three years to our center. These new funds are what we used to leverage the core facility NSF funds and to increase the capabilities, such as visualization and new software tools, provided by our center. The FY88 level effectively eliminates the re-deployable funds from our last two Industrial Partners. It forces us to remove capability to sustain capacity.

The decrease of NSF funding accentuates an ongoing trend at our center, which we view as very disturbing. In FY86, the NSF funded our center at $7.2 million, or 70% of the total cash income of $10.3 million for NCSA (the State and University of Illinois contributed $2.1 million and industry $1.0 million). Two years later, in FY88, with all the growth in capacity and capability described above, the NSF contribution has grown by only $600,000 to $7.8 million. The FY88 NSF percentage of the cash income to NCSA has dropped to 47%, while the Illinois contribution has almost doubled to $4.1 million and the the industrial share has gone up almost five times to $4.75 million. The accompanying pie graphs show dramatically how NSF's share of our centers funding has decreased in only two years. When one considers that these figures are based on only four of our projected ten industrial partners being in the program, one can see that this situation will only worsen in the years to come. We believe we need some policy guidance on this issue. Will the acquisition of additional external funding further undermine our Federal funding, which is so essential to our core program?

What does this mean for our longer range plans? At this point, our center, our university, and our users are not confident of the Federal Government's policy plans are for the supercomputing centers. Should we be pursuing upgrade plans, should we be allocating new blocks of time, should we continue an aggressive training plan, and should we continue to encourage new industrial partners? Will there be an extension to our Cooperative Agreement, which runs out in mid-FY90, or would it be more prudent for us to begin to scale back our operations in preparation for the inevitable demise of the program? This air of uncertainty has made it extremely difficult to negotiate long range upgrade agreements and it threatens to undermine the partnership with the State and our Industrial Partners. I believe the most urgent requirement I have as a center director is to receive answers to these policy issues from the Congress and the NSF.

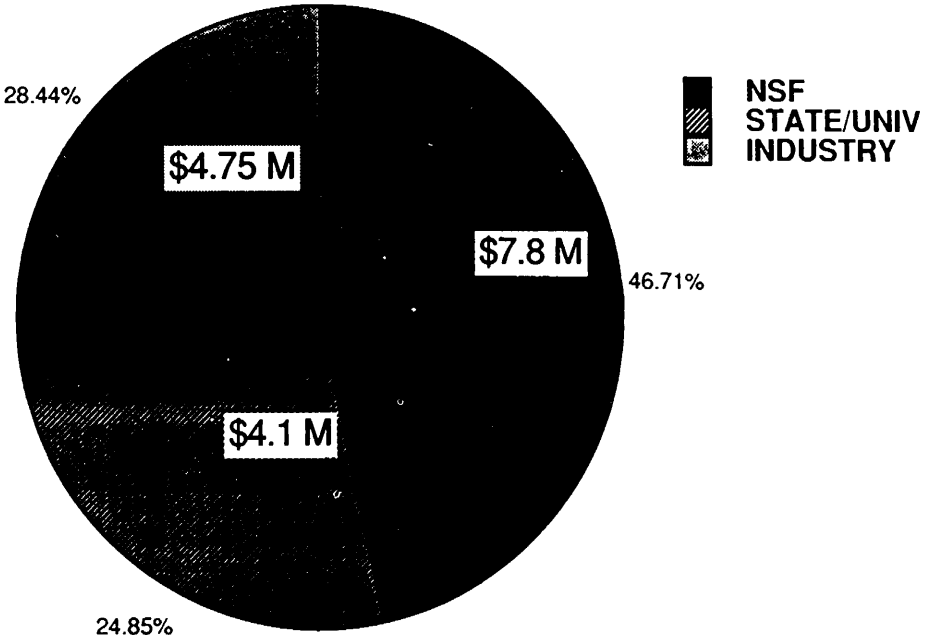
The need for predictable and stable funding from the Federal Government is particularly critical at this point in the history of the program. As I have pointed out above, we have shown that Computational Science and Engineering is a powerful new force for the future of our country. We have many good examples of how pioneering researchers can

NCSA CASH INCOME FY 86
MILLIONS OF DOLLARS



TOTAL = $ 10.3 MILLION

NCSA CASH INCOME FY 88
MILLIONS OF DOLLARS



TOTAL = $16.65 MILLION

use their new-found access to supercomputers and advanced visualization techniques to open new fields. We have planted the seeds of hope in an entire new generation of graduate students and faculty with education and training programs. And we have been successful in persuading a number of major corporations to join in enlarging the program. If we can keep the commitments made by each partner to our shared vision, then we will witness a continual increase in the academic and industrial application of our country's most advanced technologies.

RECOMMENDATIONS

In summary, I believe that we should all be proud of an incredible achievement in a very short time. The National Science Foundation Phase II Supercomputing Centers have created a major new national force for:

- Scientific innovation
- Education and training
- Technological leadership
- Bringing together government, universities, and industry.

As we move from the birth and infancy stage into the maturing growth phase, we must reiterate our commitments to keep these centers and national network at the leading edge of technology and ahead of the growing demand for access from some of our best young minds. I would respectfully advise that the following policy statements be put forward by the Congress to assure the healthy growth of this critical national program:

NATIONAL SCIENCE FOUNDATION

The Federal Government renew its stated commitment to double the research budget of the National Science Foundation over the next five years. First and foremost, the individual grantees must get increased funding for basic research and graduate education needs. In addition, this action would provide not only the needed funds to upgrade the centers and the national network, but also increase the funds available to investigator grants so that powerful workstations and other advanced computers can be installed at the remote user's research site.

NSF SUPERCOMPUTER CENTERS

The National Science Foundation supercomputer centers must be provided with predictable and stable funding with a rolling five year horizon. This is a prerequisite for negotiating long-term upgrade plans with computer manufacturers and financing intermediaries.

The Congress and the National Science Foundation should renew their commitment to maintaining their Phase II supercomputer centers at the leading edge of computing technology. Without immediate action, the centers will cease to have their "pulling" effect on supercomputing science and technology in this country. This will have a very negative impact on the United States' ability to compete internationally.

The National Science Foundation should add some new supercomputing capacity as soon as possible to saturated centers. It is clear that if we allow this saturated environment to continue much longer, we will permanently damage the efforts to spread the use of high performance computing among new users. Furthermore, it is very cost effective to add new capacity at existing centers, since the staff and infrastructure are already paid for.

The Cooperative Agreements should have automatic Federal matching funds for new funds raised by the center outside those anticipated by the Cooperative Agreements. This gives a major incentive to enlarge the cost sharing by Corporations, Foundations, State and Local Governments, and Universities. It would also mean that new computing devices or services made possible by the new funds would automatically be made available to the research community represented by the NSF.

NATIONAL NETWORK ACCESS

The Congress and the National Science Foundation should accelerate the upgrading of the NSFnet. This national lifeline for remote users has been saturated for months. This reduces the national centers to regional centers.

As a nation we must find ways to encourage universities to install effective local area networks to link the user's research office or laboratory to the campus gateway to NSFnet. Regional networks should also be encouraged to upgrade to match the NSFnet bandwidth. From the user's point of view, what is needed is a high bandwidth connection from his or her keyboard to the national supercomputer center.

We should set a national goal of creating a billion byte-per-second national information superhighway of optical fibers within the next ten years. This national network would provide a foundation for the information economy of the next few decades in the same way that the interstate highway system did for the United States economy of the 1960's-1980's. It will be necessary for remote users of the 1990's supercomputers.

APPENDIX

FACILITATING THE USE OF ADVANCED COMPUTING TECHNOLOGIES FOR COST-EFFECTIVE RESEARCH

Industrial Research Institute
1987 Fall Meeting
Philadelphia, Pennsylvania
October 25-28, 1987

Dr. Cliff Perry
Director, Computational Science Lab
Kodak Research Laboratories
Eastman Kodak Company

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It's a pleasure to be here today to discuss with you how we at Kodak are working to enhance and facilitate the use of advanced computing technologies for cost-effective research.

Throughout this morning, we've absorbed a lot of information about supercomputing and its application. It is important that we as scientists share information and knowledge to advance the potential of this vital technology.

Two hours ago, you saw some of the results of the partnership between Kodak and the National Center for Supercomputing Applications at Illinois.

As a reminder of the exciting capabilities supercomputing brings to the understanding of materials and processes, I would like to start my presentation with a short three minute version - a Reader's Digest version, if you will - of the videos Larry Smarr reviewed with you. My version has a musical sound track added, but the real excitement is in the visual images we are about to share one more time . . . [videotape]

I would now like to share with you some of the details of how we are facilitating the use of advanced computing technologies for cost-effective research. I want to share with you a few of the "why's"....some of the "how to's"...and several highlights from our initial results.

To begin, let's step back and consider the emerging role of supercomputer technology at Kodak Research in the context of our history.

Research at Kodak has very deep roots, dating back more than 100 years when, in 1886 George Eastman hired a young chemist to investigate cellulose nitrate films. Our research was formally organized 75 years ago, when in 1912, Eastman hired Dr. C.E. Kenneth Mees as director of research.

In the first full year, Mees and his 20 scientists operated on a $50,000 budget. Today, Kodak R&D activity worldwide involves some 8,000 scientists and technicians in laboratories in the U.S., England, France, Germany, Australia, and Japan. Our current billion dollar annual research budget is larger by a factor of 20,000.

To a significant degree, that number reflects not only the growth in the types of scientific inquiry in the labs...which now include photographic science, microelectronics, magnetics, biotechnology, and a range of other disciplines...but also reflects the increasing sophistication of the tools our scientists require to conduct research.

Of course, advanced computing technology is one of those tools. And when integrated in the research support system, this technology has the capacity to change--not merely facilitate--the process of scientific inquiry.

Just how successful computer technology can be depends upon how effectively it is integrated into the R&D environment. This integration process is a key function of the Information and Computing Technologies Division..and the Computational Science Laboratory. Our mission is to be a catalyst...to promote advanced R&D computing technologies and systems that will enable our people to do creative, cost-effective, business-focused research.

As we looked for ways to accomplish this mission, we quickly saw the potential value of supercomputing technology.

To further investigate the possibilities of this technology, we formed a Supercomputing Task Force. They reported in May, 1986, with an enthusiastic endorsement of supercomputing technology... and its potential to significantly increase the cost-effectiveness of computation for scientific research and engineering projects at Kodak.

The task force found that supercomputing technology could facilitate our work in three ways:

1. By assisting in solving scientific and engineering problems that are currently intractable using conventional large-scale computing.

2. By creating the core of an environment that enhances multidisciplinary science.

3. By increasing the value of computational results through the visualization and graphics output systems for analysis and presentation.

We understood that supercomputing technology is much more than a tool that would merely allow us to do things faster.

Just as important, we felt that supercomputing would be a great "enabler"...that is, giving us the capability of performing tests and viewing phenomena that had not been observed before. It would not only allow us to solve the RIGHT problems faster...it would also allow us to ask the right questions sooner.

I'd like to explain the ramifications of this capability with a simple analogy--baking a cake.

With conventional computing capabilities, we have been able to look at a cake and discover its ingredients. We can understand what goes into it, and what the finished result looks like--and tastes like.

With supercomputing technology, we are able to look deeper inside the cake.

We are able to see precisely what happens as the cake bakes...to understand what takes place with the ingredients in relation to each other...and to understand how and why they work together in creating the finished product.

Even more exciting, we can begin to explore how the cake could be made even better with different amounts of ingredients, or with different ingredients altogether.

We may discover a way to make the cake less expensively. Or we may even perfect an entirely new type of edible substance--be it related or unrelated to our original cake recipe.

As we examined the capabilities offered us by the supercomputing technology, and compared these to our business strategies and objectives, we became convinced that developing and implementing a supercomputing plan was crucial to meeting those objectives.

Top management agreed.

Through this process, we began the long steep climb up what I call..."the supercomputing learning curve." Our strategy was simple: We would begin with cost-effective, step-by-step approach. Consistent with this philosophy, the decision was made to establish a short-term "rental" agreement, rather than making a large capital expenditure.

After extensive consultation with our top scientists to establish the criteria for selection of a facility, we chose the National Center for Supercomputing Applications at the University of Illinois.

NCSA offered what we feel is the most attractive opportunity for us to explore and exploit supercomputing technology.

As we began to pursue these opportunities, we established a multi-faceted program. We sought to maximize our use of the supercomputing technology...and minimized our acclamation time.

Our program is reflected in the following four keys to success.

1. We plan and operate with a step-by-step strategy. We first began our program by entering into a three-year agreement that represents a win-win situation for both Kodak and for the University.

   This arrangement allows us to pursue our long-term objective of making use of supercomputing technology. It also gives us the flexibility that is required in a field where change is the only constant.

   Our scientists are able to travel to the University campus and work, for a few days or several months, on the supercomputer workstations.

   In addition, we have recently established a 1.5 megabits per second telecommunications link. This provides every Kodak research scientist with access to the NCSA facility.

   For the University, our contract provides an important Fortune 500 channel for moving supercomputing technology from academia to the industrial research lab.

   We plan to continue to operate on this basis until we are prepared to make cost-effective use of an in-house supercomputing facility.

   In the meantime, our current arrangement enables growing numbers of our own top physicists, chemists, biologists, and engineers to become more keenly involved in, and aware of, the opportunities offered by supercomputing.

   Best of all, from management's viewpoint, we have the benefit of the use of the fully configured facility at a cost that, although substantial, is but a fraction of the total purchase of a comparable system.

2. We have organized a program of on-the-job seminars on the latest developments in supercomputing.

   These "Computational Science Seminars," as we refer to them, feature such distinguished authorities as Dr. Kenneth Wilson, a Nobel Laureate from Cornell University...and leading scientists from other supercomputer centers such as NCSA.

   These relatively informal meetings serve to move our people along the learning curve...and enhance their front-of-mind awareness as they increase their understanding of the opportunities that are now ours. They provide a forum for discussion of the results that have been achieved using supercomputers.

This series promotes what I call "shower thinking"...the insights and ideas that occur at odd moments when we may be far removed from the actual R&D setting.

3. In addition to implementing the first two steps, we in the Computational Science Laboratory also serve as an in-house advocate for the use of supercomputing.

This involves all of us to varying degrees. But we also have a talented individual whose full-time responsibility is to go "knocking on doors." His job is to invite, explain, encourage, inform, persuade, enlighten, and otherwise facilitate the use of this technology by our research scientists.

The challenges that he faces are similar to those of the personal computer salesman, some five years ago. He must understand the various capabilities of the product and how those capabilities might be applied in various use situations. At the same time, he must have the ability to assess the customer's potential needs and uses for the product.

The salesperson must raise the potential customer's consciousness of the product, and help him to understand the product's benefits. Then, he must explain the possibilities for funding the purchase, and how the customer is to go about making use of the product in his specific situation. Dr. Rich Dempsey has a tremendous challenge. With over 2,000 scientists and technicians at Kodak's Rochester research facilities, he has his work cut out for him.

But I'm pleased to tell you that the momentum is building every day, as we see more and more of the exciting results.

In addition to Dr. Dempsey's efforts to move this technology out to the bench, we also have an applied mathematician, Dr. Anna Cha-Lin, who works with Kodak scientists to translate our existing computer code so it can be used on the supercomputer.

Another Kodak mathematician, Dr. Larry Ray, works full-time at the NCSA. In addition to his intensive collaboration on two specific scientific projects, Dr. Ray assists our visiting researchers with application codes, graphics, and overall coordination and use of the center.

We also have a quantum chemist, Dr. John McKelvey, who travels across the country to other universities. Dr McKelvey locates and secures software that enhances the capabilities of our quantum chemists for using the supercomputer.

Equally important in this total process is what happens as a follow-up to the use of the supercomputer.

This brings me to the fourth key step: Keeping top management informed.

There's an old saying: nothing breeds success like success.

As our people become more involved with the supercomputer, and experience the advantages it offers...we make sure that management is aware of the dividends from the company's investment in this technology. We document the many ways that supercomputing creates cost-effective progress in our research efforts--progress that will keep Kodak on the leading edge in R&D and in product development.

So, now the big question is: How's it working so far?

According to Mike Cowley, director of the Information & Computing Technologies Division, approximately 35 of our researchers have traveled to the NCSA to work with the CRAY supercomputer. A similar number have accessed the computer via telephone link.

Let me just share with you a few examples of the exciting projects we're working on.

The first example comes from dye research using quantum mechanics.

Researchers in our Photographic and Life Sciences divisions are keenly interested in designing molecules with specific geometrical and electrochemical characteristics. These scientists are using theoretical methods to calculate many of these properties prior to attempting actual physical synthesis of the molecules. This optimization and prioritization of structures shortens the overall process and makes it more cost effective. Costly time-consuming laboratory experimentation can focus on structures with high payoff potential.

For instance, the spectral, electrochemical, and geometric properties of Chalcogenapyrylium dyes are now supercomputed. The results, in combination with graphic modeling tools have provided significant guidance to the designers of the new analogs of these systems.

Conventional mainframe computers would not be suitable for such programs, because of the number of molecules to be considered, the large size of those molecules, the level of theory required, and the need for timely completion of the projects. Vectorizing computers provide a much more cost-effective answer for such codes.

A second example is in the mechanical assemblies to assess product performance. Our mechanical engineers at the Kodak Apparatus Division have a natural, intense interest in such tolerance analyses.

Understanding the sensitivity of performance of an assembly to variations in part dimensions which occur naturally during manufacturing processes, is critical to successful design and manufacture of quality products in this world-class manufacturing facility.

Through the use of the three-dimensional solid modeling of parts, and simulation of their fit and function in the full assembly, product development engineers have been able to gain new perspectives on the interrelations between parts and complete assemblies, and the importance of rational tolerancing for performance of an assembly. This will result in improved design and higher product quality.

Moreover, use of supercomputer calculations enabled a breakout from the confinement of two-dimensional modeling to realistic full spatial simulation, in addition to decreasing turnaround time. This lead to an n-fold increase in productivity for this crucial phase of product design.

Research in image systems is another area in which supercomputing is providing important capabilities.

Our photographic scientists use supercomputers to explore new algorithms to enhance quality of digitally scanned images through improvement in image sharpness and suppression of film grain noise.

Image processing requires the manipulation by computer of enormous amounts of data. A unit of information in an image is called a picture element, or pixel. Ordinary television pictures contain something less that 750,000 pixels. Today, an 8 X 10 inch print from a 35 millimeter negative can contain as many as 18 million pixels. Soon, we will be working routinely with pictures exceeding 100 million picture elements.

Let's examine two areas being addressed by image processing research. One is related to color balance, or reproducing the correct colors as we remember them. It also involves achieving proper exposure levels throughout the picture. The second example involves "noise" or graininess in a picture.

In this series of pictures, we can demonstrate the adjusting of density contrast of a picture to improve the detail in the highlights and the shadows.

In this original image, note the overexposure in foreground objects...the dresses worn by the young women and the lack of detail in the patio stones. Also note the shadows in the trees in the background.

(BRIEF PAUSE)

Now, you are looking at the processed image. Here you see the improvement in the color of the dresses...the improved detail in the stone, and detail emerging from the previously shadowed background.

(BRIEF PAUSE)

We can compare the original again...

Processing on a normal computer could take an hour or more, and without an appropriate color display, additional time is required to produce a print. A supercomputer with appropriate display devices reduces this time to a few seconds.

For noise suppression, however, computational complexity can increase dramatically. It is not unusual to want to try techniques that take a hundred hours on a normal computer. In addition dozens of pictures need to be processed to assure that algorithms are working properly.

Let's look at an example of noise suppression and edge enhancement.

In this original image of the baby with its toy, you can see a degree of graininess, as well as an overall softness in the focus.

This is the enhanced image. The graininess has been eliminated, and focus is sharper.

And for comparison, here is the original again...

Without this type of computational capacity, we could only speculate about the usefulness of these computer-intensive algorithms. In addition, this capability allows us to increase our understanding of how people perceive pictures and what needs to be done to produce a better picture with image processing.

Only after rigorous testing and refinement of an algorithm in supercomputer simulation would it be reasonable to undertake an assessment of hardwiring the algorithm in special-purpose hardware for production use.

A fourth example clearly demonstrates the bottom-line effect that supercomputing can have in manufacturing process design, as well as in other significant areas.

Using supercomputer simulations of the dynamics of fluids, one of Kodak's manufacturing process engineers evaluated a proposed design modification to a critical sub-system of our sensitized goods manufacturing process. Producing photographic film requires the application of many thin layers of liquid. Since any variation in the thickness of these layers changes the film sensitivity, this process is absolutely critical to film quality. Using a finite-element program on the supercomputer, our engineer was able to simulate delivery of these layers via the proposed sub-system.

He subsequently developed a superior redesign that was consistent with our high product quality specifications. This simulation, performed in less than five hours, eliminated the need to build a physical prototype of the first design and resulted in significant cost savings.

We had to calculate a number of elements to obtain the level of precision and accuracy required for meaningful results. We simply could not have performed this numerically intensive finite element calculation on a conventional computer mainframe. The CPU and memory requirement were much too large.

These are just a few of the results we're seeing as we begin to understand the tremendous enablement, speed, and visualization capabilities of supercomputing technology.

I'm grateful for this opportunity to share with you some of our thoughts, our goals, and our direction at the Research Laboratories of Eastman Kodak Company.

In closing, let me cite two quotes which put into perspective how we feel about our progress in using supercomputing technology for cost-effective research ...the first is from our founder, George Eastman.

> "One may set up an ideal and consider those things which he makes only as a step toward the idea. One never reaches the end of anything."

The second quote is from Dr. Ed P. Przybylowicz, Kodak's current director of research. He summed up our work this way:

> "In our profession, only one thing is certain: In the technology race, there are always frontrunners...but there is no finish line."

Thank you.

x

Mr. WALGREN. Thank you very much, Dr. Smarr. We appreciate that. Dr. Karin?

Dr. KARIN. Thank you, Mr. Chairman. Thank you for inviting me here today. Thank you for holding these hearings. And, thank you for prior support. I thank you and the committee as a whole. I appreciate that the committee does understand that this is a very important program as we do at the centers.

I'm going to attempt to be very brief. I'd like to, first of all, note that I can support almost all of the recommendations that were made by the earlier panel and the recommendations that Dr. Smarr just made, and endorse virtually all the comments that the first panel made, and again that Dr. Smarr made, and that's some risk, but with some confidence, I will state that I expect to be able to endorse the recommendations and the comments of the speakers to follow on this panel.

We have discussed these issues on an on-going basis, and I think you'll find that while each feel as strongly about the performance of our own individual centers, I think we are in agreement about the nature and needs of the program.

I'm going to summarize some of the situation in San Diego, and more importantly I think, some of the international issues, and then I'm going to make some specific recommendations and I hope I'll be able to leave some time to add to the question period.

I would like to report that the San Diego Supercomputer Center is now serving more than 2,700 researchers, faculty, graduate students, and so on, across the country. They are located at more than 140 different institutions in 44 different States and the District of Columbia. The wide range of research that these researchers are performing is evidenced now by something in excess of 750 contributions to the scientific literature to date.

It's no longer possible to keep track of that. I don't know whether the number is 750 or 775 or 800 as of today. It's very difficult, as those numbers grow, to even be closely aware of those details. The kind of report that Larry showed you, and I think the rest of us have also produced or are producing, is an on-going effort. And we've discovered that there are publications made by researchers we don't even hear of, and you come across them in a secondhand fashion.

With that, I would like to turn to more global issues somewhat, and I'd like to echo the question of definitions of supercomputers. Supercomputers, in my mind, are machines that have crossed the threshold of power several years ago to where we can now do useful simulations and models of the real world on supercomputers. Once they crossed that threshold, the power of these machines has continued to increase rapidly, and, as far as I can see, shows no sign of slowing down.

We are on the brink of incredible computing power, and we must stay at the leading edge of this progress or pay the consequences in lost opportunities. And I'd like to make what I believe is a very important point that has been made once or twice earlier, but I will take the time to echo it.

It's that those who apply the new computational technology will perform superior research and create superior products. Let me state that a different way. The effect on competitiveness of super-

computing is not whether or not we buy or sell machines in Japan or whether Japan buys or sells machines in Japan. The issue is the industries that use these machines. It's the industrial partners that Larry spoke about just a few moments ago. It's the automotive industry, the aerospace industry, the petroleum industry, and so on.

Those are the industries that are leading the academic community in the use of supercomputers and have for some time. That's where the true impact of the competitiveness issues related to supercomputing is currently taking place and will, I think, inevitably always take place.

I believe that the studies commissioned by the Congress and others in the early 1980s came to the correct conclusions, and presented wise and practical recommendations. The Bardon/Curtis report, in particular, recommended a budget by 1986 of about $110 million a year. That report recommended that each center have about two supercomputers for the reasons that were stated earlier, and it estimated a budget of about $20 to $25 million in 1989 dollars.

I am willing to make some concrete recommendations in that sense. I think that, in order to keep the centers at the leading edge, we do need $25 or $30 million per center. I don't see how we can stay at the leading edge in any other way.

In addition, we need a program that introduces supercomputers to researchers and trains them and nurtures them and leads demand, rather than merely responding to it. Many senior managers and researchers in industry, government, and academia earned their credentials before the onset of today's powerful systems, and they're much more familiar with small, less powerful machines. And the outreach programs that the centers have established to train people has a major impact, I believe, or can have a major impact, in changing some of that perception that exists in the—I won't call them the elite. Let me call it the establishment.

One can look at that two ways. This is an issue of whether the glass is half full or if it's half empty. I can easily quote large numbers of people that have been trained at our center. I am impressed with the numbers that Dr. Smarr just quoted for the training at the Illinois center. Those are real numbers. Those are real people being trained.

Measured against what happened before this program started, that's very impressive. Measured against what needs to be done and can be done, we've just begun to initiate those sorts of training activities.

More recent studies and reports have again examined the status and needs for supercomputing. These reports support upgrades at the NSF national centers. I'd like to make another point that I believe is quite important. None of them includes specific levels of funding for the NSF centers. And I appreciate that the Committee understands that that's an issue. In my mind, such reports don't constitute plans. And, as far as I can tell, there is no plan for the future of the centers.

I listened with interest to the very early comments this morning. I think I am somewhat differently trained than the other members of the panel here. I am an engineer. I am a product of our engineering education system. And I am concerned about plans that in-

clude budgets and schedules and milestones and so on. I don't see that in the current NSF supercomputer program.

The issue of upgrades is crucial to the future of the supercomputer centers program. The reason for having national centers is to assure that something better is provided than what individual universities can afford. With few exceptions, individual university installations simply cannot serve a broad national user community, or be brought up to leading edge capability and kept there, because the cost is prohibitive.

In the most recent NSF report, long lists of universities were accredited with having supercomputers. I would just mentioned briefly that I think the definition of "supercomputer" used in constructing that list was quite generous, to say the least. Several of us have machines at the NSF centers more powerful than some of the machines on that list that we don't mention as part of our major configuration.

The majority of the academic community must rely on the NSF national centers for access to leading edge computational resources. The NSF report notes that the computer centers of the DOD, NASA, and DOE are providing supercomputer resources, too. They are indeed, and they are truly staying at the leading edge of computational technology.

As Cliff Rhoades pointed out, Los Alamos alone has more computing power and a larger budget than the entire NSF program. I would add in passing that they spend none of their time out trying to acquire funds from other sources than the DOE. They can devote their efforts to establishing a world class facility, which they have and they are maintaining.

I'll move along quickly. The whole national infrastructure is moving upward in its capabilities and capacity. One of the roles of the NSF centers is to pull the entire infrastructure upward.

Again, we have to compare our progress with what's going on in the rest of the world, which has not been standing still either, and the comparison is a bit frightening. I visited Japan a few months ago, and I visited all of the major Japanese supercomputer manufacturers. It was stated earlier that they make very competitive products. That is exactly correct.

Hitachi, in particular, showed us on the manufacturing floor with destination tags three machines, Hitachi SA-20s—this is back in October of last year—going to Tokyo University, the Japanese Meteorological Institute, and one other installation. These machines were basically ready to be shipped, and have a peak speed—and I understand all the reservations about comparing peak speeds of computers, but I wasn't there to benchmark machines—on the order of three gigaflops. That's a lot faster than most machines that we have available. Certainly a lot faster than any machine at any of the NSF centers. And that's accomplished with a single processor and air cooling. That's very impressive technology, and that's very real.

As to whether or not those machines should be in U.S. facilities, I think Dr. Wilson made some very salient points. First of all, we must provide the most powerful machines to our researchers in this country today, or there isn't much use for having such a national program. Second of all, we can't delude ourselves about the

existence of those machines. We have to make certain that the U.S. research community is aware of the existence of those machines.

Turning from the international issue to the NSF centers again, it is urgent that we commit to upgrading the supercomputer centers. If upgrades for the NSF centers are delayed until fiscal year 1990, which is as near as I can expect with my understanding of the NSF budgets, our equipment will be five years old at that time. In this environment, five year old equipment is pretty good, but it's certainly not world class.

Again, the point I made at the beginning, those with the best tools will be the first to solve the leading problems and create the best products.

In summary, to assure that our country continues to lead the world in high technology, research, and commerce, my recommendations are as follows:

First, it is absolutely necessary to commit to a long-term program that is stable and which funds the NSF centers adequately to stay at the leading edge of computational technology. None of us are able to plan in the current environment.

Second, implement an increased budget quickly. The centers program needs a budget of $80 million in fiscal 1989 to begin major upgrades, rising to $125 million in later years.

Third, support the mission using federal funding. NSF has successfully enlisted state and industrial support for its centers, but we can't expect state funding windfalls for centers whose mission is to serve a national constituency. Further, unfortunately, there are some difficulties to go along with the various successes in acquiring industrial funds.

We are currently in the mode of approaching industry and saying, feed us or we're going to starve. I think the appropriate way to attempt to and successfully acquire industrial funds is to establish a first-class facility so that the issue will be, feed us or you'll starve. And we will not be beating the bushes down trying to find industrial sponsors. They'll be finding us.

Fourth, we need to keep the networking in computer services in balance. That issue is addressed in my written testimony in greater detail, and I'm not going to elaborate on it now.

And, finally, we need to increase the formal training opportunities.

In closing, I acknowledge my views may seem predictably in favor of giving our nation's researchers and educators an abundant supercomputing resource. I believe strongly that, if we intend to lead the world in research accomplishments in high technology products, such abundance is essential.

We are losing ground, but we have the ability to make ourselves winners or losers. I consider the price for being winners in computational science and engineering to be one that is modest in today's budgetary terms, and the national price of being losers to be an unacceptable burden for our society.

Thank you.

[The prepared statement of Dr. Karin follows:]

STATEMENT OF

DR. SIDNEY KARIN

DIRECTOR

SAN DIEGO SUPERCOMPUTER CENTER

ON THE

FY 1989 NATIONAL SCIENCE FOUNDATION BUDGET REQUEST

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

MARCH 24, 1988

STATEMENT OF
DR. SIDNEY KARIN
DIRECTOR
SAN DIEGO SUPERCOMPUTER CENTER
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U. S. HOUSE OF REPRESENTATIVES
MARCH 24, 1988

Thank you for the opportunity to appear before your Committee today. The issue of competitiveness was never more visible than it has become in the field of supercomputing -- both from the standpoint of computer products themselves, and from the broader viewpoint of computational science and engineering.

I am pleased to report that the San Diego Supercomputer Center now serves over 2,700 researchers and educators at more than 140 different institutions in 44 states and the District of Columbia. The wide range of work performed on our advanced computing systems is evidenced by over 750 contributions to scientific literature. Interaction with this broad community of scientists and engineers gives us an appreciation for the importance and value of providing them with access to leading edge computational resources.

The Impact of Supercomputing

The use and impact of advanced scientific computing are growing rapidly. The most powerful computers crossed a threshold a few years ago, enabling scientists and engineers to model phenomena in the complexity and detail found in nature, and to thereby find realistic solutions to extremely difficult problems. The power of supercomputers has continued to increase rapidly, with some reports indicating a factor of thirty over the past five years. This advancement shows no sign of slowing down.

Members of the industrial community have estimated that current chip technology may provide another increase of 100 or so. Even as its limits are approached, however, new developments such as quantum effect chips

may well extend the miniaturization and power of single processors substantially. The practical application of parallel processing systems is beginning to be demonstrated. We are on the brink of incredible computing power and we must stay at the leading edge of this progress or pay the consequences in lost opportunities. Those who can expertly apply the new computational technology will perform superior research and create superior products.

Supercomputing, large-scale computational science ad engineering, is truly becoming a third way of doing science and engineering -- adding to, and combining with, the traditional approaches of experiment and theory. The speed of the ever improving hardware, the capability to store and manipulate large bodies of data, improved software and emerging visualization techniques are achieving results that simply could not be reached any other way. Examples of this unique capability to treat problems not otherwise tractable include:

- Simulation of dynamic behavior at atomic levels, such as to study the efficacy of candidate pharmaceutical molecules;
- Simulation of areospace vehicle performance at speeds exceeding wind tunnel capabilities;
- Study of stellar atmosphere models and intergalactic collisions;
- Performance simulation of highly integrated computer chips; and
- Interpretation of X-ray crystallography to determine the structure of complex life molecules such as enzymes and DNA.

The list goes on and on. In addition to doing things not otherwise possible, advanced computing speeds the process of development for new products and enables broader consideration of alternatives so that better research and products are produced.

Supercomputing permits us to tackle the toughest, most complex problems in science and engineering, sometimes termed Grand Challenges. These include the problems of understanding the electronic structure of matter, such as high temperature superconductors and the complex molecules crucial to life processes, understanding turbulence and chaos in fluids (e.g., aerospace, atmospheric science, astrophysics, and chemical processing), performing realistic simulation of complex structural behavior to achieve improved designs (e.g., automobiles, ships, and buildings), and even developing the components and architecture for future computers.

How Can Supercomputing Be Harnessed?

With this wonderful capability permeating the world of high technology, what is the best plan to assure that our country uses it well? I believe that the studies commissioned by the Congress and others in the early 1980's came to the correct conclusions and presented wise, practical recommendations. These studies included:

- *Prospectus for Computational Physics,* NSF, William H. Press, 1981
- *Report of the Panel on Large Scale Computing in Science and Engineering,* DOD/NSF/DOE/NASA, Peter D. Lax, 1982
- *Report to the Federal Coordinating Council on Science, Engineering & Technology Supercomputing Panel,* James F. Decker, 1983
- *A National Computing Environment for Academic Research,* NSF, Marcel Burdon, Kent K. Curtis, 1983
- *IEEE United States Activities Board Scientific Supercomputer Committee Report,* Sidney Fernbach, 1984

The Bardon/Curtis report was a particularly fine study and made balanced recommendations for upgrading the entire national infrastructure for scientific computing. I agree with that report. It recommended budgeting $110M per year by 1986 for the National Centers, and a similar amount for improving local facilities at universities. This 1983 report recommended that each Center have two supercomputers and estimated an annual budget of about $20 million (about $25 million in 1989 dollars). I agree with this approach and find the estimate surprisingly current.

The conclusions in the early reports were similar: we have to be serious and timely about ensuring strong education in supercomputing, and broad access to supercomputing resources for the academic research community . . . or miss opportunities to make great progress in many high technology fields. I would like to quote one particular observation in the Bardon report, that "lack of opportunity to use sophisticated computing technology directs academic research away from those areas which demand it. This leaves vital fields unexplored and impoverishes American science."

Perhaps the key issue is the recognition in these early reports that we need

a program that introduces supercomputing to researchers and trains them; nurtures and leads demand rather than simply responding to it. Many senior managers and researchers in industry, government and academe earned their credentials before the onset of today's powerful systems, and are inclined to stay with more familiar, relatively small, local machines. The job of the Centers is to provide them with the knowledge and opportunity to make an informed choice.

More recent studies and reports have again examined the status and needs for supercomputing. These include:

- *A Research and Development Strategy for High Performance Computing,* Office of Science and Technology Policy, November 1987

- *Status of NSF National Supercomputer Centers,* submitted by NSF to the Congress, November 9, 1987

- *A National Computing Initiative, An Agenda for Leadership,* Report of the Panel on Research Issues in Large-Scale Computational Science and Engineering, Society for Industrial and Applied Mathematics. 1987

- *Report on Future Requirements fo Advanced Scientific Computing,* a report to the Congress by the NSF, February 10, 1988

In general, these later reports continue to promote upgrades at the NSF National Centers, and share the earlier vision philosophically. Except for the OSTP and SIAM reports, however, they are regrettably timid about proposing future levels of expenditure.

The OSTP report, prepared by the FCCSET Committee, proposes an agressive interagency program involving NSF, DOE, DARPA, NASA and other agencies. It proposes five-year funding $1.7B above current programs. Facilities and activities for joint research in computational science and engineering would total $0.45B over five years. These are integrated costs of all agencies and universities involved, with no suggestions on distribution of expenditures among them.

The SIAM report is similarly aggressive, and recommends that "at least $1.5B of new resources be directed at exploiting the striking commercial and scientific opportunities afforded by high performance computing" over the next five years. It further states that the foremost purpose of the proposed five-year National Computing Initiative "is to provide

significantly improved computational power to U. S. scientists and engineers."

The NSF report of November 9, 1987 supports the need for upgrades but gives no budgetary suggestions for the future. The NSF February 10th report says that "if resources permit it, the Foundation will increase the capacity at the centers . ." without discussion of NSF priorities or a proposed budget. It further states that budget plans will be developed over the next 18 months. I feel that the program's importance, and its urgency in the face of progress being made in other countries, deserve stronger leadership and more agressive follow through.

I am particularly disturbed by the apparent dependence of NSF on "competition" among the Centers for scarce upgrade funding, as opposed to aggressive support of the Centers to achieve important national goals. This is articulated in the NSF report of November 9, 1987. The mission of the Centers is, in fact, being made secondary to efforts that seek to maximize outside funding, which is necessarily limited. I consider this to exactly fit the old saw of "penny wise and dollar foolish". Expectations of funding from industrial participants should be realistic; we limit the amount of the Centers' resources made available to industry, the 1986 tax law restricts industry's rights to patents arising from work on computer systems financed with tax exempt bonds, and the IRS has moved to tax universities for actual receipts of "unrelated business income."

The February 10th NSF report to the Congress can be misunderstood if one is not personally familiar with advanced computing and the details of current programs. The NSF report presents much data about how access to computers has improved. It has; but what is missing is a comparison between what is needed (and was envisioned in the Bardon/Curtis and other reports) and what has been accomplished. We are less than half way to the program's goals because NSF budget requests have been less than half of what it takes to do the job. This may reflect the political realities of our times, but such a conclusion is an unhappy one for the future of American science and technology.

The NSF report implies through discussion and attached lists that having a few of the smaller CRAY machines (X-MP/14's or 24's) and a lot of less-than-supercomputers in the academic community outside of the NSF Centers meets a significant part of the national need for access to *leading-edge* supercomputing; it does not. A number of these machines are already out of date, and they serve a local community rather than the national community. Such machines are extremely important to education and to research studies of moderate proportion, but they do not satisfy the

need for the powerful systems required at the leading edge of science.

I suggest that, with few exceptions, individual university installations simply cannot serve a broad national user community or be brought up to leading-edge capability and kept there, because the cost is prohibitive. The reason for having National Centers is to assure that something better is provided than individual universities can afford. In the case of SDSC, our users are located at more than 140 different institutions across the United States.

The major differences between the National Supercomputer Centers and facilities at indvidual universities lie in the commitment of the National Centers to serving a national constituency. As a result, they (a) provide more economical service -- less than half the average cost paid by NSF for services during Phase I of the program, (b) are strongly oriented toward user services, and (c) provide broad access to all scientific and engineering disciplines.

The NSF report also notes that "numerous training programs" have been held and are of great value. I agree, and urge that a great deal more be spent in providing such training. In particular, the Summer Institutes should be increased in number, and perhaps have Spring, Fall and Winter counterparts.

The NSF report notes that the computer centers of the DOD, NASA and DOE are providing supercomputer access, too. They are indeed, and are truly staying at the leading edge of computational technology by acquiring new machines at a rapid pace. Several DOE laboratories have more advanced facilities than any of the NSF Supercomputer Centers. One of them has two such facilities. Another is taking delivery of two of the newest Cray machines (the Y-MP) this fiscal year. NASA and DOD also have several supercomputer facilities that contain more powerful equipment than is available at any of the NSF Centers. These agencies have applied the necessary resources to support their facilities.

Access to these DOE, NASA and DOD centers is, however, limited to those working toward the focused missions of the parent agencies. The majority of the academic community must therefore rely on the NSF National Centers for access to leading-edge computing resources. It is for this reason that the NSF Centers should be given as high a priority as the other agencies' important centers, and be kept at the leading edge.

Advocates of powerful, small computers speak of the advantages of having the power of a CRAY-1 on your desk top. They sometimes suggest that supercomputer centers aren't really needed. I respect their progress, but I

also respect the progress being made at the high end where, for example, Cray Research is about to produce the CRAY-3 that is 100 times as powerful as the original CRAY-1, and is working on the CRAY-4 at 1,000 times the CRAY-1 power. Single user work stations are a part of the overall picture, but to represent them in any sense as supercomputer substitutes is irresponsible. Furthermore, the consulting, software development, and data storage and manipulation capabilities of the Supercomputer Centers are missing for the work station owner. The analogy that springs to mind is that station wagons are useful vehicles, but they don't replace trucks. Station wagons have a better user interface, but if industry relied upon them to transport products and materials, we would all starve.

The point I wish to make is that the whole national computational infrastructure is moving upward in its capabilities and capacity. A wide spectrum of power will remain characteristic of the mix, from personal computers up to supercomputers. All of them have value and a balanced national computational infrastructure makes good use of them. The supercomputers are the peak of the structure; they alone allow the most complex, important problems to be attacked successfully, and they pull the entire infrastructure upward.

As others have noted, one cannot get to the Moon by hooking up 1,000,000 Volkswagens, or see the farthest quasar by connecting 10,000,000 pairs of binoculars. Neither can one tackle the most complex problems of science and engineering using a large number of small computers scattered over the nation. Incidentally, to supply the 2,700 researchers using SDSC systems with their own high performance workstation such as one which was recently announced would cost about $300 million initially plus an annual maintenance cost of about $25 million, according to the literature that company has sent to me extolling its virtues.

Our government has often recognized the extreme importance of access to leading-edge computers; for example, it has expended a great deal of effort in preventing access to American supercomputers by countries that are not allies. One reason for this is that superior weapons and intelligence gathering result from such access. So does superior research in many fields, and so does superior commercial product development, design and performance simulation. Supercomputers are crucial to advancement in all high technologies.

How Are We Doing?

As usual, there's good news and bad news. A good start has been made. A great many researchers and educators (over 6,000) have gained access to supercomputers because of the NSF Centers and have accomplished wonderful things. The NSF reports document these achievements well. But we must compare our progress with what is going on in the rest of the world, which has not been standing still either. The comparison is a bit frightening.

When the NSF supercomputing program was launched, there was not a single Japanese entry in the supercomputer competition. The admitted superiority of U. S. products, specifically the CRAY machines, gave us a true lead in both computer hardware and computational science and engineering. That has helped us to lead the world in such areas as aerospace, weapons, and oil field discovery and production. It has contributed strongly to our successes in fusion energy research, fission power plant design, and communications areas such as cryptography. And we are still at the forefront in many of these and other high technology areas, but other countries have new capabilities that deserve our attention.

I visited Japan a few months ago and saw new products being delivered by Fujitsu, Hitachi and NEC. They all have solid entries in the supercomputer sweepstakes. The most powerful of these is claimed to have a single processor with speeds comparable to the goal for the CRAY-3 with its 16 processors. This Japanese machine is being manufactured and delivered now; the CRAY-3 is scheduled to become available in the next year or two. The new Japanese machines will not simply be sold in competition with CRAY's and and other U. S. machines, they will be used to perform research and to design products.

Other countries have been establishing advanced computing centers of considerable power. European installations include CRAY-2 systems at the University of Stuttgart and at CCVR in France. CRAY X-MP's are installed at the Universities of Kiel and Berlin, Trondheim, SERC, Hanover, CINECA. The Aichi Institute of Technology in Japan also has an X-MP. I understand that the U. K. will be getting one of the first CRAY Y-MP machines. Canada has a center in Toronto with an X-MP. Supercomputer centers in other countries outnumber such centers in our country.

So the bad news is that we are falling behind our previous position of leading the rest of the world. As Director of one of the NSF Supercomputing Centers, I must report to you that we are having difficulty staying up at the

leading edge. We have been able to make no upgrades of significance since our founding in 1985; we are tightening our belts in FY 1988 (to an extent that services will deteriorate somewhat); and we are facing a requested NSF/DASC budget for FY 1989 that will still not permit any upgrades (other than the long anticipated startup of an ETA machine at Princeton).

These somewhat dreary circumstances exist despite successful efforts by the San Diego and other Centers to secure funding from state and industrial sources. At San Diego we have so far obtained funds plus commitments from State and industrial sources of $15 million over the first five years, in addition to generous discounts and donations, and our 25 consortium member institutions are paying over $7 million per year to enhance access to our Center from their campuses. Frankly, it's not realistic to expect a great increase in such support. I recognize that these are belt tightening times for a great many programs. My intent here today is simply to be sure that you have all of the facts at hand when you make your budget decisions.

I am concerned that the FY-1989 budgets requested for both existing commitments and new programs will all be squeezed proportionately if the full budget request is not received (as was done in FY-1988). Thus the NSF request for full funding of the Centers' Cooperative Agreements in FY-1989 is not destined to lead to actual funding at that level unless NSF receives *everything* it has requested . . . or unless the Congress or the NSF clearly exempts the Centers Program from such cuts.

It is urgent that NSF provide leadership and commitment to upgrading the Supercomputer Centers. If upgrades for the NSF National Centers are delayed to FY-1990, our equipment will be five years old at that time. In this fast paced environment, five year old equipment is still good but it's certainly not world class. In the last five years, the fastest computers have moved upward in speed by a factor of perhaps as much as 30. Such factors spell the difference in whether or not important problems become tractable, and those with the tools will be first to solve the leading problems and create the best products.

Some Recommendations

In summary, to assure that our country continues to lead the world in high technology research and commerce, my recommendations are as follows:

- Commit to a long-term program that is stable and which funds the NSF Centers adequately to stay at the leading edge of computational technology.

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The Centers are capital facilities with fixed costs representing the majority of annual funding requirements. We should give the Centers a high level of priority and stable support, as is given to the centers of DOE, DOD and NASA, because the great majority of the academic community depends on the NSF Centers for access to leading-edge computing resources.

- Implement an increased budget quickly: in FY-1989. Much of what you will hear today has been said before, perhaps many times over the past five years. We have made a good start, but the rest of the world is also moving rapidly into advanced computing. Whether we like it or not, the pace of world-class computational science is faster than the pace at which the U. S. is providing access to its scientists; the U. S. does not unilaterally control the pace of science and technology progress, and we are losing ground. Major upgrades are needed in FY-1989. The Centers program needs a budget of $80 million in FY-1989 to begin this, rising to $125M over the next three years.

- Support the mission using federal funding. NSF has successfully enlisted a degree of State and industrial support for its Centers, but:
    - We can't expect a State funding windfall for centers whose mission is to serve a national constituency, and
    - The need to preclude unfair competition with the private sector combined with new provisions in the 1986 tax law place very real limits on the nature and extent of industrial involvement.

  It is worth noting that the NSF centers are the only ones depending on such outside funding. While it's admirable to work at reducing the federal share, reasonable expectations for non-federal support are perhaps five million dollars per year per center. That amount is already required to run the Centers under current NSF budgets, and will not fund the major upgrades needed by the national academic community.

  Efforts to secure non-federal funding should be secondary to assuring program success. The problem is exacerbated by recent cuts in NSF participation, which are sending a message to state governments and industry that NSF is not a reliable partner.

- Keep networking in balance with the computer services available.

An improved national network is indeed important to assure access to computers required by researchers. The Networking and Centers programs should be balanced programs, and I am concerned that while the budget for networking has gone up dramatically, the Centers have been underfunded. The $11 million level of commitment to networking in FY-1988 is also enough to launch major upgrades for two of the National Centers to four times their present computing capacity!

For the record, I would like to note that FY-1988 funding for the San Diego Center by the NSF Networking division was unilaterally cut 50% below the Cooperative Agreement commitment, even though the total Networking budget went up 17.6%.

- Increase the formal training opportunities. In particular, increase the number and locations for Summer Institutes and similar formal "hands on" training opportunities. A typical institute session lasts for two weeks, gives intensive training and experience, and involves from 25 to 50 attendees. At the current level of funding, the total NSF Summer Institute program is reaching only about 200 new people each year. We should be training ten times as many. Our experience at SDSC is that such training is very effective; the typical attendee has computational experience but not on supercomputers.

In closing, I acknowledge that my views are predictably in favor of giving our nation's researchers and educators an abundant supercomputing resource. I believe strongly that if we intend to lead the world in research accomplishments and high technology products, such abundance is essential. We are losing ground but we have the ability to make ourselves winners or losers. I consider the price for being winners in computational science and engineering to be surprisingly modest in today's budgetary terms, and the national price of being losers to be an unacceptable burden for our society.

Mr. WALGREN. Thank you very much, Dr. Karin. We appreciate it. Dr. Knight?

Dr. KNIGHT. Good morning. Thank you for inviting me to testify before this Committee. And, again, I would like to thank this Committee for its continued support of the supercomputer centers program.

I would like to talk to you today about management, management of crisis and management of success. Early in this decade a serious crisis was identified, the crisis of supercomputer ignorance in American universities.

Reports of the Lax committee, the Bardon/Curtis report, and others identified three major problems. The first, a lack of resources to tackle the challenging problems in science and engineering research.

The second, a lack of training for graduate students in supercomputer technology. A lack of training which resulted in those students carrying their ignorance, in the words of Ken Wilson, to the laboratories of American industry; indeed, to the board of directors of the corporations in this country.

And, finally, a lack of stimulus to the U.S. supercomputer industry.

This country, through the Congress and through the National Science Foundation, responded to this crisis, and the result has been an unqualified success. More than 6,000 researchers have been provided supercomputer resources and training at the five National Science Foundation supercomputer centers. They have been part of a literal revolution in the manner in which computational science and research is conducted in this country.

It is not necessary, nor will time permit me, to describe the projects that these people have engaged in. They are detailed in the annual research reports of all five centers. There have been more than 600 refereed scientific papers published in archived scientific journals within the first two years of this program's existence.

The program has also stimulated a significant growth in computations resources by pulling forward those resources at U.S. universities. As the NSF report to this Committee articulated back on February 10th, there were, in 1983, three supercomputers installed at U.S. universities in this country. In 1987, that report notes that there were installed at American universities six CYBER-205s and six CRAY supercomputers. In addition, the report noted more than 28 IBM 3090 systems with vector facilities.

The question before us today is can this success be managed. The American public, through the Congress and through the National Science Foundation, has met the crisis of supercomputer ignorance. The issue is can we deal with the success of the program. What is needed now?

First, hardware upgrades are needed at all five centers. The John von Neumann center, as part of its initial proposals to the National Science Foundation, proposed an upgrade to an ETA-10, which arrived and was installed this month at the von Neumann center in Princeton.

That initial system, with four processors, is eight times the power of one of the existing CYBER-205's that serves our users.

The ETA-10, by one of the more commonly accepted benchmarks, is the fastest supercomputer in the world today. We have researchers who are already using the ETA-10 to solve problems in fluid dynamics, in chemistry, in optimization, in physics, and in other areas.

We will upgrade to an eight processor system this fall and, with further upgrades in processor performance, the system that will be utilized by our researchers in the spring of next year will be more than 25 times the performance of one of the existing CYBER-205s at our center.

It is important to note, however, that this program has been financed by backloading the costs. Our payments for the ETA-10 this year will be less than $1 million. It will increase in fiscal year '89 to more than $3 million, as those upgrades are received. The budget increase is critically needed to meet the commitments of upgrades at the von Neumann center and, also, additional funds are needed to meet additional needs for upgrades at the other centers.

Second, what is needed now is additional funding for software. Applications software is critical to the effective utilization of supercomputers at all centers. Software available from third-party vendors is priced based upon the performance of the machine. It is not unusual for a software package, such as the sophisticated graphics program, to cost between $50,000 and $100,000, and literally dozens of such packages are needed.

In my budget at the von Neumann Center for fiscal year 1988 there is virtually no money for software on the ETA-10. It is a painful, indeed anguishing experience to have the world's fastest supercomputer and not have the money to buy the software that the users need this year.

Thirdly, there is a critical need to increase staff. There are 54 staff members at the John von Neumann Center supporting three supercomputers, a variety of front-end mini-supercomputer systems and a regional network which provides networking telecommunications and supercomputer access to 22 institutions throughout the United States. That network was the world's first high speed research network connection research institutions when it was established in May of 1986, operating at speeds of up to one and one half million bytes of information per second, equivalent to sending 75 pages of text across the line in a second.

At our institution, von Neumann Center, we have ten people in User Services. They are responsible for consultation, for all researchers on their research programs for which we receive more than 3,000 inquiries per month. They are responsible for all training. To date the von Neumann Center has trained more than 1,000 individuals, both at training courses taught at Princeton as well as training courses taught at 13 institutions across the country.

These ten people in User Services are responsible for developing documentation for accounting, for development and—of application software.

The lack of adequate staff at the von Neumann Center is a direct result of the fact that the John von Neumann Center has taken cuts which total more than $10 million from its cooperative agreement levels which were negotiated in 1985. That cut of more than

$10 million is not wholly attributable to the 11 month delay in the installation of the ETA-10.

Those cuts have resulted in an inadequate number of staff to solve the problem.

It is difficult situation for all the directors here to go forward to our staffs every day, who are working 60 hours a week or more, and try to convince them that there is a light at the end of the tunnel, that this program will continue, that the number of staff will rise to provide what they believe is the professional level of support that they want to provide.

In closing, let me state that this Committee has supported this program in the past. It has today a critical opportunity to manage the success of this program. To manage it through the provision of adequate funds for hardware, for software and for staff, and I urge your support of the NSF budget for fiscal year 1989.

Thank you.

[The prepared statement of Dr. Knight follows:]

The John von Neumann National Supercomputer Center

Testimony for the
Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dr. Doyle D. Knight
President
Consortium for Scientific Computing

24 March 1988

Status of the John von Neumann National Supercomputer Center

The John von Neumann National Supercomputer Center (JvNC), established in December 1985, is one of five national supercomputer centers established by the National Science Foundation to support computational science and engineering research in the United States. Located in Princeton, New Jersey, the JvNC is supported by five year commitments of $69.2 million from the National Science Foundation (NSF) and $12.1 million from the New Jersey Commission on Science and Technology. The JvNC is managed by the Consortium for Scientific Computing, a non-profit corporation whose members include the University of Arizona, Brown University, University of Colorado, Columbia University, Harvard University, the Institute for Advanced Study, Massachusetts Institute of Technology, New York University, University of Pennsylvania, Penn State University, Princeton University, University of Rochester and Rutgers University.

The activities of the JvNC are focused on three principal objectives. First, the JvNC provides supercomputer resources in support of the research programs of its users. These resources include two CYBER 205 supercomputers, installed in 1985 and 1987, and the world's fastest supercomputer, the ETA10, installed in March 1988. A total of 13,464 hours of supercomputer time were provided to researchers in 1987, covering a broad range of disciplines including physics, chemistry, mechanics, structures, materials engineering, molecular biosciences, mathematics, chemical engineering, and astronomy. Second, the JvNC provides a variety of support services to its users, including on-site and remote training, extensive on-line information, user consultants and documentation. More than 1000 users were trained by the JvNC through the end of 1987 in all aspects of supercomputing. Third, the JvNC provides a research infrastructure to its user community through its sponsorship of summer research institutes, weekly seminars and visiting scientist programs. These activities, attended by researchers from both academia and industry, provide opportunities for exchange of ideas and development of collaborative research programs.

The JvNC marked several important milestones in 1987. First, the number of scientific papers published or accepted for publication exceeded 180, based upon research supported by the JvNC since its inception. These papers, covering a diverse range of scientific disciplines, represent the research productivity of the more than 1300 individuals supported by the JvNC at more than 100 institutions. In view of the lead time required for publication of a scientific paper (typically six to twelve months), this output represents the "tip of the iceberg" of the scientific productivity of JvNC researchers. Second, the JvNC expanded its activities in collaborative research with industry. Active research programs are in progress with Ciba-Geigy, Dynalysis, Exxon and Princeton Forecasting. Dr. Robert Fernholz, founder of Princeton Forecasting, obtained a performance improvement by a factor of fifty in his econometric modelling using the CYBER 205 supercomputer at the JvNC. The increased speed and processing capability of the ETA10 provide the opportunity for substantial additional performance improvements. Third, the

JvNC was awarded a two year grant by the National Science Foundation for $701,645 to add six academic institutions to its regional communications network, the JvNC regional network. This grant increases the total number of institutions on the JvNCnet to twenty-two. Nine of the institutions are connected using T-1 (1.5 million bits per second) circuits, capable of transmitting 75 pages of double-spaced text per second. The remaining institutions are connected using 56 kilobit per second circuits. The JvNCnet, the largest T-1 research network in the world, provides "instant access" to the JvNC supercomputers to researchers at institutions on the network. The JvNC may also be accessed by researchers throughout the Unites States through connecting regional networks and the NSF-supported backbone network.

The installation of the ETA10 supercomputer in March 1988 heralds a new era for the John von Neumann Center. Initially configured with four (4) central processing units (cpus) and 144 million words of memory, the ETA10 is eight (8) times more powerful than one of the existing CYBER 205 supercomputers at the JvNC. The number of processors will be increased to eight in 1988, and the speed of the processors will be increased in 1989, yielding an overall performance improvement of a factor of twenty five (25) compared to the CYBER 205. The impact on scientific research will be dramatic. Research problems requiring several months of computer time on a conventional minicomputer may be solved in a few hours on the ETA10, opening entirely new areas of research.

Impact of NSF Budget Shortfalls on the JvNC

The shortfalls in the NSF budget, particularly in FY88, have significantly impacted the JvNC. The NSF budgets have not provided sufficient funds to fully implement the first objective of the JvNC, namely, to provide supercomputer resources in support of the research programs of its users. The results of this inadequate have been felt in several areas. First, the number of staff at the JvNC is insufficient. There are presently fifty four (54) staff members at the JvNC, including two (2) temporaries and one (1) part time student, plus an additional eight (8) persons from Control Data Corporation and ETA Systems and one (1) engineer from Digital Equipment Corporation (DEC). This staff is responsible for operating a complex supercomputer center providing services on an ETA10 supercomputer, two CYBER 205 supercomputers, four DEC superminicomputers, and an extensive regional data communications network serving twenty two institutions. For example, the User Services staff, totalling ten (10) persons, is responsible for wide variety of activities supporting more than 1300 users of the JvNC including technical consultation (typically more than 3000 requests per month), development of user documentation, user training (both at the JvNC and remote sites), arranging meetings of the site coordinators for the institutions served by the JvNC, development of applications software (e.g., porting Gaussian 82 to the CYBER 205 and ETA10) and other activities. It is common for members of the User Services staff to work fifty to sixty hours per week. Nevertheless, the workload continues to increase. The Network staff, totalling five (5) persons, supports one of the largest regional networks in the world, providing telecommunications resources to twenty-two (22) research institutions in the United States, and supporting the NSFNet backbone. The Systems staff, totalling twelve (12) persons, is responsible for the entire complement of supercomputers and superminicomputers at the JvNC, including the ETA10. The group's effort is strongly focused on the support of the ETA10, and the development of software to enhance its capabilities in the JvNC environment.

Second, the shortfall in the NSF budget has resulted in insufficient hardware and software resources at the JvNC. The most significant problem is the lack of adequate disk storage on the ETA10. Budgetary constraints have limited ETA10 disk storage to 19.2 Gigabytes. This is only 33% more disk storage than presently provided on the two CYBER 205s, although the total memory on the ETA10 will be *thirty six times larger* than the combined memory of the two CYBER 205s. A significant number of scientific applications, including fluid dynamics and solid mechanics, generate output data in direct proportion to the available memory on the supercomputer. A second problem is the lack of sufficient applications software on the ETA10. A wide variety of

applications software packages are needed to support the diverse scientific disciplines at the JvNC. These packages, developed by third party vendors, are priced in relation to the performance of the systems. Consequently, many critical software packages cost $50,000 or more each. Third, the limited budgets to date have precluded the development of high speed visualization capability at the JvNC. It is critically important to provide researchers with a high speed (100 megabit per second) link to the supercomputer to visualize their computations in progress. A significant fraction of the supercomputer resources at the JvNC are employed by researchers engaged in large scientific computations. These individuals need to visualize the results of their research prior to completion, to determine the efficacy of the computation and allow new insights into their research.

The Long Term Role of the NSF Supercomputer Centers

The NSF Supercomputer Centers have a national mission - to support computational science and engineering research through provision of state-of-the-art supercomputer technology. The constituency of the Centers is truly national, as reflected in the more than 7,500 researchers in 250 institutions across all 50 states. The role of the Centers can be viewed in terms of the National Computational System which includes the hierarchy of computer resources available to academic researchers. The highest level of the hierarchy is the NSF Centers, equipped with leading edge supercomputer technology characterized by the highest performance and experimental software. The second level is represented by the small number of research universities which have installed current generation supercomputers. The National Science Foundation, in the "Report on Future Requirements for Advanced Scientific Computing" (10 February 1988), indicates that there are six (6) CYBER 205s, five (5) Cray XMPs, one (1) Cray 2 and one (1) NEC SX-2 installed at US universities. In addition, there are twenty eight (28) IBM 3090 computers with vector facilities installed. It is critically important to note that four years earlier (1983), there were only three supercomputers installed at US universities. It is evident that the NSF Supercomputer Centers program has provided a direct stimulus to the growth of University-based supercomputer resources, and has therefore acted to "pull forward" the resources for computational science and engineering. The third level is represented by the mini-supercomputers and mainframe computers installed at numerous US universities. These facilities fill a level between the current generation of supercomputers and the ubiquitous minicomputers (and their recent technological cousin, the high performance workstation), which are prevalent at all US universities.

The National Computational System, in its ideal state, is a "seamless" hierarchy of computational resources accessible through the NSFNet and regional data communications networks including the JvNC Regional Network. Successive levels are separated by one to two orders of magnitude in performance, and consequently provide the incentive for researchers to expand the scope and content of their work. It is important to emphasize that the NSF Supercomputer Centers *define* the highest level of resources available at any given time, and therefore effectively pull all levels upward. It is necessary for every US university to provide resources at the second or third level in order to remain competitive in research. *The NSF Supercomputer Centers provide a highly leveraged stimulus to continuous upgrade in US computational resources.*

The NSF Supercomputer Centers contribute to computational science and engineering research in several other key areas. First, they provide an environment for development of new algorithms. For example, future improvements in computational performance will depend heavily on research in algorithms for multitasking (parallel processing). The Centers, established to support the entire spectrum of NSF-sponsored research, are uniquely positioned to advance software technology. Second, the NSF Centers provide the opportunity for the establishment of standards in software design and function for the national research community. These include the creation of multitasking software libraries, graphics protocols and database architectures, and the distribution of these software resources to the national community. A National Algorithms Library, maintained by the NSF Centers, would facilitate research and portability of computer codes. Third, the NSF Centers provide a catalyst for interaction between academia and industry, and act as a vital link in the technology transfer between these two areas. Fifth, the NSF Centers

create a "target" for improvements in supercomputer technology. Supercomputer manufacturers recognize that the NSF Centers, by defining the state-of-the-art in supercomputer technology, create a significant market for current generation supercomputer systems among a fraction of US universities. This provides a powerful incentive to develop new technology.

The achievement of this role for the NSF Centers requires the full FY89 budget request of $55.8 million for the NSF Division of Advanced Scientific Computing. FY89 is indeed a critical year for the Supercomputer Centers Program. The impact of the FY88 budget has been severe, and numerous critical items have been postponed including hiring additional staff, and hardware and software acquisitions. The Program has been an unqualified success. Its future depends on the continued support of Congress.

Mr. WALGREN. Thank you, Dr. Knight.

I apologize for the—I'd like to get this thing to ring at the right time and only once, but I seem to have trouble doing that.

Dr. Lee, welcome, and we're pleased to hear you.

Dr. LEE. Thank you very much.

I'm very honored and pleased to address this Committee and describe the status and future requirements of the NSF Supercomputer Center at Cornell University.

To begin, let me express my thanks to the members of this Committee for your strong support in recent years of the National Science Foundation, and in particular, of the NSF supercomputer and networking programs. Thank you.

The Cornell Theory Center is a national center which is unique in providing researchers with access to a very powerful production parallel processing environment on an IBM supercomputer system and floating point systems minisupercomputers.

In three short years Cornell has brought leading edge supercomputing tools, such as large memories, vectorization, visualization, and parallelism into the hands of University-based scientists and engineers.

The many projects from across the nation that access the Cornell Center are placing heavy demands on our supercomputing resources. In November of 1986 we received our first IBM Supercomputer System and an upgrade to our already existing FPS system.

Two months later we reached saturation on both systems. In July of 1987 IBM provided Cornell with an upgrade that increased the IBM Supercomputer performance by 60 percent. Two weeks later we re-entered saturation.

In spite of the rigorous allocation process developed by the NSF, the Cornell Theory Center remained in a state of saturation ever since. Saturation means the demand is there but that not all of it is being met. It is unlikely that doubling or doubling again our current capacity will solve the saturation problem for long.

The staff at Cornell have taken great pains to develop a sophisticated outreach and training program, emphasizing the use of the most advanced tools in supercomputing. In the last 12 months more than 500 individuals have attended the Theory Center's Training Workshops.

To provide a greater level of user support to remote scientists Cornell University and 43 other universities across the nation have formed a consortium called the Smart Node Program. Each member institution has identified one person from its academic computing center to provide consulting services to its researchers working on the Cornell Center.

One unique aspect of this program is the high level of technical information exchange between the staffs of the Cornell Theory Center and the academic computing staffs of the member institutions. Twelve of these universities have smaller-scale versions of our configuration.

In partnership with Cornell University, the IBM Corporation has re-entered the supercomputer arena and has reestablished itself as a leader in scientific computing, as Dr. Wilson had said earlier. Since 1985 more than 30 universities across the nation have installed IBM vector systems. In the last six months there have been

several very significant supercomputer announcements relating to IBM, including a program in Europe to establish supercomputer centers that are to be twins of Cornell University. Six such centers are planned. IBM is contributing $35 million based on the success of Cornell.

Also, IBM, in association with the Merit Network in Michigan is to have a critical technical role in the operation and management of the National Research Network, NSFNET. Finally, IBM is pursuing an association with Steve Chen, the designer of the Cray X-MP and Y-MP Supercomputers.

Since the beginnings in 1985, the Cornell Theory Center has tackled the challenge of parallelism. We continue to pursue this. Since, one, parallel processing has the potential of delivering orders of magnitude increase in computing power, and, two, the potential for significant performance improvement in traditional sequential computing is limited.

The parallelism is that the calculations required in attacking a single scientific problem may take many weeks or months to perform on a traditional non-parallel supercomputer, but could be reduced to a few days or a few weeks on a parallel supercomputer. In our brief three years of existence Cornell has contributed to the advancement of parallel computing by working with IBM, FPS and University-based computer scientists on software tools for parallelism.

We have created a unique production parallel processing capability and have integrated it into the traditional supercomputer environment.

The leading edge supercomputer technology initiated at Cornell is rapidly spreading to other institutions, including many in the U.S., Europe and the Far East. This is developing an important market in a stronger competitive position for the U.S. in international commerce. Many emerging state-supported centers are acquiring Cornell's supercomputing technology and are becoming important contributors to the development of a national computational system.

The effort to create this national computational system will succeed only if Cornell University and the other NSF national centers maintain a leadership role in technology and research and the unique partnership between the Federal Government, state governments, universities and industry continues.

Allow me to turn to the difficult situation concerning the budget.

In fiscal year 1988 the Federal budget process resulted in a much smaller than planned NSF budget, which had to be allocated across many important scientific and engineering programs. This had a devastating impact on the Cornell Theory Center and the scientific community we serve. Our training and consulting staff is not able to meet the rapidly increasing demand by researchers to understand how to exploit the emerging new technologies of supercomputing, such as parallelism.

Our own strategic thrusts into advancing the state of parallelism is being held back. The Cornell effort to create a more common and portable environment in large-scale scientific computing with such tools as UNIX has been severely impeded. In addition, remote com-

munications access to the Center through the 800 toll free telephone numbers is being phased out.

In an attempt to make up some of the short-fall, we have turned to our other partners in this important endeavor—IBM, Cornell, Floating Point Systems and the State of New York and have requested their assistance. However, they will not be able to fill the gap between our actual fiscal year 1988 NSF budget and the funding level on which we were planning. When the Cornell Theory Center was started, we negotiated a certain level of funding for each year of our three-year agreement with the NSF.

Cornell understood the funding levels were solid commitments which would not be lowered. From these levels the Cornell Theory Center sent and made commitments to the scientific community, to our industrial partners, to Cornell University. Our fiscal year 1988 NSF budget will not allow the Cornell Theory Center to meet all of these commitments.

We are submitting a six-year plan to NSF for the continued operation and upgrade of the Supercomputer Center, but it is important to note that we are having very serious difficulty in negotiating cost sharing and deep discounts with potential contributors to Cornell. The problem is that a major partner in this endeavor, the Federal Government, has pulled back on its level of commitment to Cornell, at least for the time being.

In conclusion, let me say that in 1985 and 1986, through the wisdom of Congress and the National Science Foundation, two important programs were initiated: Advanced Scientific Commuting and Networking Together these programs, in three short years, have significantly contributed to advancing the state of U.S. supercomputer technology. Just as importantly, they have led to the development of initial stages of a national computational system.

These programs are a critical part of the support system for the NSF scientific and engineering research programs. I urge that the Congress support a large increase in the fiscal year 1989 NSF budget. This would allow the NSF national centers to carry out their missions, which are vital to keeping American technology and scientific achievements at the leading frontiers in the world.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Lee follows:]

A PERSPECTIVE ON THE NSF NATIONAL SUPERCOMPUTER CENTERS

Testimony Delivered by
Lawrence A. Lee
Cornell Theory Center, Cornell University
Before the House Committee on Science, Space, and Technology
Thursday, March 24, 1988

I am very honored and pleased to address this committee and describe the status and future requirements of the NSF Supercomputer Center at Cornell University. To begin, let me express my thanks to the Members of the House Committee on Science, Space, and Technology for your strong suppo. in recent years of the National Science Foundation and, in particular, of the NSF supercomputer and networking programs. Thank you.

The Cornell Theory Center is a national center which is unique in providing researchers with access to a very powerful production parallel processing environment on an IBM supercomputer system and Floating Point Systems (FPS) mini-supercomputers. FPS is an innovative manufacturer of advanced scientific computer systems. We see our mission as four-fold:

- To encourage the advancement of computational science and to provide the computational tools necessary to address the grand challenges of science and engineering. The grand challenges are interdisciplinary problems of major national importance that push supercomputers to the current performance limits and beyond. Examples include electronic structure, molecular basis of life, global environment, global economy, life history of astrophysical objects, and product design and manufacturing.

- To train and educate students and young investigators, as well as established researchers, in the effective use of advanced computational systems,

- To provide for the transfer of knowledge and experiences between the center and universities/corporations,

- To interact with the computer industry, on behalf of the scientific community, to achieve major advances in computer technology.

In three short years, Cornell has brought leading-edge supercomputing tools, such as large memories, vectorization, parallelism, and visualization into the hands of university-based scientists and engineers. Currently there are more than 1400 users of the Cornell Center working on 338 research projects. More than 65% of the projects are based at universites other than Cornell.

The impact of supercomputing on research has been dramatic. Supercomputing now permeates a very broad range of scientific investigations. Here are some examples of the projects on the Cornell IBM/FPS system:

- Modeling of the spread of viruses in animals,
- Modeling plasmas to understand the physics observed in natural and man-made plasmas,
- Analyzing data to optimize biological pest controls in a farm ecosystem,
- Modeling the production, transport, and political ramifications of acid rain,
- Searching for spinning stars, called pulsars,
- Modeling human joints to develop improved artificial replacements,
- Analyzing seismic data to determine the subsurface structure of the earth,
- Creating a computer graphic movie demonstrating the collapse of thousands of stars to form a black hole,
- Simulating how ultrasonic waves penetrate eye tissue in an effort to design a new treatment for eye cancer, and
- Modeling the chemistry of glass, to predict the dynamics of glass formation.

These and the many other projects from across the nation that access the Cornell Center are placing heavy demands on our supercomputing resources. In November of 1986 we received our first IBM supercomputer system and an upgrade to the already existing FPS system. Two months later we reached saturation on both systems. In July of 1987 IBM provided Cornell with an upgrade that increased the IBM supercomputer performance by 60%. Two weeks later we reentered saturation. In spite of the rigorous allocation

process developed by the NSF, the Cornell Theory Center has remained in a state of saturation ever since. Saturation means the demand is there, but that not all of it is being met. It is unlikely that doubling or doubling again our current capacity will solve the saturation problem for long.

The staff at Cornell have taken great pains to develop a sophisticated outreach and training program emphasizing the use of the most advanced tools in supercomputing. In the last twelve months more than 500 individuals have attended the Theory Center's training workshops. To provide a greater level of user support to remote scientists, Cornell University and 43 other universities across the nation have formed a consortium, called the Smart Node Program. Each member institution has identified one person from its academic computing center to provide consulting services to its researchers working on the Cornell supercomputer. One unique aspect of this program is the high level of technical information exchange between the staffs of the Cornell Theory Center and the academic computing centers of the member institutions Twelve of these universities have smaller scale versions of our configuration.

In partnership with Cornell University, the IBM Corporation has reentered the supercomputer arena and has reestablished itself as a leader in scientific computing. Since 1985 more than 30 universities across the nation have installed IBM vector systems. In the last six months there have been several very significant "supercomputer" announcements relating to IBM, including a program in Europe to establish supercomputer centers that are to be "twins" of Cornell University. Six such centers are planned. IBM is contributing $35M, based on the success of Cornell. Also IBM, in association with the Merit Network in Michigan, is to have a critical technical role in the operation and management of the national research network, NSFNet. Finally, IBM is pursuing an association with Steve Chen, the designer of the Cray X-MP and Y-MP supercomputers.

Since its inception in 1985, the Cornell Theory Center has tackled the challenge of parallelism. We continue to pursue this, since (i) parallel processing has the potential of delivering orders of magnitude increase in computing power, and (ii) the potential for significant performance improvement in traditional sequential computing is limited. The power of parallelism is that the calculations required in attacking a single scientific problem may take many weeks or months to perform on a traditional non-parallel supercomputer, but could be reduced to a few days on a parallel supercomputer. In our brief three years of existence, Cornell has contributed to the advancement of parallel computing by working with IBM, FPS, and university-based computer scientists on software tools for parallelism. We have created a unique production parallel processing capability and have integrated it into the traditional supercomputer environment.

The leading-edge supercomputing technology initiated at Cornell is rapidly spreading to other institutions, including many in the U. S., Europe, and the Far East. This is developing an important market and a stronger competitive position for the U. S. in international commerce. Many emerging state supported centers are acquiring Cornell's supercomputing technology and are becoming important contributors to the development of a national computational system. The effort to create this national conputational system will succeed only if Cornell University and the other NSF national centers maintain a leadership role in technology and research and the unique partnership between the federal government, state governments, universities and industry continues.

Allow me to turn to the difficult situation concerning the budget. In FY1988, the federal budget process resulted in a much smaller than planned NSF budget which had to be allocated across many important scientific and engineering programs. This has had a serious impact on the Cornell Theory Center and the scientific community we serve. The support for the Center is 31% lower than had been agreed to by the National Science Foundation in our cooperative agreements. Our training and consulting staff is not able to meet the rapidly increasing demand by researchers to understand how to exploit the emerging new technologies of supercomputing, such as parallelism. Our own strategic thrust into advancing the state of parallelism is being held back. The Cornell effort to create a more common and portable environment in large-scale scientific computing, with such tools as UNIX, has been severely impeded. In addition remote communications access to the Center through the "800" toll free telephone numbers is being phased-out.

In an attempt to make up some of the shortfall, we have turned to our other partners in this important endeavor - IBM, Cornell University, Floating Point Systems, and the State of New York - and have requested their assistance. However, they will not be able to fill the gap between our actual FY 1988 NSF budget and the funding level on which we were planning. When the Cornell Theory Center was started, we negotiated a certain level of funding for each year of our three year agreement with the NSF. Cornell understood that the funding levels were solid commitments which would not be lowered. From these levels the Cornell Theory Center set out and made commitments to the scientific community, our industrial partners, and Cornell University. Our FY 1988 NSF budget will not allow the Cornell Theory Center to meet all of these commitments.

We are submitting a six-year plan to NSF for the continued operation and upgrade of the supercomputer center. But it is important to note that we are having very serious difficulty in negotiating cost-sharing and deep discounts

with potential contributors to Cornell. The problem is that a major partner in this endeavor, the federal government, has pulled back in its level of commitment to Cornell, at least for the time being.

Under the current funding conditions, Cornell is not able to upgrade. If sufficient federal support were made available, Cornell University would upgrade the IBM supercomputer system, immediately, by acquiring a second identical system. The two systems would be coupled together to form a clustered supercomputer system. This would make a significantly higher level of production parallel processing available. In FY 1990 Cornell will need to upgrade the FPS system, again advancing our parallel processing capabilities. To meet the growing expectations of the research community the staff size of the supercomputer center will need to double by 1990. In the years to follow, we need to upgrade to a larger number of supercomputers within the cluster, each supercomputer having a much greater level of performance than todays' systems. If Cornell University is able to implement these plans, we will maintain our position at the leading edge of computational technology.

In 1985 and 1986, through the wisdom of Congress and the National Science Foundation, two important programs were initiated - advanced scientific computing and networking. Together these programs, in three short years, have significantly contributed to advancing the state of U. S. supercomputer technology. Just as importantly, they have led to the development of the initial stages of a national computational system. These programs are a critical part of the support system for the NSF scientific and engineering research programs. I urge that the Congress support a large increase in the FY 1989 NSF budget. This would allow the NSF national centers to carry-out their missions which are vital to keeping American technology and scientific achievements at the leading frontiers in the world..

Mr. WALGREN. Thank you, Dr. Lee.

And I know that you know of Congressman Boehlert's interest in this, particularly coming from Cornell. He was unable to be here today, but he has been a very solid promoter of this program, as you know, and I know that he would have wanted to be here.

At this point I will just make a formal point that the record will remain open for statements and submissions that other members, including Mr. Boehlert, may want to make for the record. But I know he wanted to be here.

And with that, let's turn to Dr. Roskies, who knows of my interest, coming from Pittsburgh, but we're real pleased you're here.

Dr. ROSKIES. Thank you very much, Mr. Chairman, and thank you for giving me and Dr. Levine the opportunity to appear and to talk about the NSF supercomputing initiative and to tell you some of the particulars of what's going on at the Pittsburgh Supercomputing Center. [Laughter.]

My comments are given on Dr. Levine's behalf as well as my own.

I want to start by saying that support that you have heard from colleagues here that the NSF supercomputing centers are a cost effective tool for scientific development and are essential for American economic competitiveness. These centers have raised the national level of computing and are educating the next generation of scientists and engineers in vital computational techniques.

New funds are required to assure that their initial promise is sustained.

As an example, excellent science with great practical impact, let me cite a study which was carried on at the Pittsburgh Supercomputing Center on the generation of smog over Los Angeles. As a result of this study the Environmental Protection Agency is revising its strategy for air pollution control.

The study has led to new legislation, it suggested concrete steps which are now being implemented to improve air quality significantly in the 80 or so cities not in compliance with EPA's standards.

The country spends around $30 billion a year on air pollution control. Based on the projected savings, the value of this single study exceeds the full cost of all the NSF supercomputers.

Supercomputers not only allow scientists to complete calculations faster, they allow them to ask questions which they would otherwise be afraid to tackle. Without them, the air quality studies just mentioned would not have been done.

Supercomputers change research horizons. They are essential in our efforts to design new materials which are required to keep the multibillion dollar material industry competitive. Supercomputers are crucial in helping us unravel the secrets of molecular biology, which will lead to vital medical advances. These scientific problems and many others requiring supercomputing have major economic significance.

Promising research is now not being undertaken because centers, including ours, are fully subscribed. Continued American dominance in supercomputing is essential for our economic competitiveness.

The Committee should be congratulated for its wisdom in supporting it. The program is scientifically successful and cost effective. Now is the time to reaffirm commitment to the original goals of the program and to keep these centers at the leading edge of computational technology so that scientists and engineers are not forced to abandon essential research.

New and more powerful supercomputers are becoming available. This technology will surely be in the hands of our Japanese and European competitors and it is crucial that the NSF and Congress commit themselves to providing American researchers with access to these more powerful resources. At stake are both our economic well-being and the excellence of a large part of university-based research programs.

At the Pittsburgh Supercomputing Center our prime concern is science and engineering. We are also having considerable impact on important U.S. computer manufacturers. We work closely with two of the major vendors in this country, Cray Research and Digital Equipment.

We are the site of a cooperative effort between the two to provide a better interface between their computer systems. We've written software which promotes the integration of their product lines which they have received enthusiastically and which enhances the ease of use of supercomputers by the scientific community.

We are helping U.S. industrial competitiveness through education and through promoting increased contacts between the industrial and academic communities. We are proud to be helping ALCOA retain its leadership in the materials industry, an area which has traditionally been of prime concern in Western Pennsylvania.

We are also proud to have been selected in a national competition by the National Institutes of Health as the center to provide education, training and supercomputing access to the biomedical community. This effort will surely lead to improved health care. The NIH's eagerness to exploit supercomputing was clearly inspired by the NSF initiative.

We have had to absorb some budget cuts in the present fiscal year. We're tried hard to minimize the impact on scientists and to minimize the damage to the credibility of the program because, like the NSF, we believe it is so vital.

We have slowed staffing, we have put off acquisition of new equipment, and we have even deferred repayment on old obligations. This is clearly a short-term expedient. If funding levels are not restored retroactively to their cooperative agreement levels, our ability to serve the scientific community adequately will be threatened.

Despite present stringencies, we continue to develop plans to assure that our scientists have access to the best supercomputing capability. We've identified an aggressive but prudent and very cost-effective upgrade plan. We are talking about increases in capability of a factor of ten within the next two years, a relatively modest increase in NSF funding. Additional funds must be forthcoming in the next fiscal years to allow us to pursue this path.

Our goals remain true to the Congressional intent of this program to establish—to enable scientific advances through large-scale

computing, to advance the techniques of computational science, to train students in the methods of large-scale computing providing skilled personnel for both academic and industrial research, to keep the United States at the forefront of supercomputing technology, and to assist the private sector in exploiting large-scale computing for American competitive advantage.

For us, supercomputers are a tool of science. Our users at the Pittsburgh Supercomputing Center are physicists, engineers, chemists, biologists. Increased support for supercomputing should go hand-in-hand with increased support for all of science. In addition to urging you to make the resources available so that the NSF supercomputing centers can provide the nation's scientists and engineers with the most powerful machines which they so badly need, we urge you to support the administration's request to the entire National Science Foundation.

Thank you.

[The prepared statement of Dr. Roskies follows.]

STATEMENT TO THE U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
MARCH 24, 1988

By

Michael J. Levine and Ralph Z. Roskies
Scientific Directors
Pittsburgh Supercomputing Center

NSF supercomputing centers are a cost-effective tool for scientific development and are essential for American economic competitiveness. These Centers have raised the national level of computing and are educating the next generation of scientists and engineers in vital computational techniques. New funds are required to assure that their initial promise is sustained. We will illustrate with some examples drawn from the experience of the Pittsburgh Supercomputing Center (PSC). We will also describe the impact that the PSC is having on the industrial community and on major computer manufacturers. We will briefly describe our needs.

Supercomputers are a powerful and cost-effective new tool for generating important scientific insights. Some of these insights have great practical impact. For example, a recent study of air quality over Los Angeles carried out at the PSC is causing the EPA to revise its strategy for air pollution control. The study suggested concrete steps, which are now being implemented, to improve air quality significantly in the 80 cities not in compliance with EPA's standards. The country spends around $30 billion a year on air pollution control. Based on projected savings, the value of this single study greatly exceeds the full cost of all the NSF supercomputers.

Supercomputers not only allow scientists to complete calculations faster; they allow scientists to ask questions which they would otherwise be afraid to tackle. Without them, the air quality studies just mentioned would not have been done. Supercomputers change research horizons. They are essential in our efforts to design new materials, required to keep the multi-billion dollar materials industry competitive. For example, many studies of the new high-temperature superconductors are being carried out at the NSF Centers. Supercomputers are crucial in helping us unravel the secrets of molecular biology, which will lead to vital medical advances. They were essential in helping us understand the structure of rhinovirus, which may lead to a cure for the common cold. These scientific problems and many others requiring supercomputing have major economic significance.

Simulation of physical phenomena on supercomputers is an increasingly powerful approach to making the industrial design process cheaper and more flexible. Progress in aircraft design or drug design is limited by the computational capability of current supercomputers. Continued American dominance in supercomputing is essential for our economic competitiveness.

The Centers also play a crucial educational role. They are training the next generation of scientists and engineers in the use of what may be their most important tool for progress. It is in the vital national interest to have personnel highly skilled in the use of supercomputers.

The NSF Centers have raised the computing standard across the country. The program has stimulated individual universities to buy their own supercomputers and minisupercomputers. But these campus-based machines do not suffice for the nation. In fact, smaller machines fuel the demand for more powerful resources. These NSF Centers can continue to raise the national computing level only if they themselves stay at the leading edge.

Congress should be congratulated for its wisdom in supporting the NSF supercomputing initiative. The program is scientifically successful and cost effective. Now is the time to reaffirm commitment to the original goals of the program and to keep these Centers at the leading edge of computational technology, so that scientists and engineers are not forced to abandon essential research.

The Centers are now loaded to saturation, running 24 hours/day, seven days a week. Worthy projects are being denied access to the supercomputers. Researchers' expectations of how much supercomputer time they can seek is forcing them to work on less challenging problems. Other prominent scientists are waiting on the sidelines before committing to use this powerful new tool to augment their substantial research energies, because they doubt the long-term viability of this initiative. Will the necessary resources to achieve stable funding be forthcoming, or will the NSF supercomputing Centers be allowed to die?

New and more powerful supercomputers are becoming available. This technology will surely be in the hands of our Japanese and European competitors. It is crucial that NSF and the Congress commit themselves to providing American academic researchers access to these more powerful resources. At stake are both our economic well-being and the excellence of a large part of university-based research programs.

The Centers' unique perspective on the national scientific computing effort allows them to identify research into techniques of computational science with a short term payoff to the computational community. This research is unlikely to be undertaken by vendors or by academia. Additional funds have to be made available to promote such research.

Now a few words about the Pittsburgh Supercomputing Center in particular. We have grown rapidly since our founding in January 1986. Researchers have already produced exciting scientific results with important national benefits, such as the air quality study we have already mentioned. We have assembled a dedicated and enthusiastic staff, drawn from both the industrial and academic world and motivated by the service to science. Although we are the youngest of the Centers, we too find our resources fully utilized.

In our outreach to the industrial community, we have formed close affiliations, which extend beyond providing just time on the supercomputer. We are helping U.S. industrial competitiveness through education and through promoting increased contacts between the industrial and academic communities. We are proud to be helping Alcoa retain its leadership in the materials industry, an area which has traditionally been of prime concern in western Pennsylvania. We are also proud to have been selected in a national competition by the National Institutes of Health as the Center to provide education, training and supercomputing access to the biomedical community. This effort will surely lead to improved health care. The NIH's eagerness to exploit supercomputing was clearly inspired by the NSF initiative.

We are also having considerable impact on important U.S. computer manufacturers. We work closely with two of the major computer vendors in the country, Cray Research and Digital Equipment. We were the site of a cooperative effort between the two to provide a better interface between their computer systems. We have written software which promotes the integration of their product lines, which they have received enthusiastically and which enhances the ease of use of supercomputers by the scientific community.

We have had to absorb some budget cuts in the present fiscal year. We have tried hard to minimize the damage to the credibility of the program, because we believe it is so important. We have slowed staffing, put off acquisition of new equipment, and even deferred repayment on old obligations. But this is a short term expedient. If funding levels are not restored retroactively to their cooperative agreement levels, our ability to serve the scientific community adequately will be threatened.

Despite present stringencies, we continue to develop plans to assure that our scientists have access to the best supercomputing capability. We have identified an aggressive but prudent and very cost effective upgrade path. Additional funds must be forthcoming in the next fiscal years to allow us to pursue this path. With the other matching funds we are able to attract, we could install a more powerful supercomputer next year and provide the necessary services if we received $15M/year from the NSF. That is more than is in our cooperative agreement. Commitments have to be structured so that we can reliably plan the financing of these large capital acquisitions over several years.

Our goals remain true to the Congressional intent of this program

- to enable scientific advances through large-scale computing
- to advance the techniques of computational science
- to train students in the methods of large-scale computing, providing skilled personnel for both academic and industrial research
- to keep the United States at the forefront of supercomputing technology
- to assist the private sector in exploiting large-scale computing for American competitive advantage.

For us, supercomputers are a tool of science. Our users at the Pittsburgh Supercomputing Center are physicists, engineers, chemist, biologists. Increased support for supercomputing should go hand in hand with increased support for all of science. In addition to urging you to make the resources available so that the NSF supercomputing centers can provide the nation's scientists with the most powerful machines which they so badly need, we urge you to support the Administration's request for the entire National Science Foundation.

Mr. WALGREN. Thank you very much, Dr. Roskies. I want to express our appreciation to all of you.

I think you make certainly a very compelling case and, of course, you're closer to it than almost any of the other witnesses.

What is the contribution from the industrial component of these centers? Does it vary from center to center? What are they interested in? Are they providing money? I think, as Dr. Karin said, that we're saying to them, "feed us or we starve," or somebody said that. And what is their interest and——

We're clearly trying to leverage them into the situation. We're trying to do it on the cheap by requiring them to be partners in this. Are they willing partners, Dr. Smarr?

Dr. SMARR. Absolutely, and I would say enthusiastic. I could just describe the model we have, which is to make a major change on ten of the major corporations that span the economy. The commitments require between 14 and 18 months of mutual courtship and getting to know each other, starting with the scientists and working up to the CEO and Chairman of the Board. So, it's a corporate-wide commitment.

In our case, it's a research partnership in the sense that, yes, they get access to a thousand Cray hours a year and they can use those remotely. But that's not what their real interest is. Many of them have more time than that, that they're buying from Boeing Computing Service or some of the other places one can buy cycles.

Vice president of research after vice president of research has said that the reason that they're interested in being in our center is because of the people and the environment. We had one chief financial officer refer to us as their window on the future for the corporation. It's an ability to get their people to come to our center with a problem to solve, to be able to immerse themselves in a comprehensive computing environment of hardware and software, of work stations of visualization all integrated together to find how to solve that problem in a way that they can then go back and make purchase orders to reproduce——

Mr. WALGREN. Are they willing to pay more for that then they are presently paying?

Dr. SMARR. I think that our experience with them—I'll just give you this little historical footnote. We put together an advisory committee that had high-level representatives from about ten industries to originally advise us on putting together this program. That was back in 1985. They were unanimous in saying that we would never get a million dollars a year from a corporation and that we should aim for about $100 thousand, that that would be a right level.

I believe that the impact on our country was so tremendous that that was a statement that could be changed by education. That's why I've given so many talks to these corporations.

Let me just give you an example of what the vice president of research of one of the major corporations said about their experience. When they went to their researchers and their scientists and engineers and asked them would you like to have access to a supercomputer, he got a unanimous answer, no, we don't need it.

It was only after I went and took videotape after videotape, showing them the kinds of things that can be done that they

weren't doing inside that corporation, that the engineers and scientists changed dramatically and began to say we didn't know you could do that. I want to do my work that way. Then, of course, it became easy for them to get the——

Mr. WALGREN. Well, I guess the thing I'm fishing for is whether there's any ability to draw more out of that private sector. We obviously have drawn something. But I gather, the problem is that we're looking for essentially the resources to complete the basic capability and it's a little hard to look to the private sector to add to the basic capability of the center.

Is that right, Dr. Levine?

Dr. LEVINE. Yes. I think it's a mistake to attempt to think that somehow one can get the private corporations to do the work which we have started out to do. I think you've put it well, that they have to carry it. We, ourselves, have to carry it to a certain level of completion.

In addition, we are really not looking to these people just to fund what's going on. You're not trying, after all—I know that wasn't your intention—to simply set up computers someplace. You were trying to cause a revolution to take place in the way people do their work, and the major point really of the corporate involvement on which I know all the directors have spent a great deal of time and effort is not to get money from them—that certainly helps—but to bring them along in this evolution and revolution, in fact, in the way one does science and engineering. And if we revert, at some point, to seeing them as a cash cow we will have lost our focus on the prime interest.

Mr. WALGREN. We think of these science and technology centers that have been proposed by NSF and there's a private contribution or involvement there, if I'm not mistaken. Is that right? It's not required?

But, I guess, the point is that it would strike me that the case can be made more strongly that there ought to be committed funding in this kind of a structure for a certain period of years than it could be made for a science and technology center having committed funding for a certain number of years because here you have a whole range of economic expectations and commitments, serious commitments from the private sector, that have to be based on the ability to count on whatever that structure, future structure is being there.

Would you folks argue that if Erich Bloch says that we need a future commitment for science and technology centers, that we need that several times over in supercomputer centers?

Dr. LEVINE. I think you have clearly identified a key part of the argument, and that is, one can't do these sorts of long-range projects—essentially, whatever their basis—without some long-range planning. We have to deal on two fronts. One, we have very substantial financial commitments which cannot be paid off in one year's time, and in addition, we're asking state governments, the universities, private corporations, to join us.

This being a new enterprise, people—they gain confidence by seeing what they think is confidence on the part of others and it can create an extremely unstable situation if someone who they thought was their leader and showing the way appears to be

having cold feet. It can cause an extremely rapid degeneration in what's going on.

But, yes, one needs that kind of planning.

Mr. WALGREN. Dr. Karin.

Dr. KARIN. Yes, I'd like to second the earlier comments, but I'd like to differentiate, first of all, between two types of industrial sponsors of the centers.

There are those who are in the business of building computers, basically, and are interested in working with the centers in order to develop new techniques and new tools and new hardware and new software. There are those who are in other businesses who are attempting to use the centers' facilities to advance their research and engineering developments.

In our experience, those in the first category, for those of us who have migrated slowly into being sort of computists, those are very interesting and challenging problems to work on. Unfortunately, under the current budget constraints, we're unable to provide the level of cooperation at our end that we would like to. We have had a number of offers of equipment and other kinds of collaborative efforts from such vendors that we're unable to take advantage of because of the lack of funds in our budget.

On the second category, the ones that Dr. Smarr has been talking about and I think eloquently and correctly, I find that generally we tend to glibly think of a million dollar contribution as a million dollar defrayal of costs for these facilities which are dedicated to academic researchers. In fact, a substantial fraction of the funds obtained in that way are returned in value received to those corporations.

Now, I'm not trying to knock that process. I think it's an important process. It's one of the ways in which we transfer this technology into the industrial environment. But one needs to not lose sight of the fact that to the extent the centers' efforts are focused on industry, there's some less focus on the academic world and it's just the way the world works.

Mr. WALGREN. The Gentleman from Louisiana, Mr. Hayes.

Mr. HAYES. It occurred to me when you said that and when you earlier and other panelists were talking about groups with the more varied backgrounds, we didn't go into conclusions. The adverse impact of the 1986 Tax Reform Act may be felt almost immediately on participation, then, with the amount of money required through participation by outside corporate interests on their actual return, it could be viewed by an examiner as a donation subject to the limitations. And secondly, if not subject to those limitations, subject to substantial different approaches to write off as an expense item as to a capitalized item over a long term.

Have you had any opportunities within your community to take a look at what you think might be a financially adverse impact, the cause of the consequences of the Tax Reform?

Dr. KARIN. If you're addressing it to me, we have and we're quite concerned about that and we've discussed that with some potential industrial sponsors and some existing industrial sponsors.

More directly, the immediate impact is that we had intended to finance the next upgrade with tax exempt financing for the equipment. It's now our understanding that that would drive away in-

dustrial sponsors. Since the industrial sponsors are so crucial to the financial success of the centers under the current budget considerations, we have turned away, at least with our current understanding of what the rules are, from that avenue.

On the other hand, since there isn't enough money for an upgrade, it's a moot point, and we'll await further guidance from the Congress on what the rules actually are going to be.

Mr. WALGREN. Mr. Bruce?

Mr. BRUCE. Thank you.

Let me, first of all, say that, of all the projects that we take a look at on this Subcommittee and the Full Committee, I have probably wed myself to your endeavors more than any other. The six people at that table amaze me and—when we talk about international competitiveness and the ability to excite young children, to get excited about the things we need and the disciplines we need to get them involved in if we're going to work for a stronger United States economy, I think you guys are it.

And that's why I'm concerned about what role you play if we don't upgrade your equipment, because I think universities can and are getting into the purchase of supercomputers and everyone can have one. If we don't upgrade you guys, what kind of role do you play? Where are you in the whole mix of things? Im going to ask three or four questions of you and just run down the table from Larry Smarr down maybe—what happens, Larry, if we don't upgrade? What unique role do you play, if any?

Dr. SMARR. I think we would lose the critical pulling role on the other universities and on industry that, for instance, Dr. Wilson talked about earlier and the situation with IBM where there they've had a tremendous impact on the universities that have smaller IBMs, by being at the leading edge. What we can do is explore new ways to use the same machine to be much more productive for the money you've sunk into it and that—we can then—the software, for instance—we developed new software tools that allow you to visualize things going on in the supercomputer right on your personal computer. Those are immediately available to the other universities who would not be able to develop those, but could use them.

And so, when we come one and the same as those, we lose that ability to help pull up the production of the capital investment that our country has made in those other universities.

Dr. KARIN. I would agree with those comments and add one additional one.

The industries I mentioned before, the aerospace industry and the U.S. petroleum industry and so on, are already well-versed in the use of supercomputers and they are production tools in those industries, not just in the research environment but also in the engineering design environment. And there are many examples of products today that have been designed using supercomputers in segments of our industrial economy.

One of the roles of the NSF Centers is to train these new researchers so that they go out and can be productive in those industries. But another role is to provide an environment for researchers on our campuses that are similar to the environment that researchers at the major players in those industries who are already

using supercomputers, and there are many of them, have for themselves.

And so, I would point out that already we're having some difficulty with that. We're way ahead of where we were before this program started,—but I can brag to you about having 2,700 researchers, but I can tell you that Apple computer, which is just a few miles up the road from where I'm located, has almost an identical machine, has about 30 researchers. They haven't failed by 2,670 researchers; they've succeed. Those 30 have a much more valuable resource available to them on an individual basis, and researchers at our center and the other NSF Centers that are attempting to do relevant things to what goes on at Apple don't really have the tools that the researchers at Apple have. And I think that extends through many other industrial segments.

We're already in a position of having such difficulties and I think a lack of upgrades just simple exacerbates that.

Dr. KNIGHT. If I could make a few remarks to your question.

As others have indicated, I believe that the NSF supercomputer centers are the data point against which university computer facilities measure themselves. By placing that data reference point at the leading-edge technology the National Science Foundation is utilizing a rather substantial leverage in encouraging American research universities to continuously upgrade their resources for computational science and engineering research.

I believe your question was, what, in fact, happens if the NSF Centers are not kept at the leading edge?

I believe that the impetus for upgrading computer resources at all U.S. research universities will be lessened, that plans will be laid back or, indeed, eliminated for additional acquisitions and that we will slowly, and perhaps even more rapidly, sink towards what, in fact, computing was like in this country at the last part of the previous decade and the early part of this decade, which I characterize as the university professor as computer director.

The situation which university faculty found themselves going out and acquiring their own minicomputers singly or in pairs or in combinations and spending their valuable time running computer shops with temporary personnel, better known as graduate students.

It is critically important that that data reference point of the NSF Supercomputer Centers, as leading-edge technology be maintained to avoid our reverting back to that earlier position.

Mr. LEE. I concur with everything that was said prior to this, but let me add a few points here.

I think the key word is leadership, leadership in training, leadership in education, leadership in computational research, and in acquiring advanced technology and making it available to the community. That's not an easy thing to do. It requires a staff that has worked with the vendors, understands the technology and is willing to put the effort into making it available to the community.

You won't find a lot of universities that will be able to maintain a staff like that unless they're supported at the leading edge, like the National Centers should be.

And one point, should be made again from earlier discussions, is that the role of the centers, I believe, is to interact with the com-

puter industry on behalf of the scientific community to achieve and push major advances in computer technology. That interaction has resulted in important developments in the computer industry and in standards that must continue, and we, as National Centers, must do that on behalf of the community we serve.

Mr. ROSKIES. I would like to add really one more thought, but I think it's a very important one, and that is there are a large number of very important scientific problems that need increased capability. And if we don't get upgraded, the academic community is not going to be able to undertake research on those problems.

I think that's a very serious concern.

Dr. LEVINE. Let me just add the observation that this is not the same situation as exists, for example, in my own research group, which is a high-energy physics research group, where one can essentially fulfill one's scientific obligations for that group at a certain level of computing. This enterprise in which we're all embarked here has, by its very nature, to stay at the top and to keep moving, and so that if you don't do upgrades, it's no longer the same program. The program has simply failed or gone out of existence. Without the upgrades, the program just isn't what you thought it was.

Mr. BRUCE. If I can just ask one final question which has three parts and then that will finish it up. If we can just run down—well, you guys are just fantastic here.

The question is, can you live with the original cooperative agreement? If we funded you at that level, is that adequate? If we didn't do that and won't do that, should we reduce the number of centers so that one, two, three or four of you have sufficient funds to go on? And if we refuse to fund you at the maximum level and we keep all five centers going, should one—or each of you specialize in areas where you are the best one in meteorology, best one in, you know, pick a discipline, where we divide you up and make you the national computing center on metallurgy, or whatever?

I just wonder, should we—will a cooperative agreement, if we stood by that, would that be adequate? Should we reduce the numbers if we don't? Or should we specialize?

Dr. SMARR. I just read my cooperative agreement this morning. I keep it under my pillow——

[Laughter.]

Dr. SMARR [continuing]. To remind me what my job is.

In that cooperative agreement we are talking about bringing into existence what we have brought into existence, and so I think we have done what the cooperative agreement funded us to do.

What the cooperative agreement did not do was to deal with the issue of then keeping these centers at the state of the art, and in particular, one of the clauses in the cooperative agreement says that this cooperative agreement anticipates an equipment upgrade in the fourth year, fiscal year 1989, and will require a renewed five-year commitment of NSF funds, beginning October 1, 1988. And in that, I presume, would be a renegotiation to see what the appropriate funding levels would be.

So, the cooperative agreement levels, if we had been funded at those levels, I think, would have been adequate to do the job that we have done. I think it's not much beyond those levels to be able

to provide a continuous upgrade, because what one can do is, as we've tried to do, is to negotiate agreements with the vendors where basically you have a trade-in every two years. It's the way people used to buy cars for themselves in this country.

You can then plan, and I think we're not too far from the kind of numbers—we're not talking about more than doubling. In fact, perhaps even less, as was mentioned earlier.

As far as the number of centers—let me just make one point on that. It's very important for you to realize how incredibly powerfully levered these particular Federal dollars are; okay? I mean, first, there's the cooperative agreement levels. We went—these are in your document, but this was the first full year, fiscal year 1986, of our cooperative agreement. At that point 70 percent of the cash income to our center was from the Federal Government, the NSF, and only $2 million from the state and $1 million from industry.

Two years later, this fiscal year, 1988, the NSF dollars are $600,000 more. That's all. That's less than—that's essentially cost of living. It's constant with where we were when we started the first full year of the program for our center.

In the meantime, the state dollars have doubled and the industrial dollars have quintupled. Now, something is not quite right about that and this is where we're getting into trouble, because we're trying, on the basis of the dollars for the industrial program and the state program, to desperately go ahead and make five-year commitments to upgrades and capacities without the NSF participating in that. We do not have in place anything that is going to meet this October 1 deadline right at the moment with our negotiations with NSF.

So, I go back to Doyle's point about we must have better management of where we're going. You need to let us know what our job is. We will do that job for you, I think, if we have a little bit more money than what we have now.

As far as the number of centers, again, I would come back to the question of what is it that you want us to do? I think you could argue Los Alamos and Livermore have done a wonderful job for their mission with only two centers and—one has 11 supercomputers and the other one has 8 or something, because they've discovered this economy of scale of how little extra it costs to put more capacity in the existing center. The NSF centers haven't yet even got into that regime of economy of scale.

And so, I would say that what I'd like to see is more of a statement of what is it that the centers are trying to do functionally and then we can study that and give you answer. Is it two, is it three, is it five, is it ten? But we have to know what you want us to do for the country. I know what I want to do for the country, but we need some leadership from you.

As far as the specialization, I think it would be a mistake. The great advantage that our center has seen, I think, in attracting industrial sponsors has been precisely because we have all these disciplines working together in our interdisciplinary research center.

I mean, to give you an example, here are two cover stories. One from *Computers and Science* and one from *Government Data Systems.* They have the identical three-dimensional visualization of a severe storm generating a tornado that was done at our center by

people coming from Los Angeles who had previously worked on TV commercials, like TRIX, rabbits and things like that, and feature films, 2010. And yet, here is *Science* and here is *Government Data Systems* and so forth.

You know, *Time* magazine, you know, that's the cover story. They have gone all through this at the NSF Centers.

So it's this breadth. There are fewer ways to use computers than there are kinds of people to use them. There's an economy of scale—there's hyperbolic equations, elliptic equations. There's just a few kinds of equations, really, and there's thousands of application fields. So you don't get that economy of scale if you just have a center specializing in one area.

Dr. KARIN. I would comment that in the San Diego situation, in particular, the cooperative agreement that we signed a few years back identified the fact that the scope of the project that was minimally agreed to as being necessary to make it a successful facility required $7.5 million in addition to the funds identified in the cooperative agreement because even then the Science Foundation did not have sufficient funds to make those commitments.

And the cooperative agreement contains words to the effect that both the Science Foundation and the San Diego Supercomputer Center would attempt to go and find those additional funds just to meet the minimal scope of the project, which includes no upgrades. And to date, we have found several million dollars. The Science Foundation has found negative $1.5 million so far.

And so, when you ask if simply restoring the cooperative agreements would be sufficient, my answer, is no. If you ask, should you reduce the number or centers, my answer is, if you don't restore the cooperative agreements you will reduce the number of centers. It's just not clear which ones you're going to reduce. You'll certainly reduce them from being national centers and from facilities who provide leadership to the supercomputer community and the academic community and the research community.

It would be the grape press approach and it's not obvious who's going to bleed first and so on. But without restoring the funds, it's inconceivable to me that we'll remain five national supercomputer centers. We may retain our titles and several-year-old equipment.

The issue of specialization is an interesting one. It's often tempting to try to take our center into some area of specialization like that. The reason it's tempting is that as soon as one does that, there's a ready-made scientific constituency with organizations, organized scientists to speak for it. But as Larry pointed out, we're very interdisciplinary and it is one of the strengths. But it's a strength from a technical and a performance standpoint than from a success of the center's standpoint. It's a weakness in the budget process and in negotiating in general because, while there's an American Chemical Society and an American Society of Mechanical Engineers and American Physical Society and lots of sub-societies of those societies, there isn't any American computational science society or anything like that yet. That causes all of the centers, I believe, great difficulty.

Dr. KNIGHT. First of all, the cooperative agreement level for the John von Neumann Center in FY 1989 will permit us to complete our objectives as stated in our initial proposal to the National Sci-

ence Foundation, namely to fully integrate the ETA-10 into our user base of more than 1,300 users.

It will also allow us to overcome the deficiencies in lack of sufficient staff and software associated with insufficient funding from the Foundation in previous years.

With regard to the number of centers, I agree entirely with what Dr. Karin stated, that if in fact the funding from the National Science Foundation is at a level below the cooperative agreements, they will in fact be faced with precisely that issue.

Regarding the question of specialization, I believe that the centers themselves are developing areas of emphasis, visualization, in computational chemistry and others, but it would be a serious mistake to identify one center as the center for computational chemistry and another as the center for computational fluid dynamics.

The reason, as discussed earlier, is that industrial corporations are interested not only in the technology but they are interested in the culture. The culture of supercomputing which extends beyond specific disciplinary boundaries but is indeed interdisciplinary. Corporations have mechanical engineers, they have electrical engineers, they have chemical engineers, and they want a resource and a culture which speaks to all of them and not just a single group.

Dr. LEE. Cornell University is in a slightly different situation than the other national centers. Our cooperative agreement ends this year and it was at a lower level than the others to begin with. We feel it is very important for the cooperative agreement level for the future years to increase at a great level, otherwise we will not be able to do the upgrades that we need to do.

On the question about reducing the number of centers, I agree with Sid Karin that, if the funding does not get back up to the cooperative agreement levels, that the centers will just become rather ordinary and that will be a very serious problem.

I would hope there are two priorities, instead of reducing the centers, that we bring the existing centers up to the cooperative agreement levels, as the number one priority, and the second priority, where and when upgrades are required and needed, funding is added to the cooperative agreement levels, so that they can do the upgrades and stay at the leading edge of technology.

On the question of specialization, specialization in activities at the centers, I think are a good idea but for the centers themselves, just specializing in a particular discipline is not so good. We have seen at Cornell serious computational activities in areas that are not traditionally computational. Examples are the biomedical field, mathematical biology, social sciences, geometry; very few efforts in the past have been made to bring those communities into computational science. They are there now and we are pleased about that.

Another aspect about specialization which is important to recognize is that it would not encourage interdisciplinary work and that is a very important aspect of what has been happening and will be happening down the road.

Dr. ROSKIES. I just want to make a couple of additions to the statements you have already heard. First of all, I want to go back over the fact that, when the studies were done in the early 1980s about the number of centers required, the smallest number that was talked about was 10 to 12 centers. I think those early studies

were probably right. I think we shouldn't be thinking of going down from five. We should perhaps be thinking about how to get money into a program to do better

I want to say something that I don't really understand but something that I have noticed about this program. It has harnessed the energy of some very talented people, and not only other people at this table but also the staffs at the centers. It is very creative energy. I don't think we could have foreseen three or four years ago the directions in which this program would have gone. I think to narrowly specify that you are going to be the center that does "x" and you are going to be the center that does "y," is to defeat that kind of energy.

I would argue that it would be a bad idea to target each of the centers at a very specific target.

Mr. BRUCE. You guys are doing an excellent job. I certainly don't want you to think we are thinking about reducing. I want to make arguments and you have helped me make them against the reduction of any of these centers and not complying with our cooperative agreements and certainly specialization is one of the areas.

I know well the center at the University of Illinois, Dr. Smarr's area, and to see the cooperation we received from the dairy people and the south campus that didn't think computers really were part of their discipline is just fantastic. They now pressure Larry to add more and more time. We have a national center for soybean research that may be going in at the University of Illinois; and, the first thing that they wanted to talk about to me was how do we get access to the supercomputer because we want to link every major agricultural university, and not only in the United States but around the world to soybean research.

It was interesting to see how they changed their thinking from the time the center came to now, that they want to make the building with adequate wiring and all the other things that are required for supercomputing and the power requirements.

You are doing a fantastic job. It is one of the real crown jewels of the National Science Foundation and the work of this Subcommittee. We are very proud of what you have done and stand ready to help you in any way we can in getting adequate funding for you to continue a mission that is really of long term importance to the United States and has just not been recognized. Those of us who have the centers recognize it, and we will be your advocates here in Washington.

Thank you all for coming here today.

Mr. WALGREN. I certainly would like to associate myself, and I know a lot of other members of the Committee would like to as well, with the remarks of the gentleman from Illinois. I want to express our appreciation to you for being a resource to us. Thank you all very much.

We want to welcome Dr. Terry Walker, who is the Director of the Center for Advanced Computer Studies at the University of Southwestern Louisiana. Dr. Walker, welcome to our process, and we are always interested in hearing views on how the NSF is doing and what they are doing.

We are pleased to have you here. Any written comments that you would like to submit will be made a part of the record and

please feel free to focus and make whatever emphasis on points you care to in the oral testimony.

STATEMENT OF DR. TERRY M. WALKER, DIRECTOR, CENTER FOR ADVANCED COMPUTER STUDIES, UNIVERSITY OF SOUTHWESTERN LOUISIANA

Dr. WALKER. Thank you very much for allowing me to provide testimony. Let me open by saying that the comments I am going to make have to do with elitism and sacred cows. I'd like to begin by having you envision that there are at least 40 people sitting up here beside me testifying, because I believe I represent a much larger audience, a much larger constituency than myself.

Unfortunately, there are a lot of department heads and a lot of researchers that would be afraid to do what I am doing because they are afraid they might be punished in some way, shape or form for doing it.

My written testimony is very brief, it is limited to five pages. The rest of the document is all supporting information. Basically the message I want to bring to the Committee is that in fact we are not playing on a level playing field. There is an elite group of 10-12-15-20 departments in computer science and computer engineering in the United States that are receiving the bulk of the funding, and I have supporting documents culled from NSF reports to support that contention.

Today, we have over 50 percent of the Ph.D.'s being awarded in the United States going into industry rather than academia. A number of those people have told me that their choice is because they do not want to fight the NSF grant funding rat race. They would rather have the funding come from a nice steady source that is not subject to whims.

Just to give you a little background on our university, the university is what I would call a no-name university, no one ever gets it right, including the agenda today. The name was somewhat convoluted. It is a limited scope university so it is not a Cornell or a Berkeley or a Carnegie-Mellon, but we do have good quality research. We currently have 125 doctoral students, which makes us one of the larger programs in the United States. This year we will probably award something on the order of 75 master's degrees and 15 doctoral degrees in computer science and engineering. We feel as though we are serving a very important role.

The quality is substantiated in appendices A and B in my testimony and I won't go into those. We have been reviewed by some very prestigious people in the United States, from academia.

Let me come directly to the bottom point. That is, there are problems and I have some documents to substantiate it, but there are six examples of symptoms as to the problems. One is there is a delayed response to grant proposal submissions. We have had sometimes as much as 12 and 13 months go by before we receive acknowledgement as to whether or not a grant is going to be funded. That clearly deviates from NSF's stated policy of 6 months or so, maximum.

Second, we have denial of funding based on reviews from unqualified reviewers. I am going to just ask you to turn to what

amounts to the fourth to the last page of the handout I gave you. I highlighted on your copies something that I think will be revealing to you. This is not an exception; this is just an example.

This is a review we received on a research grant just about a month ago. This is from a reviewer:

> I do not know the world of design or computers and my acquaintance with AI is minimal, probably I ought not to have been asked to referee this proposal and my reactions to it should not carry much weight. My qualifications as referee is dubious.

He rates the proposal as poor, and that was NSF's basis for rejecting the proposal.

I might add that in fact the other two on this proposal was excellent and one said clarifications were needed, very good or excellent.

This same researcher on our faculty currently has a proposal in and it has been there for 7 months. He called to find out the status of the proposal. They said, well, we just sent it out for three more reviews. He said, what has happened with the earlier reviews? They said, well, we got two excellent's and a very good but we wanted to go out for three more reviews just to be sure. Now when I call NSF, I get stonewalled. They say, well, this is the way we are doing things. I can't get a good answer or justification from them at all.

There is another symptom. That is the dramatic range of ratings on a single proposal. We had a proposal that came in with a very good, a good, a fair and a poor. If you can't get more consensus than that out of four scientists who review a proposal, as a project director, I would say something smells there.

Another matter is potentially biased treatment of proposals. I just gave you the example about the person that has a proposal out that is still out for additional reviews. By the way, it was sent out for additional reviews the day that the person—the day the person called to find out what the status on the proposal was. The person at NSF never returned the phone calls. It took him five days to finally get an answer and then he says, by the way, last Friday, which is the day you called, we sent it out for three more reviews.

We have an SBIR proposal which is the small business initiative, and that proposal was rated as excellent. It was ranked second out of 17; three were rated excellent. It was recommended for funding. NSF chose not to fund it. They chose only to fund one proposal from that group.

Budget terms, just as an example, academic year release time, I talked to people at Stanford and Berkeley, and they are funded all the time. When we get a grant, the NSF people say, well, we don't fund release time, academic year release time. Your university has to cover those costs.

Finally, large grants, such as the CER and CIER, which are sort of like the Good Housekeeping seal of approval to get them. I'd like to refer you to an appendix. You can look at it later. We have been turned down on that three times. We went to Gordon Bell when he was still Assistant Director of NSF. He reviewed our proposal from the second submission. You will find a letter saying that he feels it is of high quality, and the research would be very worth while, and yet we continuously get turned down.

Furthermore, on the review sheets, there is no data as to why we are turned down. There are just very ambiguous, no comment, things like that? I go to the program director, how do we improve our proposal. Basically the conclusion I get, and perhaps there is a certain amount of paranoia on my part, is basically, well, you are from a no-name place, you are not supposed to be applying for one of these, why don't you wise up and get out of here.

As to potential solutions, I think the solutions to this problem fall into two areas, and I will certainly leave it to you to read the rest of the proposal. One, I think, accountability has to be instituted in the review process. These large grants and the presidential young investigators and so on, these programs are all handled through panels. I feel as though there is a lack of accountability in panels. I would recommend consideration to be given to abolishing panels.

Second, this is probably a major problem, the use of blind reviews. This is the one place in our whole society where there isn't any accountability. Reviewers review a proposal, shoot it down, make all kinds of wild comments, and they don't have to sign their name to it, such that the person, if you will, who is being turned down knows. This is life and death for these young scientists.

Third, the person getting the proposal before a final decision is made should be able to respond to the peer review. We are really talking about due process here. There is no due process within NSF. NSF is an authority that has more power than IRS in the community in which it operates.

A second basic area and you can read my testimony, would be to institute accountability measures for NSF program directors and management. These people don't return their phone calls half the time. You can't get answers from them. They are little Gods. It's a crime. I think they need to be given accountability requirements.

Thank you very much.

[The prepared statement of Dr. Walker follows:]

Some Problems with NSF Support for Computer Science and Engineering Research

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INTRODUCTION

Numerous articles have been written and speeches delivered regarding the competition for technological superiority that is being waged between the United States and other nations, such as Japan. Many experts believe that we may be losing this competition, particularly in important areas of technology such as computer science and engineering. I am appearing before you today to raise the issue of the allocation of NSF research funding to the various university departments of computer science and engineering in the United States. This issue is important because much of NSF's support is currently being awarded to a small number of departments and researchers while younger faculty in emerging departments are not receiving a reasonable level of NSF funding. As a result, much worthwhile research is not receiving support and the growth of the careers of many young scientists is being stunted.

BACKGROUND

UNIVERSITY OF SOUTHWESTERN LOUISIANA (15,600 Students)
Limited Scope Research Institution (6 PhD programs)

CENTER FOR ADVANCED COMPUTER STUDIES (Founded 1984)

Degree Programs (Current Enrollment):

Computer Engineering:	MS (started 1982)	= 38 Students
	PhD (started 1986)	= 28 Students
Computer Science:	MS (started 1964)	=114 Students
	PhD (started 1968)	= 97 Students

23 Faculty with very good research publication records
(see Exhibit A)

Recent out-of-state review by recognized experts in the field.
(see Exhibit B)

Research/Equipment Grants since 1982 = $3,600,000.00

Research Laboratory Equipment from State Funds since 1982
= $2,000,000.00+

15 PhD Fellowships valued at $14,000.00 - $18,000.00 per year from State Funds.

TERRY M. WALKER
PhD, University of Alabama, 1966
Director, Center for Advanced Computer Studies, 1984-present
Head, Computer Science Department, U.S.L., 1973-1987
Professor of Computer Science, U.S.L., 1972-present
Associate Professor of Computer Science,
University of Houston, 1967-1972
Assistant Professor of Computer Science,
Georgia State University, 1965-1967

Author of Eleven (11) Textbooks in Computer Science
Involved in Computer Science Education for 20+ years
Member of Computing Research Board (National), 1983-present

SYMPTOMS

1. DELAYED RESPONSE TO GRANT PROPOSAL SUBMISSIONS (some NSF responses are received as much as 12 months after submission). Often phone calls are needed to prompt NSF Program Directors into action. Also, they often do not return phone calls.

2. DENIAL OF FUNDING BASED ON RATINGS BY UNQUALIFIED REVIEWERS (see Exhibit C).

3. DRAMATIC RANGE OF RATINGS ON A SINGLE PROPOSAL. One recent proposal received ratings of Very Good, Good, Fair, and Poor. Clearly, some of the reviewers were completely out of touch.

4. POTENTIALLY BIASED TREATMENT OF PROPOSALS. Currently a proposal which received three high ratings (2 excellents and 1 very good) was sent out for three "additional reviews" more than six months after the original submission of the proposal. A satisfactory explanation has not been given by the Program Director or the Division Director. An SBIR proposal in 1987 that was rated excellent and recommended for funding was denied funding by NSF.

5. BUDGET TERMS (Academic Year Release Time) ARE DENIED for our grants but are approved for researchers at some other universities.

6. LARGE GRANTS SUCH AS CER/CIER INSTITUTIONAL INFRASTRUCTURE ARE NOT FUNDED NOR GIVEN FAIR OR REASONABLE REVIEWS. Comments on review forms are cryptic, ambiguous, and often consist of "no comment." Many questions on review forms are not answered. When an inquiry was made to the Program Director, he was unable to provide additional data and admitted the comments and evaluation were inadequate. After a meeting with the former NSF Assistant Director for CISE, he wrote a favorable reply regarding the merit of the 1986 proposal (see Exhibit D attached). This proposal had received highly favorable presubmission reviews from authorities in the research area. Funding for an enhanced and modified 1987 version of the same proposal was also denied.

PROBLEMS

1. INEQUITABLE DISTRIBUTION OF NSF COMPUTING RESEARCH FUNDS, with much of the funding being concentrated in a small number of departments (see Exhibit E).

2. MERITORIOUS PROPOSALS ARE NOT BEING FUNDED because of bias in the reviewing process. This includes reviewer selection and NSF Program Director orchestration.

3. LACK OF DUE PROCESS under current review procedures. Final decision of the NSF Program Director is virtually final; no interaction can occur between grant proposers and peer reviewers to correct inaccuracies and misconceptions.

4. LACK OF RESPONSIVENESS FROM NSF PROGRAM DIRECTORS to grant proposers.

CANDIDATE CAUSES

1. LACK OF ACCOUNTABILITY FOR PEER REVIEWERS because review process is blind (identity of reviewers is not revealed to grant proposers), which promotes abuses arising from academic incest and research content, institutional, and individual researcher bias.

2. USE OF PANELS to review certain proposals, such as CER/CIER Institutional Infrastructure grants and Presidential Young Investigator Awards, which increases importance of institutional image, departmental reputation, and group dynamics.

3. LACK OF ACCOUNTABILITY FOR NSF PROGRAM DIRECTORS AND MANAGEMENT, which dilutes the quality of the review process and results in more attention being devoted to procedures rather than to results.

POTENTIAL SOLUTIONS

1. INSTITUTE ACCOUNTABILITY IN THE PROPOSAL REVIEW PROCESS: (A) use individual reviewers and abolish panels, (B) abolish blind reviews - all reviews should be signed and the reviewer's identity revealed to the grant proposer to provide accountabilty, (C) grant proposer should be allowed to respond to peer reviewer comments so as to correct, challenge, or rebut reviewer inaccuracies and/or misconceptions, (D) grant proposer comments to be considered by reviewer before final rating assigned, (E) final grant award decision made by NSF Program Director considering all peer reviewer comments and grant proposer responses, and (F) arbitration procedure should be available to grant proposer when he/she believes decision not based on an accurate assessment.

2. INSTITUTE ACCOUNTABILITY MEASURES FOR NSF PROGRAM DIRECTORS AND MANAGEMENT: (A) proper selection of qualified peer reviewers, (B) respond to grant proposals in a timely manner, (C) screen reviews for inconsistencies and eliminate those with problems, (D) rate NSF Program Directors and Managers based upon performance evaluations and external performance audits that include input from peer reviewers and proposal applicants.

EXHIBIT A

The Center for Advanced Computer Studies
List of Faculty Publications
Since 1 January 1982
As of March 9, 1988

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Bayoumi, M. A., G. A. Jullien and W. C. Miller, "A VLSI Implementation of Residue Adders," *IEEE Transactions on Circuits and Systems*, (March, 1987), pp. 284-288.

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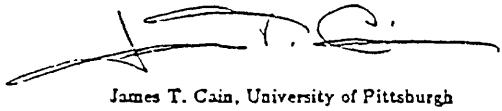
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An Evaluation of the Proposed Ph.D. Program
in Computer Engineering at the University of Southwestern Louisiana

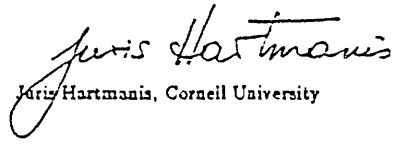
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EXHIBIT B

The Report of the Review Committee



James T. Cain, University of Pittsburgh



Juris Hartmanis, Cornell University



G. Jack Lipovski, University of Texas, Austin

An Evaluation of the Proposed Ph.D. Degree Program in Computer Engineering at the University of Southwestern Louisiana.

Introduction

The University of Southwestern Louisiana under able leadership has developed solid, well-balanced and effective graduate programs in Computer Science. Currently, the University is offering a Ph.D. degree in Computer Science, a Masters Degree in Computer Science and a Masters Degree in Computer Engineering. The Computer Science programs were established first and the Masters degree program in Computer Engineering was added in 1982. More recently the University established the Center for Advanced Computer Studies merging the Computer Science and Computer Engineering groups.

The review committee is impressed by the quality of the Computer Science and Engineering graduate faculty and the sharpness and enthusiasm of the graduate students. It is also impressed by the energetic and very successful faculty recruiting by the Center for Advanced Computer Studies. The competition for the top computer experts is fierce and the current faculty should be sincerely congratulated for its efforts and success in recruiting.

The review committee also believes that the Center for Advanced Computer Studies is an innovative and very good organizational structure to unify the University of Southwestern Louisiana's substantial effort in Computer Science and Engineering. Furthermore, the Center has enhanced the national visibility of USL Computer Sciences faculty and must have aided in recruiting.

Finally, the review committee was impressed by the University's commitment and support of the Computer Science and Engineering effort. In particular, the computer laboratories are well equipped with up-to-date computing equipment to support the extensive experimental work in Computer Science and Engineering.

The review committee carefully studied the well prepared "Proposal for a Doctor of Philosophy in Computer Engineering" (September 1985) and the other supporting material submitted before the site visit. During the site visit on June 12-14, 1986, the review committee was briefed on the current state and future plans for the Center of Advanced Computer Studies by Professor Terry Walker, and the Deans of the related colleges, it interviewed the senior and junior faculty faculty of the Center as well as a group of graduate students, and it toured the relevant facilities at USL. The visit was concluded with an interview with the university administration.

Recommendation

After intensive discussion on June 14, 1986, the review committee arrived at the following unanimous recommendation:

We found the proposed Ph.D. program in Computer Engineering at USL technically sound and we strongly recommend that it be approved and established as soon as possible. This recommendation is made with full awareness of the current economic difficulties with which the state of Louisiana and the university system is grappling.

In the following, we give some of the main reasons for this recommendation.

First of all, as stated earlier, USL has a strong graduate faculty in Computer Science and Engineering and the Center is administrating three successful graduate degree programs in Computer Science and Engineering with a gifted and growing group of graduate students. At the same time, the current degree programs do not fully reflect the interests of the faculty and graduate students. Nor do they fully meet the state's needs for computer manpower. Of the current faculty of twenty-one, about fourteen members are directly involved in Computer Engineering and many of the graduate students have undergraduate degrees in Electrical Engineering and plan

to specialize in Computer Engineering. As a matter of fact, with the creation of the Masters degree in Computer Engineering in 1981, and the expansion of the faculty, there is essentially a Ph.D. program in Computer Engineering in place, in all but name.

Because of the strength of the existing faculty in Computer Science and Computer Engineering, we believe that the proposed Ph.D. program can be started without additional faculty and thus without any *direct* additional funding. Moreover, although this program should attract additional graduate students, whose additional credit hour load will require state funding, a majority will also be research assistants in new projects that will bring substantial research funds into the state (It should be noted that the Center is already receiving substantial research funding from outside sources).

Furthermore, a significant part of the required computing equipment is on hand, on order, or committed.

The one need we see for additional facilities is for a graduate laboratory for development and testing of hardware-software systems. A laboratory for printed circuit board design and layout, microprocessor development, and integration and testing of hardware-software systems, would eventually be necessary for a strong Ph.D. program in Computer Engineering. It should be considered in future planning for the Center for Advanced Computer Studies.

The review committee would also like to emphasize that the computing field is still evolving and there is no unanimity as to the distinction between Computer Science and Computer Engineering. A plausible distinction between Computer Science and Computer Engineering is to define Computer Science as the expansion of theory and scientific principles and Computer Engineering as the systematic application of theory in implementing systems. There are great latitudes in distinctions between theory and practice that justify different degree programs, but they have a *significant core of common knowledge* that can best flourish by developing the programs in the same Center. However, the distinction between Computer Science and Computer Engineering should not be between software and hardware. This was an early distinction, but one that is widely recognized as flawed. We strongly urge the Center to avoid this software-hardware

common core of technical knowledge that is shared by Computer Science and Computer Engineering. USL has a unique opportunity to try to evolve a possibly trend setting symbiotic pattern in Computer Science and Computer Engineering education and research.

EPILOGUE

The state of Louisiana is very fortunate to have the Center for Advanced Computer Studies and should support this Center even though the economic situation is very difficult. This Center has been successful in attracting high quality faculty and external research in a highly competitive funding area, and in keeping high the morale of its faculty and students. We note that the state of Michigan supported the University of Michigan's Engineering College through difficult economic times, and that effort is now being rewarded by the concentrated development of robotics industries in Michigan. We feel that Louisiana should support the Center because it is in a growing area that has a long-term potential to help the state attract some high tech industry.

The competition among states for high tech industry is intense and a number of states have been very successful in this area. We feel that Louisiana has to intensify it efforts to attract high tech industry and that the State cannot afford to lose momentum and fall behind in this competition. We believe sincerely that the Center for Advanced Computer Studies at USL is very sound and essential investment in Louisiana's future.

NATIONAL SCIENCE FOUNDATION

PROPOSAL EVALUATION FORM

NSF Form 1 484
Supersedes All Previous Editions

PROPOSAL NO	INSTITUTION	PLEASE RETURN BY
[redacted]	Univ. of Southw. Louisiana	07/24/87
PRINCIPAL INVESTIGATOR	NSF PROGRAM	
[redacted]	[redacted]	
TITLE	[redacted]	

Please evaluate this proposal using the criteria presented on the back of this review form. Continue on additional sheet(s) as necessary.

I do not know the world of design or computers, and my acquaintance with AI is minimal. Probably I ought not have been asked to referee this proposal, and my reactions to it should not carry much weight. But I was asked and I'm at best unimpressed.

Most of the proposal is abstract methodology unattached to a research proposal. I find it windy throughout and sometimes wrong-headed, especially but not exclusively in its insistence on erasing the distinction between engineering and scientific method. (It would be strange if the difference in objectives, which are acknowledged, were compatible with identity of methodology; nothing depends on making design or any other engineering pursuit into a science.)

Almost nothing at all is said about the research for which support is requested. The so-called DSD paradigm seems too obvious and empty to be usefully deployed or tested; the key to the project, if there is one, would be the author's "theory of

Impact of the proposed research on advancing the knowledge or technology base

plausible design" which is often mentioned but about which far too little is said. I've not read the articles in which it's developed, but doubt that they'd do much to allay my doubts. This just just does not seem a thoughtful or interesting proposal, and I can't think its outcome will advance either the "knowledge or technology base". I repeat, however, that my qualifications as a referee are dubious.

Please include, in a separate paragraph(s), comments on the quality of the prior work described in the "Results from Prior NSF Support" section.

No relevant information.

OVERALL RATING ☐ EXCELLENT ☐ VERY GOOD ☐ GOOD ☐ FAIR ☒ POOR

EXHIBIT C

EXHIBIT D

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

nsf

OFFICE OF THE
ASSISTANT DIRECTOR
FOR COMPUTER AND INFORMATION
SCIENCE AND ENGINEERING

May 18, 1987

REC'D.
MAY 26 1987
CACS

Dr. Terry M. Walker, Director
The Center for Advanced
Computer Studies
P.O. Box 44330
Lafayette, LA 70504-4330

Dear Terry:

Your visit on Thursday certainly raised a set of recurring issues about the review process. While I haven't read your CER Proposal very carefully, I was quite impressed with the scope of the work and basis for the machines. The only possible intellectual economy you might get is to use the shared memory multiprocessor to simulate the other two architectural approaches, i.e., the Hypercube and the Butterfly, since they both have longer latency times for access and message passing. I suspect if you have the three machines, students would discover the critical parameters of the different approaches and be able to enlighten the community about the various parallel processing paradigms. The set of experiments looks like a good starting point for issues in parallelism today and in the future.

The faculty and students look quite impressive. Overall, I am interested to learn more about the department, which brings up the second point.

Regarding your letter of April 28th, I would be happy to visit the Center for Advanced Computer Studies in the fall. I have just promised to keynote the Alliant Users Group in New Orleans on the 29th of October and, therefore, would like to be at Lafayette on the 30th and give a talk as part of your Distinguished Lecture Series.

Again, I am glad we had the meeting and look forward to meeting with you in the future.

Sincerely,

Gordon Bell
Assistant Director

- EXHIBIT E -

NSF GRANTS IN FY 1987
COMPUTER AND INFORMATION SCIENCE AND ENGINEEERING
ANALYSIS BY DOLLAR VALUE OF GRANTS AWARDED TO STATES

	Rank	Grant $	% Total	Cum %
California	1	24,389,000	21.2	21.2
New York	2	17,438,000	15.2	36.4
Illinois	3	12,721,000	11.1	47.5
New Jersey	4	11,553,000	10.1	57.6
Pennsylvania	5	9,876,000	8.6	66.2
Massachusetts	6	6,038,000	5.3	71.5
Colorado	7	3,282,000	2.9	74.4
Michigan	8	3,102,000	2.7	77.1
Indiana	9	2,809,000	2.4	79.5
Texas	10	2,507,000	2.2	81.7
Louisiana	33	93,000	0.08	-

DATA ON LOUISIANA
(in relation to balance of the United States)

Population Rank:	18
Number Scientists/Engineers in Academic Institutions (Rank)	19
Federal Research Support (Rank)	30
NSF Support (Rank)	32
Federal Average $ per Grant (Rank)	42
NSF Average $ per Grant (Rank)	44

NSF GRANTS IN FY 1987
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING
ANALYSIS BY DOLLAR VALUE OF GRANTS AWARDED TO UNIVERSITIES

University	U.S. Rank	Grant $	% within State
U Illinois	1	11,225,000	89.6
Carnegie Mellon	2	7,357,000	75.9
Cornell	3	3,637,000	30.2
Stanford	4	3,023,000	25.9
U Cal-Berkeley	5	2,866,000	24.5
NYU	6	2,840,000	23.6
MIT	7	1,998,000	34.1
U Mass	8	1,832,000	31.2
U Cal-Irvine	9	1,714,000	14.7
U Pennsylvania	10	1,506,000	15.5

EXHIBIT E (Continued)

NSF CER/CIER GRANT AWARDS

University	Total	1st Award	2nd Award	3rd Award
Univ Washington	$8.73M	1980($4.20M)	1985($0.92M)	1987($3.61M)
Cornell Univ	$6.26M	1981($2.65M)	1986($3.61M)	
Yale Univ	$4.96M	1981($2.66M)	1986($2.30M)	
Univ Illinois	$4.02M	1981($4.02M)		
Univ Wisconsin	$8.06M	1981($4.67M)	1986($3.39M)	
Brown Univ	$2.69M	1982($2.69M)		
Rice Univ	$5.47M	1982($2.38M)	1987($3.09M)	
UCLA	$3.62M	1982($3.62M)		
Univ Texas-Austin	$3.72M	1982($3.72M)		
Univ Utah	$2.89M	1982($2.89M)		
Duke Univ	$1.72M	1983($1.72M)		
Univ Maryland	$4.50M	1983($4.50M)		
Univ North Carolina	$3.05M	1983($3.05M)		
Univ Pennsylvania	$3.84M	1983($3.84M)		
Univ Arizona	$3.64M	1984($3.64M)		
New York Univ	$4.11M	1984($4.11M)		
Univ Rochester	$3.91M	1984($3.91M)		
SUNY-Stony Brook	$4.42M	1984($4.42M)		
Princeton Univ	$4.65M	1985($2.03M)	1987($2.62M)	
Univ Colorado-Boulder	$2.80M	1985($2.82M)		
Univ Massachusetts	$2.05M	1985($2.05M)		
Univ Minnesota	$0.75M	1985($0.75M)		
Indiana Univ	$2.85M	1986($2.85M)		
Univ California-Irvine	$3.13M	1986($3.13M)		
Purdue Univ	$3.93M	1987($3.93M)		
Georgia Tech	$3.38M	1987($3.38M)		

Mr. WALGREN. We certainly appreciate your being sensitive to the time. I especially appreciated your coming forward and talking about NSF in that capacity because we know that these things happen. I don't know that we have been able to address them properly at all. We have attempted to emphasize distributive programs that would at least open the NSF up a little bit from the peer power that they exercise. There has always been this tension, as I understand it, from the very beginning, between those who feeling comfortable vesting complete power in this academic group and those who felt they had a real obligation to serve a broad swath in this society.

I want to express my appreciation for your adding to the record.

I would like to recognize the gentleman from Louisiana, who I know has a special interest in both you as a witness and in this problem with NSF.

Mr. HAYES. I think that not only does the university from which I graduated from, your university, owe you a debt of gratitude in appearing here but I think the point that you make ought to be repeated and reiterated. This weekend, we are going to see an athletic competition where everyone is given an opportunity and because of that, tiny Rhode Island and Temple University are going to have an opportunity to compete at the national level.

I wonder if it were done by ballot, by a handful of sports writers, if either Temple or Rhode Island would have the opportunity they are getting. What you are asking for is no less than what we accord a basketball team. Yet, the impact of what we are doing can have extraordinary implications on going forward and meeting the challenges of the 21st Century. While it is true that our university does not have broad recognition in all endeavors, it is equally true that it has been recognized by national periodicals in the computer science field as being among leaders in this nation. Although not of the substantive and quantitative size of the Cornell's, it nevertheless is able to compete and compete effectively at high levels of computer science competition, and the graduates from that university are able to place themselves in positions, both inside academia and in the business community, that are affordable and attainable only with the kind of education they have been given.

It is unfortunate that situations occur in which some institutions become locked out of a process, but I think the importance of your testimony today is to show it is unfortunate for them, too. When you make any endeavor open to only a few, it becomes subject to legislative criticism, and it could be that the NSF should take a good look at its own activities in order to be concerned about their own existence.

When enough people such as yourself have come forward and in this body in which we exist, when enough legislative power is gathered around a program that is not open to everyone, then that program itself is and should be in jeopardy.

I appreciate your coming. I appreciate the remarks. I assure you that you can expect everybody from the Chairman on down to the newest member of this Subcommittee to be sensitive to it and to just see that you as a representative, not of one university but of many out there have an opportunity to compete for those funds.

Thank you.

Dr. WALKER. Thank you.

Mr. WALGREN. I do want to express our appreciation, and I certainly will be working with Congressman Hayes and others to see if there isn't some way we can work on this problem and see if we can't make some improvements in the way they have, number one, treated individuals applying. And there must be some way we can redirect some of their efforts so that people like yourself wouldn't find yourself so frustrated in your interaction with them.

Dr. WALKER. Actually I came here because I feel this is sort of a move of last resort. If we were unable to get satisfaction after trying to work with NSF for three and four years, and if you can't, then you have to go to the ultimate authority, which of course is you, members of Congress.

Mr. WALGREN. We appreciate that very much. With that, we will end our authorization hearings for this year. I want to thank the various people for their interest in the proceedings.

[Whereupon, at 2:10 p.m., the Subcommittee recessed, to reconvene at the call of the Chair.]

APPENDIX I

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

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OFFICE OF THE
DIRECTOR

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

As the Committee requested in its May 28, 1987 report on the National Science Foundation Authorization Act for Fiscal Year 1988 (Report 100-110, accompanying H.R. 2330), I am pleased to enclose a report which describes the review process, criteria to be used, and schedule for evaluating Science and Technology Research Centers (STCs).

As you know, STCs are a part of the President's science and technology centers initiative, intended to take advantage of promising opportunities in science and technology which require the advantage of scale, duration and equipment or facilities. The program is designed to help maintain U.S. preeminence in science and technology, and to contribute to the Nation's economic competitiveness.

If I may provide any further details on the STC initiative, please do not hesitate to call on me.

Sincerely,

Erich Bloch

Erich Bloch
Director

Enclosure

cc: Honorable Sherwood L. Boehlert w/Enclosure

SCIENCE AND TECHNOLOGY RESEARCH CENTERS REVIEW AND EVALUATION PROCESS

SCIENCE AND TECHNOLOGY RESEARCH CENTERS

The National Science Foundation has developed a program for Science and Technology Research Centers (STC) as part of the President's science and technology centers initiative. The STC program draws strongly on recommendations from the National Academy of Sciences, and on the Foundation's experience with Engineering Research Centers and other research center support. There will be a single competition across all fields of science and technology.

The primary goal of the STC effort is to take advantage of promising opportunities in science and technology where complex research problems require the advantages of scale, duration, and equipment or facilities. Other goals include increasing the transfer of knowledge from discovery to application, and providing unique educational experiences.

Centers will share the following characteristics:

- STCs will have unifying intellectual themes, in a single or multiple disciplines. The focus will be on advancing basic knowledge in science and engineering.
- STCs will be based in academic institutions, but will involve linkages among various types of institutions.
- STCs will include mechanisms for knowledge transfer and significant intellectual exchanges with other groups, including the private sector, Federal laboratories, and other institutions. Linkages will also be established with other sectors such as state and local governments, Federal agencies, industry and other private organizations.
- STCs will provide education and research opportunities for students, faculty, visiting faculty, industrial fellows, and others.
- STCs will have a finite life, with NSF funding for up to eleven years if a high level of achievement is maintained.

Two types of awards will be made: (1) S&T Research Center (STC) awards, and (2) S&T Research Centers Planning Grants (STCPG) to assist institutions in development of plans for S&T Research Centers proposals for Federal or other support.

OFFICE OF SCIENCE AND TECHNOLOGY CENTERS DEVELOPMENT

The Office of Science and Technology Centers Development has been established to provide leadership and coordination of the STC

activity. An external Advisory Committee for Science and Technology Centers Development, with 17 distinguished experts, has been appointed to provide advice to the Foundation on the STC program and to perform oversight of program management, balance, and other aspects of program performance. (Membership list attached.)

The Office of Science and Technology Centers Development, with an internal committee of 15 technical coordinators representing Foundation directorates and offices, has designed a thorough external merit review process for the evaluation and selection of Science and Technology Research Center proposals. The process includes substantive ad-hoc mail and panel review, site visits, review by a multi-disciplinary Foundation-wide panel, and final consideration by the National Science Board. The Advisory Committee will discuss this process at its first meeting, November 9, 1987.

REVIEW AND SELECTION PROCESS

Selection Criteria

The following selection criteria have been established for STC proposals:

- **Intrinsic merit of the intellectual focus and research:** overall quality of the proposed research; likelihood that the research will lead to fundamental advances within the field, new discoveries, and/or technological developments.

- **Research performance competence:** capability of the investigators, technical soundness of the proposed approach, and adequacy of the institutional resources available or proposed.

- **Utility or relevance of the research:** likelihood that the research can contribute to the achievement of a goal that is extrinsic or in addition to that of the research field itself, and thereby serve as the basis for new or improved technology or assist in the solution of societal problems.

- **Appropriateness of the Center approach:** Are the proposed research center approach and structure essential and appropriate to the research activities described? Will a Center approach add significantly to what could be done through other models of research support?

- **Appropriateness of institutional and management plans and arrangements:** likely effectiveness of the management plan for the Center and the strength and form of commitments to the Center; mechanisms to enable evaluation of the Center's progress.

- **Effect of the Center on the infrastructure of science and engineering:** potential of the proposed Center and the research to be conducted there to contribute to better understanding or improvement of the quality, distribution, or effectiveness of the nation's scientific and engineering research, education, and human resources capabilities.

- **Quality and appropriateness of the education and training components of the Center's activities:** approaches used to attract and involve undergraduate and graduate students, postdoctorals, and others in meaningful ways in the work of the center.

- **Form, appropriateness and strength of linkages and knowledge transfer efforts to other sectors:** concrete plans to involve appropriate other sectors and groups in the work of the Center, and the form and strength of that involvement; appropriateness, form and likely success of knowledge or technology transfer efforts.

Review Process

The selection criteria will be applied in a multi-tiered review process, described below. Letters of intent to submit proposals will be received by the Foundation in mid-November 1987, followed by formal STC proposals in January. The letters of intent will allow the Foundation to begin to identify appropriate reviewers and panelists.

- **Phase I: Substantive ad-hoc mail and panel review.** This review will managed by technical coordinators from the Foundation's research divisions, with overall coordination by the Science and Technology Centers Development Office. Mail reviews will be conducted January - March 1988, followed by panel meetings March - April 1988.

- **Phase II: Site visits.** Site visits for the most highly rated proposals will be based upon recommendations of the phase I reviews. The visits will be coordinated jointly by the relevant STC technical coordinators and the Science and Technology Centers Office. Site visit teams will examine issues raised in earlier phases of the review and issues related to institutional commitment, facilities, and management arrangements. Site visits will take place in May 1988.

- **Phase III: Multidisciplinary Foundation-wide panel.** NSF Assistant Directors will review the results of phase I and phase II reviews prior to the multi-disciplinary panel. This panel will consist of the Advisory Committee for Science and Technology Centers Development, and additional experts. It will review the most highly rated proposals, site visit reports, and input from the Assistant Directors. In addition to criteria listed above, the panel will look

at such factors as balance among fields, and whether the group of Centers will meet the STC Program's overall objectives. The multi-disciplinary panel will meet in June 1988.

- **Phase IV: National Science Board.** Review and award approval by the National Science Board. This is expected to take place at the August 1988 meeting of the NSB.

In FY 1988 the Foundation expects to make awards for 15 - 20 STCs, with annual support levels between $500,00 and $5,000,000 for each Center. Awards will be announced in September.

Formal proposals for STC planning grants will be received by the Foundation in early February. Planning grants will undergo panel review in May 1988. Final decisions to fund approximately 30 awards will be made during that month. Each award will total $35,000 and indirect costs will not be supported. In addition, each award requires a matching commitment from the institution. The Science and Technology Centers Development Office will coordinate the review and decision process.

EVALUATION OF SCIENCE AND TECHNOLOGY RESEARCH CENTERS

STC awards will be made as continuing cooperative agreements with an initial commitment of five years. The size of NSF's investment in each Center will depend upon the needs, plans and performance of the Center, as well as availability of NSF funds.

The appropriate NSF substantive divisions will have a primary role in oversight of technical management and progress of the STCs. The progress and plans of each STC will be assessed annually, prior to continuing NSF support. Toward the end of the third year of operation, each STC's progress and future plans will undergo comprehensive evaluation to determine if the STC is meeting its goals and objectives.

This comprehensive third year review will determine whether funding for the STC will be continued with a second five year commitment (making a total of eight years of support), or whether support from NSF will be phased out in the remaining two years.

If a second five year commitment is made, the STC would again be evaluated after another three years (during the sixth year of support). If funding were renewed at this time, the STC would receive continuing support for a final five years (making a total of 11 years of support), including a specifically planned two-year phase out period for NSF STC program support.

Attachment

NSF SCIENCE AND TECHNOLOGY RESEARCH CENTERS

ADVISORY COMMITTEE

Dr. Carl Lineberger, Chair
Joint Institute of
Laboratory Astrophysics (JILA)
University of Colorado

Dr. Dean Eastman
IBM Research Center

Dr. Helen Donis-Keller
Collaborative Research

Dr. Peter Flawn
University of Texas

Dr. Susan Graham
Computer Science Division
University of California - Berkeley

Dr. Priscilla C. Grew
Minnesota Geological Survey
University of Minnesota

Dr. Peter Lax
Courrant Institute of
Mathematical Sciences
New York University

Dr. Neil Lincoln
ETA Systems, Inc.

Dr. Gardner Lindzey
Center for Advanced Study
in the Behavioral Sciences

Mr. Richard Messinger
Cincinnati Milacron

Dr. Norman Ramsey
Harvard University
(until 12/15/87:
Enrico Fermi Institute
University of Chicago)

Dr. Leon Silver
Division of Geological
and Planetary Sciences
California Institute of Technology

Dr. Robert Sproull
Department of Physics
University of Rochester

Dr. Kathleen Taylor
Physicl Chemistry Department
General Motors Research Laboratories

Dr. Peter von Hippel
Institute of Molecular Biology
University of Oregon

Dr. Kenneth Wiberg
Chemistry Department
Yale University

Dr. Luther Williams
National Institute of
General Medical Sciences
National Institutes of Health

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

November 4, 1987

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OFFICE OF THE
DIRECTOR

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

As the Committee requested in its report accompanying the National Science Foundation Authorization Act for Fiscal Year 1988 (H.R. 2330), I am pleased to enclose an FY 1987 list of awards for research involving acid rain.

Sixty-three awards were active in FY 1987. Within each award, only the amount estimated by the cognizant program to be directly applicable to acid rain research is displayed, for a total of $2.30 million. Although this represents only three more awards than reported in FY 1986, the dollar total is more than 50% above the FY 1986 level of $1.49 million.

Two factors contribute to the increased support. A few large projects in the Division of Biotic Systems and Resources are devoted to large-scale experimental manipulation of the nitrogen cycle. An example is the award to J. D. Abler at the University of New Hampshire for a study of Chronic Nitrogen Additions to Forest Ecosystems ($263,000 related to acid rain.) And, there is increased interest in biogeochemical cycles related to sources of "Greenhouse" gases in the atmosphere.

We will continue to monitor awards for fundamental research in this environmentally and economically important area and will be happy to supply you with award lists in future fiscal years.

Sincerely,

Erich Bloch
Director

Enclosure

cc: Honorable Sherwood L. Boehlert w/Enclosure

NATIONAL SCIENCE FOUNDATION

ATMOSPHERIC SCIENCES DIVISION

Acid-Rain Related Awards in FY 1987 (including references to projects ongoing in FY 1987 funded in earlier fiscal years but zero-funded in FY 87).

P.I./Institution	Title/Duration/Total	Acid-Rain Related Percent	Acid-Rain Related Dollars/Year*
A. Clarke U. Hawaii	Real-Time Characterization of Tropospheric Acid Sulfate Aerosol 12 mos. $80,000	20%	$ 21,000
G. Black SRI-International	Photochemistry and Kinetics of Atmospheric Sulfur Species 12 mos. $76,500	10%	$ 7,600
J. Anderson W. Brune Harvard	Kinetic Studies of Sulfur, Halogen, Hydrogen and Oxygen-Containing Radicals 12 mos. $118,400	10%	$ 11,800
R. Dickerson U. Maryland	Convection and Troposheric Trace Gases 12 mos. $178,700	10%	$ 17,900
A. Bandy Drexel	Development and Deployment of Analytical Instrumentation for Studying the Atmospheric Chemistry of Gaseous Sulfur, Nitrogen and Organohalogen Compounds in the Background Atmosphere 12 mos. $137,000	10%	$ 13,700
A. Bandy Drexel	DYCOMS Data Interpretation (Dynamics and Chemistry of Marine Stratocumulus) 12 mos. $34,000	10%	Zero in FY 87
J. Prospero D. Savoie U. Miami	Measurements of Gaseous Nitric Acid and Ammonia in Marine Environments 12 mos. $95,000	20%	$ 19,000

P.I./Institution	Title/Duration/Total	Acid-Rain Related Percent	Acid-Rain Related Dollars/Year*
P. Wine A. Hynes Georgia Tech	Laboratory Studies of Tropospheric Sulfur Chemistry 12 mos. $100,000	20%	$ 20,000
J. Seinfeld R. Flagan Caltech	Fundamental Studies of Gas-to-Particle Conversion in the Atmospheric Sulfur System 12 mos. $114,900	10%	$ 11,500
C. Richardson U. Arkansas	A Laboratory Study of Acid Particles 12 mos. $70,400	20%	$ 14,100
P. Samson U. Michigan W. Pierson Ford Motor Co.	Industry-University Cooperative Research: Interpretation of Atmospheric Trace-Element Measurements in Southwest Pennsylvania 12 mos. $57,000	20%	Zero in FY 87
W. Chameides Georgia Tech	The Chemistry of Clouds and its Role in Atmospheric Chemical Cycles 12 mos. $88,000	20%	$ 18,900
T. Novakov Lawrence Berkeley Laboratory	Heterogenous SO_2 Oxidation by Combustion Products 12 mos. $125,400	20%	$ 25,100
P. Davidovitz Boston College	Heterogenous Reaction Rate Studies of Cloud and Fog Droplets 12 mos. $120,000	20%	$ 24,000
R. Zika J. Prospero E. Saltzman U. Miami	Methane Sulfonic Acid and the Chemistry of Organosulfur Compounds in the Marine Atmosphere 12 mos. $105,500	10%	Zero in FY 87
M. Andreae Florida State	Air-Sea Exchange of Reduced Sulfur Gases 12 mos. $18,000	20%	$ 3,600

P.I./Institution	Title/Duration/Total	Acid-Rain Related Percent	Acid-Rain Related Dollars/Year*
L. Anderson U. Colorado (Denver)	Kinetics and Mechanisms of Important Atmospheric Reactions 12 mos. $54,000	10%	$ 5,400
B. Huebert SRI-International	Atmospheric Acidity: The Dry-Deposition of Nitric Acid Vapor 12 mos. $130,000	20%	$ 26,000
R. Charlson W. Zoller U. Washington	Acid-Base Chemistry of Marine Air 12 mos. $111,000	20%	$ 22,200
P. Steudler J. Hobbie Marine Biological Laboratory	Carbonyl Sulfide and Carbon Disulfide Emissions from Temperate and Boreal Forests Along an Acid-Rain Gradient 12 mos. $127,400	20%	Zero in FY 87
W. Viezee SRI-International	Analysis and interpretation of Available Tropospheric Measurements of Organic Nitrogen Compounds 12 mos. $45,200	10%	Zero in FY 87
D. Davis R. Stickel Georgia Tech	A Vacuum-Ultraviolet Photofragmentation/Laser-Induced Flourescence Sensor for Measurement of Atmospheric Trace Gases 12 mos. $164,900	20%	$ 33,000
F. Rowland U. Cal., Irvine	Radioactive Tracer Investigations of Some Gas-Phase Reactions of Potential Atmospheric Importance 12 mos. $91,800	10%	$ 9,000
P. McMurry U. Minnesota	Experimental Studies of Gas-Aerosol Reactions 12 mos. $60,700	20%	$ 12,100

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P.I./Institution	Title/Duration/Total	Acid-Rain Related Percent	Acid-Rain Related Dollars/Year*
P. Hobbs D. Hegg L. Radke U. of Washington	Studies of Cloud Chemistry on the Mesoscale 12 mos. $179,600	20%	$ 35,900
A. Thompson Spelman College	The Chemical Composition of Precipitation at a Southeastern Urban Site 15 mos. $37,500	20%	$ 7,500
V. Mohnen J. Kadlecek State Univ. New York, Albany	Aqueous Phase Atmospheric Chemistry: Field Studies of Cloud and Precipitation Chemistry 30 mos. $205,136	20%	Zero in FY 87
B. Davis South Dakota School of Mines	A Laboratory & Field Study of the Origin of Urban Sulfates and Nitrates 12 mos. $64,600	10%	Zero in FY 87
D. Lamb Penn State	A Laboratory Study of Aerosol Scavenging by Ice in Supercooled Clouds 12 mos. $60,000	10%	Zero in FY 87
Subtotal Atmospheric Sciences Grants Programs			$ 413,400
Acid-Rain Related Research at NCAR in FY 87			$ 220,000
Total Division of Atmospheric Sciences			$ 633,400

Biotic Systems and Resources Division

PI/Institution	Title/Duration	Acid Rain Related Percent	Dollars/Year*
T.M. Burton MI State U.	The Effects of Whole-Tree Harvest on Stream Communities of the Hubbard Brook Experimental Forest, New Hampshire 12 mos. $100,000	10%	$ 10,000
K.B. Searcy Mt. Holyoke College	Selective Seed Abortion in Plants Tolerant to Heavy Metals 24 mos. $133,000	15%	$ 2,000
J. Titus SUNY Binghamton	Submersed Macrophytes: Three Levels of Response to Lake Acidification 12 mos. $60,000	10%	$ 6,000
J.D. Aber U New Hampshire	Chronic Nitrogen Additions to Forest Ecosystems 12 mos. $375,000	70%	$ 263,000
F.H. Bormann Yale 84-06633	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Man-Manipulated Ecosystems 12 mos. $178,627	30%	$ 54,000
J.J. Cole NY Botanical Garden 85-16897	Evaluation and Regulation of Nutrient Sources for Mirror Lake 24 mos. $250,000	20%	Zero in FY 87
D.L. Correll Ches. Res. Consortium Inc. 83-16948/86-15902	Nutrient Dynamics of the Rhode River System 18 mos. $200,000	20%	$ 40,000
C.T. Driscoll Syracuse U. 84-06634	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Man-Manipulated Ecosystems 12 mos. $104,000	70%	$ 73,000

PI/Institution	Title/Duration	Acid Rain Related Percent	Dollars/Year*
T.J. Fahey Cornell U	Long-term Research at Hubbard Brook 12 mos. $399,841	20%	$ 80,000
M.K. Firestone UC-Berkeley 83-06181	Collaborative Research: Process Controls and Nitrogen Transformations in Terrestrial Ecosystems 12 mos. $234,516	10%	$ 24,000
A. Giblin Ecosystems Center, MBL	The Changing Sulfur Cycle of Lakes 12 mos. $311,746	80%	$ 249,000
G.E. Likens NY Botanical Garden 84-06632	Collaborative Research: Hydrologic-Nutrient Cycle Interaction in Small Undisturbed and Manipulated Ecosystems 12 mos. $209,274	50%	$ 105,000
J.J. Magnuson U WI-Madison 85-14330	Comparative Studies of a Suite of Lakes in Wisconsin 12 mos. $350,000	10%	$ 35,000
J.G. McColl UC-Berkeley 84-16661	Organo-Aluminum Interactions in Soil Solutions of Forested Ecosystems 12 mos. $126,137	70%	$ 88,000
E.A. Paul MI State U 86-03827	Collaborative Research: Process Controls and Nitrogen Transformations in Terrestrial Ecosystems 12 mos. $117,082	10%	$ 12,000
J.M. Tiedje MI State U 83-18387	Denitrification in Terrestrial Ecosystems 12 mos. $245,058	20%	$ 50,000
	Subtotal Ecosystem Studies Grants Programs		$1,091,000
A. Chalmers U of GA	Arsenic in Thermal Spring Ecosystems: Distribution and Cycling 12 mos. $41,986	10%	$ 4,199

PI/Institution	Title/Duration	Acid Rain Related Percent	Dollars/Year*
M. Davis J. Pastor U of MN	Reconstructing Forest Stand Histories and Soil Development From Paleoecological Evidence 12 mos. $135,922	20%	$ 27,184
C. Jones NY Botanical Garden	REU: Multiple Stress Interactions on Cottonwood and Their Chemical Mediation 12 mos. $6,220	100%	$ 6,220
N.W. Paerl U of NC	Physiological Ecology of Cyanobacterial-microbial Consortia During Development of a Polieration of Nuisance Blooms 12 mos. $119,920	20%	$ 23,984
S.L. Rose O. Schimel C.S. U	Below Ground C and N Exchanges Between Plants Connected by Mycorrhizal Fungal Hyphae 12 mos. $47,550	10%	$ 4,755
O.R. Whitehead Indiana U	Paleoecological Investigation of Recent Acidification Trends in the Sierra Nevada 12 mos. $140,000	100%	$ 140,000
	Total Ecology Grants Programs		$ 202,143
J. Titus SUNY-Binghamton 85-06730/87-44957	Submersed Macrophytes: Three Levels of Response to Lake Acidification 12 mos. $53,000	10%	$ 5,000
A.J. Shaw Ithaca College 87-00375	Genetic Basis of Heavy Metal Tolerance in the Moss, Fumaria hygrometrica 12 mos. $55,044	10%	$ 6,000
	Total Population Biology Grants Program		$ 11,000
	Total Biotic Systems and Resources Grants Program		$1,304,143

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Division of Earth Sciences

P.I./Institution	Title/Duration/Total	Acid Rain Related Percent	Dollars/Year*
R. Defries NAS/NRC	Support for Scientific Committee on Problems of the Environment (SCOPE)	100%	$ 5,000
G. Kling Duke U	Lake NYOS CO_2 Gas Disaster, Cameroon, W. Africa	100%	$ 6,960
H. Mullins Syracuse U	Paleolimnology and Climatology of New York State Finger Lakes	50%	$ 19,233
S. Epstein C.I.T.	Oxygen, Hydrogen, Carbon, Silicon and Nitrogen Isotope Studies of Natural Occurring Materials	20%	$ 37,109
L.F. Roland Morehouse College	An Undergraduate Research Program in Earth and Atmospheric Science	Continuing Grant, No funds in FY 87	
	Total Earth Sciences Grants Program		$ 68,302

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Division of Fundamental Research
in Emerging and Critical Engineering Systems
Environmental Engineering Program

PI/Institution	Title/Duration/Total	Acid Rain Related Percent	Dollars/Year*
G.J. McRae Carnegie-Mellon	PYI--Analysis and Optimization of Environmental Models 12 mos. $62,500	50%	$ 37,630
E.L. Peck Hydex Corp.	SBIR--Phase II. Remote Measurement of Haze Layers Over Land 24 mos. $199,605	25%	Zero in FY 87
NRC/NAS	Support for the Scientific Committee on Problems of the Environment (SCOPE) (Funded jointly with other NSF-Programs for a total of $70,000--entries listed separately.)	100%	$ 7,500
C. T. Driscoll Syracuse Univ.	PYI-- Drainage Basin Ecosystem Response to Inputs of Sulfuric and Nitric Acids in the Northeastern United States 12 mos. $62,500	100%	$ 62,500
P. S. Eagleson Mass. Inst. of Technology	Equilibrium Models of Climate-Soil-Vegetation Interaction 12 mos. $99,374 including $36,476 from FY 1987	100%	$ 36,476
K. Lal Gauri Univ. of Louisville	Effects of Air Pollutants on the Deterioration of Marble 24 mos. $133,540	100%	$ 75,480
E. Christenson U. WI-Milwaukee	Historical Fluxes of Pollutants from Deconvolution of Sedimentary Records	50%	$ 44,211
	Total of Environmental Engineering Grants Program		$ 263,797
	Total for the National Science Foundation		$2,299,642

*Rounded to nearest $100.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

November 9, 1987

nsf

OFFICE OF THE
DIRECTOR

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

I am enclosing materials in response to the Committee's request for additional information concerning the status of NSF supercomputer centers.

This activity is of major importance in the development of the nation's science base. In the first two years of operation over 6,000 university researchers in over 200 institutions in all fifty states have been provided allocations at one of the five NSF centers. Virtually every area of science and engineering has been represented. Nearly 700 papers have been published as a result of computations performed in these facilities, and it appears that the availability of these powerful research instruments is beginning to alter the nature of scientific inquiry and engineering methodology.

I appreciate the Committee's interest in and support of this program and look forward to our continuing mutual efforts to further its development.

Sincerely,

Erich Bloch

Erich Bloch
Director

Enclosure

cc: Honorable Sherwood L. Boehlert w/Enclosure

STATUS OF NSF NATIONAL SUPERCOMPUTER CENTERS

INTRODUCTION

After a national competition in 1984, five national centers were established: the Cornell National Supercomputer Facility (CNSF), the John von Neumann Center (JVNC) near Princeton, New Jersey, the National Center for Supercomputing Applications (NCSA) at the University of Illinois, the Pittsburgh Supercomputing Center, and the San Diego Supercomputer Center (SDSC). Details of each center including installed hardware are provided in Attachment 1.

UPGRADE PLANS

The NSF centers must be at the leading edge of high-performance computing if they are to continue to provide leadership in computational science. This implies an upgrade about every three years, as new models become available with significant performance improvements and as researchers increase their requirements.

The NSF centers are operating near capacity, and upgrades are needed in FY1988 to meet expected increases in demand. Some upgrade requirements were anticipated at the initiation of the program, and funds for these were included in the awards. At the JVNC, an upgrade is built into the Cooperative Agreement as part of ETA Systems's development of the ETA-10 supercomputer. The PSC Cooperative Agreement includes some, but not all, of the funds required for a major system upgrade.

The NSF has received proposals for other upgrades which were not budgeted, and will meet them to the extent reasonable. There are several reasons for this. When the Centers Program began, there were expectations of high levels of industrial funding for cooperative research to offset any funding problems and help pay for the cost of upgrades. However, despite considerable effort and some success, industrial cooperation has not occurred to the degree expected. At present, industrial funds add worthwhile enhancements but do not contribute greatly to the basic operations and facilities of the centers, such as regular upgrades.

Computing innovations and the expanding use of supercomputers in research will continue to create opportunities for upgrades and expansion which exceed available resources. To manage this situation in the current budget climate, NSF has planned a competitive upgrade program. By this management mechanism, upgrade and expansion proposals are accepted from the centers, and priorities for support within budget constraints are established, using independent external expert advice. Criteria for funding will include things such as past performance, levels of demand, overall balance of services in the program, and opportunities created by potential cost sharing, especially industrial participation.

STAFFING LEVELS

Current and planned staffing levels for each center are shown in the table below. These levels show substantial growth to meet service requirements. The centers are encouraged to obtain support for research staff from other NSF programs.

Center	10/1/87 Actual	10/1/88 Plan
SDSC	74	74
NCSA	85	85
CNSF	63	75
PSC	42	62
JVNC	34	54

BUDGET AND COST-SHARING INFORMATION

The centers are supported through "Cooperative Agreements" which project budgets and federal and non-federal support for several years. The agreements represent expected support levels and are subject to annual negotiation based on performance and available budgets.

Attachment II includes tables on the funding of the NSF centers. Budgets for the centers are assessed in the context of the overall NSF program and, accordingly, compete for resources within the NSF budget. Beginning in FY86, NSF gave some centers less than had been planned. Proper management requires such adjustments in response to events and available budgets. The NSF is assisted in this oversight through a yearly budgetary review by a panel of outside experts. This panel recommends budget targets for each of the centers. For example, at the John von Neumann Center, there was a delay in the start of operations in FY86, and, in FY87, a delay in the arrival of their new supercomputer. Both events lead to budget adjustments. At Cornell, a carryover of unspent funds into FY87, and a change in emphasis from an experimental to a more conventional supercomputer allowed savings. NSF will also adjust budgets upward as need is demonstrated and funds are available.

The tables also provide information on contributions from other major sources of funding at the centers. It is expected that non-federal funding sources will remain steady beyond FY88, except for industrial funding. There, growth is expected as the industrial research community realizes the advantages of advanced computing, and as the centers continue to seek industrial collaboration to be more competitive in the competition for major facility upgrades. Collaborative industrial support is a major factor in achieving real industrial innovation and increased competitiveness.

ATTACHMENTS

ATTACHMENT I - DETAILS OF EACH CENTER

San Diego Supercomputer Center

This Center's Cray XMP48 has been providing service since January 1986 and is operating at full capacity, i.e. delivering 2500 central processing unit hours per month. An upgrade proposal is under consideration.

Supercomputer System - Cray XMP/48 and 14.6 Gbytes of rotating disk storage

Mass Storage - IBM 4381-based disk, cartridge, and tape hierarchy with 50Gbytes disk, four cartridge drives and one tape drive

Network - SDSCnet 56Kbps for consortium members, gateways to ARPAnet, BITNET, CSnet, HEPnet, and the NSFnet backbone. Also, low-speed dial-in digital telephone access and the TYMnet public network.

Building - 60,000 sq. ft. built on the campus of the University of California at San Diego. Funded by NSF.

Location - Campus of UCSD

Other Equipment - SCS-40 mini-supercomputer, high-end workstations

Start Date - January 1986

Academic Affiliates - Consortium of 25 research institutions, primarily in California (all nine campuses of the University of California system) but also including the University of Maryland, the University of Wisconsin, the University of Utah, the University of Washington, the University of Michigan, the University of Hawaii, and Kitt Peak National Observatory in New Mexico. The consortium provides policy advice, receives training, small blocks of supercomputer resources, and network technical assistance.

National Center for Supercomputing Applications
The University of Illinois at Urbana-Champaign

This center began providing services in January 1986 on a Cray XMP24 and upgraded to an XMP48 in December 1986. A plan has been submitted to NSF for additional upgrades.

Supercomputer System - Cray XMP/48, 128MW Solid State Disk (auxiliary memory), and 17 Gbytes of rotating disk storage

Mass Storage - IBM 4341-based disk and tape; 12 Gbytes disk and one tape drive

Network - Gateways to ARPAnet, BITNET, and the NSFnet backbone. Also, low-to-medium speed dial-in digital telephone access and the Telenet public network. Participating in NSF Vitalink satellite experiment.

Building - 26,000 sq. ft. including 3000 ft. of computer room and 20,000 ft. of office space, newly renovated with funds from the University of Illinois.

Location - Campus of University of Illinois in Champaign, Ill.

Special Equipment - Advanced visualization graphics facility with film and video capabilities

Start Date - January 1986

Academic Affiliates - Thirty participating universities spread across the U. S., with six additional members planned in FY88. The Affiliates act as local support for the NCSA on their campuses, and receive training and assistance in networking problems. The NCSA has a separate National Advisory Council of 35 individuals from academia, industry, and government to provide policy advice.

Cornell National Supercomputer Center

The Cornell National Supercomputer Center (CNSF) is part of the Cornell Theory Center. The Theory Center also encompasses an interdisciplinary research arm, an experimental computing facility, and a networking unit. CNSF began operations in late FY85 with an IBM 3084 mainframe computer and several attached array processors from Floating Point Systems. This was upgraded in November 1986 with the installation of the IBM 3090/400 with four processors, each with vector processing hardware. The FPS processors were also upgraded. In July 1987, a second upgrade of the IBM supercomputer was made to the 3090/600, with six processors, vector hardware, and additional memory. IBM has donated all of its equipment to date. A proposal for another upgrade is under consideration.

Supercomputer System - IBM 3090/600E with vector facilities and 512 Mbytes of high-speed electronic auxiliary memory, and five FPS Model 264 attached array processors.

Mass Storage - 115 Gbytes of rotating disk storage attached to the IBM 3090

Network - Gateways to ARPAnet, BITNET, CSnet, and the NSFnet backbone. Connected to NYSERnet, the New York State network. Also, low-to-medium speed dial-in digital telephone access.

Building - Planning 100,000 sq. ft. in a new building. At present, staff and equipment are dispersed in several locations

Location - Campus of Cornell University in Ithaca, NY.

Other Equipment - Advanced workstations and beginning graphics facility

Start Date - October 1985

Academic Affiliates - The Theory Center has an affiliation with 29 "Smart Node" universities across the U. S. each of which provides a local consultant on the Cornell supercomputer system in exchange for which Cornell provides specialized training, networking assistance, and a small block of supercomputer resources for distribution at each Smart Node site.

Pittsburgh Supercomputing Center

The PSC began operations in June 1986 with a Cray XMP48. This machine is now at full capacity. The NSF Agreement includes some funds for an upgrade in late FY89. A request for additional funds for an upgrade is under consideration.

Supercomputer System - Cray XMP/48 with 128MW Solid State Disk (auxiliary memory) and 20 Gbytes of rotating disk storage

Mass Storage - Tape-oriented archiving system with eight tape drives

Network - Gateways to ARPAnet, BITNET, CSnet, and the NSFnet backbone. Forming a regional network at 56Kbps. Also, low-to-medium speed dial-in digital telephone access.

Building - The supercomputer system is located at Westinghouse Electric, which manages the facility, including office/storage space and machine room under a contract to the PSC. Carnegie-Mellon has recently completed the renovation of 3000 sq. ft of office space on their campus, with 2000 additional feet planned in the next year.

Location - Offices in the Mellon Institute on the CMU campus, with the supercomputer facility at Westinghouse in the Pittsburgh suburb of Monroeville, 15 miles from the Mellon Institute.

Other Equipment - Digital Equipment Corp. front-end minicomputers, PIXAR graphics computer, scientific workstations, specialized hardware/software for the National Radio Astronomy Observatory

Start Date - June 1986

Academic Affiliates - The Pittsburgh Affiliates program includes 25 universities across the U. S. which provide local consulting on the PSC and constitute a policy advisory group in exchange for special training and networking assistance from the PSC.

John von Neumann Center

The Center will receive its baseline supercomputer, the four-processor ETA-10, in December 1987. As a very early model, significant work will be required to make this a production tool. Funds are included in the Agreement for an upgrade to an eight processor machine with faster components in late FY88 or early FY89.

Supercomputer System - Two Cyber 205 machines which will be phased out over 3-6 months after delivery of an ETA10 supercomputer in December 1987. This new system will include 20 Gbytes of rotating disk storage and six magnetic tape units.

Mass Storage - Storage is primarily on the large Digital Equipment Corp. front end mainframes. At present, this totals 40 Gbytes of rotating disk storage, with 8 tape drives.

Network - In addition to the high-speed (T1) JVNC consortium network, there are gateways to ARPAnet, BITNET, and the NSFnet backbone.

Building - The JVNC is housed in a new 40,000 sq. ft building in the Forrestal Research Park a few miles from Princeton University.

Location - Princeton New Jersey

Other Equipment - Digital Equipment Corp. front-end minicomputers, STELLAR graphics workstation

Start Date - June 1986

Consortium - The John von Neumann Center is administered and operated by the Consortium for Scientific Computing, a non-profit organization comprising 13 research institutions, located largely on the Eastern seaboard, but also including the University of Arizona and the University of Colorado. These institutions provide policy advice through a Board of Trustees which meets quarterly and contribute technical and networking advice to the Center. Each institution has designated a local supercomputer consultant at its campus in return for training and a block of supercomputer resources for educational and research start-up projects.

ATTACHMENT II - BUDGETARY AND FUNDING DATA

NSF Funding

Center	1985		1986		1987	
	Coop. Agreement	Actual	Coop. Agreement	Actual	Coop. Agreement	Actual
SDSC	4.7	4.7	9.1	9.1	12.1	11.5
NCSA	5.0	5.0	7.0	7.0	8.5	8.5
CNSF	4.9	4.9	6.3	5.3	6.2	5.2
PSC	N/A	N/A	2.0	2.0	4.0	4.0
JVNC	8.3	8.3	9.0	5.0	11.7	8.5
TOTAL	22.9	22.9	33.4	28.4	42.5	37.7
Adjustment		0.0		5.0		4.8

NOTE

o No other NSF funds e.g. networking, have been included.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

January 28, 1988

OFFICE OF THE
DIRECTOR

RECEIVED
FEB - 2 1988
Committee on Science, Space,
and Technology

Honorable Robert A. Roe
Chairman
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

This letter responds to your questions of December 1, 1987, concerning our plans to upgrade the NSF supported supercomputer centers.

As a result of the FY 1988 appropriation level, NSF-funded upgrades proposed for FY 1988 have been deferred in order to maintain FY 1988 current services at as high a level as possible. We do plan to reconsider these proposed upgrades next year, along with others proposed for FY 1989 and FY 1990. Since we will not be able to accomplish all the upgrades proposed by the centers, we will evaluate requests on the basis of center performance, research community needs, the state of the art in scientific computing, and available resources. Details of the competition have not yet been worked out, but all centers will be advised at the appropriate time. We have no current plans to phase out any of the existing supercomputer centers. The next formal review of the centers is planned for FY 1989.

Finally, with respect to a center for parallel processing research, we expect that several S & T Center proposals will deal with this topic. We will know whether any are to be funded after their review this spring and summer.

We are most appreciative of your interest and support for the supercomputer centers, and look forward to continued efforts to secure the best possible computing environments for scientific and engineering research and education.

Sincerely,

Erich Bloch
Director

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR GEOSCIENCES

December 14, 1987

RECEIVED
DEC 17 1987

Honorable Robert A. Roe
Chairman, Science, Space
and Technology Committee
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

As requested by the House Science, Space and Technology Committee Report No. 100-110 I am forwarding, herewith, "A Report on Relative Costs/Benefits of Coast Guard Icebreakers Compared to Other Ship Options for Antarctic Research."

Sincerely,

Robert W. Corell
Assistant Director

Copy to: Honorable Manuel J. Lujan
U.S. House of Representatives

REPORT ON RELATIVE COSTS/BENEFITS OF COAST GUARD ICEBREAKERS COMPARED TO OTHER SHIP OPTIONS FOR ANTARCTIC RESEARCH

Report No. 100-110 of the House Committee on Science, Space, and Technology of May 28, 1987 requested NSF to submit a report "... on the relative costs and benefits associated with using Coast Guard icebreakers, using leased commercial icebreakers, or pursuing other options to support Antarctic research." The Coast Guard and the Foundation have been engaged in a continuing dialogue concerning icebreaker requirements, alternatives and costs. This dialogue has served to illuminate benefits and costs of different approaches that reflect, in part, the two agencies' differing missions.

Background

Current Executive Office guidance on the U.S. Antarctic Program is provided by the President's Memorandum of February 5, 1982. Among its relevant provisions are the following in paraphrased form:

- The United States Antarctic Program shall be maintained at a level providing an active and influential presence in Antarctica designed to support the range of U.S. Antarctic interests.
- This presence shall include the conduct of scientific activities in major disciplines; year-round occupation of the South Pole and two coastal stations; and availability of related necessary logistics support.
- NSF is to budget for and manage the program.
- Every effort shall be made to manage the program in a manner that maximizes cost effectiveness and return on investment.
- NSF should continue to use commercial support and management facilities where they are determined to be cost effective.
- The USCG is to provide icebreaker services requested by NSF on a reimbursable basis, and to develop in collaboration with NSF, logistic arrangements and cost structure required for effective and responsive program support at minimum cost.

The Coast Guard has legislative authority to acquire two new icebreakers "... ensuring that all military, scientific, economic, and environmental interests are taken into account" (PL 98-557, 1984).

In line with the Presidential guidance, the U.S. Antarctic Program (USAP) has had and will continue to have important ship requirements of both a scientific and an operational nature.

Scientific Requirements

Historically, the NSF has operated two research vessels in the Antarctic starting with ELTANIN and HERO. Additionally, the USCG has provided some research support required by NSF funded research. However, GLACIER, the most suitable icebreaker for research, was decommissioned because of age and wear this year with the concurrence of NSF and other user agencies. NSF currently operates under charter R/V POLAR DUKE, an ice-strengthened research vessel.

U.S. scientists also have used the polar research vessels of Germany, the Soviet Union, Canada and Scandinavian countries to meet recent requirements. The U.S. Antarctic Program does not control the scheduling of these ships, which curtails drastically the research that can be done.

A research vessel with icebreaking capability and crew experienced in high latitude research support is critical. Planned research includes work in the sea-ice zone on marine biology, and studies of atmospheric chemistry, ocean circulation, air-sea interaction, and submarine geology and geophysics. The USAP has a need for two ships on a year round basis. Current and planned work requires both a research vessel with icebreaking capability for year-round use and the existing ice-strengthened research vessel, POLAR DUKE. Projects requiring POLAR DUKE have been deferred for lack of ship time as have projects which require a research ship with icebreaking capability. Expected use amounts to about 300 days per year for each ship.

In NSF's view, the USCG icebreakers cannot meet these current requirements, nor similar requirements in the future, because of normal deployment procedures and other scheduling requirements for these multi-purpose vessels.

Operational Requirements

The U.S. Antarctic Program has used icebreakers to meet a variety of operational tasks. The primary requirement is the annual break-in of the channel to McMurdo and the escort of the supply ship and tanker to that station. The USAP continues to depend on the icebreaking capability of the USCG to perform this task.

A second task, but not a requirement, for USCG vessels has been the annual resupply of Palmer Station. This task has involved moving freight and fuel from the continental U.S. to Palmer Station, and has not required icebreaking capability. In the future this task may be handled by use of commercial transport to Punta Arenas, and further transport by POLAR DUKE and the new ship to Palmer Station, depending on cost effectiveness.

Cost Analysis

Cost comparison of a Coast Guard multi-purpose icebreaker and a dedicated NSF-chartered research ship with icebreaking capability shows that the latter is less costly to the Government, and provides more research

capability. Annual costs of an NSF vessel will be about one fourth (25%) of the Coast Guard icebreaker.

In addition, research vessels have laboratory space and equipment, and the basic configuration is not compromised by the conflicting, multi-purpose requirements of an icebreaker. A dedicated research vessel thus keeps costs low while allowing excellent response to research needs.

This dedicated ship, however, is not suitable for breaking heavy ice, for which Coast Guard vessels are essential. Nor is the NSF ship likely to be available in the Northern Hemisphere as are the Coast Guard ships. The NSF vessel could not serve as a military asset. Finally, a Coast Guard ship can be used for research in the course of its deployment for other purposes and it may have a role as a research platform in ice too heavy for the NSF-leased ship to penetrate.

Given past operating procedures, Coast Guard icebreakers have been requested and made available to the USAP about 120 days per year. This is not sufficient to meet the existing research requirements.

The following table compares selected specifications and the cost of the USCG Polar Icebreaker Replacement (PIR) and the NSF Research Vessel with Icebreaking Capability (RVIB):

	USCG PIR Multi-purpose	NSF RVIB Dedicated
Length	450 feet	300 feet or less
Horsepower	30000	10000
Icebreaking: feet of ice at 3 knots	4.5	3
Crew	124	20
Scientists	30	37
Lab Space (sq. ft)	2418	4000
Annual Costs to Government:		
Interest /Lease cost	$31.5M [1]	$7.6M
Personnel	2.6	(included in lease cost)
Maintenance	2.7	(included in lease cost)
Fuel	1.8	2.4 [2]
Annual Cost	$38.6M	$10.0M

[1] Annual interest at 9%, with no amortization of principal (based on $350 million ship)

[2] Includes port cost, maintenance of science gear, and fuel for year-round operations.

In NSF's opinion other relevant points to consider in comparing the two ships are that:

- o It may be possible to negotiate a contract with an option to purchase the NSF-RVIB at 25% off initial price after 6 years and 50% after 12 years.

- o The number of deployment days of the NSF ship are about 2 1/2 times those of the Coast Guard ship. This is made possible by the use of two crews and the avoidance of the 50-60 day transit time to and from the Antarctic each year.

- o To the extent that user satisfaction is a measure of effectiveness or benefit, the NSF ship is heavily favored. About five out of six users prefer an NSF vessel. The best efforts of the Coast Guard may be able to reduce this disparity, but it will remain because of the characteristics of the icebreaker.

Conclusion

This cost comparison together with the earlier section on requirements is intended to indicate the complementary nature of the research vessel planned by NSF and a new Coast Guard icebreaker. The Coast Guard vessel is a significantly more powerful ship. The vessel sought by NSF is dedicated to research and is much less expensive. An additional consideration is the impending retirement of the two WIND-class icebreakers. This argues for early steps toward their replacement by the Coast Guard so that it can maintain a viable icebreaker fleet to meet national needs, including those of the NSF U.S. Antarctic Program.

December 3, 1987

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

April 4, 1988

nsf

OFFICE OF THE
DIRECTOR

Honorable Robert A. Roe
Chairman, Committee on Science, Space
and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

This responds to the letter of February 9, 1988 from you and Congressmen Walgren, Lujan and Boehlert concerning the icebreaker cost analysis provided as requested in the Committee's report on the National Science Foundation Authorization Act for FY 1988. With respect to Coast Guard direct participation in and approval of the report, the numbers on new icebreaker operating costs were provided by the Coast Guard. Also, on October 23, 1987, the Coast Guard was given a copy of the draft of the report and requested to indicate any recommended changes. During telephone follow-up in the succeeding weeks the USCG provided no recommended changes.

With respect to the first of the two numbered points on which your letter requests clarification, the following is a comparison of estimated and actual usage of the ships:

	Actual Days Use 1986-87	Estimated Future Use
USCG Polar Sea	131	110
USCG Glacier	132	-0-
RV Polar Duke	307	300
New RV Icebreaking	-0-	300
	570	710

A research vessel with icebreaking capability, which the Foundation's contractor, ITT/Antarctic Services, is currently seeking to lease, would be used about 300 days a year, primarily for research, as is Polar Duke. It will allow far more effective research at much lower cost to the government than new Coast Guard icebreakers. However, the annual channel breaking at McMurdo Station will continue to be a need that we rely on the Coast Guard to meet at an estimated level of 110 days per year.

With regard to the second point, the payments to the Coast Guard for icebreaker use, these are negotiated annually. The basis for charging is certain direct costs--currently for fuel, plus a maintenance and helicopter surcharge. For FY 1988 we expect these expenses to be between $16,000 and $19,000 per day for Polar Star. For FY 1989 we are anticipating $21,000 to $22,000 per day.

It is inappropriate to compare the daily rate of a Coast Guard ship to that of the planned NSF icebreaking research vessel. The rates are not directly comparable since acquisition costs are not included in the Coast Guard rate. The cost/benefit report showed that total costs of a Coast Guard vessel are significantly higher than total costs of the research ship planned by the NSF.

Another NSF concern is that, with only one or two polar icebreakers available for the next few years, ship time even for the vital annual channel breaking for resupply of McMurdo Station will be in short supply.

I trust this information supplements material previously provided in the cost/benefit analysis.

Sincerely,

/s/

Erich Bloch
Director

Copy to: Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research, and Technology
Washington, D.C. 20515

Honorable Manuel J. Lujan
U.S. House of Representatives
Washington, D.C. 20515

Honorable Sherwood Boehlert
U.S. House of Representatives
Washington, D.C. 20515

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

February 23, 1988

nsf

OFFICE OF THE DIRECTOR

RECEIVED
FEB 25 1988

Honorable Robert Roe
Chairman
Committee on Science, Space and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

The House Science, Space and Technology Committee's report that accompanies H.R. 2330, the FY 1988 National Science Foundation Authorization Act requested a report on future demand for supercomputing.

Specificially, the Committee asked for a description of the plan to create a high capacity, high speed national research network within a decade. Along with that, the Committee asked for an assessment of user needs, current and projected technology options, deficiencies/plans for the management of the network, and cost estimates both for creating and for maintaining the network.

I am pleased to provide you with a copy of the requested report. If I can provide you with any additional information, please let me know.

Sincerely,

Erich Bloch
Director

Enclosure

cc: Honorable Manuel J. Lujan

Report on Future Requirements

for

Advanced Scientific Computing

National Science Foundation
February 10, 1988

INTRODUCTION

In the legislative report accompanying the FY 1988 Authorization Bill for the National Science Foundation, the House Committee on Science, Space, and Technology requested a report on expected future demand and access to supercomputers for research, the role of supercomputers in science and engineering, and long range plans for future development and maintenance of the NSF supercomputer centers.

These matters are interrelated, and complex. Forecasting university demand or the role of new technology at a time of very rapid hardware and software change is perilous, and there is little sound basis for making estimates. Assessing the scientific impact of the NSF centers after so short a period of operation (average of 24 months), given their role in training and their use in basic research, is premature. NSF plans necessarily reflect educated guesses about these things, but attend to broader issues of resource availability, overall priorities, and the general health of the whole basic research enterprise. These issues are thus discussed here in the larger context of the computing and networking needs of the academic research community over the next five years and in relation to strategic plans to provide the resources to meet these needs.

A broad approach is taken because advanced research computing needs go beyond access to supercomputers. NSF fosters the development of a balanced, distributed computing environment in order to maximize the productivity of science and engineering researchers. This environment encompasses the supercomputer centers, a national computing network, widespread computing facilities and the computational theory and software needed to effectively employ hardware innovations in computer technology.

The questions raised by the House Committee on Science, Space, and Technology are addressed throughout. The report reviews what has been accomplished since 1983, in the four major categories of scientific and engineering computing highlighted in the Bardon/Curtis report, "A National Computing Environment for Academic Research", from which emerged NSF's program in advanced scientific computing. These are: supercomputer facilities, networks, local facilities and infrastructure, and computational science and engineering. Each section examines current status, problems, opportunities, and present plans to meet the academic scientific and engineering computing needs.

The report draws on the recommendations of the academic research community expressed in the recent Society for Industrial and Applied Mathematics study, A National Computing Initiative; on the recent OSTP Federal Coordinating Committee for Science, Engineering, and Technology study, A Research and Development Strategy for High Performance Computing; on the advice of NSF program staff, and an expert advisory group assembled to discuss the Congressional request. While somewhat different in scope and emphasis, each of these sources

of advice was in agreement with the idea of a balanced computational environment.

ACCESS TO SUPERCOMPUTERS

The Bardon/Curtis report outlined a plan for establishing a national research computing environment, based on the fact that modern computer technology was rapidly making possible broad new approaches to scientific and engineering research. Developments in industrial laboratories and national laboratories, in western European and Japanese universities, and in a few specific disciplines such as the atmospheric sciences and magnetic fusion energy, confirmed the potential of these approaches. However, U.S. academic researchers in 1983 had only limited access to advanced computational facilities, especially supercomputers.

The 1983 plan envisioned a decentralized computing environment that would provide a range and balance of capabilities appropriate to different levels and types of research activity. Along with centers incorporating the most powerful computers available, it called for a research network to provide access and communication; local computational capabilities, including campus networks, personal workstations, shared medium-sized computers, and special purpose devices; and research on advanced computer systems and computational mathematics.

In addition to the National Center for Atmospheric Research facility (NCAR), which serves the atmospheric sciences, the Bardon/Curtis report envisioned 10 NSF-supported supercomputer centers with a total annual budget of $100 million by the end of FY 1986. In FY 1985 and FY 1986, the National Science Foundation established five new National Supercomputer Centers. These facilities were to provide U.S. researchers with broad access to the most advanced computing capabilities, to introduce a new generation of students and young researchers to the potential of these advanced computing tools, and to stimulate innovation in the U.S. computer industry. The NSF budget for the five new centers, representing some 60 percent of their total support, was about $38 million in FY 1987.

Since 1983, the number of independently supported supercomputers on university campuses has grown substantially, so that the national "supply" of high performance computers has grown far beyond that envisioned. A listing of the high performance computing facilities potentially available to the academic community in FY 1983 and FY 1987, respectively, including those at Federal and DOE national laboratories, appears in Appendix A. One way of assessing the national "supply" of supercomputers is to evaluate the capacity of the facilities available to university researchers in 1983 and 1987 in terms of "CRAY-1" equivalents. The data in Appendix A show that in 1983, capacity was about 12, and it is now between 140 and 150, a twelvefold increase. NSF Centers now constitute 23% of the capacity.

USE OF SUPERCOMPUTERS

The Foundation's program has substantially achieved its goals of providing access during the 24 months it has existed. Some 6,000 faculty, postdoctoral student, and undergraduate students from nearly all scientific and engineering disciplines, as well as industrial researchers, have been authorized accounts at the centers, and more than 2,000 research projects have been conducted.

The range and diversity of the research carried out are illustrated by the following examples:

- o Numerical image processing of optical telescope data to improve resolution by a factor of 2-5.
- o Molecular dynamics simulation of the action of biological enzyme inhibitors, with potential application for rational drug design.
- o Extended lattice gauge calculations and new algorithms for the solution of problems in quantum chromodynamics.
- o Optimization modelling for the development of acid rain abatement strategies.
- o A study of rapid brittle fracture in a metallic solid under dynamic loading, including graphic visualization of the driving wave propagation.
- o Simulation of gallium arsenide semiconductor device behavior, thereby significantly reducing the need for laboratory measurements.

Recent distribution of use, by Research Directorate at NSF, was approximately as follows: Mathematical and Physical Sciences, 68%; Engineering, 10%; Biological, Behavioral and Social Sciences, 10%, Geosciences, 11%; Computer and Information Sciences and Engineering, 1%. This pattern and quantity of usage reflects both the needs of the sciences represented and the prior experience of the researchers.

The NSF programs, and other users, exhaust the full capacity of NSF supercomputer centers, using approximately 150,000 central processor hours per year. In this sense, the centers are "saturated". If there were additional capacity, there would be additional use; applicants would be awarded more time, and/or additional users would be served. Use increases discontinuously as new or improved

facilities are made available. Experience with NCAR and the NSF supercomputer centers indicates that a new or upgraded machine becomes fully saturated approximately 18 months after its introduction.

There is, however, more to improving "access" than supplying computer cycles. The NSF centers provide researchers with a broad array of technical assistance. Consulting services, training workshops, newsletters, and documentation aid users to effectively employ the unique features of the machines and the extensive networking services linking them with users. Each of the centers has a collection of applications software for selected scientific and engineering disciplines, and assists researchers to use them. These services have been critical to researchers with little or no previous exposure to the supercomputer environment, and are an important factor in the high level of utilization achieved at the centers.

The numerous training programs offered by the supercomputer centers are an investment in the future computational sophistication of the U.S. research community. These range from 2 - 3 day introductory courses though intensive 2-week summer institutes. Some 250 participants for the institutes have been selected each year from more than a thousand applicants. During these institutes, faculty, postdoctoral, and graduate students are taught the intricacies of supercomputing. They are also encouraged to work on optimizing and refining their own applications programs.

An outcome of the program is that it has resulted in requests for access which exceed available central processor capacity. In the context of the NSF program goals, that simply reflects good management; nothing less would be acceptable. Success, however, creates continual "pressure" for additional upgrading of capacity. In response, the process of reviewing requests for access has become more competitive, and more discriminating.

This is no different a situation than that faced by typical NSF disciplinary research support programs, which have declination rates ranging from 50% to 80%. As NSF resources are finite, over time the percentage of declinations of requests for supercomputer access will necessarily grow from the present rate of under 5%. Peer review panels at the centers, consisting of researchers representative of the user community, are the Foundation's mechanism of choice in allocating these resources. In turn, the process gets continual scrutiny by NSF staff, and periodic oversight by specially constituted advisory panels.

In mature disciplinary fields, shortages of resources serves, up to a point, to improve the competitive quality of the research. In this

fairly new endeavor, however, available capacity fosters use, but also leads to improvements in research quality and productivity. Certainly, if capacity and accessibility are not reasonably in line with utilization potential, the growth of computational science and engineering may be truncated, and much important work may not be initiated. The Foundation's advanced scientific computing program goals are not based demand alone, but also seek to improve the research art.

DEMAND

The NSF program of access to supercomputers was, among other things, designed to introduce the technology and train researchers to use it. Rather than reacting to demand, the program nurtures it. Reasonable assessment of demand requires that "purchasers", or in this case researchers, can allocate their resources in support of their research, and trade off alternatives for computing of any form, staff, students, or whatever is legitimate for research purposes. Only historical, empirical evidence provides firm indication of demand; projections typically are based on questions about expected resource allocation choices. The "market" mechanisms which would reveal demand are not present in the NSF program.

There are several reasons for the absence of market-like mechanisms. One is the classic "start up" problem: resources required to enter the field of supercomputing and to create facilities are larger than those which can be aggregated from the many small disciplinary programs which support individual researchers. Another is that the goals of the activity go beyond supplying cycles to individual investigators. They include long term cooperative efforts with vendors to improve the computer systems and software needed by scientific researchers.

It is, in part, to avoid disrupting the momentum toward success in achieving the overall program goals that the requests for supercomputer resources have not been placed into funding competition with other research facility and project proposals in Foundation research support programs. Indeed, the Center directors and many in the user community are convinced that such a practice would create undesirable disruptions.

If resources permit it, the Foundation will increase the capacity at the centers through upgrades over the next several years to continue to "prime the pump" for high performance computing, provide leadership in the improvement of software, and, working with the manufacturers, to develop the computational environment needed to effectively and efficiently use advanced supercomputer systems. In doing so, we recognize that this centralized method of support may create "distortions" from the theoretically more efficient outcomes which would result from having the research programs (and communities) allocating their computing resources directly.

NSF will be considering methods of funding which involve individual researchers more directly in allocating resources to the Centers.

The presence of the NSF centers has stimulated the purchase of supercomputers by universities, and the development of supercomputers by U.S. manufacturers. As the data in Appendix A show, very high performance computers are today widely distributed. The non-NSF university supercomputers represent a resource that could be more widely used by the general academic research communities. Until this year, no special effort was made to facilitate NSF research program use of them. Funds currently earmarked for use in non-NSF facilities will provide some evidence about the research community's desire for these advanced computer resources.

CAPABILITY

Capability is as important as capacity in supercomputing. In a technical sense, capability derives from the speed and number of central processors, the size and the adequacy of memory, and the ability to make all of these work together. The NSF advanced scientific computing program has had as a major goal the improvement of computing capability as much as capacity. The NSF Centers have worked in partnership with supercomputer manufacturers to improve the capability of U.S. supercomputer systems.

Optimizing the performance of any advanced computer depends on many factors in addition to the physical capability of the computer. It requires efficient algorithms for the solution or simulation of complex problems, optimizing/parallelizing compilers, effective mass storage and data management systems, and graphics systems for visualizing the complex results of large-scale computations. Although significant progress has been made recently in each of these areas, they have generally failed to keep pace with supercomputer technology itself.

Today's multiple processor computers have the ability to use multiple processors on a single program. Concentrating processors in this way multiplies effective capability. That is to say, parallel processing converts capacity to capability. For example, the work on parallel FORTRAN application codes at the Cornell Center has yielded nearly six-fold performance increases on selected applications. Together with other technical improvements, this appears to be a major factor in the growing number of IBM supercomputers at U.S. universities. The Centers program involves similar efforts with all of the U.S. supercomputer manufacturers, and with a number of the vendors of mini-supercomputers as well.

The NSF Centers are scheduled to be upgraded over the next several years to keep pace with improvements in supercomputer technology. The history of scientific computing, like that of scientific

instruments, shows that improved technology leads to improved understanding. Minor upgrades at the Centers, deferred because of the sharply reduced FY 1988 appropriation for research and related activities, will begin in FY 1989. Major upgrades will begin, as planned, in FY 1990. The specific plan and design of mechanisms to select the upgrades will be developed over the next 18 months.

During the next five years, new supercomputers having capability an order of magnitude greater than today's most powerful computers will become available. Maintaining the NSF advanced scientific computing effort at the leading edge will also require intensified basic research and exploratory development in all of the areas that optimize performance, and incorporation of the results into the center programs. This research effort will grow in importance as software compatibility increases across a broader range of scientific computers. The industry and the research community have begun to focus on computing techniques based on vector arithmetic, parallel processing hardware and software, and on standard operating systems. Thus, additional research will help achieve a more flexible, potentially more integrated computing environment similar to that envisioned in the Bardon/Curtis report.

ASSESSMENT

The NSF National Supercomputer Centers have been successful in providing academic researchers with access to some of the most powerful computing resources available, appear to have stimulated widespread interest and activity in computational science and engineering, and to have lead academic institutions into the supercomputer era.

Performance reviews were conducted last year, using experts from the research and computing resource communities. They gave the NSF Centers high grades for operations, and suggested many management and operations improvements. The science conducted at the centers was also found to be quite good. Formal reviews are to be conducted biennially, assessing service, management, operation of proposal review panels, and the quality of the research conducted.

LOCAL FACILITIES: MINI-SUPERCOMPUTERS to COMPUTATIONAL INSTRUMENTS

An integrated computing environment for research should provide access to whatever computational resources are required. These resources include computers appropriate to the problem, ranging from workstations to supercomputers, libraries of applications programs, databases, and the network which ties them together. NCAR, and the Magnetic Fusion Energy computing center, are paradigms of a balanced range of computational resources for particular research communities.

The Bardon/Curtis report viewed local facilities to be as important as the national supercomputer centers. It called for an annual level of support in this area of $107 million by 1986. NSF provided about $20 million for this purpose in FY 1987, primarily as part of its support for computational science and engineering research projects and through instrumentation programs distributed throughout the Foundation. There has been substantial industrial participation through manufacturers discounts and donations to individual faculty and academic institutions. Nevertheless, it is in the area of local facilities that the greatest shortfall from the Bardon/Curtis report has occurred.

The trends in the types of equipment provided by NSF to universities are away from personal computers and minicomputers, and toward powerful new workstations and improved graphics packages. At present most instrumentation is in the $5 - $50 thousand range, with more costly items provided only rarely. Much computational research is appropriately carried out on personal workstations, mid-level computers, and special purpose devices rather than on supercomputers. For example, local facilities are often used for developing programs and preliminary computations prior to running full-scale experiments on a supercomputer and for subsequent post-processing of the results of full-scale computations. Local facilities and networks are essential for accessing the supercomputers and other remotely available computational resources.

A balanced computational environment permits a cost-effective fit of computational science and engineering applications to appropriate computational resources. The emergence of increasingly powerful computers at all levels of the computational spectrum presents major new opportunities for strengthening the capabilities of local facilities in order to attain a more proper balance. The personal computer has undergone a revolution in computing power, new workstations more powerful than the mainframe computers of only a few years ago have appeared, and mini-supercomputers approaching the power of full-scale computers for some applications have become available. Each of these advances has been accompanied by substantial reductions in cost per computation.

Approximate performance comparisons for today's common science and engineering research computers are given in the following table. The performance numbers are Cray-1 "equivalents units", which measure average throughput performance, a measure of total system capacity. Figures on supercomputers and mini-supercomputers are taken from a recent report prepared by the Minnesota Consortium for Supercomputer Research. Various performance estimates, particularly those measuring peak central processor performance, tend to show higher relative performance for mini-supercomputers.

Scientific Computer Performance Relative to Cray-1

Computer	Performance relative to Cray 1
Supercomputers	
Cray 1	1.00
Cray X-MP/48	7.00
Cray 2	6.60
CDC 205	1.40
IBM 3090-200VF	1.00
IBM 3090-600VF	3.00
Mini-supercomputers	
Alliant FX-8	0.18
Convex	0.25
SCS-40	0.35
Super-minicomputers	
DEC 7 series	0.01
DEC 86 series	0.08
IBM 4381-13	0.10
Workstations	
DEC MicroVAX	0.01
SUN 3/260	0.04

The data show that today's general purpose mini-supercomputers are up to 1/3 as powerful as a Cray 1. For many research applications, the time necessary to complete a given computation on a such a machine is acceptable, perhaps 5 to 10 times as long as to perform the same calculation on a supercomputer.

Many new parallel processor computers have been announced for introduction in the near future, promising sharp performance increases. In principal, these will provide significant cost-performance improvements over today's supercomputers. While it is not yet possible to measure their impact, it appears that many users of the NSF centers may be well served by these new systems. This will never satisfy those users whose typical jobs have extended run times. Since many of these projects are at the frontiers of research, there are no alternatives to the most advanced supercomputers available at a given time.

The cost of the mini-supercomputers relative to full-scale supercomputers ($.5-1M range vs. $10-20M) make them attractive alternatives for university centers and research departments. It is not yet known if software and systems support costs for mini-supercomputers will offer disadvantages in time or cost, relative to centralized facilities. The cost-effective use of these systems will

depend on the availability of application software and support staff.

The present migration toward common operating systems and similar hardware architectures is expected to make the full range of computing resources easily available to the research community. An example of this is the ETA-10 line which ranges in price from $1 million to over $20 million, and provides compatible performance across the whole mini-super to supercomputer range.

We appear to be nearing a period of diminishing economies of scale, at least on a cost/performance basis, which will open new options for computational researchers. This is nowhere more clear than in the area of special purpose computing devices. There is an enormous range in the class of special purpose computing devices, from single chip signal processors to full scale specialized computers like the Thinking Machine Corporation Connection Machine which performs on some problems beyond conventional supercomputer speeds. Of particular interest are the highly specialized, very small and relatively inexpensive, "board" sized systems built mainly from standard components.

For example, a group of physicists and computer scientists at MIT, recently built a "Digital Orrery" for modelling the long term stability and location of objects of the solar system. For this class of problems, the device performs at about a tenth the speed of a supercomputer, but runs continuously. It occupies a space slightly larger than a shoebox, and requires power comparable to a 150-watt light bulb. Such devices trade off generality and complexity (and administrative, operational, and software expenses), for restricted functionality (in this case a single problem), simplicity, and the risk and expense of creating the device.

The declining cost of creating new microelectronic structures and the increased availability of basic building blocks have made it feasible to do forefront research on machines which are optimized research instruments. Thus, we expect that special purpose scientific computers will become a significant part of the research computing environment.

COMPUTER NETWORKS

The 1983 Bardon/Curtis report recommended that the Foundation assist in the formation of appropriate computer communications networks "linking academic and laboratory researchers with each other and with supercomputer centers to provide access to facilities, file transfer capability and scientific communication." Networks which allow ready access to large expensive facilities figure prominently in their overall cost effectiveness. In the case of the NSF program in supercomputing, they are an integral part of the computing system.

When the Foundation established its national supercomputer centers in 1985 and 1986, it also created a communications network, NSFNET, to give remote locations access to these state-of-the-art facilities. Although access was a principal motivation for building NSFNET, it is clear that the network offers academic researchers access to other scarce scientific and computing resources and that it has an important role to play in general scientific communication and collaboration.

NSFNET has been in use since July 1986. It is based on a "backbone" which connects the five supercomputer centers and NCAR to separately administered mid-level (frequently regional) networks such as JVNCNET (John von Neumann National Supercomputer Center Network), NYSERNET (a New York State Network), and MIDNET (a multistate network). Each of the mid-level networks interconnects with between five and 30 academic, industrial, and/or government research campus networks. (A full list of the mid-level networks with member institutions is attached as Appendix B). Based on the number of actual connections and those in the late planning stages, it is expected that about 200 university sites will be on the network by the end of 1988, with another 200 connected by a link to BITNET.

The Foundation at present provides partial start-up funding for a period of up to three years for the mid-level networks. After the initial three-year funding is over, however, it is expected that the mid-level networks will be largely self-supporting. The backbone has always been assumed to be an NSF responsibility. In addition to supporting the national networking operations, it is the object of advanced research on computer network technology and applications.

NSF has assumed a "lead agency" role, in working with DARPA, NASA, DOE, and HHS in interconnecting existing civilian federal research networks. It coordinates network development to make more efficient use of federal resources, assure greater connectivity and to plan future advanced research facilities and services.

The communication protocol set of the network is TCP/IP, a widely used set that permits NSFNET to connect to and interoperate with existing networks such as ARPANET and the NASA Science Network. Under the same interagency agreement that provides for the interconnections, NSF is currently sponsoring 30 additional connections to ARPANET in order to provide NSFNET access to universities which are not a part of any other mid-level network.

NSFNET will move to the new standards set by the International Standards Organization as they are established and implemented in accordance with the federal government ISO plan. This will make the network universally accessible, although additional research is needed before it will be possible to establish protocols for higher speed transmission.

Expenditures for the network have not reached the levels suggested by the Bardon/Curtis report. In 1983, the report called for annual expenditures of $2, $7, and $11 million on research networks in FY 1984, 1985, and 1986. In actuality, about $2 million was spent in FY 1986. In FY 1987, approximately $6 million was spent on NSFNET and its connections. As a result, today's networking resources are not adequate to support even the current needs of U.S. researchers, and by 1990, scientists and engineers will need access to wide area networks that are one thousand times more capable than those available today.

A major problem currently confronting network users is the speed of the network. At the present time, the network is rated at 56 kilobits per second, but effective performance is less. The limited capacity of NSFNET makes it inefficient to transmit large amounts of data to many users. Without improved networks, speed of data transmission will continue to be a limiting factor in the ability of future researchers to carry out complex analyses. For example, presenting computer generated color images that appear to move, such as are generated by complex models of physical processes, requires 30 frames per second; each frame represents about 30 million bits of information. To support applications of this type, even using advanced compression technology, would require backbone speeds in hundred of millions of bits per second to connect multiple users, such as are found at research centers.

Less dramatic, but equally daunting problems, arise in simultaneously transmitting compound electronic documents, or large rapidly changing databases typical of biotechnology and the global geosciences. NSF is moving to increase network speeds to 1.5 megabits per second by the end of FY 1988. Longer range estimates of network requirements vary, but it is clear that by the year 2000, scientists and engineers will need a high capacity national network with speeds measured in billions of bits per second.

Another issue is the provision of funding mechanisms for the long term support and maintenance of the mid-level networks. During the present start-up period, NSF is exploring methods of extending traditional research support mechanisms, that is, using direct and indirect cost methods of regular research grants.

Finally, there is the need for better access to NSFNET across the research community, especially in smaller institutions. Although network access is now fairly widespread among the larger research universities many institutions still do not have access to the network. In consequence, scientists affiliated with these institutions are limited in their ability to conduct research. In all, there are at least 2,000 institutions of higher education in the U.S. that could benefit from network access. Technologies to connect them to the network are either available now or will be available in the near future, and financial means are needed to do so.

COMPUTATIONAL SCIENCE AND ENGINEERING

Computational science and engineering is research based on mathematical models intended to solve scientific and engineering problems using computers. It is a multidisciplinary activity that integrates the following components: construction of a mathematical model of the scientific or engineering phenomenon; design of computational methods that permit the numerical or symbolic solution of the equations which constitute the mathematical model; and the implementation and graphic visualization of these methods on computers.

Computational science and engineering is claimed to be a new manner of research, joining traditional methods of theoretical and experimental research. Computational science and engineering research is carried out most effectively utilizing widely varying capabilities ranging from supercomputers to personal workstations. Its growing importance and potential were clearly recognized in the Bardon/Curtis recommendations for a broad, integrated national computing environment.

There is a substantial level of computational research carried out on more localized facilities and funded through regular NSF research programs. In FY 1987, the Foundation undertook an initiative in computational science and engineering. This initiative was based on the growing importance of computational approaches in research, the availability of increasingly powerful computer and computational techniques, and the contributions that multidisciplinary or collaborative groups of researchers could make to progress in the field. The NSF budget devoted to computational research, exclusive of local facilities and the computer access and support services provided by the Centers, increased by more than 25 percent to about $65 million. The initiative was highlighted by the introduction of several new formal research programs in a number of fields. These included Computational Mathematics ($3 million), Theoretical and Computational Chemistry ($1.7 million), and Computational Engineering ($2.5 million).

Historically, the performance of computers has been improved as much by optimizing their use as by improvements in technology. This process involves the development of more effective algorithms for solving problems and the design of more efficient programs for implementing these algorithms on a given type of computer. Though not exclusively, this is to a great extent the province of computational mathematicians and computer researchers. Collaboration between disciplinary scientists and engineers and those expert in algorithm development and program design can often enhance the quality and productivity of computational research projects. This collaborative approach was developed in some detail in the Rheinboldt

report, Computational Mathematics, Algorithms, and Scientific Software, and represented a key element in the FY 1987 NSF computational science and engineering initiative.

Computational mathematicians and computer researchers can also play another key role in the future development of computational science and engineering. Because many classes of problems are common to many research areas, effective computational solutions to them can have broad, general applicability. For example, the use of finite element methods, in which the system of interest is approximated by a grid of elementary areas or volumes, ranges from atmospheric science through solid mechanics. Similarly, the intrinsic nonlinear properties of nature give rise to phenomena such as instability, oscillation, turbulence, and chaotic behavior that are of major interest in a broad range of scientific and engineering systems. Study of these phenomena in realistic or complex situations is often accessible only through the use of high speed computers. As computers grow in capability and as new computer systems based on highly parallel architectures are introduced, the effective solution of broad classes of research problems will become increasingly challenging and important.

There are also several promising software-based technologies that have demonstrated potential for greatly expanding our scientific and engineering problem solving abilities. One of these is "visualization", which transforms the complex results of a computation into graphical, geometrical, or pictorial representations. This technology allows the researcher to make use of the considerable visual pattern recognition ability that humans possess to visualize the essential features of a solution and to interact actively with the computer in real time. Combining detailed seismic data with sophisticated computer visualization techniques, for example, can provide detailed three-dimensional images of the earth's interior using principles similar to those utilized in the medical CAT-scan.

A second software-based area is that of symbolic and algebraic computation. This computational approach, which enables one to carry out the algebraic manipulation of symbols on a computer, complements and augments the more traditional and fully developed numerical computing. Because the current vector pipeline supercomputers are not well suited to algebraic computation, this research involves innovative new computer architectures as well. Algebraic computation has been successfully applied to computing the orbits of objects in space, calculation of Feynman path integrals in high energy physics, and carrying out proof procedures in pure mathematics.

High performance computations also involve increasingly massive amounts of output and data storage and manipulation. However, current data representation, storage, and transfer techniques are barely adequate for today's requirements. As computational research expands, improved efficiency in data handling will become more

critical. Improved technologies for the effective storage, manipulation, and accessing of data will depend on intensive research in the relevant areas of algorithm development and software design.

Finally, we emphasize the central importance of education and training to the future development of computational science and engineering. Many researchers, particularly students and younger faculty, have both the potential and the need to incorporate modern computational techniques into their research. However, this potential is not being fully realized in part because of limited training opportunities. While the training seminars and institutes currently made available in connection with the NSF supercomputer centers are important, similar opportunities need to be made available at all levels of the computational spectrum.

CONCLUSIONS

The desire of the research community for access to the available supercomputing resources, and for higher capability computing, will keep NSF supercomputer facilities saturated so long as they are managed properly and can provide adequate service. These conditions can be met by a strategy of upgrades to maintain advanced capability in both the hardware and software at the NSF centers, and the development of better balance in the overall computational environment for scientific and engineering research. NSF is committed to the Centers concept, and within resource constraints, will implement this strategy.

NSF activities in advanced scientific computing will necessarily take into account the need for a balanced computing environment. Apart from supercomputer centers, this includes: improving Foundation funding mechanisms for providing alternative forms of high-performance computing to the research community; encouraging the research programs in all Directorates to support worthy proposals from the research community for access to unique supercomputer resources outside of the NSF Centers; creating and supporting the operation of a research and educational network capable of meeting advanced research applications and supporting the efficient use of the highly distributed computing environment; and support of basic research on computing and scientific and engineering computing applications.

APPENDIX A

ADVANCED COMPUTING CENTERS AVAILABLE TO
THE U.S. ACADEMIC RESEARCH COMMUNITY

FACILITY AND SUPPORTING AGENCY	MAJOR SYSTEMS 1983	1987
NSF		
CORNELL	---	IBM 3090/600VF
JVNC	---	Cyber 205 (2)
NCAR	Cray 1 (2)	Cray 1 Cray XMP48
NCSA	---	Cray XMP48
PSC	---	Cray XMP48
SDSC	---	Cray XMP48
NASA		
Ames	Cray 1	Cray 2 Cyber 205 Cray XMP48
Goddard	Cyber 205	Cyber 205
Langley	Cyber 203	Cyber 205
Lewis	Cray 1	Cray XMP24
Marshall	---	Cray XMP48
DOE (Unclassified)		
Fla. State Un.	---	Cyber 205 ETA10/2
Los Alamos	Cray 1	Cray 1 (2) Cray XMP24 Cray XMP48
MFECC	Cray 1 (2)	Cray XMP48 Cray 2
Independent		
Arizona State	---	IBM 3090/200VF
Boston Univ.	---	IBM 3090/200VF
Cal. Tech.	---	Cyber 205
Colorado State Un.	Cyber 205	Cyber 205
CUNY	---	IBM 3090/200VF
Drexel Univ.	---	IBM 3090/150VF
Emory Univ.	---	IBM 3090/180 VF
HARC	---	NEC SX2
Michigan State	---	IBM 3090/180VF
N. Dakota State	---	IBM 3090/120VF
Ohio State	---	Cray XMP24
Oklahoma State	---	IBM 3090/150VF

Old Dominion Univ.	---	IBM 3090/180VF
Purdue Univ.	Cyber 205	Cyber 205
Stanford Univ.	---	IBM 3090/300VF
Scripps Clinis	---	Cray XMP14se
SUNY-Binghampton	---	IBM 3090/180VF
Texas A&M	---	IBM 3090/200VF
Univ. of Akron	---	IBM 3090/200VF
Univ. of Alabama	---	Cray XMP24
Univ. of Cal-Berk	---	Cray XMP14 IBM 3090/200VF
Univ. of Cal-LA	---	IBM 3090/200VF
Univ. of Conn.	---	IBM 3090/150VF IBM 3090/180VF
Univ. of Florida	---	IBM 3090/400VF
Univ. of Georgia	---	Cyber 205 IBM 3090/200VF
Univ. of Ill.	---	IBM 3090/120VF
Univ. of Kentucky	---	IBM 3090/300VF
Univ. of Maine	---	IBM 3090/180VF
univ. of Michigan	---	IBM 3090/400VF
Univ. of Minnesota	Cray 1	Cray 2 (2) Cyber 205
Univ. of Miss.	---	Cyber 205
Univ. of Penn.	---	IBM 3090/180VF
Univ. of SW La.	---	IBM 3090/200VF
Univ. of Tenn.	---	IBM 3090/200VF
Univ. of Texas	---	Cray XMP24
Univ. of Wash.	---	IBM/ 3090/200VF
Virg. Poly. Inst.	---	IBM 3090/200VF

NOTES

- The NASA and DOE laboratories listed are available in part to the academic research community who are grantees of those agencies. Supercomputers exist in other Federal laboratories but are available only to internal researchers.

- The ability to process calculations in vectors produces a high processing speed. While all Cray, Cyber, and ETA supercomputers include vector processing as an inseparable part of their supercomputer architecture, IBM 3090 models are available with and without vector processing capabilities. Only those universities who have IBM 3090 models with vector processing have been listed above.

- There exist a variety of more exotic computer models from various manufacturers which can perform at supercomputer speed or better for certain applications. In contrast, the list above assumes that supercomputers must perform at high speed for a general class of scientific and engineering problems using standard FORTRAN. Under this assumption, the exotic computer models are not supercomputers.

Appendix B

List of Mid-Level Networks

NSFNET BACKBONE SITES

-Cornell National Supercomputer Facility
-John von Neuman National Supercomputer Center
-National Center for Atmospheric Research
-National Center for Supercomputing Applications
-Pittsburgh Supercomputing Center
-San Diego Supercomputer Center

NSF-Sponsored ARPANET

-U. of California Los Angeles
-California Institute of Technology
-Carnegie Mellon U.
-U. of Delaware
-U. of Maryland
-U. of Minnesota
-National Science Foundation
-Northwestern U.
-Purdue U.
-Rice U.
-Triangle Universities Computation Center
-U. of Washington
-U. of Wisconsin

-Bell Laboratories *
-U. of California Santa Barbara *
-U. of California San Diego *
-U. of Colorado - Boulder *
-Colorado State U. *
-Cornell U. *
-U. of Illinois at Urbana-Champaign *
-Indiana U. *
-John von Neumann National Supercomputer Center *
-U. of Michigan *
-Northrop Corporation *
-Ohio State U. *
-U. of Rochester *
-National Center for Atmospheric Research
-University of Texas-Austin
-Georgia Institute of Technology

BARRNET (Bay Area Regional Research Network)

- U. of California Berkeley
- U. of California Davis
- U. of California Santa Cruz
- U. of California San Francisco

-NASA/Ames
-Stanford U.

-Lawrence Berkeley Laboratory * #
-Lawrence Livermore National Laboratory * #
-Stanford Linear Accelerator Center * #

CSNET X25 Sites

-Apple Computer Corporation
-Bell Communications Research
-Boeing Computer Services
-Data General (Massachusetts & North Carolina)
-Emory U.
-Hewlett-Packard Laboratories
-IBM Research Labs
-Mass Microelectronics Center
-McGill U.
-Ohio State U.
-Toronto U.
-Waterloo U.

JVNCNET (John von Neumann National Supercomputer Center Network)

-U. of Arizona
-Brown U.
-U. of Colorado
-Columbia U.
-Harvard U.
-Institute for Advanced Study
-Massachusetts Institute of Technology
-U. of Medicine and Dentistry of New Jersey
-New Jersey Institute of Technology
-New York U.
-U. of Pennsylvania
-Pennsylvania State U.
-Princeton U.
-U. of Rochester
-Rutgers U.
-Stevens Institute of Technology

MERIT

-Central Michigan U.
-Eastern Michigan U.
-U. of Michigan
-Michigan State U.
-Michigan Technological U.
-Oakland U.
-Wayne State U.
-Western Michigan U.

MIDNET

-U. of Arkansas-Fayetteville
-U. of Iowa
-Iowa State U.
-U. of Kansas
-Kansas State U.
-U. of Missouri-Columbia
-U. of Nebraska-Lincoln
-U. of Oklahoma
-Oklahoma State U.
-U. of Tulsa
-Washington U.

NCSANET (National Center for Supercomputer Applications Network)

-Argonne National Laboratories #
-U. of Chicago
-U. of Illinois - Chicago
-Indiana U.
-NCSA
-Northwestern U.

-Notre Dame *
-U. of Wisconsin-Milwaukee *

NORTHWESTNET

-U. of Alaska System *
-Boeing Computer Services *
-U. of Idaho *
-Montana State U. *
-North Dakota Higher Education Computer Consortium *
-U. of Oregon *
-Oregon Graduate Center *
-Oregon State U. *
-U. of Washington *
-Washington State University *

NYSERNET (New York State Education and Research Network)

-Brookhaven National Laboratory #
-City U. of New York
-Clarkson College of Technology
-Columbia U.
-Cornell U.
-SUNY at Albany
-SUNY at Binghamton
-SUNY at Buffalo
-SUNY at Fredonia #
-SUNY at Stony Brook
-New York Telephone #
-New York U.
-NYNEX Science and Technology #
-Polytechnic U. of New York

-Rensselaer Polytechnic Institute
-U. of Rochester
-Rockefeller U.
-Syracuse U.

-IBM * #
-Kodak *#

PSCNET (Pittsburgh Supercomputing Center Academic Affiliates Group network)

-Alcoa
-Drexel U.
-Lehigh U.
-U. of Maryland
-U. of Pennsylvania
-PSC
-Temple U.

-Case Western Reserve U. *
-U. of Michigan *
-Ohio State U. *

SDSCNET (San Diego Supercomputer Center Network)

-U. of California Berkeley
-U. of Califonia San Diego
-U. of California Santa Barbara
-San Diego Supercomputer Center
-Salk Institute

-Brigham Young U. *
-U. of California Irvine *
-U. of California Riverside *
-U. of Utah *
-U. of Washington *
-U. of Hawaii
-California Institute of Technology
-U.C.S.D. Scripps Institute
-Agouran Institute
-U.C. San Francisco
-San Diego State
-Standford University
-U. of Michigan
-U. of Maryland
-U.of Wisconsin
-U.C.L.A.
-Southwest Fisheries
-Kitt Peak Observatory

SESQUINET (Texas Sesquicentennial Network)

-Baylor College of Medicine
-Houston Area Research Center

-U. of Houston University Park
-Rice U.
-Texas A & M University
-Texas Southern U.

SURANET (Southeastern Universities Research Association Network)

-U. of Alabama at Birmingham
-Catholic U. of America
-Clemson U
-Continuous Electron Beam Accelerator Facility
-U. of Delaware
-U. of Florida
-Florida State U.
-Gallaudet College
-George Mason U.
-George Washington U.
-Georgia Institute of Technology
-Johns Hopkins U.
-U. of Kentucky
-U. of Maryland
-Naval Research Laboratory #
-NASA/Goddard #
-National Science Foundation
-University of Tennessee
-Triangle Universities Computation Center
    Duke University
    North Carolina State U.
    U. of North Carolina
-Vanderbilt U.
-U. of Virginia
-Virginia Polytechnic Institute
-College of William & Mary

-U. of Alabama at Tuscaloosa *
-Georgetown U. *
-U. of Georgia *
-Louisiana State U. *
-National Bureau of Standards * #
-National Institutes of Health * #
-West Virginia U. *

USAN (University Satellite network)

-U. of Maryland
-U. of Miami
-U. of Michigan
-National Center for Atmospheric Research
-Oregon State U.
-U. of Wisconsin
-Woods' Hole Oceanographic Institute #

-Institute for Naval Oceanography * #

-Naval Research Laboratory * #

WESTNET

-U. of Colorado - Boulder
-U. Colorado - Colorado Springs
-U. Colorado - Denver
-Colorado School of Mines
-Colorado State
-U. of Denver
-NCAR

-U. of Arizona *
-Arizona State U. *
-U. of New Mexico - Albuquerque *
-New Mexico Institute of Mining & Technology - Socorro *
-New Mexico State U. - Las Cruces *
-Utah State U. - Logan *
-U. of Wyoming - Laramie *

* Expected on-line as of 3/15/88
# Not NSF Funded

FY 1987 NATIONAL SCIENCE FOUNDATION PROGRAMS

in

Undergraduate Research and Education

REPORT TO THE CONGRESS

January 1988

FY 1987 National Science Foundation Programs in Undergraduate Research and Education

Report to the Congress

In FY 1987, the National Science Foundation (NSF) took significant initial steps toward a comprehensive program to strengthen and support undergraduate education across the Nation. The actions taken were responsive to the National Science Board Report on Undergraduate Education and based on the advice and analysis of many responsible groups concerned with the U. S. scientific and technological enterprise. Five distinct impact points may be described:

- The Office of Undergraduate Science, Engineering, and Mathematics Education (USEME) was established within the Directorate for Science and Engineering Education.
- The College Science Instrumentation Program (CSIP) was continued for a third year at a significantly increased level;
- The Research Experiences for Undergraduates (REU) Program was initiated;
- The Research in Undergraduate Institutions (RUI) program exceeded the $9.5 million target; and
- The Research Opportunity Awards (ROA) program continued to be successful.

The total FY 1987 NSF expenditure for undergraduate education was $37.5 million, distributed as follows:

	FY 1987 Actual
College Science Instrumentation	$ 9.5 million
Research Experiences for Undergraduates	$11.9 million
Supplements to Awards	[6.7 million]
REU Site Awards	[5.2 million]
Research at Undergraduate Institutions	$14.6 million
Research Opportunity Awards	$ 1.5 million
TOTAL, Undergraduate	$37.5 million

The distribution of the FY 1987 undergraduate awards among the directorates follows:

	FY 1987 Actual
Biological, Behavioral and Social Science	$9.06 million
Computer and Information Science and Engineering	$1.73 million
Engineering	$3.37 million
Geosciences	$5.05 million
Mathematical and Physical Sciences	$8.80 million
Scientific, Technological, and International Affairs	$0.04 million
Science and Engineering Education	$9.50 million
NSF, Total	$37.55 million

CSIP, REU and RUI are individually summarized in the following sections. Much of this information is announced and widely disseminated to the scientific and educational media and communities at the completion of each year's operation.

The Office of Undergraduate Science, Engineering, and Mathematics Education (USEME)

A significant step toward demonstrating NSF leadership in undergraduate education was the establishment in July 1987 of the Office of Undergraduate Science, Engineering, and Mathematics Education (USEME) in the Directorate for Science and Engineering Education. The Office is the focal point for the Foundation's effort at the undergraduate level.

USEME has three principle areas of responsibility:

- Program management for undergraduate activities budgeted within the Science and Engineering Education Directorate;
- Coordination of the NSF mission in undergraduate education across the Foundation;

- Stimulation of the further involvement of academic scientists and their institutions, the States, the private sector, and other Federal agencies in improving undergraduate science and engineering education.

With the staff of the former Office of College Science Instrumentation serving as nucleus for the new Office, USEME has moved aggressively to begin meeting these responsibilities and fulfilling its role as focal point. Soon after the Office was created, a USEME Steering Committee was established; its membership comprises the USEME Acting Office Head as chair and senior officers from each of the NSF research directorates. The Steering Committee participated actively in development of a plan for NSF's FY 1988 program to serve as the basis for long range plans for NSF support of undergraduate education. This plan incorporated extensive contributions from scientists and engineers throughout the Foundation and from the corresponding national professional communities. It represents a coherent NSF-wide approach to the problems of undergraduate education based on both leadership activities and leveraged program support.

USEME and other staff have conducted extensive outreach activities with all types of institutions, 2-year and 4-year colleges and universities, to gain and share a better understanding of the national needs, and to disseminate Foundation plans and goals in undergraduate education.

The College Science Instrumentation Program (CSIP)

CSIP was established in FY 1985 with the goal of improving the quality of the undergraduate curriculum by supporting projects to develop new or improved instrumentation-based undergraduate laboratory and/or field courses in science, mathematics, or engineering. Budgets were required to match the NSF funds requested for the purchase of necessary instrumentation, and eligibility for the program was limited to bachelor's and master's degree granting institutions that do not grant doctoral degrees in the NSF-eligible sciences.

Table 1 (see Attachment 1) summarizes the FY 1987 CSIP Program and shows that CSIP awards cover all of the NSF supportable major scientific disciplines. It also reveals that although selection of awards is made by a highly competitive peer review process, the program enjoys a wide geographic impact. The program made 337 awards at 235 institutions in 43 states, the District of Columbia, Puerto Rico, and the Virgin Islands. Attachment 1 provides a complete list of the FY 1987 CSIP awards arranged alphabetically by state.

CSIP received 970 proposals in FY 1987 requesting $26 million, with resultant success rates of 35% for numbers of proposals/-awards, and of 33% for funds requested/awarded.

CSIP numbers several other significant actions among its FY 1987 accomplishments aimed at enhancing and leveraging program impact. These include:

- o A conference on the role of instrumentation in undergraduate mathematics aimed at making more effective use of computing;
- o Several symposia at scientific society meetings on undergraduate instrumentation at no cost to the government;
- o Initiating a formal procedure to evaluate and assess the impact of the program; and
- o Publishing the brochure, "Instrumentation for Undergraduate Science and Engineering Instructional Improvement: Summaries of FY 1985 and FY 1986 College Science Instrumentation Awards," a source book for laboratory instructional development. [This project book summarizes the program's funding for FY 1985 and FY 1986.]

The Research Experiences for Undergraduates (REU) Program

REU was initiated in FY 1987 in response to the recommendations of many groups and organizations. The purpose of REU is to attract talented students into research careers in the scientific fields, and to help ensure that they receive the best upper-division undergraduate education possible.

REU supports projects that provide undergraduate students with research and scholarly experiences under the tutelage of accomplished scientists, mathematicians, and engineers. REU emphasizes heavily the involvement in these activities of women, minority, and disabled students.

Two distinct categories of project are supported under REU: (1) "Sites" projects are based on new proposals conceived and designed for the involvement of undergraduate students; whereas (2) "Supplements" to ongoing NSF research grants provide a mechanism to allow the addition to these projects of undergraduate students.

Tables 2 and 3 (Attachment 2) summarize the REU program for FY 1987, its initial year of operation. These show that the Foundation supported a total of 978 awards valued at $11.9 million. Of them, 143 Site awards were made valued at $5.2 million, and 835 Supplements were made valued at $6.7 million.

Awards were made to institutions located throughout 47 states, Guam, and Puerto Rico.

In the Sites component of REU, 494 proposals requesting $33 million were received. Thus the success rates were 29% based on number of proposals and 16% based on the amount of support requested.

The REU program is operated within the Foundation in a broadly distributed mode, with all of the NSF research directorates participating. The distributions of funds and awards by directorate are shown in Tables 2 and 3.

It is estimated from proposal data that as many as 2800 students nationwide were supported through FY 1987 projects. Eighteen of these projects were sited at 4-year colleges, 118 at doctoral universities, and 7 at other organizations, such as industrial or independent laboratories. Attachment 2 contains a complete list of the REU Sites awards. Attachment 3 displays the geographic distribution of both REU site awards and CSIP awards.

In addition to the support of the regular awards described above, the REU program provided partial funding for a national student conference on undergraduate research. This conference permitted many students to meet and present the results of their research work.

The Research in Undergraduate Institutions (RUI) Program

Predominantly undergraduate institutions currently graduate 36% of the students who go on for Ph.D.s in science and engineering. In recognition of the role of these institutions, the Research in Undergraduate Institutions (RUI) activity was initiated in FY 1984 as part of the Foundation's effort to broaden the base for science and engineering research and to enhance the scientific opportunities for students in these institutions. The program's objectives are to strengthen the research environments in academic departments that are oriented primarily to undergraduate education in science and engineering, and to promote the coupling of research and education at predominantly undergraduate institutions.

RUI provides support for research and research equipment for investigators in non-doctoral departments in predominantly undergraduate institutions, defined as those which awarded no more than 20 Ph.D. degrees in fields supported by the Foundation. RUI proposals are submitted to the disciplinary research directorates. These proposals are identified by a special cover sheet and by a statement in the appendix describing the expected impact of the proposed research on the research and training

environment of the department. While scientific merit is the primary evaluation criterion, reviewers are asked to recognize that the heavy teaching loads and lack of available resources in many of these institutions make research progress slower than at a research-oriented institution. Reviewers are also asked to consider the RUI impact statement.

Although RUI is the targeted program for predominantly undergraduate institutions, it is only part of the Foundation's effort to support faculty research at these institutions. The Foundation has always supported individual faculty in the regular research programs. Research Opportunity Awards enable a faculty member at an institution with limited research capability to work with someone who has a NSF grant at another institution. While these are generally funded as supplements to the original awards at the host institutions, they may be components of new proposals. In FY 1987, 90 ROA awards were made totalling $1.5 million.

The Foundation target for predominantly undergraduate institutions support in FY 1987 was $46 million; awards (1,061) totaled $55.9 million. Of this amount, $14.6 million was for RUI awards (294), far exceeding the $9.5 million target. Thus, NSF achieved 121.4 % of its overall target for PUIs, and 153.7% of its RUI target. All disciplinary directorates exceeded both their RUI and their total PUI targets.

Attachment 4 summarizes the ROA, RUI and PUI FY 1987 data for the Foundation and provides an RUI award listing.

ATTACHMENT 1

DIRECTORATE FOR SCIENCE AND ENGINEERING EDUCATION TABLE 1

COLLEGE SCIENCE INSTRUMENTATION PROGRAM
1987 AWARDS

DISCIPLINE	# PROPOSALS AWARDED	$ (THOUSANDS) AWARDED
BIOLOGY	73	$1,748
PSYCHOLOGY	24	$328
CHEMISTRY	81	$1,957
COMPUTER SCI	21	$807
ENGINEERING	56	$1,788
EARTH SCI	10	$373
INTERDISIPLINE	21	$590
MATHEMATICS	5	$193
PHYSICS	36	$566
OTHER SOC SCI	10	$200
(*) OTHER	-	$950
TOTALS -	265	$9,500
GEOGRAPHIC DISTRIBUTION	43 STATES DC,PR,& VI	

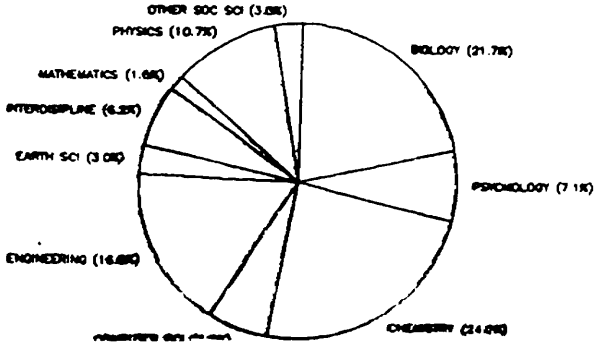
(*) OTHER INCLUDES: PANELS, CONFERRENCES, PLANNING AND EVALUATION

TYPES OF INSTITUTIONS FUNDED

	2-YEAR COLLEGES	4-YEAR COLLEGES	PhD UNIVERSITIES	OTHER
# OF AWARDS	0	337	0	-
% OF AWARDS	0%	100%	0%	-

PERCENTAGE OF AWARDS BY DISCIPLINE

337 INSTRUMENTATION AWARDS



STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Alabama				
Birmingham Southern Col Birmingham 35254 Equipment for a Modern Undergraduate Cell Biology Laboratory	Leo Perzementi Biology	BZ	$22,046	8750089
Samford Univ Birmingham 35229 Improvement of Undergraduate Instruction in Chemistry through NMR	James D. Fisk Chemistry	CH	$26,000	8750054
Univ of South Alabama Mobile 36688 Introduction of an Advanced Undergraduate Software Development Station	Russell M. Hayes, Jr. Electrical Engineering	EN	$16,317	8750613
Univ of South Alabama Mobile 36688 Unix Based Graphics Work Station Laboratory for Computer Science Students	William A. Ward, Jr. Div.of Computer & Informa	CS	$50,000	8750616
Arkansas				
Arkansas College Batesville 72501 Infrared Spectrophotometry in Undergraduate Chemistry Instruction	Bert E. Holmes Chemistry	CH	$25,057	8750879
Arkansas Tech University Russellville 72801 An Undergraduate Thermofluids Measurement and Analysis Laboratory.	Nasser Rashidnia Engineering	EN	$30,656	8750103
Hendrix College Conway 72032 High Resolution Gamma Spectroscopy and X-ray Fluorescene for the Advanced Undergraduate Laboratory	Peter J. Pella Physics	PY	$7,250	8750232
Hendrix College Conway 72032 Acquisition of Infrared Spectrophotometers for Microscale Organic Laboratory	Thomas E. Goodwin Chemistry	CH	$8,589	8750417
U Arkansas Little Rock Little Rock 72204 A Modern Undergraduate Engineering Technology Measurement Laboratory.	Kirak C. Patangia Electronics Engineering T	EN	$50,000	8750732
California				
Cal St Poly Univ Pomona Pomona 91768 Modern Optics and Spectroscopy for Undergraduates	Steven W. McCauley	PY	$34,172	8750530
Cal St Univ Fullerton Fullerton 92631 Equipment for Neurobiological Experiments and Computerized Data Acquisition/Analysis in an Undergraduate Physiology Program.	Joyce K Ono Biology	BZ	$43,082	8750586

STATE INSTITUTION CITY,ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Cal St Univ Hayward Hayward 94542 Portable Equipment for Teaching Undergraduate Biology Students to Conduct Digital Video Analyses along Environmental Gradients.	Christopher L. Kitting Biological Sciences	BZ	$13,422	8750588
Cal St Univ Long Beach Long Beach 90840 Hydrowinch and Automated Probe Sampling System for an Undergraduate Ocean Studies Laboratory Aboard a Six Campus Consortium Vessel	Murrey D. Dailey Southern Calif Ocean Stud	IN	$23,053	8750058
Cal St Univ Long Beach Long Beach 90840 Implementation of Field-Oriented Projects into the Senior Level Undergraduate Geophysics Curriculum	Roswitha B. Grannell Geological Sciences	EZ	$38,704	8750776
Cal St Univ Long Beach Long Beach 90840 Instrumentation for a Newly Revised Undergraduate Biochemistry Laboratory Course	Jeffrey A. Cohlberg Chemistry	CH	$38,778	8750821
Cal St Univ Los Angeles Los Angeles 90032 An Undergraduate Coastal Hydraulics Laboratory Wave Generating Channel.	Young C. Kim Civil Engineering	EN	$12,880	8750146
Cal St Univ Los Angeles Los Angeles 90032 Gene Manipulation: A Practical Undergraduate Education in the Theory, Methods, and Potential of Biotechnology.	Sandra B. Sharp Biology	BZ	$49,421	8750387
Cal St Univ Los Angeles Los Angeles 90032 Economics and Statistics Microcomputer Laboratory	Eduardo M. Ochoa Economics & Statistics	SZ	$50,000	8750397
Cal State Univ Chico Chico 95929 An Undergraduate Optical Electromagnetic Wave Laboratory.	Ralph Gagnon Electrical/Electronic Eng	EN	$29,950	8750147
Cal State Univ Chico Chico 95929 Liquid Chromatography in Undergraduate Chemistry Instruction	William D. Korte Chemistry	CH	$13,515	8750218
Calif St U San Lu Obispo San Luis Obispo 93407 An Undergraduate, Robotics Application, Instructional Workcell.	Unny Menon Computer Integrated Manuf	EN	$32,080	8750022
Calif St U San Lu Obispo San Luis Obispo 93407 An Undergraduate Thermo-mechanical Test Laboratory.	Daniel W. Walsh Metallurgical Engineering	EN	$50,000	8750170
Calif St U San Lu Obispo San Luis Obispo 93407 Upgrading of Undergraduate Structural (Seismic) Testing Laboratories.	Satwant S. Rihal Architectural Engineering	EN	$23,250	8750748
Harvey Mudd Col Claremont 91711 Introduction of Computer-Aided Data Acquisition and Analysis in Advanced Undergraduate Physics Instructional Laboratories	Richard C. Haskell Physics	PY	$15,873	8750246

STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Harvey Mudd Col Claremont 91711 Parallel Processing System for Undergraduate Instruction	Michael A. Erlinger Computer Science	CS	$50,000	8750727
Loyola Marymount U Los Angeles 90045 An Undergraduate Materials Science/Metallurgy Laboratory.	Franklin E. Fisher Mechanical Engineering	EN	$43,000	8750454
Mount St Mary's College Los Angeles 90049 Updating Instrumentation in the Natural Sciences	Eleanor D Siebert Physical Sciences & Mathe	CH	$17,101	8750280
Northrop University Los Angeles 90045 Creating an Undergraduate Electro-optics Laboratory at Northrop University.	David G. Pelka Electrical Engineering	EN	$50,000	8750242
Pitzer Col Claremont 91711 Statistical-Quantitative Methods in the Social Sciences	Homer D. Garcia Sociology/Chicano Studies	SZ	$37,900	8750888
Pomona Col Claremont 91711 Laboratory Equipment to Improve Undergraduate Instruction in Physiological Psychology	Richard S. Lewis Psychology	PS	$6,205	8750744
San Diego State Univ San Diego 92182 Digital Techniques in an Undergraduate Electrical Engineering Laboratory.	David Wright Electrical & Computer Eng	EN	$50,000	8750415
San Diego State Univ San Diego 92182 Computer Aided Learning Lab for Undergraduate Computer Science	Roger E. Whitney Mathematical Sciences	CS	$18,647	8750569
San Jose State University San Jose 951920139 Introduction of Gas Chromatography - Mass Spectrometry (GCMS) into the Undergraduate Chemistry Curriculum	Leon S. Yengoyan Chemistry	CH	$29,116	8750906
Sonoma State University Rohnert Park 94928 Development of a Modern Undergraduate Computer Graphics Laboratory	Richard H. Gordon Computer & Information Sc	CS	$17,973	8750557
Whittier College Whittier 90608 Photographic Image Analysis by Undergraduates in the Natural and Social Sciences	Dallas D. Rhodes Geology	IN	$14,200	8750314
Whittier College Whittier 90608 Microcomputer-Assisted Laboratory Stations for Undergraduate Physiology Courses	Alfred W. Hanson Biology	BZ	$11,833	8750389
Whittier College Whittier 90608 Computer Simulated Negotiation in a Cross-Cultural Context	Joyce P. Kaufman Political Science	SZ	$15,008	8750465

STATE / INSTITUTION / CITY.ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Colorado				
Colorado College Colorado Spring 80903 Integrated Chemometrics Program for the Undergraduate Curriculum	Nathan W. Bower Chemistry	CH	$25,830	8750040
Metropolitan State Col Denver 80204 A Spring Thunderstorm Project for Undergraduate Meteorology Students	Anthony A. Rockwood Earth Science	EZ	$6,967	8750929
Regis College Denver 80221 Laboratory Equipment to Initiate an Integrated Junior-year Course in Investigative Biology.	John F. Nolte Biology	BZ	$50,000	8750958
U Colo at Colo Springs Colorado Spring 80933 Image Processing/Analysis System and Remote Sensing Center for Undergraduate Students	Thomas P. Huber Geography & Environmental	EZ	$49,474	8750041
Univ of Southern Colorado Pueblo 81001 Introduction of Fourier Transform-Infrared Spectroscopy (FT-IR) into the Chemistry Curriculum and Integration with Computer-Controlled Gas Chromatography	Melvin L. Druelinger Chemistry	CH	$36,456	8750177
Connecticut				
Connecticut College New London 06320 Improving Electron Microscopic Study in the Undergraduate Curriculum	Lisa M. Baird Botany	BZ	$50,000	8750877
Southern Conn State Col New Haven 06515 An Undergraduate Computer Hardware Laboratory	Ataollah Elahi Computer Science	CS	$31,300	8750749
St Joseph College West Hartford 06117 Incorporation of New NMR Applications in the Undergraduate Chemistry Curriculum	Harold T. McKone Chemistry	CH	$31,585	8750142
Trinity College Hartford 06106 Undergraduate Instruction in FT-NMR	Richard V. Prigodich Chemistry	CH	$50,000	8750507
Trinity College Hartford 06106 Laboratory Equipment to Improve Undergraduate Instruction in Personality Assessment.	Sharon Herzberger Psychology	PS	$6,265	8750763
Trinity College Hartford 06106 Automating the Undergraduate Engineering Materials Laboratory.	Roy B. Davis, III Engineering & Computer Sc	EN	$11,602	8750859
U S Coast Guard Academy New London 06320 An Undergraduate Computer Assisted Scalor Network Analysis Laboratory.	Michael E. McKaughan Engineering	EN	$11,000	8750498

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
University of Bridgeport Bridgeport 06602 An Undergraduate Communication Systems Laboratory.	Gerald T. Volpe Electrical Engineering	EN	$49,650	8750110
University of Bridgeport Bridgeport 06602 An Undergraduate Interdisciplinary Artificial Intelligence Laboratory.	Porter D. Sherman Computer Science	CS	$50,000	8750129
University of New Haven West Haven 06516 Biochemical Equipment for an Undergraduate Forensic Science Laboratory in Blood/Body Fluid Identification and Individualization.	R. E. Gaensslen Forensic Science	BZ	$15,086	8750754
District of Columbia				
Gallaudet University Washington 20002 An Undergraduate Laboratory Course in Experimental Psychology	Robert L. Williams Psychology	PS	$15,441	8750332
Gallaudet University Washington 20002 Undergraduate Engineering Technology Program for the Hearing Impaired.	H David Snyder Physics	EN	$36,869	8750356
Gallaudet University Washington 20002 Equipment for Teaching Field, Survey, and Analysis Techniques in Environmental Biology to Undergraduates.	Paul J. Cunningham Biology	BZ	$24,571	8750493
Florida				
Rollins College Winter Park 32789 A Liquid Scintillation Counter to Improve Undergraduate Instruction in Cellular and Subcellular Biology.	Stephen Kiemann Biology	BZ	$12,700	8750272
Rollins College Winter Park 32789 Fourier Transform Infrared Spectroscopy in the Chemistry Curriculum at Rollins College	Brian G Ramsey Chemistry	CH	$20,800	8750373
Stetson Univ Deland 32720 The Upgrade of a DEC Microvax II to an Undergraduate Laboratory Teaching Tool	David Lawson Mathematics/Computer Scie	CS	$21,255	8750568
Stetson Univ Deland 32720 Instrumentation in the Microscale Organic Laboratory	Theodore W. Beiler Chemistry	CH	$6,974	8750720
Univ of West Fla Pensacola 32514 The Establishment of an Undergraduate, Real-time, Embedded System Software and Interfacing Laboratory	Theodore F. Elbert Systems Science	CS	$47,179	8750068
Univ of West Fla Pensacola 32514 Mass Spectrometry as an Instructional Tool in the Undergraduate Laboratories	Clifford W. Chang Chemistry	CH	$25,708	8750196

STATE / INSTITUTION / CITY.ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Georgia				
Fort Valley State Col Fort Valley 31030 Data Acquisition Workstations for the Undergraduate Linear Circuit Laboratory.	F. Jalali Electronic Engr Technolog	EN	$18,570	8750539
Morehouse College Atlanta 30314 Multi-Course Instrumentation Laboratory	Troy L. Story, Jr. Chemistry	CH	$45,648	8750001
Paine College Augusta 30910 Computer-Controlled Instrumentation for the Improvement of Introductory Undergraduate Biology Laboratories.	Marion Furr Biology	BZ	$29,604	8750881
Hawaii				
Chaminade U of Honolulu Honolulu 96816 Behavioral Sciences Laboratory Instrumentation	Joseph R. Mobley, Jr. Behavioral Sciences	BZ	$5,650	8750868
Chaminade U of Honolulu Honolulu 96816 NMR in Undergraduate Chemistry Curriculum	Arthur L. Mori Physical Science	CH	$26,550	8750869
Illinois				
Columbia Col Chicago 60605 Instrumentation for Undergraduate Instruction in Chemistry for Science, Technology and Communications	Zafra M. Lerman Science	CH	$20,653	8750193
Knox College Galesburg 61401 Equipment for Undergraduate Biological Chemistry Laboratories for Teaching Gene Expression.	Billy W. Geer Biology	BZ	$14,658	8750319
Millikin University Decatur 62522 Modern Instrumentation for Project-Based Undergraduate Chemistry Laboratories	Homer A. Smith, Jr. Chemistry	CH	$16,489	8750853
Western Illinois Univ Macomb 61455 Development of a Computational Chemistry Laboratory	Janos Szamosi Chemistry	CH	$22,268	8750029
Indiana				
Butler University Indianapolis 46208 Acquisition of Phase Contract and Fluorescence Microscopes for Biology Education.	Michael S. Maloney Biological Sciences	BZ	$25,775	8750263
Depauw University Greencastle 46135 Modernizing the Undergraduate Instrumental Analysis Laboratory	David T. Harvey Chemistry	CH	$21,995	8750039

STATE INSTITUTION CITY,ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Earlham College Richmond 47374 Equipment to Expand Undergraduate Instruction in Cellular and Molecular Biology.	William H. Harvey Biology	BZ	$34,544	8750217
Earlham College Richmond 47374 Undergraduate Instructional Use of a Diode Array UV/VIS Spectrophotometer	Gerald R. Bakker Chemistry	CH	$7,800	8750543
Goshen College Goshen 46526 Equipment for Computer Interfacing in Undergraduate Physiology Laboratories.	James S. Miller Biology	BZ	$16,108	8750690
Marion College Marion 46953 Integration of the Use of an NMR Spectrometer in an Undergraduate Chemistry Program	Edward J. Kelly Chemistry	CH	$9,180	8750289
Purdue U Ft Wayne Fort Wayne 46805 Acquisition of an X-ray Diffractometer for the Undergreduate Geology Curriculum	Scott F. Argast Earth & Space Sciences	EZ	$45,175	8750250
Purdue U Calumet Hammond 46323 A Microcomputer Applications Course and Laboratory for All Undergraduate Engineers	Richard L. Gonzales Engineering	EN	$47,970	8750330
Rose-Hulman Inst of Tech Terre Haute 47803 Introduction of Biotechnology into the Undergraduate Chemical Engineering Curriculum.	Ronald S. Artigue Chemical Engineering	EN	$9,687	8750150
Rose-Hulman Inst of Tech Terre Haute 47803 New Instrumentation and Equipment to Extend Instructional Capabilities in Undergraduate Mechanical Engineering at Rose-Hulman.	Leland K. Shirely Mechanical Engineering	EN	$50,000	8750480
Rose-Hulman Inst of Tech Terre Haute 47803 Undergraduate Laboratory Instruction in Electrochemistry	Frank A. Guthrie Chemistry	CH	$9,300	8750501
St Mary's College Notre Dame 46556 Electron Microscopy in the Undergraduate Biology Curriculum	David M. Sever Biology	BZ	$49,825	8750005
St Mary's College Notre Dame 46556 Development of the Undergraduate Biochemistry Laboratory	Pamela L. Plouher Chemistry & Physics	CH	$27,380	8750481
Taylor University Upland 46989 High Performance Liquid Chromatography/Ion Exchange Chromatography at Taylor University	Stanley L. Burden Chemistry	CH	$22,195	8750172
Taylor University Upland 46989 An Undergraduate Artificial Intelligence Teaching Laboratory.	Timothy C. Diller Information Sciences	CS	$30,476	8750513

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Valparaiso Univ Valparaiso 46383 A Universal Testing Machine for an Undergraduate Civil Engineering and Materials Engineering Laboratory.	Gerald R. Seeley Civil Engineering	EN	$27,100	8750643
Valparaiso Univ Valparaiso 46383 Instrumentation for Astronomical Photoelectric Photometry	Bruce J. Hrivnak Physics	PY	$22,395	8750722
Iowa				
Coe College Cedar Rapids 52402 Computer Interfaced UV/Visible Spectrophotometry for the Chemistry Undergraduate	Stanley R. Watkins Chemistry	CH	$9,111	8750159
Cornell Col Mount Vernon 52314 Scientific Equipment for Undergraduate Instruction in Animal Physiology and Behavior.	Ann Blakley Biology & Chemistry	BZ	$7,767	8750306
Grinnell Col Grinnell 50112 Fourier Transform Infrared Spectrophotometer System	Richard Biagioni Chemistry	CH	$23,987	8750712
Grinnell Col Grinnell 50112 Using Powerful Computer Software in a Laboratory Environment to Help Undergraduate Students Develop Mathematical Insight	Eugene A. Herman Mathematics	MA	$50,000	8750715
Luther College Decorah 52101 Improving Undergraduate Instruction Through Applications of Nuclear Magnetic Resonance Spectrometry.	Carolyn Mottley Chemistry	CH	$38,000	8750016
Luther College Decorah 52101 Improvement of Microcomputing in the Undergraduate Physics Curriculum	Dennis Barnaal Physics	PY	$14,390	8750400
Univ of Northern Iowa Cedar Falls 50614 Improvement of Undergraduate Optics Laboratory	Dale W. Olson Physics	PY	$9,799	8750915
Wartburg College Waverly 50677 Application of Mossbauer Spectroscopy in Undergraduate Laboratories	Mohamed Ellid Physics	PY	$6,665	8750536
Kansas				
Bethany College Lindsborg 67456 Improvement of Undergraduate Chemistry Curriculum by Addition of an NMR Spectrometer	Mike L. Mitchell Chemistry	CH	$26,350	8750702
Washburn Univ of Topeka Topeka 66621 An Ultracentrifuge and a Spectrophotometer for an Undergraduate Molecular Biology Laboratory.	Betty J. Cole Biology	BZ	$27,607	8750077

STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Washburn Univ of Topeka Topeka 66621 A Computer Laboratory for the Teaching of an Interdisciplinary Course in Psychology and Legal Issues	Fred L. Yaffe Psychology	PS	$16,142	8750212
Kentucky				
Eastern Kentucky Univ Richmond 40475 Update of Equipment Used in Undergraduate Biochemistry Labs	Jeffrey R. Baxter Chemistry	CH	$32,847	8750036
Kentucky State University Frankfort 40601 Equipment to Improve Undergraduate Instruction in Cellular and Developmental Biology.	Karan Kaul Biology	BZ	$7,510	8750558
Kentucky Wesleyan Col Owensboro 42301 Immunology--A New Capstone Course for Undergraduate Biology Majors.	David F. Oetinger Biology	BZ	$15,143	8750098
Murray State Univ Murray 42071 Integration of Multinuclear Magnetic Resonance Spectroscopy into a Modern Chemistry Laboratory Program	Arlene R. Courtney Chemistry	CH	$50,000	8750472
Louisiana				
Loyola Univ-New Orleans New Orleans 70118 Computerized Laboratories in an Undergraduate Psychology Department	Mary M. Brazier Psychology	PS	$11,500	8750403
Southrn U A&M Baton Rouge Baton Rouge 70813 An Undergraduate Digital Communications Laboratory Project.	Ibibia K. Dabipi Electrical Engineering	EN	$49,956	8750565
Maine				
Bates College Lewiston 04240 Gas Chromatograph Mass Spectrometer for Undergraduate Instruction	Thomas J. Wenzel Chemistry	CH	$27,710	8750027
Bates College Lewiston 04240 Development of the Laboratory for Non-Majors	Eric K. Wollman Physics & Astronomy	PY	$23,441	8750084
Bates College Lewiston 04240 Equipment to Teach Microprocessor Analysis of Video and Analog Signals in an Undergraduate Physiology Laboratory.	Laura G. Malloy Biology	BZ	$30,192	8750377
Bowdoin College Brunswick 04011 A Scanning Electron Microscope for Undergraduate Biology Instruction and Student Research.	William L. Steinhert Biology	BZ	$50,000	8750285
Univerasity of New Englnd Biddeford 04005 Experiments in Receiving Water Analysis	Peter Sereico Div.of Life Science	IN	$11,911	8750719

STATE / INSTITUTION / CITY.ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Maryland				
Capitol Inst of Tech Laurel 20708 An Undergraduate Network and Distributed Processing Laboratory.	Harry Harrison Computer Engineering Tech	EN	$37,991	8750313
Goucher College Towson 21204 An Atomic Absorption Spectrometer for Undergraduate Environmental Studies in Biology and Chemistry	Esther J. Gibbs Chemistry	IN	$22,107	8750765
Morgan State University Baltimore 21239 Enhancement of an Undergraduate, General Purpose Interface Bus (GPIB) Controlled Electrical Engineering Laboratory	Peter H. Anderson Electrical Engineering	EN	$50,000	8750327
Univ of Md Eastern Shore Princess Anne 21853 Upgrading of an Undergraduate Materials Testing Laboratory.	Emin Yilmaz Industrial Education & Te	EN	$16,425	8750325
Washington College Chestertown 21620 Microcomputer and Data Acquisition System for Undergraduate Physics Projects	Juan Lin Physics	PY	$6,767	8750025
Washington College Chestertown 21620 A Polerographic Analyzer System for Undergraduate Laboratories and Student Research	James R. Locker Chemistry	CH	$5,235	8750059
Massachusetts				
Col of the Holy Cross Worcester 01610 Improvement in Advanced Laboratory Using an Instrumental Laboratory Timesharing Concept	George A. Vidulich Chemistry	CH	$50,000	8750477
Col of the Holy Cross Worcester 01610 Modernization of Psychology Natural Science Courses	John F. Axelson Psychology	PS	$26,270	8750546
Col of the Holy Cross Worcester 01610 Equipment to Support Interdisciplinary Research in Anaerobic Bioconversion for Undergraduates.	Banadakoppa T. Lingappa Biology	BZ	$21,064	8750960
Five Colleges Inc Amherst 01002 A Boat Equipped with Survey, Sampling, and Analysis Equipment for a Five College Undergraduate Marine Sciences Program	Paulette M. Peckol Biological Sciences	IN	$30,115	8750160
Mt Holyoke Col South Hadley 01075 Computer Laboratory for Mathematical Experimentation	Robert J. Weaver Mathematics	MA	$36,525	8750848
Mt Holyoke Col South Hadley 01075 Instrumentation for the Physical Chemistry Laboratory	Abha Sur Chemistry	CH	$21,725	8750925

STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Smith College Northampton 01063 Improvement of an Advanced Undergraduate Acoustics Laboratory	Elizabeth S. Ivey Physics	PY	$6,397	8750163
Southeastern Mass Univ North Dartmouth 02747 The Use of a Computer-Interfaced Differential Scanning Calorimater in the Undergraduate Laboratory: A Class-Project Oriented Program	Chang-Ming Wu Chemistry	CH	$14,934	8750943
Wellesley Col Wellesley 02181 Lasers and Other Instrumentation for Modern Spectroscopic Laboratories in the Undergraduate Physics Curriculum	Theodore W. Ducas Physics	PY	$34,883	8750777
Western New England Col Springfield 01119 Computer-Aided Design Hardware and Software for Integration of CAD into the Undergraduate Mechanical Engineering Curriculum.	Mohammad Khosrowjerdi Mechanical Engineering	EN	$40,464	8750738
Williams College Williamstown 01267 Meteorologic and Hydrologic Instrumentation for Undergraduate Field Work	David P. Dethier Geology	IN	$27,723	8750838
Michigan				
Adrian College Adrian 49221 Increased Access to High Quality NMR Spectra	Willard L. Craft Chemistry	CH	$29,630	8750399
Adrian College Adrian 49221 Computer-Aided Radio Telemetry Equipment for Undergraduate Studies in Animal Behavior and Ecology.	Craig Weatherby Biology	BZ	$7,977	8750442
Albion College Albion 49224 Instrumentation for an Integrated Undergraduate Laboratory Program	Robert E. Dininny Chemistry	CH	$34,435	8750716
Central Mich Univ Mount Pleasant 48859 An Undergraduate Laboratory in High Resolution Graphics and Image Processing.	Hari B. Bidasaria Computer Science	CS	$37,330	8750078
Central Mich Univ Mount Pleasant 48859 Courses and Development of a New Course in Analytical Scanning Electron Microscopy and Image Analysis	David J. Matty Geology & Biology	IN	$28,750	8750320
Concordia College Ann Arbor 48105 Computerization of Concordia's Introductory Physics/Earth Science Laboratory	Theodore P. Aufdemberge Div of Natural Sci & Math	IN	$6,948	8750082
Eastern Michigan Univ Ypsilanti 48197 Modernization of the General Chemistry Laboratory by Integration of Computer-Based Experiments	John W. Moore Chemistry	CH	$38,464	8750324

STATE INSTITUTION CITY,ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Eastern Michigan Univ Ypsilanti 48197 Equipment for Undergraduate Instruction in Toxicology	Michael J. Brabec Chemistry	CH	$26,490	8750458
GMI Engr & Mgmt Institute Flint 48502 Improvement of an Undergraduate Electrical Machines Laboratory.	Bhag S. Guru Electrical & Computer Eng	EN	$50,000	8750931
GMI Engr & Mgmt Institute Flint 48502 An Undergraduate Quantitative Materials Measurement and Assessment Laboratory for the Manufacturing and Systems Engineering Program.	Charles V. White Mechanical Engineering	EN	$22,100	8750457
Kalamazoo Col Kalamazoo 49007 Physiological Psychology Expansion Project	Lyn H. Raible Psychology	PS	$13,474	8750179
Kalamazoo Col Kalamazoo 49007 Computerized Data Acquisition in Undergraduate Animal Physiology Laboratories	Paul R. Sotherland Biology	BZ	$9,846	8750850
Lawrence Inst of Tech Southfield 48075 An Undergraduate Electrical Machines Laboratory.	Robert D. Chute Electrical Engineering	EN	$22,494	8750563
Saginaw Valley State Col University Cent 48710 Improving Undergraduate Laboratgory Instruction in Chemistry Through the Use of Energy Dispersive X-Ray Fluorescense Spectroscopy	Peter J. Moehs Chemistry	CH	$34,500	8750521
Univ of Michigan Dearborn Dearborn 48128 An Undergraduate Laboratory for Real Time Computing and Control.	Kiumi Akingbehin Electrical & Computer Eng	EN	$44,586	8750293
Univ of Michigan Dearborn Dearborn 48128 Undergraduate Mechanical Engineering Laboratory Improvement.	Keshav S. Varde Mechanical Engineering	EN	$40,012	8750321
Minnesota				
Bemidji State University Bemidji 56601 Computer Assisted Engineering in an Undergraduate Engineering Physics Program.	Robert C Pickett Physics	EN	$16,310	8750197
Carleton College Northfield 55057 An Undergraduate Computer Graphics Laboratory for Mathematics and Computer Science.	Jack Goldfeather Mathematics	CS	$39,430	8750099
Carleton College Northfield 55057 Improving Undergraduate Instruction in Chemistry Through the Use of a Gas Chromatograph/Mass Selective Detector System	Jerry R. Mohrig Chemistry	CH	$33,412	8750210

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Carleton College Northfield 55057 Purchase of an X-Ray Diffraction Unit for Undergraduate Geology	Mary Savina Geology	EZ	$45,500	8750682
Concordia Col Moorhead Moorhead 56560 Undergraduate Laboratory Equipment for Isolating DNA, RNA, Proteins and Lipids.	James S. Backer Biology	BZ	$23,255	8750632
Gustavus Adolphus College Saint Peter 56082 Instructional Equipment for an Undergraduate Cell Biology Laboratory.	William H. Heidcamp Biology	BZ	$41,011	8750085
Gustavus Adolphus College Saint Peter 56082 Experimental Modern Physics Laboratory Development Project	Steven Mellema Physics	PY	$27,670	8750140
Macalester Col Saint Paul 55105 Equipment for an Undergraduate Field Station Laboratory to Provide On-Site Instruction in Terrestrial and Aquatic Ecology. .	Daniel J. Hornbach Biology	BZ	$17,773	8750483
Mankato State University Mankato 56001 A Gas Chromatograph/Mass Spectrometer for Undergraduate Instruction in an Interdisciplinary Toxicology Program	Steven D. Mercurio Biology	BZ	$41,628	8750844
Mankato State University Mankato 56001 Development of Biochemistry Laboratory Curriculum	Theresa A. Salerno Chemistry & Geology	CH	$22,274	8750845
St Cloud State Univ Saint Cloud 56301 Instrumentation to Develop an Analytical Chromatography Laboratory for Undergraduate Biology.	David K. DeGroote Biological Sciences	BZ	$24,292	8750520
St Olaf College Northfield 55057 Polymer Chemistry in the Physical Chemistry Laboratory Using a Differential Scanning Calorimeter and Gel Permeation Liquid Chromatography Equipment	George L. Hardgrove, Jr. Chemistry	CH	$29,278	8750342
St Olaf College Northfield 55057 Undergraduate Laboratory Equipment for the Teaching of Genetics.	Alice J. Burton Biology	BZ	$21,670	8750343
St Olaf College Northfield 55057 Electronic Instruments and Peripherals for a Computerized Physics Laboratory	Duane N. Olson	PY	$17,469	8750344
Winona State Univ Winona 55987 Psychology Experimental Methods Lab	Kerry G. Williams Psychology	PS	$17,392	8750609

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Mississippi				
Delta State University Cleveland 38733 Enhancement of General Chemistry through a Microcomputer Laboratory for Tutorial Work and Data Analysis	J.Paul Hollomon Physical Sciences	CH	$12,580	8750608
Mississippi College Clinton 39058 Modern Gas Chromatography for an Instrument-Oriented Chemistry Program	John W. Legg Chemistry	CH	$7,076	8750248
Missouri				
Southeast Mo State Univ Cape Girardeau 63701 Centrifugation Equipment to Enhance Undergraduate Education in Molecular Biology.	Walt L. Lilly Biology	BZ	$23,855	8750903
Southwest Mo State Univ Springfield 65804 Strengthening Undergraduate Organic and Analytical Chemistry--NMR	Vernon J. Thielmann Chemistry	CH	$50,000	8750708
Southwest Mo State Univ Springfield 65804 Improving Undergraduate Cartography Education with Graphics and Data Base Systems	William T. Corcoran Geosciences	IN	$37,878	8750709
Montana				
Eastern Montana Col Billings 59101 The Use of Microcomputers to Substitute for and Supplement Traditional Laboratory Equipment in Psychology	Judith A. McLaughlin Psychology	PS	$13,609	8750882
Mt Col Mineral Sci & Tech Butte 59701 An Undergraduate Rock Fragmentation Laboratory for Mining Geophysical Engineers.	Karl E. Burgher Mining & Geophysical Engi	EN	$14,499	8750031
Nebraska				
Col of St Mary Omaha 68124 Computerization of the Introductory Physiology Laboratory	Jerome J. King Biology	BZ	$7,193	8750201
New Hampshire				
Saint Anselm College Manchester 03102 The Research Commons Approach to Teaching General Biological Research Processes.	Daniel J. Lavoie Biology	BZ	$17,632	8750891

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New Jersey				
Kean College of NJ Union 07083 An Integrated Approach to the Teaching of NMR Methods at the Undergraduate Level	Dale E. Vitale Chemistry & Physics	CH	$30,850	8750267
Rutgers University Camden Camden 08102 Equipment for Preparing Plastic Histologic Sections for an Undergraduate Light Microscopy Program.	William J. Bacha, Jr. Biology	BZ	$6,575	8750222
Rutgers University Camden Camden 08102 Observational Laboratory in Developmental Psychology	Harvey Lesser Psychology	PS	$23,976	8750957
Rutgers University Camden Camden 08102 Update of the Microprocessor Laboratory Equipment	David A. Prescott Physics	PY	$14,535	8750969
Trenton State College Trenton 08625 An Undergraduate Automated Test and Measurements Laboratory.	Alois J. Riederer Electrical Engineering Te	EN	$45,683	8750950
New Mexico				
Col of Santa Fe Santa Fe 87501 Equipment for Improving Undergraduate Studies in Physiology and Microscopy.	David W. Johnson Science & mathematics	BZ	$12,999	8750401
New York				
Albany Col of Pharmacy Albany 12208 Application of NMR Instrumentation in the Undergraduate Pharmacy Curriculum	Dan R. Bruss Physical Science	CH	$31,700	8750088
CUNY H L Lehman College New York 10468 Modernization of Introductory Physics Laboratories Using Computers	John R. Gillespie Physics & Astronomy	PY	$6,694	8750657
CUNY H L Lehman College New York 10468 Improvement of Instrument Based Instruction in Chemistry	Reuben L. Baumgarten Chemistry	CH	$36,216	8750789
CUNY Hunter College New York 10021 A New Computer Interfaced Undergraduate Physics Laboratory	Rodney L. Varley Physics & Astronomy	PY	$16,777	8750582
CUNY Hunter College New York 10021 Equipping an Undergraduate Instructional Laboratory with the Tools of the Molecular Biologist.	Rivka Rudner Biological Sciences	BZ	$45,150	8750842
CUNY Hunter College New York 10021 Undergraduate Laboratory for Remote Sensing, Digital Image Processing, Automated Cartography and Geographic Information Systems	Alan H. Strahler Geology & Geography	EZ	$50,000	8750866

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Canisius Col Buffalo 14208 Chemical Separations and Microscale Syntheses	Joseph F. Bieron Chemistry	CH	$22,291	8750139
Canisius Col Buffalo 14208 An Undergraduate Imaging and Operating Systems Laboratory Enhancement.	James A. Leone Computer Science	CS	$37,890	8750291
Colgate University Hamilton 13346 An Undergraduate Parallel Processing Computer Laboratory	Christopher H. Nevison Computer Science	CS	$35,892	8750392
Colgate University Hamilton 13346 Physiological Instrumentation for Basic and Advanced Undergraduate Laboratories.	Nancy L. Pruitt Biology	BZ	$40,014	8750793
Colgate University Hamilton 13346 Instrumentation for an Undergraduate Recombinant DNA Laboratory.	Robert F. Pohlman Div.of Natural Scie.& Mat	BZ	$50,000	8750861
Colgate University Hamilton 13346 High Sensitivity Charged Coupled Device (CCD) Imaging in Undergraduate Astronomy	Thomas J. Balonek Physics & Astronomy	PY	$32,297	8750955
Hobart & Wm Smith Cols Geneva 14456 Macroeconomic Model Building Workshop with Computer Support for Upper Level Quantitative Economics Courses	Patrick A. McGuire Economics	SZ	$6,523	8750766
Hobart & Wm Smith Cols Geneva 14456 Growth Chambers for Use in Laboratory Studies and Undergraduate Research.	Joel T. Kerlan Biology	BZ	$14,550	8750916
Iona College New Rochelle 10801 NMR Spectroscopy: Course Revision, Interfacing and Dissemination for Undergraduate Instruction	Jerome S. Levkov Chemistry	CH	$26,546	8750953
Long Island U Brooklyn New York 11201 Microcomputer Interfacing and Microelectronics	Donald W. Rogers Chemistry	CH	$7,116	8750827
Manhattan College Riverdale 10471 Membrane Gas Separation Experiments for an Undergraduate Chemical Engineering Laboratory.	C.Stewart Slater Chemical Engineering	EN	$21,504	8750858
Medaille Col Buffalo 14214 Equipping a Microscope Resource Center for Undergraduates.	Brian R. Shero Science	BZ	$24,425	8750282
Rochester Inst of Tech Rochester 14623 Development of an Undergraduate Laser Doppler Anemometry Laboratory	Alan H. Nye Mechanical Engineering	EN	$29,697	8750703

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Rochester Inst of Tech Rochester 14623 A Workstation Environment for an Undergraduate Computer Graphics Sequence	Evelyn P. Rozanski Undergraduate Computer Sc	CS	$50,000	8750705
SUNY College at Buffalo Buffalo 14222 Improving an Undergraduate Interdisciplinary Aquatic Science Program on Lake Erie and the Niagara River	James R. Spotila Aquatic Science Program	IN	$46,872	8750426
SUNY College at Buffalo Buffalo 14222 Videotape-Computer-Assisted Introductory Laboratory for Physics	Michael J. DeMarco Physics	PY	$16,779	8750443
SUNY College at Buffalo Buffalo 14222 Improvement of Undergraduate Advanced Cell Biology and Recombinant DNA Technology Courses.	Bonnie M. Sampsell Biology	BI	$22,612	8750648
SUNY College at New Paltz New Paltz 12561 Upgrading an Interdisciplinary Electron Microscopy Facility for Undergraduates	B L Redmond Electron Microscopy Facil	IN	$46,775	8750376
SUNY College at Oneonta Oneonta 13820 Plant Growth Chambers for Undergraduate Laboratories	Currie D. Marr Biology	BI	$11,160	8750023
Siena College Loudonville 12211 Computer Graphics Equipment to Enhance Undergraduate Curriculum	Edward M. Crosson Computer Science	CS	$49,404	8750275
Siena College Loudonville 12211 The Development of a Facility for Symbolically-Aided Instruction in Mathematics and Physics.	Russell Dubisch Physics	MA	$28,610	8750276
Siena College Loudonville 12211 Modern IR and UV/VIS Spectrophotometry in the Undergraduate Chemistry Curriculum	Karen S Quasl Chemistry	CH	$21,890	8750540
Skidmore Col Saratoga Spring 12866 Developing Archaeological Field Methods and Laboratory Analysis in Undergraduate Education and Research.	Susan J. Bender Sociology/Anthropology/So	SI	$9,580	8750390
Vassar College Poughkeepsie 12601 Enhancement of Laboratory Facilities in Human Perception and Cognition	Janet K. Andrews Psychology	PS	$14,576	8750798
Webb Inst of Naval Arch Glen Cove 11542 Improvement of a Model Towing Tank for an Undergraduate Naval Architecture Laboratory	Lawrence W. Ward	EN	$15,726	8750485

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North Carolina				
Appalachian State Univ Boone 28608 Modern Optics Equipment for Undergraduate Laboratories	Karl C. Mamola Physics & Astronomy	PY	$18,149	8750796
Appalachian State Univ Boone 28608 Gas Chromatography/Mass Spectrometry in an Undergraduate Chemistry Curriculum	Stephen D. Williams Chemistry	CH	$20,050	8750809
Appalachian State Univ Boone 28608 Enhancement of Computer Cartography Instruction and Laboratory	William A. Imperatore Geography & Planning	SZ	$12,617	8750863
Catawba Col Salisbury 28144 Modern Cellular and Molecular Biology in the Undergraduate Curriculum.	Steven J. Coggin Biology	BZ	$30,256	8750386
Davidson Col Davidson 28036 Improving Undergraduate Instruction in Chemistry Through the Use of a Photodiode Array Ultraviolet-Visible Spectrophotometer	Felix A. Carroll Chemistry	CH	$9,921	8750021
Johnson C Smith Univ Charlotte 28216 Enhancement of the Laboratory Experience in Introductory Physics Courses through the Use of Computers	Geoffrey L. Wilson Chemistry & Physics	PY	$17,767	8750823
Methodist Col Fayetteville 28301 Developing Scientists in Psychology	Theodore B. Jaeger Psychology	PS	$9,522	8750245
N C Agric & Tech St Univ Greensboro 27411 Enhanced Undergraduate Instruction in Graphics Science	Sanjiv Sarin Industrial Engineering	EN	$38,660	8750634
U of N C at Charlotte Charlotte 28223 Upgrade and Computerization of Undergraduate Solid State Laboratories	Robert G. Aitken Physics	PY	$13,155	8750361
U of N C at Charlotte Charlotte 28223 Undergraduate Laboratory Enhancement Through Computer Interective Experimentation	G P Mohanty Mechanical Engr & Engr Sc	EN	$41,773	8750412
Univ of N C at Asheville Asheville 28814 Microcomputers for Introductory and Advanced Undergraduate Physics Laboratories	Charles A. Bennett, Jr. Physics	PY	$8,700	8750195
Univ of N C at Asheville Asheville 28814 An Undergraduate VLSI Design Workstation Laboratory	Wayne Lang Computer Science	EN	$12,732	8750237
Univ of N C at Asheville Asheville 28814 Advances in Research Methods Education: Computer Applications in Design, Analysis, and Interfacing	Tracy L. Brown Psychology	PS	$13,746	8750369

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Western Carolina Univ Cullowhee 28723 Expanding Experimental Psychology Laboratory: A Three-Field Tachistoscope for Enhancing Undergraduate Research and Courses in Human Information Processing	Hedy White Psychology	PS	$6.717	8750204
North Dakota				
Jamestown Col Jamestown 58401 Undergraduate Biology & Chemistry Equipment for Upgrading Course Laboratories and Student Research Opportunities.	John F. Brauner Biology	BZ	$47.692	8750255
Ohio				
Denison Univ Granville 43023 The Use of Computer Algebra Systems in Teaching Introductory Calculus	Zaven A. Karian Mathematical Sciences	MA	$36.000	8750137
Denison Univ Granville 43023 Improving Undergraduate Economic Instruction with a Computer Laboratory.	Robin L. Bartlett Economics	SZ	$30.173	8750174
Denison Univ Granville 43023 FTIR Instrumentation for Undergraduate Instruction	William A. Hoffman, Jr. Chemistry	CH	$21.150	8750741
Hiram Col Hiram 44234 Instrumentation for Undergraduate Studies of Physiology, Endocrinology, Cellular and Molecular Biology	Dennis J. Taylor Biology	BZ	$22.389	8750865
Kenyon Col Gambier 43022 Equipment for Teaching in Vitro Plant Tissue and Organ Culture Techniques to Undergraduates.	Dorothy E. Jegla Biology	BZ	$13.683	8750368
Marietta Col Marietta 45750 Providing Expert System Development Tools to Undergraduate Students	Larrie V. Hutton Computer Science	CS	$22.005	8750596
Oberlin Col Oberlin 44074 Equipment for an Undergraduate Neurochemistry and Neuropharmacology Laboratory.	Dennison A. Smith Neuroscience Program	BZ	$14.448	8750118
Oberlin Col Oberlin 44074 Purchase of a Fourier-Transform Infrared Spectrometer	Norman C. Craig Chemistry	CH	$19.300	8750723
Otterbein Col Westerville 43081 Computer Simulation and Computer Data Acquisition in Undergraduate Physics	Louis G. Arnold Physics & Astronomy	PY	$9.525	8750148
Xavier Univ Cincinnati 45207 Modernization of an X-Ray Physics Laboratory Program for Undergraduates	Stephen C. Yerian Physics	PY	$10.081	8750228

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Oregon				
Concordia Col Portland 97211 Facilitation of Research by Undergraduates in Life Science.	Charles J. Kunert Life Science	BZ	$9,153	8750673
Linfield Col McMinnville 97128 NMR in Undergraduate Instrumentation in Chemistry and Physics	Robert G. Wolcott Chemistry	CH	$26,372	8750192
Reed Col Portland 97202 Acquisition of a FT-IR Instrument, and its Integration into Reed College's Chemistry Curriculum	John E. Hancock Chemistry	CH	$30,531	8750840
Southern Oregon State Col Ashland 97520 A Scanning Electron Microscope for Undergraduate Biological Instruction and Independent Research.	Darlene N. Southworth Biology	BZ	$28,354	8750176
Univ of Portland Portland 97203 An Undergraduate Systems Software Engineering Laboratory.	Michael C. Mulder Electrical Engineering	CS	$50,000	8750355
Univ of Portland Portland 97203 An Undergraduate, Interdisciplinary, Computer-Integrated Manufacturing Laboratory.	Ming-Shu Hsu Mechanical Engineering	EN	$50,000	8750487
Pennsylvania				
Albright Col Reading 19604 A High Speed Centrifuge to Complete the Development of an Undergraduate Course in Molecular Genetics.	Gerald L. Kreider Biology	BZ	$8,462	8750872
Bucknell Univ Lewisburg 17837 Modernization of the Undergraduate Geotechnical Engineering Laboratory.	Jeffrey C. Evans Civil Engineering	EN	$26,807	8750157
Bucknell Univ Lewisburg 17837 A Laboratory Course at the Interface of Chemistry and Biology	Mitchell I. Chernin Biology & Chemistry	IN	$43,462	8750783
Bucknell Univ Lewisburg 17837 Velocity Measuring Equipment for the Undergraduate Thermo-Fluids Laboratory.	James N. Zaiser Mechanical Engineering	EN	$23,630	8750917
Chestnut Hill Col Philadelphia 19118 Quality Laboratory Instruction for the Undergraduate Chemistry/Biochemistry Major in Analytical Techniques and Research Capabilities	Helen M. Burke Chemistry	CH	$8,784	8750633
Franklin & Marshall Col Lancaster 17604 A Research-Intensive Approach to Undergraduate Education in Psychology	Mark Wagner Psychology	PS	$16,699	8750413

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Gannon University Erie 16541 Development of an Undergraduate Computer-aided Design and Test Laboratory.	Samuel L. Hazen Electrical Engineering	EN	$46,170	8750876
Gwynedd-Mercy Col Gwynedd Valley 19437 Integration of Biochemical Analysis Techniques into an Undergraduate Biology Curriculum.	Felicia Corsaro-Barbieri Natural Science & Mathema	BZ	$7,400	8750069
Haverford Col Haverford 19041 Acquisition of a Transmission Electron Microscope for Undergraduate Instruction and Research	M.Kaye Edwards Biology	BZ	$50,000	8750418
Holy Family Col Philadelphia 19114 Improving Undergraduate Instruction in Organic Chemistry Through Proton NMR Spectrometry	M.Bernice Andrelczyk Chemistry	CH	$26,500	8750597
Indiana U of Pennsylvania Indiana 15705 Sputtering Facility for Undergraduate Students	John N. Fox Physics	PY	$9,147	8750009
Juniata Col Huntingdon 16652 Unix C and Graphics Upgrade of the Undergraduate Computer Science Program.	Dale L. Wampler Mathematics & Computer Sc	CS	$37,930	8750290
La Salle University Philadelphia 19141 Incorporation of Fourier Transformation Methodology into La Salle University's Undergraduate Chemistry Curriculum	David J. Cichowicz Chemistry	CH	$11,500	8750760
Lafayette Col Easton 18042 FT-IR for Upper Division Undergraduate Chemistry Laboratories	Dana P. McDermott Chemistry	CH	$19,200	8750822
Lebanon Valley Col Annville 17003 The Introduction of a Gas Chromatograph/Mass Spectrometer into the Chemistry Curriculum to Strengthen Laboratory Instruction	Owen A. Moe, Jr. Chemistry	CH	$22,890	8750577
Lebanon Valley Col Annville 17003 Ultracentrifuge and Electrophoresis Equipment for Undergraduate Instruction in Genetics, Molecular Biology, and Biochemistry	Sidney Pollack Biology	IN	$26,107	8750769
Pa St U Behrend College Erie 16563 An Ultraviolet-Visible Computing Spectrophotometer for Laboratory Courses and Undergraduate Research	Alan J. Jircitano Div.of Sci. Engr.& Techno	CH	$7,431	8750396
Rosemont Col Rosemont 19010 NMR Spectrometry for an Improved Undergraduate Chemistry Program	Suzanne P. Varimbi Chemistry	CH	$25,850	8750834

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St Joseph's University Philadelphia 19131 Integration of Tissue Culture Techniques into the Undergraduate Biology Curriculum.	Paul M. Tefft Biology	BZ	$22,985	8750549
Swarthmore Col Swarthmore 19081 A Graphics Workstation Laboratory for Upper-Level Undergraduate Engineering Education	Stephen M. Platt Engineering	EN	$19,738	8750799
Univ of Pitt Johnstown Johnstown 15904 A Computerized Data Acquisition System for an Undergraduate Engineering Technology Strength of Materials Laboratory.	M.Richard Feller Engineering Technology Di	EN	$13,912	8750050
Univ of Scranton Scranton 18510 An Undergraduate Software Engineering Laboratory	John A. Beidler Math/Computer Science	CS	$48,660	8750630
W Chester Univ of Penn West Chester 19383 Instrumentation to Improve Undergraduate Instruction in Physiology and Cellular Biology.	Jack Weber Biology	BZ	$26,600	8750434
Westminster Col New Wilmington 16142 Improvement of the Chemistry Advanced Laboratory Program Through the Addition of Differential Scanning Calorimetry	Percy Werrick, Jr. Chemistry	CH	$5,300	8750678
Westminster Col New Wilmington 16142 The Addition of Laser Techniques to Advanced Laboratories in Physics and Chemistry	G.Samuel Lightner Physics	IN	$9,786	8750952
Widener Col Penn Campus Chester 19013 On-Line Analysis for an Undergraduate Chemical Engineering Laboratory.	John W. Hoopes, Jr. Chemical Engineering	EN	$14,425	8750339
Widener Col Penn Campus Chester 19013 Open Circuit Low Turbulence Wind Tunnel with Three-Component Sting Balance for an Undergraduate Fluid Dynamics Laboratory	John E. Molyneux Mechanical & Civil Engine	EN	$33,700	8750611
Puerto Rico				
Humacao University Col Humacao 00661 Upgrading of the Environmental Chemistry Laboratory through the Implementation of Water and Air Quality Surveillance Stations	Sonia L. Vazquez-Garcia Chemistry	CH	$31,677	8750795
Int-Amer U PR San German San German 00753 Field and Laboratory Equipment for an Undergraduate Ecology and Environmental Sciences Program in the Caribbean.	Hector Quintero Biology	BZ	$24,413	8750717
Inter Amer U PR Metro Cam Hato Rey 00919 Equipment to Upgrade the Undergraduate Biology Curriculum, with Emphasis on Microbiology.	Freddy R. Medina Biology	BZ	$43,244	8750497

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Rhode Island				
Rhode Island College Providence 02908 Improving Undergraduate Instruction with High Pressure Liquid Chromatography and Atomic Absorption	James G. Magyar Physical Science	CH	$19,481	8750620
Roger Williams College Bristol 02809 Updating the Biology and Chemistry Curriculums with a a High Performance Liquid Chromatograph	Daniel D. Von Riesen Chemistry	IN	$6,400	8750134
South Carolina				
College of Charleston Charleston 29424 A Four College Automatic Photoelectric Telescope for Astronomical Training and Research	Robert J. Dukes Physics	PY	$70,000	8616362 *
Erskine Col & Seminary Due West 29639 Improved Teaching of Analytical Methods in an Undergraduate Molecular-Cellular Biology Laboratory.	George W. Shiflet, Jr. Biology	BZ	$26,854	8750138
Furman Univ Greenville 29613 Introduction of High-Field Nuclear Magnetic Resonance Spectroscopy into the Undergraduate Curriculum	Noel Kane-Maguire Chemistry	CH	$50,000	8750209
Furman Univ Greenville 29613 Psychology Microcomputer Laboratory	John D. Batson Psychology	PS	$29,098	8750875
Presbyterian Col Clinton 29325 A Computer-Managed Laboratory for Physiological and Experimental Psychology	Marion T. Gaines, IV Psychology	PS	$7,741	8750514
South Dakota				
Augustana Col Sioux Falls 57197 Equipment to Enhance an Undergraduate Biotechnology Curriculum.	Oscar H. Will, III Biology	BZ	$18,417	8750043
Tennessee				
Austin Peay State Univ Clarksville 37040 Integration of a Fourier Transform Infrared Spectrometer into the Chemistry Curriculum	Harvey F. Blanck Chemistry	CH	$18,608	8750101
Belmont Col Nashville 37203 Upgrading of an Undergraduate Modern Physics Laboratory	W.David Driskill Chemistry & Physics	PY	$5,500	8750561
Christian Brothers Col Memphis 38104 Undergraduate Electrical Engineering Student Development Workstations.	Donald Glaser Electrical Engineering	EN	$50,000	8750504
Maryville Col Maryville 37801 Introduction of Psychobiology into the Curriculum	Jerry E. Waters Div of Natural Sciences	PS	$9,487	8750121

* Jointly funded project--College Science Instrumentation Program, $20,000; Stars and Stellar Evolution Program, $50,000.

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Texas				
Incarnate Word Col San Antonio 78209 Equipment for Undergraduate Instruction in Biochemistry, Molecular Biology and their Applications in Biotechnology.	Catalina Fresquez Chemistry	BZ	$11,696	8750970
Sam Houston State Univ Huntsville 77341 Undergraduate Laboratory Equipment for Teaching Molecular Biology and Biotechnology.	Harold F. Foerster Life Sciences	BZ	$11,587	8750770
Trinity Univ San Antonio 78284 Optical Activity Determinations in Chemistry and Biochemistry	Nancy S. Mills Chemistry	CH	$14,540	8750180
Trinity Univ San Antonio 78284 Energy-Dispersive X-ray Fluorescence Spectrometry: Undergraduate Applications in Geology and Geochemistry	Diane R. Smith Geology	EZ	$38,650	8750215
U of Houston Downtown Col Houston 77002 Integration of Microcomputer-based Instruction into Business Statistics Courses	Carol Jones Applied Mathematical Scie	MA	$42,000	8750352
Utah				
Weber St Col Ogden 84408 Upgrading an Undergraduate Engineering Technology Process Instrumentation and Control Laboratory.	G.Reed Marchant Electronic Engr.Technolog	EN	$50,000	8750603
Weber St Col Ogden 84408 Acquisition of Gamma-ray Spectrometer System for Undergraduate Nuclear Physics Laboratory	Rondo N. Jeffery Physics	PY	$18,027	8750830
Vermont				
Lyndon St Col Lyndonville 05851 Modernizing an Undergraduate Synoptic Meteorology Laboratory	William Fingerhut Meteorology	EZ	$13,475	8750236
Middlebury Col Middlebury 05753 A Multi-Telescope Observatory for Undergraduate Astronomy	Stephen J. Ratcliff Physics	PY	$24,632	8750416
Norwich Univ Northfield 05663 An Undergraduate Environmental Monitoring Laboratory Data Acquisition System.	Gregory D. Wight Engineering & Technology	EN	$9,160	8750154
Virgin Islands				
Col of the Virgin Islands Charlotte Amali 00802 Computer Graphics Laboratories for Dynamic Modeling and Visualization of Mathematical and Scientific systems	Lynn Rosenthal Science & Mathematics	IN	$17,510	8750928

STATE INSTITUTION CITY,ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Virginia				
Christopher Newport Col Newport News 23606 A Low Temperature Thermal Measurement System for Undergraduate Students	Raouf L. Selim Physics	PY	$14,675	8750149
Hampden-Sydney Col Hampden Sydney 23943 Atomic Absorption Spectrometry for a Project-Based Laboratory Program	Herbert J. Sipe, Jr. Chemistry	CH	$10,050	8750395
Hollins College Hollins College 24020 Electrophoretic Equipment for Improving Undergraduate Biology and Chemistry Programs.	Sandra Boatman Biology & Chemistry	BZ	$7,160	8750380
James Madison Univ Harrisonburg 22807 Experimental Nuclear Chemistry in the Undergraduate Curriculum	Daniel M. Downey Chemistry	CH	$19,992	8750124
Mary Washington College Fredericksburg 22401 Broadening Opportunities for Undergraduate Laboratory Research in Psychology	Steve R. Hampton Psychology	PS	$9,365	8750681
Radford Univeraity Radford 24142 Automated Land Resources Inventory and Analysis System	Bernd M. Kuennecke Geography	EZ	$50,000	8750086
Radford Univeraity Radford 24142 Environmental Chambers to Improve the Undergraduate Biology Curriculum.	Eugene V. Gourley Biology	BZ	$25,500	8750261
Randolph-Macon Col Ashland 23005 Statistical Computing in Undergraduate Psychology	Lucien T. Winegar Psychology	PS	$12,564	8750408
Randolph-Macon Col Ashland 23005 Introductory Astronomy Laboratory Upgrade	George F. Spagna, Jr. Physics	PY	$7,536	8750772
Randolph-Macon Womans Col Lynchburg 24503 Development of Physiological Psychology and Psychophysiology Laboratory Facilities	Dennis M. Goff Psychology	PS	$20,008	8750734
Washington and Lee Univ Lexington 24450 Nuclear Magnetic Resonance Spectroscopy	Michael A. Pleva Chemistry	CH	$30,850	8750106
Washington				
Central Washington Univ Ellensburg 98926 Undergraduate Instruction in Geographic Information Systems	William C. Smith Anthropology	IN	$50,000	8750132
Eastern Washington Univ Cheney 99004 An Upgraded Undergraduate Materials and Mechanical Engineering Laboratory.	Michael A. Brzoska Technology	EN	$8,052	8750650

STATE INSTITUTION CITY,ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Evergreen State College Olympia 98505 Upgrading the Undergraduate Interdisciplinary Science Programs with X-Ray Microanalysis and Scanning Electron Microscopy.	James M. Stroh Earth & Biological Scienc	IN	$42,996	8750411
Evergreen State College Olympia 98505 Improving the Undergraduate Chemistry Curriculum with a Gas Chromatograph-Mass Spectrometer	Frederick D. Tabbutt Chemistry	CH	$39,887	8750598
Gonzaga Univ Spokane 99258 A Multiple Local Area Network for Undergraduate Engineering Education in Computer-integrated Design and Manufacturing.	Ferd H. Mitchell Electrical Engineering	EN	$50,000	8750725
Heritage College Toppenish 98948 Instrumentation for Undergraduate Biochemistry and Cellular Biology Laboratories.	Virginia B. Brown Science & Mathematics	BZ	$16,309	8750901
Seattle Pacific Univ Seattle 98119 Undergraduate Instrumentation and Design Computer Workstations.	Edward J. Baumen Electrical Engineering	EN	$44,964	8750819
Seattle Univ Seattle 98122 An Undergraduate Very Large Scale Intergrated Circuit Design and Test Laboratory.	Gary J. Erickson Electrical Engineering	EN	$49,150	8750312
Seattle Univ Seattle 98122 Enhancing Undergraduate Laboratory Experiences in Wastewater and Hazardous Waste Treatment.	Rolf T. Skrinde Civil Engineering	EN	$7,682	8750571
St Martin's College Lacey 98503 Improvement in Engineering Education through Computer Aided Design and Drafting	Nader Ghafoori Civil Engineering	EN	$29,632	8750674
Univ of Puget Sound Tacoma 98416 Development of an Undergraduate Computer Graphics Laboratory	Carol M. Smith Computer Science	CS	$31,405	8750013
Univ of Puget Sound Tacoma 98416 Integration of a Fourier Transform Infrared Spectrometer into the Chemistry Undergraduate Curriculum	Kenneth Rousslang Chemistry	CH	$25,500	8750047
Univ of Puget Sound Tacoma 98416 An Undergraduate Fluid Phenomena Laboratory	Alan S. Thorndike Physics	PY	$6,440	8750048
Univ of Puget Sound Tacoma 98416 Equipment to Quantify Undergraduate Course Work and Independent Studies in Animal Behavior.	Terrance R. Mace Biology	BZ	$18,471	8750166
Univ of Puget Sound Tacoma 98416 An X-ray Microanalysis System for Undergraduate Geology	J.Stewart Lowther Geology	EZ	$34,682	8750167

STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Univ of Puget Sound Tacoma 98416 Multidisciplinary X-ray Laboratory	Keith O. Berry Chemistry	IN	$50,000	8750284
Western Washington Univ Bellingham 98225 Improvement of an Undergraduate Laboratory Curriculum in Molecular/Cellular Biology.	Hubertus E. Kohn Biology	BZ	$21,457	8750902
West Virginia				
Marshall Univ Huntington 25701 Instrumentation for a Core Undergraduate Course Laboratory in Cellular Biology.	Alan R. White Biological Sciences	BZ	$42,460	8750488
Wisconsin				
Edgewood Col Madison 53711 Atomic Absorption Spectroscopy to Enhance the Undergraduate Laboratory Science Curriculum	Philip K. Welty Physical Science	CH	$8,985	8750475
Edgewood Col Madison 53711 Environmentally Controlled Chambers to Improve Project-Centered Experience in Biology for Non-Majors.	James Lorman Biology	BZ	$5,577	8750548
Lawrence Univ Appleton 54912 Lasers and Modern Optics in Undergraduate Institutions	John R. Brandenberger Physics	PY	$32,260	8750076
Lawrence Univ Appleton 54912 Equipment to Improve the Light Microscopy Program in Undergraduate Biology Laboratories.	William J. Perreault Biology	BZ	$12,573	8750525
Lawrence Univ Appleton 54912 Improvement of Psychology Laboratory Curriculum.	Peter S. Glick Psychology	PS	$9,650	8750965
Ripon Col Ripon 54971 Psychophysical Laboratories in Spatial Vision	J.Timothy Petersik Psychology	PS	$5,814	8750004
Ripon Col Ripon 54971 Undergraduate Nuclear Physics Laboratory	Mary E. Williams-Norton Physics	PY	$8,221	8750024
St Norbert Col De Pere 54115 Equipment to Support Undergraduate Instruction in Riverine Ecology.	James R. Hodgson Biology	BZ	$8,105	8750735
St Norbert Col De Pere 54115 Microcomputer Based Psychology Student Research Laboratory	Sharyl B. Peterson Psychology	PS	$12,634	8750737
St Norbert Col De Pere 54115 Nuclear Magnetic Resonance Spectroscopy in Undergraduate Chemistry Instruction	David L. Klopotek Chemistry	CH	$30,400	8750790

STATE / INSTITUTION / CITY,ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISCIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Univ of Wis Eau Claire Eau Claire 54701 Multidisciplinary Use of an Atomic Absorption Spectrometer in Undergraduate Chemistry and Geology	Robert J. Eierman Chemistry & Physics	IN	$12,807	8750810
Univ of Wis La Crosse La Crosse 54601 Incorporation of Modern Molecular Techniques into the Undergraduate Microbiology Curriculum.	Michael R. Winfrey Biology & Microbiology	BZ	$47,310	8750784
Univ of Wis La Crosse La Crosse 54601 An Undergraduate Computer Aided Software Engineering Laboratory.	David D Riley Computer Science	CS	$50,000	8750820
Univ of Wis Oshkosh Oshkosh 54901 Fourier Transform Infrared Spectroscopy in the Undergraduate Chemistry Laboratory Curriculum	Timothy F Crimmins Chemistry	CH	$22,250	8750071
Univ of Wis Oshkosh Oshkosh 54901 Simulation of the National Economy for Macroeconomics Classes	David G. Blanchard Economics	SZ	$16,995	8750534
Univ of Wis Oshkosh Oshkosh 54901 Undergraduate Laboratory Instrumentation for Biotechnology	Robert L Williams Biology & Microbiology	BZ	$11,774	8750560
Univ of Wis Oshkosh Oshkosh 54901 A Computer Graphics Workstation for Digital Signal Processing In Undergraduate Physics and Geophysics	John H. Karl Physics	PY	$16,256	8750800
Univ of Wis Parkside Kenosha 53141 Acquisition of X-ray Powder Diffraction Facilities and Upgrading of the Undergraduate X-Ray Scattering Laboratory	Peter A Nielsen Geology Program/Science D	IN	$34,687	8750162
Univ of Wis River Falls River Falls 54022 The Incorporation of Fundamentals of Ultrasonic Materials Characterization into the Undergraduate Physics Curriculum	Curtiss O Larson Physics	PY	$11,960	8750111
Univ of Wis Whitewater Whitewater 53190 Computer Graphics for Geographic Analysis and Problem Solving	Dennis M. Richter Geography	SZ	$15,775	8750740
Univ of Wis Whitewater Whitewater 53190 Equipment to Facilitate Undergraduate Laboratory Investigations in Cellular Biology.	John J. Ruffolo Biology	BZ	$28,551	8750803

ATTACHMENT 2

TABLE 2

NATIONAL SCIENCE FOUNDATION

RESEARCH EXPERIENCES FOR UNDERGRADUATES
1987 AWARDS - SITES AND SUPPLEMENTS

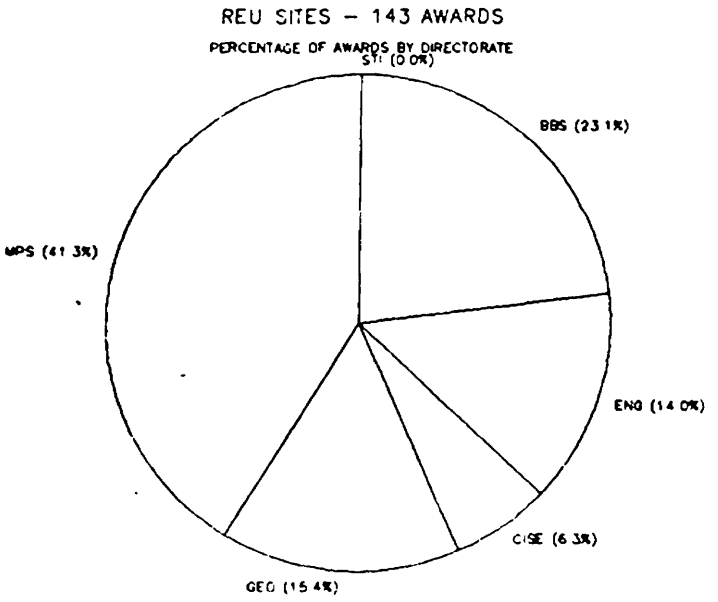
NSF DIRECTORAT	# SUPP AWARDS	$ (K) AWARDED	# SITE AWARDS	$ (K) AWARDED	TOTAL AWARDS	TOTAL $ (K)
GEO	178	$1,463	22	$630	200	$2,093
ENG	90	$862	20	$1,054	110	$1,916
BBS	293	$2,374	33	$1,212	326	$3,586
MPS	183	$1,371	59	$1,912	242	$3,283
STI	14	$21	0	$0	14	$21
CISE	77	$618	9	$397	86	$1,015
TOTALS -	835	$6,709	143	$5,205	978	$11,914

TYPES OF INSTITUTIONS FUNDED

		2-YEAR COLLEGES	4-YEAR COLLEGES	PhD UNIV.	OTHER	TOTALS
SITES	# AWARDS	0	18	118	7	143
	% AWARDS	0%	12%	83%	5%	100%
SUPPLEMENT	# AWARDS	0	67	739	27	835
	% AWARDS	0%	8%	89%	3%	100%

GEOGRAPHIC DISTRIBUTION - SITE AWARDS 43 STATES
SUPPLEMENTS - 47 STATES, GUAM & PUERTO RICO

TABLE 3


REU SITES – 143 AWARDS
PERCENTAGE OF AWARDS BY DIRECTORATE
STI (0.0%)
BBS (23.1%)
ENG (14.0%)
CISE (6.3%)
GEO (15.4%)
MPS (41.3%)

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RESEARCH EXPERIENCES FOR UNDERGRADUATES
FY 1987 SITES AWARDS

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
ALASKA				
U of Alas-Geophys Inst Fairbanks 997750800 Summer Intern Program for Undergraduates	Daniel W. Swift Geophysical Institute	ATM	$40.000	8712048
ALABAMA				
Auburn Univ Auburn 36849 Research Experiences for Undergraduates (Materials Research)	Ralph M. Zee Mechanical Eng Department	ENGR	$40.000	8712221
U of Ala in Huntsville Huntsville 35899 Knowledge Organization for Machine Systems: A Research Program for Undergraduate Students (Computer and Information Science)	Daniel G. Keys Dept of Psychology	OTH	$40.000	8712686
University of Alabama Tuscaloosa 354872856 REU Site at the University of Alabama Department of Chemistry	Lowell D. Kispert Chemistry	CHEM	$31.000	8712225
ARKANSAS				
U Arkansas Med Scis Cam Little Rock 72205 REU: Research Experience for Undergraduates in the Pharmaceutical Sciences	Danny L. Lattin Biopharmaceutical Science	LIFE	$39.850	8713002
ARIZONA				
National Optical Ast Obs Tucson [illegible]17 The National Optical Astronomy Observatories Research Experience for Undergraduate Site Programs	Goetz K. Oertel National Optical Astronomy Observato	AST	$53 337	8713136
CALIFORNIA				
California Inst of Tech Pasadena 91109 Proposal to Establish an REU Site in Engineering at Caltech	Glen R. Cass Env.Quality Lab.& Env Eng Science	ENGR	$39 500	8712810
California Inst of Tech Pasadena 91109 Research Experiences for Undergraduates in Physics	Thomas A. Tombrello Physics, Math., & Astron	PHYS	$39 500	8712835
California Inst of Tech Pasadena 91109 REU Site in Chemistry at Caltech	Fredrick N Shair Division of Chemistry & Chemical Eng	CHEM	$35 000	8712858
California Inst of Tech Pasadena 91109 Proposal to Establish an REU Site in Computer and Information Science and Engineering at Caltech	Jerome Pine	COMP	$39 500	8713035
Harvey Mudd Col Claremont 91711 Mathematical Sciences: Research Participation in Applied Mathematics	John Greever Mathematics	MATH	$32 000	8712353

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Harvey Mudd Col Claremont 91711 Research Experiences for Undergraduates in Chemistry at Harvey Mudd	Mitsuru Kubota Chemistry	CHEM	$35,000	8712409
Occidental Col Los Angeles 90041 REU: Undergraduate Research in Biology	Jon E. Keeley Biology	OCE	$20,000	8712502
San Diego State Univ Fdn San Diego 92115 Empirical Investigation of Difficulties in Understanding Optics, Kinematics, and Heat and Temperature Among Pre-College Teachers	Fred M. Goldberg Physics	OTH	$3,000	8746170
U of Cal Irvine Irvine 92717 Chemical Research Experience for Undergraduates University of California, Irvine	William J. Evans Chemistry	CHEM	$35,000	8712649
U of Cal Irvine Irvine 92717 Research Experiences for Undergraduates (Materials Research)	Riley D. Newman Physics	PHYS	$40,000	8712709
Univ of Cal Berkeley Berkeley 94720 Research Experience for Undergraduates: Research Participation Site in Engineering at the Univeristy of California Berkeley	Pravin P. Varaiya Electronics Research Laboratory	OTH	$20,000	8712954
Univ of Cal Los Angeles Los Angeles 900241606 Research Experiences for Undergraduates at UCLA Plasma Physics Laboratory/HIPAS Observatory	Alfred Y. Wong Physics	PHYS	$40,000	8712615
Univ of Cal Los Angeles Los Angeles 900241606 Research Experiences for Chemistry Undergraduates at UCLA	Mario E. Baur Chemistry/Biochemistry	CHEM	$31,250	8712738
Univ of California Davis Davis 95616 REU: Summer Undergraduate Affirmative Action Research Program	Raymond L. Rodriguez Genetics	LIFE	$40,000	8712924
Univ of Southern Cal Los Angeles 900890741 A Joint U S.-Italian Research Project in Solar Seismology	Edward J. Rhodes Astronomy	AST	$8,000	8744987
COLORADO				
Univ Colorado at Boulder Boulder 80309 Mathematical Sciences REU Research Experiences for Undergraduates Nonlinear Phenomena and Parallel Processing	James Curry Mathematics	MATH	$32,000	8712283
CONNECTICUT				
Connecticut College New London 06320 REU Summer Research Program at Connecticut College	R Scott Warren Botany	LIFE	$32,000	8713347

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Wesleyan Univ Middletown 06457 Research Experiences for Undergraduates in Chemistry at Wesleyan University	Wallace C. Pringle Chemistry	CHEM	$31,250	8712992
DISTRICT OF COLUMBIA				
Amer Soc For Eng Ed Washington 20036 Future Supply of Undergraduates in Engineering--Workshop Organized by Engineering Deans Council, ASEE	F.Karl Willenbrock Engineering Education	ENGR	$75,401	8719660
DELAWARE				
University of Delaware Newark 19716 REU: Marine Sciences Summer Intern Program	Jonathan H. Sharp College of Marine Studies	OCE	$35,861	8712962
FLORIDA				
Florida State University Tallahassee 323062043 Summer Junior Fellowships in Undergraduate Research (Physics)	Neil R. Fletcher Physics	PHYS	$30,527	8712601
Florida State University Tallahassee 323062043 Determination of the Dominant Forcing Mechanisms for Energetic Fluctuations on the West Florida Shelf	Wilton Sturges, III Oceanography	OCE	$47,158	8742898
Florida State University Tallahassee 323062043 Equatorial Ocean-Climate Air-Sea Interaction	James J. O'Brien Meteorology	OCE	$12,700	8743044
Univ of Central Florida Orlando 32816 Research Experience in Computer Vision for Undergraduates (Computer and Information Science)	Mubarak A. Shah Computer Science	OTH	$40,000	8713120
University of Florida Gainesville 32611 REU: Undergraduate Research Training at the Whitney Laboratory	Barbara-Anne Battelle Whitney Laboratory	LIFE	$31,500	8712420
GEORGIA				
University of Georgia Athens 30602 REU: Research Experience in Marine Sciences for Undergraduates	Edward Chin Marine Sciences Program	OCE	$40,000	8712433
University of Georgia Athens 30602 REU Site - Computational Chemistry	Charles F. Bender Adv Computational Methods	OTH	$40,000	8712803
HAWAII				
Univ of Hawaii Manoa Honolulu 96822 A Study of Seasonal and Interannual Variations of Synoptic Oscillations in the Central Equatorial Pacific	Roger B. Lukas Joint Inst for Marine & Atmospheric Rsch	OCE	$8,050	8743043

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
ILLINOIS				
Northwestern University Evanston 60201 REU: Summer Research Program for Undergraduates	Mary K. Rundell Microbiology/Immunology	LIFE	$30,140	8712628
Northwestern University Evanston 60201 New Directions in Civil Engineering Research for Undergraduates	Charles H. Dowding Civil Engineering	ENGR	$40,184	8712716
Univ of Illinois Urbana Champaign 61820 Light Energy Transduction in the Purple Membrane of Halobacterium halobium	Thomas G. Ebrey Physiology/Biophysics	LIFE	$3,587	8744795
Univ of Illinois Urbana Champaign 61820 Nuclear Physics Research and High Duty Factor Electron Accelerator	Robert A. Eisenstein Physics	PHYS	$3,333	8744901
University of Chicago Chicago 60637 REU: Research Experiences for Undergraduates in Chemistry at Chicago	Jeremy K. Burdett Chemistry	CHEM	$32,000	8713014
INDIANA				
U of Notre Dame Notre Dame 46556 REU Site in Civil Engineering at Notre Dame	William G. Gray Civil Engineering	ENGR	$39,936	8712598
U of Notre Dame Notre Dame 46556 REU Site Program for Physics	Terrence W. Rettig Physics	PHYS	$40,000	8712943
IOWA				
Univ of Iowa Iowa City 52242 Development of a REU Site in Chemistry at the University of Iowa	Louis Messerle Chemistry	CHEM	$32,000	8712734
KANSAS				
U of Kansas Main Campus Lawrence 66045 REU: Undergraduate Research Participation in Biochemistry and Cell Biology	Marjorie Z. Newmark Biochemistry	LIFE	$28,336	8712938
LOUISIANA				
La St Univ Baton Rouge Baton Rouge 708034101 REU: Research Experiences for Undergraduates in Biological Sciences at Louisiana State University	Marshall D. Sundberg Botany	LIFE	$40,000	8712704
MAINE				
University Maine Orono Orono 044690114 REU Site in Structural and Geotechnical Engineering at the University of Maine	H. Joseph Dagher Civil Engineering	ENGR	$40,092	8712705

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
MARYLAND				
Univ of Md College Park College Park 20742 REU: Undergraduate Research Project in Automation and Communication Systems	Odd A. Asbjornsen Chemical Engineering	COMP	$180,000	8713420
MASSACHUSETTS				
Boston University Boston 02215 Undergraduate Research in Chemistry at Boston University	Standish C. Hartman Chemistry	CHEM	$31,300	8712942
Boston University Boston 02215 REU: Undergraduate Research in Biology at Boston University	Michael J. Baum Biology	LIFE	$32,000	8713037
Brandeis University Waltham 02254 Research Experiences for Undergraduates in Chemistry at Brandeis University	Irving R. Epstein Chemistry	CHEM	$35,000	8712438
Col of the Holy Cross Worcester 01610 Research Experiences for Undergraduates in Chemistry at Holy Cross	Richard S. Herrick Chemistry	CHEM	$31,250	8712543
GTE Laboratories Inc Waltham 02154 Industrial Research for Undergraduates	Peter Cukor Research Admin & Support	OTH	$40,000	8712656
Harvard University Cambridge 02138 REU: An Interdisciplinary Program in Ecology, Evolution, Behavior, and Genetics	Bruce Waldman Organismic & Evolu Biol	LIFE	$40,000	8712624
Mass Inst of Tech (MIT) Cambridge 02139 RUI: Research Experience in Biotechnology Processing	Daniel I. Wang ENGR	ENGR	$130,000	8711992
Mass Inst of Tech (MIT) Cambridge 02139 Establishment of the Haystack Observatory as a Research Experiences for Undergraduates Site for 1987	Joseph E. Salah Haystack Observatory	AST	$22,650	8712431
Mass Inst of Tech (MIT) Cambridge 02139 THEORY AND PRACTICE OF PHYSICAL SEDIMENTOLOGY	John B. Southard Earth, Atmos & Plan Sci	GEOL	$43,000	8712515
Southeastern Mass Univ North Dartmouth 02747 Teaching Students to Use Mathematics: Eliminating Errors in Mapping from Natural Representational Systems to the Abstract Symbol Systems of Mathematics	Judith E. Sims-Knight Psychology	MATH	$8,000	8746151
Tufts University Medford 02155 REU: In Biology	Shuk-mei Ho Biology	LIFE	$32,000	8713540
Univ of Mass Boston Boston 02125 REU: Research Experience for Undergraduates in Biochemistry Microbiology Neurobiology and Conservation Biology	Kamaljit S. Bawa Biology	LIFE	$40,000	8712813

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
MICHIGAN				
Hope College Holland 49423 REU: Support for Undergraduate Research in the Biological Sciences	James M. Gentile Biology	LIFE	$40,000	8712566
Michigan State University East Lansing 48824 Research Internships in Physics	George F. Bertsch Phy. & Ast. & NSCL	PHYS	$40,000	8711828
Michigan State University East Lansing 48824 REU: REU Site: Physiology Minority Student Summer Research Internship	Merle L. Heidemann Physiology	LIFE	$37,150	8712116
Northern Michigan Univ Marquette 49855 REU: Computer Science Institute	Harold W. Martin Mathematics & Comp Scien	COMP	$47,740	8712927
Univ of Mich Ann Arbor Ann Arbor 481091115 INITIATION AND SUPPORT FOR AN UNDERGRADUATE RESEARCH PARTICIPATION SITE AT THE SPACE PHYSICS RESEARCH LABORATORY, UNIVERSITY OF MICHIGAN	Timothy L. Killeen SPA PHY RES LAB ATM & OCE	ATM	$63,900	8712631
MINNESOTA				
University of Minnesota Minneapolis 55455 Mathematical Sciences: Undergraduate Research Program - Special Project	Joseph A. Gallian Mathematics & Statistics	MATH	$20,000	8709428
University of Minnesota Minneapolis 55455 Research Experiences for Undergraduates Site	Henry S. White Chem Eng & Materials Sci	ENGR	$40,081	8712719
University of Minnesota Minneapolis 55455 University of Minnesota Research Experiences for Undergraduates, Program in Chemistry	Wayland E. Noland Chemistry	CHEM	$35,000	8712736
University of Minnesota Minneapolis 55455 REU: University of Minnesota REU Site in Behavioral Sciences	Lesley K. Cafarelli Off of Educational Develo	PSYC	$40,000	8712823
MISSOURI				
Univ of Missouri Columbia Columbia 65211 Undergraduate Research in Particulate Systems Engineering	Sudarshan K. Loyalka Particulate Sys Res Ctr	ENGR	$40,000	8712824
Univ of Missouri St Louis Saint Louis 63121 Research Experiences for Undergraduates in Chemistry at the University of Missouri-St. Louis	Gordon K. Anderson Chemistry	CHEM	$31,250	8712558
MISSISSIPPI				
Mississippi State Univ Mississippi State 39762 REU: Undergraduate Summer Program in Social Research	Norma J. Bond Burgess Sociology & Anthropology	SOC	$32,000	8712487

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
MONTANA				
Eastern Montana Col Billings 59101 REU: Undergraduate Research in the Biological and Physical Sciences	Jay F. Kirkpatrick Biological Sciences	LIFE	$40.000	8712474
NORTH CAROLINA				
Duke Univ Durham 27706 Research Experiences for Undergraduates in Physics	Hugh G. Robinson Physics	PHYS	$32.000	8712980
Duke Univ-Marine Lab Beaufort 28516 Duke University Marine Laboratory as REU Site Facility	Joseph F. Ustach Oceanographic Consortium	OCE	$41.685	8712195
East Carolina Univ Greenville 27834 REU: Research Experiences for Undergraduates Site at East Carolina University for Disabled Students	David Lunney Chemistry	LIFE	$40.000	8712957
N C St Univ at Raleigh Raleigh 276958208 Research Experiences for Undrgraduates (Materials Research)	Michael A. Peesler Physics	PHYS	$39.600	8712599
U of N C at Chapel Hill Chapel Hill 27514 Research Experiences for Undergraduates in Chemistry at University of North Carolina, Chapel Hill	Tomas Baer Chemistry	CHEM	$32.000	8712485
U of N C at Charlotte Charlotte 28223 Development of an Interinatitutional REU Site	G. P. Mohanty Mech Eng & Eng Science	ENGR	$40.384	8712947
NEW HAMPSHIRE				
Dartmouth College Hanover 03755 Research in Engineering for Undergraduate Women and Minorities	Horst J. Richter Eng Undergraduate Studies	ENGR	$38.180	8712707
Dartmouth College Hanover 03755 Dartmouth Research Experiences for Undergraduates Program in Chemistry	Dean E. Wilcox Chemistry	CHEM	$35.000	8712934
Univ of N H Durham Durham 03824 REU: Research Experiences for Undergraduates in Computer Science (Computer and Information Science)	Philip J. Hatcher Computer Science	OTH	$39.956	8712730
Univ of N H Durham Durham 03824 REU: Research Experiences for Undergraudates at the Hubbard Brook Experimental Forest	Willi a B. Bowden Forest Resources	LIFE	$38.899	8712826
Univ of N H Durham Durham 03824 REU: Undergraduate Research Experience Site Proposal	Donald M. Green Biochemistry	LIFE	$32.000	8712832

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Univ of N H Durham Durham 03824 REU: Undergraduate Research in Marine Biology	Winsor H. Watson, III Zoology	OCE	$24,960	8712842
NEW JERSEY				
New Jersey Inst of Tech Newark 07102 NJIT Undergraduate Research Program	Reginald P. Tomkins Chemical Eng & Chemistry	ENGR	$40,000	8712496
Princeton University Princeton 08544 REU: Undergraduate Research in Biology and Molecular Biology	Malcolm S. Steinberg Biology	LIFE	$40,000	8713159
Rutgers U New Brunswick New Brunswick 08903 Research Experiences for Undergraduates (Materials Research)	Joe H. Pifer Physics and Astronomy	PHYS	$40,000	8712735
NEW MEXICO				
N M Inst of Mining & Tech Socorro 87801 Research Experiences for Undergraduates in Atmospheric Sciences	Carl J. Popp CHEMISTRY DEPARTMENT	ATM	$40,000	8712850
University of New Mexico Albuquerque 87131 Research Experiences at University of New Mexico for Undergraduates in Chemistry	Cary J. Morrow Chemistry	CHEM	$30,700	8712559
NEW YORK				
Cold Spring Harbor Lab Cold Spring Harbor 11724 REU: Cold Spring Harbor Summer Undergraduate Research Program	Winship Herr	LIFE	$32,000	8712971
Columbia University New York 10027 Research Experiences for Undergraduates in Chemistry at Columbia University	Leonard W. Fine Chemistry	CHEM	$35,000	8712419
Cornell Univ - Endowed Ithaca 14853 Research Experiences for Undergraduates (Computer and Information Science)	Kenneth Birman Dept of Computer Science	OTH	$40,000	8712688
Cornell Univ - Endowed Ithaca 14853 RESEARCH EXPERIENCES FOR UNDERGRADUATES IN GEOLOGICAL SCIENCES	William M. White Geological Sciences	GEOL	$48,000	8712950
Ithaca Col Ithaca 14850 Summer Research in Chemistry at Ithaca College and Cornell University	Heinz F. Koch Chemistry	CHEM	$35,000	8712498
Polytechnic University Brooklyn 11201 Research Experiences for Undergraduates	Spencer S. Kuo Elec Eng & Computer Sci	ENGR	$59,936	8713139

STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Rensselaer Polytech Inst Troy 12181 Integrating Undergraduates into the Research Activities of the Computer Science Department (Computer and Information Science)	Robert P. Ingalls Dept of Computer Science	OTH	$40,000	8712838
Rensselaer Polytech Inst Troy 12181 Research Experiences for Undergraduates (Materials Research)	Walter Eppenstein Physics	PHYS	$40,000	8712847
Roswell Park Health Res Albany 12237 REU: Undergraduate Research Participation Program in Science	Edwin A. Mirand Education	LIFE	$40,000	8712307
SUNY College at Fredonia Fredonia 14063 REU: The Amino Acids of the Floral Nectars of Northeastern Plants and Their Role in Attracting Pollinators	Janet Lanza Biology	LIFE	$40,000	8712902
Yeshiva University New York 10033 REU: Research Experiences for Undergraduates in the Biomedical Sciences	John S. Blanchard SueGoldingGradDivofMedSci	LIFE	$40,000	8712969
OHIO				
Col of Wooster Wooster 44691 Research Experience for Undergraduates in Chemistry at The College of Wooster	Theodore R. Williams Chemistry	CHEM	$32,000	8712514
Kent State University Fdn Kent 44242 REU: Research Experiences in Psychology	F.Robert Treichler Psychology	PSYC	$40,000	8712450
Kenyon Col Gambier 43022 REU: Student Research on the Naco Valley Archaeological Project, Northwestern Honduras	Patricia A. Urban Anthropology/Sociology	ANTH	$39,798	8712979
Ohio St Univ Columbus 43210 Research Experiences for Undergraduates in Chemistry at the Ohio State University	Robert M. Mayer Chemistry	CHEM	$31,250	8713117
OKLAHOMA				
Oklahoma State Univ Stillwater 74078 Mathematical Sciences: REU Site for Experiences in Applied Statistics	P. L. Claypool Statistics	MATH	$37,850	8712540
Oklahoma State Univ Stillwater 74078 Research Experiences for Undergraduates (Materials Research)	George S. Dixon Department of Physics	PHYS	$39,100	8712557
OREGON				
Oregon St Univ Corvallis 97331 Research Experiences for Undergraduates in Physical Oceanography and Fluid Dynamics	Douglas R. Caldwell College of Oceanography	OCE	$39,968	8712350

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Oregon St Univ Corvallis 97331 Mathematical Sciences: REU Site Proposal - Oregon State University	Robert O. Robson Mathematics	MATH	$40,000	8712402
Univ of Oregon Eugene Eugene 97403 Undergraduate Research Program in Chemical Physics at the University of Oregon	Thomas R. Dyke Chemistry	CHEM	$40,000	8713008
PENNSYLVANIA				
Beaver Col Glenside 19038 REU: Student-Faculty Research on Behavioral Biology	William J. Carr Psychology	LIFE	$31,344	8713130
Bucknell Univ Lewisburg 17837 Research Experiences for Undergraduates in Chemistry at Bucknell University	Charles A. Root Chemistry	CHEM	$31,250	8712639
Carnegie Mellon Univ Pittsburgh 15213 Magnetic Information Technology	Alfred B. Bortz Electrical & Computer Eng	ENGR	$50,846	8712715
Carnegie Mellon Univ Pittsburgh 15213 REU: Research Experience for Undergraduates in Biological Sciences at Carnegie Mellon University	Elizabeth W. Jones Biological Sciences	LIFE	$40,000	8712919
Drexel University Philadelphia 19104 Research Experience for Undergraduates (Mechanical Engineering and Mechanics)	Arthur M. Mellor Mechanical Eng & Mechanic	ENGR	$40,000	8712997
Lehigh Univ Bethlehem 18015 Chemical Sciences Research Experience Program for Undergraduates	Ned D. Heindel Chemistry	ENGR	$60,000	8712909
Penn State Univ Cen Off University Park 16802 Research Experiences for Undergraduates (REU) in Chemistry at Pennsylvania State University	Barbara J. Garrison Chemistry	CHEM	$35,000	8712365
Univ of Pennsylvania Philadelphia 19104 Research Experiences for Undergraduates (Physics)	Paul Soven Physics	PHYS	$40,000	8712297
Univ of Pennsylvania Philadelphia 19104 Research Experience for Undergraduates in Sensor Technologies	Jan Van Der Spiegel Electrical Engineering	ENGR	$37,232	8712499
RHODE ISLAND				
Brown Univ Providence 02912 Summer Undergraduate Research in Chemistry at Brown University	Ronald G. Lawler Chemistry	CHEM	$32,000	8712987

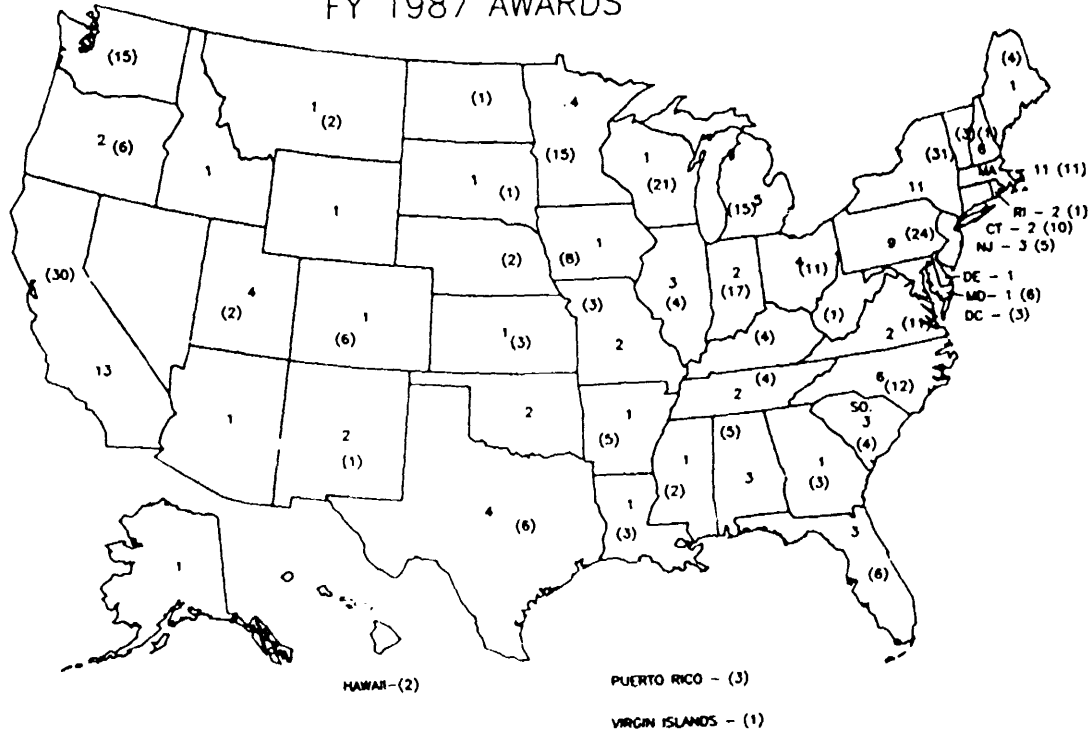
STATE / INSTITUTION / CITY, ZIP / AWARD TITLE	PROJECT DIRECTOR / PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Univ of Rhode Island Kingston 02881 REU: Training Program in Bioeocial Adaptation: Assessment of Paleonutritional Techniques	Marc A. Kelley Sociology & Anthropology	ANTH	$40,000	8713295
SOUTH CAROLINA				
Clemson Univ Clemson 29631 Research Opportunities in Software Measurement and Evaluation	John S. Davis	COMP	$30,000	8712816
Clemson Univ Clemson 29631 Influence of Drop Size Distribution Variations on Rainfall Parameters Determined from Dual-Measurement Techniques	Carlton W. Ulbrich Physics & Astronomy	ATM	$46,200	8741346
Furman Univ Greenville 29613 Summer Undergraduate Research Program in Chemistry at Furman University	Noel Kane-Maguire Chemistry	CHEM	$32,000	8712230
Med Univ of S Carolina Charleston 29425 REU: Summer Undergraduate Research Program	Rosalie K. Crouch Ophthalmology & Biochemis	LIFE	$40,000	8712712
SOUTH DAKOTA				
Augustana Col Sioux Falls 57197 REU: Stable Isotopic Applications to Great Plains Ecology, Paleoecology, and Archeology	Larry L. Tieszen Biology	LIFE	$32,714	8712603
TENNESSEE				
Meharry Medical Col Nashville 37208 REU: Research in Basic Biology Program	Fred Jones Dean	LIFE	$38,318	8712843
Univ of Tenn at Knoxville Knoxville 379960140 Summer Undergraduate Research Program in Chemical Analysis	Michael J. Sepaniak Chemistry	CHEM	$49,000	8706581
Univ of Tenn at Knoxville Knoxville 379960140 Mathematical Sciences: Research Experience for Undergraduates	Lawrence S. Husch Mathematics	MATH	$40,000	8712961
TEXAS				
Rice Univ Houston 77251 Mathematical Sciences: REU: The Laplace Operator on Spheres	B.Frank Jones, JR Mathematics	MATH	$40,000	8712330
Texas A&M Research Fdn College Station 77843 Engineering Research Experience for Women and Minority Undergraduates	Leroy S. Fletcher College of Engineering	ENGR	$40,000	8712623

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
Texas A&M Research Fdn College Station 77843 Monitoring the Abyssal Production and Course of the Outflow from the Weddell Sea (MAPCOWS)	Thomas Whitworth, III Oceanography	OCE	$5.579	8742930
Texas A&M Univ College Station 77843 Research Experiences for Undergraduates in Chemistry at Texas A&M University	Charles R. Martin Chemistry	CHEM	$31.250	8712811
U of Texas HSC - Dallas Dallas 75235 REU: Summer Undergraduate Research Fellowship Program	Elliott M. Ross Pharmacology	LIFE	$32.000	8712031
Univ of Houst Univ Pk Houston 77004 Petrological, Geochemical and Structural Study of ALVIN - Recovered Peridotites From the Mid-Atlantic Ridge Near 23'N	John F. Casey Geosciences	GEOL	$84.715	8700345
UTAH				
U of Utah Salt Lake City 84112 REU Site Project in Mechanical Engineering	Robert F. Boehm Mechanical & Industrl Eng	ENGR	$62.079	8712373
U of Utah Salt Lake City 84112 Research Experience for Undergraduates at the University of Utah	Richard P. Steiner Chemistry	CHEM	$31.250	8712429
U of Utah Salt Lake City 84112 Mathematical Sciences: REU: Project in Algebra and Statistics	Robert M. Brooks Mathematics	MATH	$37.450	8712516
Utah St Univ Logan 84322 Proposal for the Establishment of a Research Experiences for Undergraduates (REU) Site at Utah State University	Kent L. Miller Centr for Atmos & Spa Sci	ATM	$42.925	8713133
VIRGINIA				
Col of William and Mary Williamsburg 23185 Physics Research Experiences for Undergraduates	Rolf G. Winter Physics	PHYS	$40.000	8712370
WASHINGTON				
Fdn Glacier & Envrnl Res Seattle 98164 Research Experiences for Undergraduates on the Juneau Icefield, Alaska	Maynard M. Miller Mines & Earth Resources	GEOL	$40.321	8712857
WEST VIRGINA				
Nat'l Radio Astronomy Ob Green Bank 24944 National Radio Astronomy Observatory Undergraduate Research Program	Robert J. Havlen Basic Research	AST	$65.000	8713607

STATE INSTITUTION CITY, ZIP AWARD TITLE	PROJECT DIRECTOR PI DEPARTMENT	DISIPLINE CODE	AWARD AMOUNT	GRANT NUMBER
WISCONSIN				
Univ of Wis Milwaukee Milwaukee 53201 REU: Research Experience for Undergraduates at the Center for Great Lakes Studies	Kenneth W. Nealson Center for Great Lakes Studies	OCE	$39,872	8713027
WYOMING				
University of Wyoming Laramie 82071 The Wyoming Infrared Observatory Summer Research Program for Undergraduates	Ronald W. Canterna Physics and Astronomy	AST	$27,200	8712280

ATTACHMENT 3

RESEARCH EXPERIENCES FOR UNDERGRADUATES
(COLLEGE SCIENCE INSTRUMENTATION PROGRAM)
FY 1987 AWARDS



ATTACHMENT 4

SUPPORT FOR PREDOMINANTLY UNDERGRADUATE INSTITUTIONS FY 1987

BY DIRECTORATE

DIR.	FY 1987 TARGET 1/ $ 000s	RPS PUI AWARDS NUMBER AND DOLLAR AMOUNT								% TARGET ACHIEVED	PENDING 2/ PROPOSALS	
		RPS		RUI		ROA		Total				
		No.	$ 000s	No.	$ 000s	No.	$ 000s	No.	$ 000s		No.	$ 000s
BBS	11,200	199	10,107.6	94	5,041.7	36	443.1	329	15,592.4	139.2	386	78,509.8
CISE	1,800	35	1,242.2	15	636.4	5	73.7	55	1,952.4	108.5	52	12,144.6
ENG	5,500	103	5,285.8	14	1,330.0	4	141.7	121	6,747.5	122.7	85	42,774.7
GEO	11,700	139	12,593.5	51	2,914.2	5	53.5	195	15,561.2	133.0	177	31,517.4
MPS	11,300	148	5,957.4	119	4,657.3	40	845.5	307	11,460.2	101.4	153	21,324.4
STIA	4,500	56	5,380.2	1	22.4	0	0.0	57	5,408.6	120.2	99	4,131.6
TOTAL	46,000	680	40,572.6	294	14,592.1	90	1,557.6	1064	56,722.2	123.3	952	190,396.6

1/ FY 1987 targets are as follows:
RPS - $34.7 Million
RUI - $ 9.5 Million
ROA - $ 1.8 Million

2/ Includes 35 proposals recommended for FY 1988 funding at $575,100.

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)

BY DIRECTORATE FY 1987

DIRECTORATE	TARGETS	AWARDS		PERCENT TARGET ACHIEVED	DECLINATIONS		WITHDRAWALS INAPPROPRIATES		PENDING 2/ PROPOSALS		SUCCESS RATE 1/
	$ 000s	No.	$ 000s		No.	$ 000s	No.	$ 000s	No.	$ 000s	
BBS	4,000	94	5,041.7	126.0%	141	19,742.6	11	1,429.6	102	15,285.2	32%
CISE	500	15	636.4	127.3%	15	1,653.4	2	20.7	10	1,832.6	50%
ENG	750	14	1,320.0	176.0%	49	6,350.8	1	73.5	17	4,526.8	22%
GEO	1,250	51	2,914.2	233.1%	50	5,113.3	0	0.0	31	5,067.3	49%
MPS	3,000	119	4,657.3	155.2%	109	10,686.0	8	1,093.9	52	5,817.5	41%
STIA	N/A	1	22.4	N/A	0	0.0	0	0.0	0	0.0	N/A
TOTAL	9,500	294	14,592.1	153.6%	364	43,554.2	22	2,617.7	212	32,529.4	37%

1/ The success rate is calculated by dividing the number of competitive awards by the number of competitive awards and declines.

2/ Includes 6 proposals recommended for FY 1988 funding at $460,471.

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8713230	Alston L. J. From the New Deal to the Great Society. The Role of the South in Opposing the Welfare State	Williams College	$40,721	BBS BBS
8611889	Ballal S. K. RUI: The Effect of Auxins and Kinetin on in vitro Morphogenesis and Plantlet Formation in Simmondsia chinensis with Anti-Auxin Interaction	Tenn Technological Univ	$94,735	BBS BBS
8614944	Bernhard S A "RUI Molecular Basis for Signal Recognition and Catalysis of Coupled Enzyme Reactions"	Pomona Col	$50,000	BBS BBS
8706318	Bierzychudek P F The Ecological Consequences of Sexual and Apomictic Reproduction	Pomona Col	$105,000	BBS BBS
8618959	Briggs C L RUI Contextualization and Metacommunication in Warao Discourse	Vassar College	$55,883	BBS BBS
8646242	Brown P S Prolactin Regulation of Water During Early Vertebrate Development	Siena College	$40,737	BBS BBS
861365R	Rundy H F. RUI Purification and Characterization of Carbonic Anhydrase From Zea Mays	Mount St Mary's College	$28,000	BBS BBS
8646606	Claassen C RUI Investigation of Monthly Growth Variation in Shellfish for Application to Archaeological Shells	Appalachian State Univ	$42,695	BBS BBS
8646769	Claiborne J B RUI Acid Base Balance and Ion Regulation in Euryhaline Fish	Georgia Southern College	$33,000	BBS BBS
8645689	Cohlberg J A RUI Structure and Assembly of Intermediate Filaments	Cal St Univ Long Beach	$60,000	BBS BBS
8645946	Cornell R P Regulation of Liver Regeneration by Gut Derived Bacterial Endotoxin	Northeast Mo State Univ	$47,000	BBS BBS
8700298	Coyle F A RUI Systematics of the Funnel Web Mygalomorph Subfamily Ischnothelinae (Araneae, Dipluridae)	Western Carolina Univ	$136,603	BBS BBS
8706568	Dickinson P S RUI Role of Peptides in Modulating the Output of a Small Neural System	Bowdoin College	$45,912	BBS BBS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8709233	Estes R. D. RUI: Systematics and Evolutionary History of the Rosaseaura and Their Relatives	San Diego State Univ	$140,000	BBS BBS
8709498	Filer R. K. Occupational Sex-Segregation Causes and Changes	CUNY Hunter College	$58,000	BBS BBS
8713325	Fondy B. R. RUI: Distribution of Starch in Tissues of Source Leaves During Various Phases of the Life Cycle	Seton Hill Col	$90,215	BBS BBS
8701202	Frey T. G. RUI: A Facility for High Resolution Cryo-Electron Microscopy	San Diego State Univ Fdn	$79,023	BBS BBS
8615578	Gapp D A Endocrine Pancreas Structure and Function in the Turtle, Chrysemys picta	Hamilton Col	$75,000	BBS BBS
8704333	Gray L J RUI Biotic Linkages Between Terrestrial and Lotic Habitats	Ottawa University	$52,132	BBS BBS
8618847	Gretz M R RUI A Multi User Request for a Gas Chromatograph - Mass Spectrometer	George Mason University	$35,956	BBS BBS
8616641	Groutas W C RUI Acquisition of Polarimeter	Wichita State University	$14,000	BBS BBS
8707046	Grover S D RUI Molecular Aspects of Effector Binding to Phosphoenolpyruvate Carboxylase from Crassula argentea	Cal St Univ Los Angeles	$41,830	BBS BBS
8705101	Hamlett N V Genetic and Physiological Analysis of Tn21-Encoded Mercury Transport	Swarthmore Col	$62,931	BBS BBS
8645864	Haskell R C Measurement of Spontaneous Thickness Fluctuations of the Lipid Bilayer	Harvey Mudd Col	$57,000	BBS BBS
8618837	Herriott S R The Effects of Deregulation in the Bulk Electricity Markets	Maharishi Intl Univ	$30,923	BBS BBS
8645715	Kasschau M R RUI Red Blood Cell Lysis by Schistosoma Mansoni	U of Houston-Clear Lake	$64,710	BBS BBS
8704139	Keller J W Decarboxylase Structure-Function Relationships	Univ Alaska Fairbanks Cam	$42,000	BBS BBS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8515584	Kingsford L. RUI: Acquisition of a High-Performance Liquid Chromatography	Cal St Univ Long Beach	$33,912	BBS BBS
8615788	Korn R. W. Vein Patternization in Dicot Leaves	Bellarmine College	$49,073	BBS BBS
8704366	Kutter E. M. Early Regulatory Mechanisms of Bacteriophage T4	Evergreen State College	$50,000	BBS BBS
8711069	MacMurray R. B. U.S. Patent Indices	Bloomsburg St Col of Penn	$73,575	BBS BBS
8709970	Maher J. RUI Language Variation and Syntactic Change in St Barthelemy, French West Indies	Marist Col	$8,996	BBS BBS
8646691	Martin G G RUI Classification and Maturation of Decapod Hemocytes Morphology, Cytochemistry and Function	Occidental Col	$31,420	BBS BBS
8646726	McCumber L. J RUI. Cellular Defense Mechanisms in the Crayfish	Francis Marion College	$16,508	BBS BBS
8646179	McKee B. D RUI. Cloning Y Genes in Drosophila by Chromosome Jumping	Univ of Wis Eau Claire	$75,000	BBS BBS
8709627	Moore C. A. The Role of Appellate Courts in Sentencing Decisions	Univ of Wis Eau Claire	$25,016	BBS BBS
8612701	Nagel G M RUI Ultracentrifuge System for Macromolecular Research	Cal St Univ Fullerton	$47,577	BBS BBS
8707992	Neuringer A RUI Reinforcement and Control of Behavioral Variability	Reed Col	$61,647	BBS BBS
8645882	Newman J E Dynamic Light Scattering Studies of Actin Gelation	Union College	$35,000	BBS BBS
8641357	Owen J A RUI The Fluorescein-Specific Cytotoxic T Lymphocyte Response	Haverford Col	$65,359	BBS BBS
8646536	Perrott D R RUI. Perception of Motion in the Auditory Modality	Cal St Univ Los Angeles	$29,160	BBS BBS
8645686	Prusch R D. RUI Physiological Basis of Endocytosis in Amoeba Proteus	Gonzaga Univ	$39,844	BBS BBS
8609231	Pumo D E RUI Acquisition of a Table Top Ultracentrifuge and Rotor	Hofstra Univ	$21,500	BBS BBS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8716860	Randall J. A. RUI: Comparison of Mechanisms of Sociality in Solitary Rodents	San Francisco State Univ	$48,727	BBS BBS
8645933	Rappeport R. J. RUI: Experimental Analysis of Animal Cell Division	Union College	$51,085	BBS BBS
8616136	Ratner D. I. Cell-Specific Gene Expression in Dictyostelium	Amherst College	$70,265	BBS BBS
8616989	Reinnes C. G. RUI: Development of Neuromuscular Junction in Active and Inactive Mouse Muscles	Pomona Col	$65,000	BBS BBS
8703996	Renthal R D. RUI Acquisition of Digital Electronics and Computer Control for UV/Vis/NIR Spectrophotometer	U Tex San Antonio	$21,000	BBS BBS
8617161	Rowlett R Modeling the Catalytic Mechanism of Carbonic Anhydrase	Colgate University	$51,454	BBS BBS
8613881	Sabbadini R A. RUI: Function of a Mg ATPase from Skeletal Muscle T-Tubules	San Diego State Univ	$90,000	BBS BBS
8741811	Sepsenwol S RUI Isolation and Characterization of a Nematode Sperm-Activating Substance	Univ of Wis Stevens Point	$10,897	BBS BBS
8616358	Sheardy R D RUI The Synthesis and Characterization of Oligodeoxyribonucleotides Containing B Z Junctions	Penn State Univ Cen Off	$81,000	BBS BBS
8746066	Sheardy R D RUI The Synthesis and Characterization of Oligodeoxyribonucleotides Containing B Z Junctions	Penn State Univ Cen Off	$15,000	BBS BBS
8613754	Smith J. D. RUI Tetrahymena A Model for Eukaryotic Phospholipid Metabolism	Southeastern Mass Univ	$94,408	BBS BBS
8706958	Stearman A. M RUI Social Change and Adaptation in Two Bolivian Lowland Societies	Univ of Central Florida	$78,640	BBS BBS
8617073	Stiffler D F Interactions Between Acid Base and Electrolyte Balance in Acquatic and Terrestrial Amphibians	Cal St Poly Univ Pomona	$75,000	BBS BBS
8615964	Stumph W. E Expression of a Variant U4 Small Nuclear RNA Gene	San Diego State Univ	$42,057	BBS BBS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8614597	Tamas I. A. RUI, Acquisition of a Liquid Scintillation Counter	Ithaca Col	$21,864	BBS BBS
8646723	Tymoczko J. L. RUI: Glucocorticoid Receptor RNA Interaction Characterization of the RNA and Factors Responsible for its Association with the Receptor	Carleton College	$72,000	BBS BBS
8616159	Villars T.. RUI. Steroid Correlates of the Short-Term Reproductive Behavior Sequence of the Paradise Fish	Wheaton College	$20,000	BBS BBS
8600422	Walker G K. RUI Acquisition of Ancillary Equipment for Scanning Electron Microscopy	Eastern Michigan Univ	$10,165	BBS BBS
8617776	Weist R M RUI Temporal Systems in Child Language	SUNY College at Fredonia	$71,345	BBS BBS
8616572	Yasukawa K RUI Behavioral Status and Vocal Communication	Beloit Col	$70,270	BBS BBS
8706678	Zyskind J W RUI Acquisition of a DNA Synthesizer System	San Diego State Univ	$40,000	BBS BBS
		DIV SUBTOTAL BBS	$3,305,770	
8741467	Candland D K RUI Comparative Studies of Visual Attention and Recognition	Bucknell Univ	$40,000	BBS BNS
8743028	Claassen C RUI Investigation of Monthly Growth Variation in Shellfish for Application to Archaeological Shells	Appalachian State Univ	$8,394	BBS BNS
8708379	Herzog H A RUI Analysis of Antipredator Behavior	Western Carolina Univ	$28,008	BBS BNS
8704103	Moerman D E RUI Native American Medical Ethnobotany	Univ of Michigan Dearborn	$71,400	BBS BNS
8705180	Saarni C I The Development of Children's Beliefs about Emotional Expressiveness in Interpersonal Contexts	Sonoma State University	$64,269	BBS BNS
8741568	Sanjek R . RUI New Immigrants and Old Americans The Political, Social and Cultural Impact of the New Immigration	CUNY Queens College	$66,000	BBS BNS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8616814	Solomon P. R. RUI: A Model Systems Approach to Age-Related Learning Deficits	Williams College	$82,677	BBS BNS
		DIV SUBTOTAL: BNS	$340,748	
8616711	Caine E. A. RUI: Feeding and Foregut of Caprellid Amphipods (Crustacea)	U of SC Beaufort Campus	$51,000	BBS BSR
8742344	Kruse K. C. RUI: Life History Patterns in an Aquatic Insect	Eastern Illinois Univ	$1,954	BBS BSR
8614960	Pastor J J. RUI The Effects of Large Mammal Browsing on the Dynamics of Northern Ecosystems	Univ of Minn at Duluth	$258,645	BBS BSR
R614587	Reichardt P B RUI Acquisition of a Nuclear Magnetic Resonance Spectrometer	Univ Alaska Fairbanks Cam	$30,000	BBS BSR
8743942	Wasserman M RUI Evolution of the Caribbean Drosophila Repleta Group	CUNY Queens College	$39,146	BBS BSR
8706081	Wheelwright N T RUI Facilities Improvements and Scientific Equipment for the Research Laboratory of the Bowdoin Scientific Station	Bowdoin College	$35,000	BBS BSR
		DIV SUBTOTAL: BSR	$415,745	
8711068	Bachman N J RUI Organization and Expression of Bovine Cytochrome Oxidase Subunit IV Genes	Franklin & Marshall Col	$79,021	BBS DCB
8711590	Blankenship J W RUI Inhibitors of Polyamine and Histone Acetylases and Deacetylases	Univ of the Pacific	$70,000	BBS DCB
8702725	Cameron J S Ion Channels in Hypoxia and Hypothermia	Wellesley Col	$31,752	BBS DCB
8616240	Goudsmit E M RUI Mechanism of Action of a Reproductive Neurohormone Regulation of Galactogen Synthesis	Oakland Univ	$41,000	BBS DCB
8701752	Hoffman R. A Studies on the Role and Regulation of Mammalian Harderian Glands	Colgate University	$40,000	BBS DCB
8646156	Kuhn D T. RUI Abdominal Segmentation Genes (Tuh) in D Melanogaster	Univ of Central Florida	$55,000	BBS DCB

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION		AMOUNT	DIR/DIV
8645704	Lindemann C. B. RUI: Control Mechanisms in Sperm Motility	Oakland Univ		$45,118	BBS DCB
8645709	Loewy A. G. Enzyme Dissection of the Covalently-Crosslinked Cell Matrix	Haverford Col		$46,210	BBS DCB
8709594	Nag A. C. RUI: Control of Cell Proliferation and Differentiation in Adult Cardiac Muscle	Oakland Univ		$70,000	BBS DCB
8619867	Oswald C. RUI Metabolism and Recycling of Water in Lactating Rodents	Seton Hill Col		$29,900	BBS DCB
8700685	Peabody D. C. RUI Genetic and Nuclear Cycle Analyses of Armillaria Species	Bridgewater State College		$53,387	BBS DCB
8711403	Rao K. R. RUI Crustacean Pigment Dispersing Neuropeptide Hormones Heterogeneity, Actions, and Distribution	Univ of West Fla		$80,000	BBS DCB
8646022	Sepsenwol S. RUI Isolation and Characterization of a Nematode Sperm-Activating Substance	Univ of Wis Stevens Point		$65,000	BBS DCB
8645694	Travis J. L. RUI Immunochemical Dissection of Dynein Structure and Function	Vassar College		$48,000	BBS DCB
8710424	Whitaker R. RUI Photoaffinity Labeling of T Lymphocyte Activation Complex	Bates College		$59,000	BBS DCB
		DIV SUBTOTAL	DCB	$813,385	
8645908	Hansch C. RUI Definition of Bioreceptors	Pomona Col		$75,000	BBS DMB
		DIV SUBTOTAL	DMB	$75,000	
8709237	Chafrin M. M. RUI Market Models in Behavioral Economics	Santa Clara University		$40,854	BBS SES
8706348	Stewart J. A. Intellectual and Social Predictors of Citations to Scientific Articles	University of Hartford		$57,394	BBS SES
		DIV SUBTOTAL	SES	$98,248	
		DIR SUBTOTAL	BBS	$5,048,896	

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NUMBER	INVESTIGATOR TITLE	INSTITUTION		AMOUNT	DIR/DIV
8702553	Fisher D. RUI: Systolic Arrays with Sublinear Time Complexity	Harvey Mudd Col		$41,073	CSE CCR
8711229	Kreher D. L. RUI: Computing Combinatorial Configurations: t-Designs & Ramsey Numbers	Rochester Inst of Tech		$70,747	CSE CCR
8612674	Leone J. A. Instrumentation Support for Debugging in Distributed Systems and Program Complexity	Canisius Col		$18,000	CSE CCR
8611325	Sweet R. A Mathematical Sciences: FFT Algorithms for Advanced Architectures	Univ of Colo at Denver		$117,000	CSE CCR
8612638	Sweet R. A RUI: Computer Research Equipment (Computer Science)	Univ of Colo at Denver		$75,750	CSE CCR
		DIV SUBTOTAL	CCR	$320,570	
8712121	Blum L (RUI) Computational Complexity of Continuous Functions	Mills College		$54,487	CSE CSE
		DIV SUBTOTAL	CSE	$54,487	
8614924	Chen S. RUI: Computer Vision and Image Understanding (Computer and Information Science)	U of N C at Charlotte		$52,137	CSE IRI
		DIV SUBTOTAL	IRI	$52,137	
8710757	Goel A. K. Propagation Delays in the Bilevel and Trilevel Multilayer High Density Interconnections on the GaAs based VHSIC	Mich Technological Univ		$59,996	CSE MIP
8705473	Mourad S. RUI: BENCHMARK CIRCUITS FOR TEST PATTERN GENERATION	San Jose St Univ Fdn		$7,419	CSE MIP
		DIV SUBTOTAL	MIP	$67,415	
8702546	Christensen M. RUI: CSNET Membership	Swarthmore Col		$10,400	CSE NCR
8619407	Hill J. C. RUI: CSNet Services	Smith College		$5,400	CSE NCR
8604211	Karlof J. RUI: Group Codes for the Gaussian Channel	Univ of NC at Wilmington		$100,000	CSE NCR

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NUMBER	INVESTIGATOR TITLE	INSTITUTION		AMOUNT	DIR/DIV
8701443	Lonske E. RUI: Support of CSNET dues and Operating Expenses	Wellesley Col		$12,400	CSE NCR
8703895	Marshall R. Q. RUI CSNET Services	Loyola College		$11,200	CSE NCR
8719267	Moreno O. On a Conjecture of Golumb for Costas Arrays	Univ of P R Rio Piedras		$46,644	CSE NCR
8706214	Scragg G. W. RUI: CSNET Acquisition	Franklin & Marshall Col		$8,650	CSE NCR
8616881	Stoneback J P. RUI CSNet Services	Moravian Col		$10,150	CSE NCR
		DIV SUBTOTAL	NCR	$204,844	
		DIR SUBTOTAL	CSE	$699,453	
8745522	Rode E J RUI Synthesis of Oxygenates from Aldehydes and Olefins Over Metal Oxides and Zeolites	San Jose State University		$58,661	ENG CBT
8705576	Senft J R Mechanical Efficiency of Kinematic Heat Engines	Univ of Wis River Falls		$84,572	ENG CBT
		DIV SUBTOTAL	CBT	$143,233	
8718392	House D H Surgical Simulation Model of the Meniscus	Williams College		$25,000	ENG CDR
		DIV SUBTOTAL	CDR	$25,000	
8714633	Elder E D RUI Bactericidal Screening of Organic N Halamines	Georgia Southwestern Col		$11,742	ENG CES
		DIV SUBTOTAL	CES	$11,742	
8707919	Staley S M Conceptual Structures and Data Structures for Engineering Database Design	Fla International Univ		$56,699	ENG DMC
8708872	Wittels N Quantitative Image Simulation for Industrial Machine Vision	Worcester Polytech Inst		$69,940	ENG DMC
		DIV SUBTOTAL	DMC	$126,639	
8646960	Lockhart J M Research in Undergraduate Institutions - Experimental Studies of Excess Inverse Frequency Noise in SOLID Systems (Materials Research)	Frederic Burk Fdn Inc		$25,000	ENG ECS

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8744598	Lockhart J. M Research in Undergraduate Institutions Experimental Studies of Excess Inverse Frequency Noise in SQUID Systems (Materials Research)	Frederic Burk Fdn Inc	$22,500	ENG ECS
		DIV SUBTOTAL ECS	$47,500	
8611970	Poon C. RUI: Estimation of Ventilation/Perfusion Distribution in Lung Disease	N D St U Central Office	$69,130	ENG EET
8714716	Shabaheng R. Development of a General Transfer Theory for Semi-Bounded Medium with Discrete Scatterers	Embry-Riddle Aeron U AZ	$29,225	ENG EET
		DIV SUBTOTAL EET	$98,355	
8611239	Caverly R H RUI The Analysis of Distortion Generated by Conductivity Modulation in Pin Diode Circuits	Southeastern Mass Univ	$29,968	ENG ENG
8706186	Dshalalow J Mathematical Sciences Stochastic Processes in Multi Channel Queueing Systems with Controlled Input and State Dependent Service	Univ of Pitt Bradford	$3,774	ENG ENG
8701462	Geesey G G RUI Copper binding Properties of Microbial Exopolymers in Rivers Sediments	Cal St Long Beach Fdn	$230,244	ENG ENG
8618807	Massey G A RUI Laser Photoelectron Beam Sources	San Diego State Univ	$198,000	ENG ENG
8700541	O'Clock G D RUI Acquisition of a Secondary Ion Mass Spectrometer	Mankato State University	$100,000	ENG ENG
8709141	Rao M V RUI EIA Study of Halogen Lamp Rapid Thermal Annealing on Implanted InP and InGaAs	George Mason University	$65,000	ENG ENG
8711740	Simmons L D Modelling and Design Optimization for Helical Rotor Expanders (RUI)	Univ of Portland	$84,423	ENG ENG
8617066	Van Stryland E W Engineering of Two Photon Nonlinearities in Bulk and Artificially Structured Semiconductors	Univ of Central Florida	$80,000	ENG ENG
8707669	Zulinski R E Development of a New Application of Class E Rf Circuit Design Principles to Distributed Power Conversion Systems	Mich Technological Univ	$69,638	ENG ENG

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NUMBER	INVESTIGATOR TITLE	INSTITUTION		AMOUNT	DIR/DIV
		DIV SUBTOTAL:	ENG	$461,047	
8713594	Majerus J. N. Quantitative Validation and Statistical Error-Assessment of Coupled Computer-Aided Modeling of Forging Sequences of Axisymmetric Parts	Villanova Univ		$68,995	ENG MSM
		DIV SUBTOTAL:	MSM	$68,995	
		DIR SUBTOTAL:	ENG	$1,382,511	
8743331	Anderson L G Kinetics and Mechanism of Important Atmospheric Reactions	Univ of Colo at Denver		$50,000	GEO ATM
8610159	Donnald A A Influence of the Boundary Layer Stability on Deep Convection	S D Sch of Mines and Tech		$55,900	GEO ATM
8611614	Helsdon J H Numerical Modeling Studies of Thunderstrom Electrification in Two and Three Dimensions	S D Sch of Mines and Tech		$93,750	GEO ATM
8612385	Musil D J Completion of Studies of Precipitation Processes in CCOPE Hailstorms	S D Sch of Mines and Tech		$45,000	GEO ATM
8620156	Parker G D Solar Coronal Rotation and Recurrent Phenomena in Interplanetary Space	Norwich Univ		$32,600	GEO ATM
8712333	SOBRAL J A Search for Ionospheric Gravity Waves at Low Latitude (SEGALL Project)	Humacao University Col		$5,600	GEO ATM
8620145	Smith P L Armored T 28 Aircraft Facility for Research Requiring Storm Penetrations	S D Sch of Mines and Tech		$200,000	GEO ATM
8713211	Steinitz Kannan M Collaborative Research Climatic History of the Western Amazon Basin and the Equatorial Andes Since 18k	Northern Kentucky Univ		$20,000	GEO ATM
8612624	Tenenbaum J RUI Computer Graphics Displays of Tropospheric Jet Streams	SUNY College at Purchase		$45,000	GEO ATM
8741339	Thompson A N RUI The Chemical Composition of Precipitation at a Southeastern Urban Site	Spelman College		$37,500	GEO ATM
8701538	Ulanski S L The Structure and Dynamics of the Convective Mixed Layer Over the Tropical Rain Forest of the Amazon	James Madison Univ		$23,000	GEO ATM

NUMBER	INVESTIGATOR TITLE	INSTITUTION		AMOUNT	DIR/DIV
			DIV SUBTOTAL: ATM	$614,350	
8613565	Domack E. W. RUI: Depositional Environments of the Antarctic Continental Shelf	Hamilton Col		$49,630	GEO DPP
8619394	Oliver J. S. Feeding Ecology of Sea Otters in Soft-Bottom Habitats	San Jose State University		$44,008	GEO DPP
			DIV SUBTOTAL: DPP	$89,638	
8618626	Berger G. W. RUI: Accurate Dating of Quarternary Sediments and Tephra by Thermoluminescence Methods	Western Washington Univ		$49,883	GEO EAR
8618691	Beus S. S. RUI Environmental Interpretation of the Surprise Canyon formation, Norwestern Arizona	Northern Ariz Univ		$45,000	GEO EAR
8618474	Beutner E. C. RUI Early Deformation of the Cloridorme Formation, Quebec	Franklin & Marshall Col		$70,810	GEO EAR
8613560	Blakey R. C. RUI Collaborative Research Paleontology and Depositional Environments of a Lower/Middle Triassic Continental Red Bed Sequence (Moenkopi Formation, Southern Colorado Plateau)	Northern Ariz Univ		$30,500	GEO EAR
8615646	Brennan W. J. Interdisciplinary Research in Paleomagnetism and Biomagnetism	SUNY College at Geneseo		-$11,575	GEO EAR
8706960	Cercone K. Late Silurian Hypersaline Seas in the Michigan Basin and their Impact on Ancient and Modern Groundwater	Indiana U of Pennsylvania		$37,480	GEO EAR
8707345	Geary E. E. RUI Collaborative Research Metamorphism and Deformation Associated with Late Cenozoic Strike-Slip Faulting in the Philippines	San Jose St Univ Fdn		$64,790	GEO EAR
8708244	Goldstein A. RUI Motion History and Tectonic Significance of Major Faults in Southeastern New England	Colgate University		$47,046	GEO EAR
8708524	Hoffman K. A. Paleomagnetic Studies of Transitional Field Behavior with Emphasis on the Comparison of Different Types of Recordings	Calif St U San Lu Obispo		$114,491	GEO EAR
8616403	Hovis G. L. Solution Calorimetric, Crystallographic, and Phase Equilibria Investigations of the Thermodynamic Properties of Minerals	Lafayette Col		$113,334	GEO EAR

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8617074	Karl J. H. Processing & Interpretation of Land-Sea Data from the Glimpce Seismic Experiment	Univ of Wis Oshkosh	$50,413	GEO EAR
8707746	Karlstrom K. E. RUI. Collab. Research Chronology and Processes of Deformation and Metamorphism During Early Proterzoic (1.8-1.6 Ga) Continental Assembly, Arizona	Northern Ariz Univ	$55,392	GEO EAR
8617747	Kelsey H. M. RUI Late Neogene Faulting and Tectonic Evolution A Study of Forearc Plate Margin Settings in New Zealand and California	Western Washington Univ	$100,259	GEO EAR
8617682	La Tour T. E. Establishment of a Facility for X ray Fluorescence Analysis	Georgia State University	$94,400	GEO EAR
8618206	Lockley M. G. Dinosaur Tracksites of the Colorado Plateau Region Implications for Behavior and Habitat	Univ of Colo at Denver	$66,200	GEO EAR
8705717	McKee J. W. RUI Field Study in Northeastern Mexico of the Southern Edge of North America During the Late Paleozoic	Univ of Wis Oshkosh	$85,000	GEO EAR
8708287	Mead J. I. Late Pleistocene Animal and Plant Associations and Extinctions on the Central Colorado Plateau	Northern Ariz Univ	$44,900	GEO EAR
8617929	Mills, III H. H. RUI Lateral Migration and Topographic Inversion of Hollows on Shale Hillslopes in the Valley and Ridge Province, and Significance for Hillslope Evolution	Tenn Technological Univ	$25,914	GEO EAR
8615259	Morales M. RUI Collaborative Research Paleontology and Depositional Environments of a Lower/Middle Triassic Continental Red Bed Sequence (Moenkopi Formation, Southern Colorado Plateau)	Northern Ariz Univ	$28,600	GEO EAR
8618629	Moye F. J. Stratigraphy, Geochemistry and K Ar Dating of Eocene Volcanic and Intrusive Rocks from the Southeastern Chellis Volcanic Field, Central Idaho	Idaho State University	$60,600	GEO EAR
8611608	O'Brien N. R. RUI Determining Sedimentary Environments of Argillaceous Rocks by Clay Fabric	SUNY College at Potsdam	$63,459	GEO EAR
8708221	Prothero D. R. RUI Magnetostratigraphy of the Later Eocene Uinta Formation, Utah	Occidental Col	$14,258	GEO EAR

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8618450	Spinosa C. RUI: Permian Continental Margin Tectonics, Eastern Nevada, The Response of the Miogeocline to Terrane Accretion	Boise State University	$40,600	GEO EAR
8613639	Stoessell R. K. Acquisition of Scanning Electron Microscopy and Microanalyzer Systems for Geological Research	Univ of New Orleans	$70,000	GEO EAR
8612362	Uzochukwu G. A. Acquisition of a Truck-Mounted Soil Sampling Machine	N C Agric & Tech St Univ	$18,000	GEO EAR
8618028	Wiebe R. A. RUI The Bridges Layered Intrusion and the Paul Island Anorthosites, Nain, Labrador	Franklin & Marshall Col	$78,000	GEO EAR
8618141	Wojtal S F Purchase of Equipment for Upgrading X-ray Diffractometer and Emission Spectrometer for Geologic Research	Oberlin Col	$22,280	GEO EAR
		DIV SUBTOTAL EAR	$1,502,184	
8707316	McLelland J RUI U Pb Zircon Geochronology of Adirondack Metamorphosed Igneous Rocks	Colgate University	$28,796	GEO GEO
8720366	Torrini R RUI Arc-Continent Interaction and Evolution of the Caribbean South American Plate Boundary	Univ of P R Mayaguez	$20,000	GEO GEO
		DIV SUBTOTAL GEO	$50,796	
8620308	Carpenter R C RUI The Physiological Basis of Grazing Effects on the Primary Productivity of Algal Turfs	Fairleigh Dickinson Univ	$96,880	GEO OCE
8612884	Goldberg W M Synthesis, Structure and Chronometric Validation of Skeletal Growth Rings in the Black Coral Antipathes Aperta	Fla International Univ	$86,626	GEO OCE
8707448	Hickey B L Geographic and Temporal Geochemical Variations in Volcanic Rocks from the Philippine Sea	Fla International Univ	$37,234	GEO OCE
8707704	Hickey B L RUI Acquisition of an Inductively Coupled Plasma Emission Spectroanalyzer for Florida International University	Fla International Univ	$50,100	GEO OCE
8741625	Ierley G. R RUI - Topics in Large Scale Circulation Theory	Mich Technological Univ	$41,322	GEO OCE

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8620249	Jones R D Interrelation Between Nitrogen and Carbon Cycling in Marine Waters	Fla International Univ	$78,270	GEO OCE
8743303	Paul V J. Chemical Defenses in Tropical Marine Algae Herbivore Deterrence and Its Relationship to Variation in the Production of Secondary Metabolites	University of Guam	$4,130	GEO OCE
8609273	Rueter J G Effect of Aeolian Iron Input on Carbon and Nitrogen Fixation	Portland State University	$145,189	GEO OCE
8700495	Shiller A M Gallium in Seawater and its Relationship to Aluminum	San Jose State University	$48,226	GEO OCE
8710717	Vanko D A Hydrothermal Fluid Inclusions in Rocks Dredged from Mid Ocean Spreading Centers	Georgia State University	$60,294	GEO OCE
		DIV SUBTOTAL OCE	$648,271	
		DIR SUBTOTAL GEO	$2,914,229	
8614503	Baird S R RUI Evolutionary Status of RV Tauri Stars	Benedictine College	$23,400	MPS AST
8745195	Benson P J RUI Radio and Infrared Studies of Interstellar Clouds	Wellesley Col	$61,100	MPS AST
8741910	Burke E W RUI Photometric Studies of Bright Variable Stars	King Col	$21,800	MPS AST
8705770	Caton D B RUI Accuracy of Method Determining Eclipsing Binary Times of Conjunction	Appalachian State Univ	$17,100	MPS AST
8744843	Chapman G A RUI A Photometric Study of Solar Irradiance and Luminosity Variations	Cal St Univ Northridge	$60,400	MPS AST
8613735	DuPuy D L RUI Charge Coupled Device Image Processing Microcomputer	Va Military Inst	$19,902	MPS AST
8616362	Dukes R J A Four College Automatic Photoelectric Telescope for Astronomical Training and Research	Col of Charleston	$50,000	MPS AST
8712249	Graver A D RUI Purchase and Implementation of Equipment for Astronomical Time Series Photometry	U Arkansas Little Rock	$60,000	MPS AST

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8741522	Heintz W D. RUI: Observations of Binary and Proper-Motion Stars	Swarthmore Col	$73,000	MPS AST
8820094	Herbst W.. RUI; MULTI-BAND SPECTRAL PHOTOMETRY OF ORION POPULATION AND DWARF M STARS AT VAN VLECK OBSERVATORY	Wesleyan Univ	$88,200	MPS AST
8713394	Hoffman G.. RUI LOCAL SUPERCLUSTER STUDIES	Lafayette Col	$48,000	MPS AST
8745194	Marcy G W RUI A Search for Sub-Stellar Objects Around Late-Type Stars	Frederic Burk Fdn Inc	$25,900	MPS AST
8700701	Rafert J B RUI Observational Study of the W Serpentis Stars	Florida Institute of Tech	$30,800	MPS AST
8743006	Roeder R C RUI Quasar Investigations	Southwestern Univ	$6,500	MPS AST
8701979	Weisberg J M RUI Pulsar Studies of Gravitation and the Interstellar Medium	Carleton College	$33,200	MPS AST
8744840	Winkler P RUI Observational Studies of Supernova Remnants	Middlebury Col	$29,100	MPS AST
		DIV SUBTOTAL AST	$646,202	
8646985	Barbas J T Radical and Ionic Reactions on Silica	Valdosta State College	$16,700	MPS CHE
8705340	Beam C F Purchase of a Fourier Transform Infrared Spectrometer (Chemistry)	Col of Charleston	$30,300	MPS CHE
8606681	Berberian J G Molecular Relaxation Using Dielectric Permittivity	St Joseph's University	$72,116	MPS CHE
8700848	Blair L K 2-Coordinate Complexes of Positive Halogens	Berea College	$48,500	MPS CHE
8743769	Carroll F A Photochemical Studies Exciplex Processes, Solar Energy Storage and Light Induced pH Change	Davidson Col	$16,000	MPS CHE
8615808	Damrauer R Gas Phase and Related Studies of Organosilicon Compounds	Univ of Colo at Denver	$59,700	MPS CHE

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8742587	Davies M. 3 + 4 Cycloadditions of Vinyl Carbenoids with Dienes (Chemistry)	Wake Forest Univ	$33,130	MPS CHE
8743201	Dehaan F. P. Intermediates, Kinetics, and Mechanisms of Electrophilic Aromatic Substitution Reactions	Occidental Col	$24,900	MPS CHE
8742248	Devore T. C. The Oxidation of Small Metal Clusters	James Madison Univ	$21,467	MPS CHE
8611588	Ditzler M A Effect of Immobilization on the Inherent Selectivity of Spectrophotometric and Spectrofluorometric Reagents	Col of the Holy Cross	$48,023	MPS CHE
8743259	Djordjevic C A Transition Metal Peroxo Complexes	Col of William and Mary	$27,876	MPS CHE
8703018	Engstrom R C Electrogenerated Chemiluminescence Imaging for Spatially-Resolved In situ Surface Analysis	Univ of South Dakota	$87,000	MPS CHE
8703443	Engstrom R C Purchase of a Fourier Transform Infrared Spectrophotometer (Chemistry)	Univ of South Dakota	$55,000	MPS CHE
8700399	Goodwin T E Enantioselective Synthesis via Allylic Sulfide Anions and Carbohydrate Derived Chirons	Hendrix College	$43,088	MPS CHE
8608881	Gupton J T Purchase of a 200 MHz NMR Spectrometer	Univ of Central Florida	$64,850	MPS CHE
8740389	Jensen J L Catalysis of Hemiacetal Breakdown	Cal St Univ Long Beach	$30,000	MPS CHE
8704395	Joens J A Purchase of a UV-VIS Spectrophotometer (Chemistry)	Fla International Univ	$31,000	MPS CHE
8615284	Kegley S E Chiral Transition Metal-Olefin Complexes Applications to Organic Synthesis	Williams College	$21,400	MPS CHE
8711615	Kiefer R. L Purchase of a Nuclear Magnetic Resonance Spectrometer	Col of William and Mary	$110,000	MPS CHE
8709918	Knight L B Purchase of a High Field Nuclear Magnetic Resonance Instrument	Furman Univ	$156,210	MPS CHE

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8741295	Ramette R. W. Potentiostatic Coulometry for Equilibrium Studies and Chemical Analysis	Carleton College	$26,121	MPS CHE
8617556	Reingold I.. Through-Space Interactions in Organic Molecules (Chemistry)	Lewis and Clark Col	$23,000	MPS CHE
8741583	Richardson W. H. Chemical Production of Excited State Molecules	San Diego State Univ	$21,600	MPS CHE
8742329	Ring M A. Kinetics and Mechanism of Silicon Deposition from the Pyrolysis of Silanes and Chlorosilanes	San Diego State Univ	$42,000	MPS CHE
8711549	Rosenberg E Synthetic and Mechanistic Studies in Metal Cluster Chemistry	Cal St Univ Northridge	$55,315	MPS CHE
8740985	Scamehorn R G Nucleophile Reactivity and Basicity in Radical Chain Substitution Reactions	Ripon Col	$17,100	MPS CHE
8614418	Schuh M D Dynamics of Intermolecular Flow of Vibronic Energy	Davidson Col	$12,000	MPS CHE
8740946	Settle F. A An Expert System for Selecting Chemical Analysis (Chemistry)	Va Military Inst	$600	MPS CHE
8703684	Singh M Applications of Fourier Transform Infrared Spectroscopy	Wartburg College	$23,459	MPS CHE
8744567	Smith R M Synthesis and Hydrolysis Mechanisms of 3 Substituted 1, 3 Dialkyltriazenes	Western Maryland Col	$22,500	MPS CHE
8703285	Stanton R E Quantum Chemical Research on Carbon Clusters and Other Projects	Canisius Col	$33,862	MPS CHE
8645317	Stevenson G R Alkaline Earth Metal Systems and Alkali Metal Anion Radical Solvation Enthalpies	Illinois State Univ	$45,000	MPS CHE
8743921	Thompson D W The Synthesis of Pyrans Via the Lewis Acid Promoted Cyclization of Unsaturated Acetals (Chemistry)	Col of William and Mary	$25,400	MPS CHE
8740984	Van Eikeren P Mechanism of Hydrogen Transfer in Nicotinamides	Harvey Mudd Col	$20,000	MPS CHE

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8706050	Koch H. F. Elementary Steps Associated with Addition and Elimination Reactions	Ithaca Col	$84,400	MPS CHE
8744780	Lee M.. Study of Collision Dynamics Using the Wigner Phase-Space Approach (Chemistry)	Oakland Univ	$27,000	MPS CHE
8611766	Mattson B.. Organometallic Reaction Chemistry with a N, P, P Type Ligand: An Instrumentation Proposal	Creighton University	$15,000	MPS CHE
8742989	Merritt M. V. Oxygen Exchange as a Function of Racemization in Optically Active Alcohols	Wellesley Col	$34,400	MPS CHE
8744438	Mills N S Metallacyclobutanes and Trimethylenemethane Metal Complexes via Delocalized Dianions	Trinity Univ	$26,410	MPS CHE
8620242	Minelli M Purchase of a 10mm Standard Selective 183W Probehead for 300 MHz NMR Spectrometer	Grinnell Col	$7,900	MPS CHE
8744754	Mohrig J R Stereochemistry of Elimination and Addition Reactions	Carleton College	$36,000	MPS CHE
8646976	Myhre P C Solid State NMR Studies of Reactive Intermediates	Harvey Mudd Col	$54,000	MPS CHE
8617068	Onak T P Carborane Chemistry	Cal St Univ Los Angeles	$51,700	MPS CHE
8742159	Palma R J Pfeiffer Effect of Chiral Molybdenum VI Complexes	Midwestern State Univ	$13,500	MPS CHE
8742985	Piepho S B Theoretical Studies of Mixed Valence Compounds	Sweet Briar Col	$26,686	MPS CHE
8741298	Pladziewicz J R Intramolecular Electron Transfer in Cytochrome c-Ferrocene Derivatives	Univ of Wis Eau Claire	$33,000	MPS CHE
8742162	Plummer B F Excited State Dynamics of Perturbed Acenaphthylenes	Trinity Univ	$26,600	MPS CHE
8702592	Popham R E Purchase of Chemical Instrumentation for Trace Element and Anion Analysis	Southeast Mo State Univ	$17,500	MPS CHE

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NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8705490	Williams G. M. Chemistry and Synthesis of Metal Pentadienyl Complexes	Cal St Univ Fullerton	$34,000	MPS CHE
8743774	Hubbels G. G. Catalysis and Mechanism in Nucleophilic Aromatic Photosubstitution	Grinnell Col	$30,500	MPS CHE
8742585	Yoder C. H. Calorimetric and NMR Studies of the Lewis Acidities of Group IV and Group V Halides	Franklin & Marshall Col	$37,155	MPS CHE
8742110	Zelle Krevor J V Alkanediyl Complexes of Platinum	Frederic Burk Fdn Inc	$24,355	MPS CHE
8710016	Zwier T S Electronic Spectroscopy and Dynamics of Cold, Gas Phase Hg containing Excimers (Chemistry)	Calvin College	$48,540	MPS CHE
		DIV SUBTOTAL CHE	$1,973,863	
8612904	Acrivos J V RUI Intercalated Low Dimensional Solids By X-Ray Absorption ESR (Electron Spin Resonance) and NMR (Nuclear Magnetic Resonance) Spectroscopy (Materials Research)	San Jose State University	$69,600	MPS DMR
8713559	Bernstein H J RUI Neutron Interferometry (Materials Research)	Hampshire College	$21,400	MPS DMR
8645481	Collings P J Research in Undergraduate Institutions Optical Rotatory Dispersion in the Blue and Isotropic Phases of Cholesteric Liquid Crystals (Materials Research)	Kenyon Col	$14,500	MPS DMR
8740353	Feller S A Research in Undergraduate Institutions Properties of Alkali Borate Glasses Related to Atomic Arrangements (Materials Research)	Coe College	$19,800	MPS DMR
8743178	Feller S A Research in Undergraduate Institutions Properties of Alkali-Borate Glasses Related to Atomic Arrangements (Materials Research)	Coe College	$26,700	MPS DMR
8742180	Frank R C RUI Trapping of Hydrogen Isotopes by Lattice Defects in Metals (Materials Research)	Augustana Col	$27,200	MPS DMR
8743124	Fritz L S RUI Microscopic Structure and Magnetism in Rare Earth Amorphous Alloys with the Mossbauer Effect (Materials Research)	Franklin & Marshall Col	$20,500	MPS DMR

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8742383	Gollub J. P. Research in Undergraduate Institutions: Pattern Formation from Interfacial Instabilities: Dendritic Solidification (Materials Research)	Haverford Col	$61,000	MPS DMR
8702994	Kihlstrom K. E. RUI: Tunneling Measurements on Bi Superconductors (Materials Research)	Westmont College	$10,000	MPS DMR
8646804	Kimball C. W Research in Undergraduate Institutions: Conversion Electron Mossbauer Study of Advanced Superconducting Materials (Materials Research)	Northern Illinois Univ	$88,000	MPS DMR
8702034	McCarroll W. H RUI Synthesis and Properties of Low Valent Molybdenum Oxides (Materials Research)	Rider College	$22,100	MPS DMR
8706219	Novaco A. D RUI Structure and Dynamics of Physisorbed Monolayer Films (Materials Research)	Lafayette Col	$27,900	MPS DMR
8704347	Oliva J RUI New Application of the Thomas Fermi Theory to Electronic Screening of Point Charge Impurities in Insulators (Materials Research)	Cal St Long Beach Fdn	$16,000	MPS DMR
8703597	Patsiga R. A RUI Synthesis of Amine-terminated Polydimethylsiloxanes and Block Copolymeric Silicones	Indiana U of Pennsylvania	$65,500	MPS DMR
8705568	Roelofs L RUI Combined First Principles Theory and Simulation Study of Displacive Surface Reconstructions W(001) and Mo(001) (Materials Research)	Haverford Col	$11,200	MPS DMR
8617595	Stark R. E RUI Acquisition of Equipment for Solid State Nuclear Magnetic Resonance (Materials Research)	CUNY Col of Staten Island	$41,600	MPS DMR
8742282	Williams R. T RUI Observing Lattice Defect Formation and Electron Relaxation on the Time Scale of Optical Phonon Periods (Materials Research)	Wake Forest Univ	$65,200	MPS DMR
		DIV SUBTOTAL DMR	$608,200	
8606040	Alligood K. T Mathematical Sciences Global Continuation of Periodic Orbits	George Mason University	$17,585	MPS DMS

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8703631	Busenberg S. N Mathematical Sciences Analysis of Models with Nonlocal Temporal and Spatial Dependece	Harvey Mudd Col	$58,000	MPS DMS
8708015	Cecil T. E. Mathematical Sciences: Applications of Lie Sphere Geometry to the Study of Taut and Dupin Submanifolds	Col of the Holy Cross	$34,900	MPS DMS
8701109	Gevecl T.. Mathematical Sciences Time-Discretization Schemes for Incompressible Navier-Stokes Equations and Burgers' Equation	San Diego State Univ	$41,500	MPS DMS
8717186	Haskell P. E. Mathematical Sciences Chern Characters and Correction Terms in Index Theory on Noncompact Manifolds	U S Naval Academy	$18,000	MPS DMS
8704169	McCormick S F Multilevel Algorithms for Advanced Computers	Univ of Colo at Denver	$30,000	MPS DMS
8706072	Schwartman N C Mathematical Sciences RUI Partition Study for Successive Difference Analysis	Cal State Univ Chico	$24,763	MPS DMS
8701997	Shultz F W Mathematical Sciences Duality of Pure States, Equivalence Relations, and C* algebras (Mathematical Sciences)	Wellesley Col	$44,900	MPS DMS
8701456	Stech H W Mathematical Sciences Local and Global Techniques for the Location of Periodic Solutions of Parameter Dependent Systems with Time Delay	Univ of Minn at Duluth	$60,000	MPS DMS
8704354	Sweet R A Mathematical Sciences Research Equipment	Univ of Colo at Denver	$72,000	MPS DMS
8707080	Trench W F Mathematical Sciences RUI Numerical Solution of the Eigenvalue Problem of Symmetric Rationally Generated Toeplitz Matrices	Trinity Univ	$33,300	MPS DMS
8701791	Venema G A Mathematical Sciences Topological Embeddings in Piecewise Linear Manifolds	Calvin College	$27,600	MPS DMS
		DIV SUBTOTAL DMS	$466,548	
8714022	Baksay L RUI Physics with the L3 Detector at LEP	Union College	$69,990	MPS PHY

RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8710260	Barad K., RUI: Numerical Studies with Staggered Fermions in Lattice Gauge Theory (Physics)	Barnard College	$27,270	MPS PHY
8712241	Boughn S. P. RUI: Search for a Stochastic Background of Gravitational Waves Using the Normal Modes of the Earth (Physics)	Haverford Col	$15,040	MPS PHY
8617538	Cederberg J., RUI: Measurement of Hyperfine Interactions in Small Molecules (Physics)	St Olaf College	$40,000	MPS PHY
8742888	DeYoung P. A. RUI Light Particle Emission in Heavy Ion Reactions (Physics)	Hope College	$28,000	MPS PHY
8701401	Dowd J P Research in Hadron Spectroscopy (Physics)	Southeastern Mass Univ	$123,467	MPS PHY
8616663	Esteban E P RUI The Magnetized Kerr-Newman Metrics (Physics)	Humacao University Col	$27,934	MPS PHY
8708093	Gonthier P. L RUI: Probing Heavy Ion Reactions with Light Charge Particle Emission (Physics)	Hope College	$28,286	MPS PHY
8711639	Haan S. L. RUI Effects of Continuum Structure in Photodetachment and Recombination Processes in Atomic Theory (Physics)	Calvin College	$12,300	MPS PHY
8711395	Holbrow C. H RUI Laser Spectroscopy to Measure Charge Moments of Nuclei Far from Beta Stability (Physics)	Colgate University	$26,157	MPS PHY
8741711	Hunter L R RUI A Search for an Electric Dipole Moment of the Electron (Physics)	Amherst College	$71,769	MPS PHY
8745427	Jolivette P. L RUI: Charge Symmetry Breaking and Other Intermediate Energy Nuclear Physics Experiments	Hope College	$26,000	MPS PHY
8704125	King F. W RUI: Indirect Calculation of Lamb Shifts in Three-Electron Atoms (Physics)	Univ of Wis Eau Claire	$15,700	MPS PHY
8706100	Lahiri J RUI Photoionization of Excited States of Atoms and Ions (Physics)	Southern Col Technology	$11,996	MPS PHY

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RESEARCH IN UNDERGRADUATE INSTITUTIONS (RUI)
AWARDS LIST FY 1987

NUMBER	INVESTIGATOR TITLE	INSTITUTION	AMOUNT	DIR/DIV
8713444	Padalino S.. RUI: Projectile Fragmentation Studies in Heavy Ion Reactions (Physics)	SUNY College at Geneseo	$23,477	MPS PHY
8706614	Partovi M.. RUI. Nonlocal Regularization of Quantum Field Theories and Lattice Fermion Doubling (Physics)	Cal State Univ Sacramento	$15,000	MPS PHY
8614695	Prior R. M. Transition from Compound Nucleus to Direct Processes (Physics)	U Arkansas Little Rock	$26,214	MPS PHY
8704200	Rolnick P. RUI Self-Consistent Applications of Equations of Motion to Collective Motion in Even Mass Nuclei	Deep Springs College	$8,000	MPS PHY
8742848	Rouze N C RUI Studies of Atomic Collisions at Intermediate Velocities (Physics)	Hope College	$36,000	MPS PHY
8707456	Saenz R A RUI Theoretical Studies in Gravitation and Astrophysics	Cal St Polytech Col Fdn	$17,418	MPS PHY
8706748	Sommermann H RUI Dynamics of Skyrmion Interactions in Three Dimensions (Physics)	Westmont College	$15,465	MPS PHY
8704552	Vourvopoulos G Study of Heavy Ion Reactions (Physics)	Western Kentucky Univ	$34,500	MPS PHY
8741758	Warner R E RUI Nuclear Reaction Studies at Low and Intermediate Energies (Physics)	Oberlin Col	$25,985	MPS PHY
		DIV SUBTOTAL. PHY	$725,977	
		DIR SUBTOTAL MPS	$4,420,790	
8610463	Parnell R A U S -Norway Cooperative Research Effects of Acid Precipitation on Aluminum Release to Surface Waters Whole Watershed Manipulations	Northern Ariz Univ	$14,406	STI INT
8616765	Partridge R. B RUI New Ways to Find Primeval Galaxies	Haverford Col	$111,800	STI INT
		DIV SUBTOTAL INT	$126,206	
		DIR SUBTOTAL STI	$126,206	
		FINAL TOTAL:	$14,992,099	

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

January 19, 1988

nsf

OFFICE OF THE
DIRECTOR

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Walgren:

The House Science, Space and Technology Committee's report that accompanies H.R. 2330, the FY 1988 National Science Foundation Authorization Act requested a report on the status of the Foundation's efforts to develop a computer network management system.

Specifically, the Committee asked for a description of the plan to create a high capacity, high speed national research network within a decade. Along with that, the Committee asked for an assessment of user needs, current and projected technology options, deficiencies/plans for the management of the network, and cost estimates both for creating and for maintaining the network.

I am pleased to provide you with a copy of the requested report. If I can provide you with any additional information, please let me know.

Sincerely,

Erich Bloch
Director

Enclosure

cc Honorable Sherwood Boehlert

1. INTRODUCTION

The House Committee on Science, Space, and Technology report accompanying the National Science Foundation Authorization Act for 1988 states:

> "The Committee now understands that NSF has formulated and begun to implement an overall plan which has as its goal the creation of a high capacity, high speed national research network within a decade. The Committee requests the NSF provide a description of this plan, including the interim goals and estimated timetable for achieving them by November 1, 1997. The Committee is particularly interested in NSF's assessment of user needs, current and projected technology options, deficiencies/plans for the management of a completed network, and cost estimates both for creating and for maintaining the network."

The plan referred to is, in fact, an ongoing planning process involving representatives of several Federal agencies including NSF, DARPA, DoE, NASA, DHHS, ONR, and NBS under the aegis of the FCCSET, in response to a charge of the 99th Congress to the OSTP.

This report responds to the Committee's information requests, describes that plan, and outlines the NSF parallel plan.

2. INTERAGENCY CONTEXT

Agencies participating in interagency network planning are DARPA, DOD, DOE, NASA, NBS, NSF,and NIH.

In the past year, they have addressed the following:

- the networking needs of the Nation's academic and Federal research computer programs, including supercomputer programs, over the next 15 years, including requirements in terms of volume of data, reliability of transmission, software compatibility, graphics capabilities, and transmission security;
- the benefits and opportunities that an improved computer network would offer for electronic mail, file transfer, and remote access and communications; and
- the networking options available for linking academic and research computers, including supercomputers, with a particular emphasis on the advantages and disadvantages of fiber optic systems.

Their deliberations were aided by experts from government, industry, and academia. White papers were produced on networking

trends, requirements, concepts, applications, and plans. The group reviewed the status of existing research networks, analyzed the requirements of researchers to access networks, and assessed the capabilities of current technology.

Development Strategy

The evolving strategy is to develop a three-tiered upgrade of existing research support network(s), providing short, medium, and long term solutions. Although the planned upgrades are initiated simultaneously, they reach fruition in (respectively) one to two years, three to five years, and ten to fifteen years. The plan builds on and expands the policy of inter-agency collaboration among network service providers begun by NSF and DARPA. Although economies of scale are projected, some reprogramming, and incremental support may be needed. Because the final form in which the plan will be implemented cannot now be forecast, NSF's own program plan for networking is aligned with the interagency plan and is flexible.

The first tier in the development of a national research network assumes that the current Internet system developed by DARPA and networks supported by agencies should be interconnected over the next two years. These facilities, if coordinated and centrally managed, have the capability to interconnect many computer networks into a single virtual computer network. The first tier also assumes that the government should encourage and assist research facilities and academic institutions to establish local and campus area networks to connect to the Internet system. The estimated cost for this proposed upgraded service is $5 million per year, implemented through the shared resources of NSF, DOE, DARPA, NASA, and HHS.

The second tier requires an additional $5 million per year over the next five years for development and pilot projects to demonstrate advanced capabilities and to achieve data communications at 1.5 Mbit/s to 200-400 U.S. research institutions. It is estimated that these expanded and upgraded facilities will require additional annual funding of approximately $50,000,000 (across the Federal Government) to operate and maintain.

The third tier is a vigorous program of research and development across the Federal agencies. A total of $400 million is needed over ten years to advance the knowledge base and technology of computer network capabilities in order to achieve data communications and switching capabilities to support transmission of three billion bits per second within fifteen years. This will support a network 100,000 times more capable than currently available. The cost of operating this advanced network is estimated to be $200 million per year, given the current commercial tariffs for data communications.

The foregoing effort would also involve development of standards and their harmonization in the international arena. User participation in the standards development process would be expanded to get requirements for standards expressed early in the development process, and would speed the implementation of standards including those needed for enhancing network security, in commercial off-the-shelf products.

3. ESTIMATION OF DEMAND

The following methods of estimating network demand were used: analysis of a typical research campus, extrapolation from local area network utilization, and extrapolation of user needs.

A direct estimation of network demand was made using a major NSF university site as a basis. Network usage included wide area network facilities for supercomputer access as well as an extensive local area network. An absolute level of network demand for the next five years was estimated using three different models; task, user, and external flow. The task model focused on the network load generated by typical network tasks. The user model identified demand as a function of typical university network users. The external flow model centered on the university as an entity and estimated networking demand between it and other external locations. The three values of predicted network traffic were in agreement within an order of magnitude. They indicated that a thousandfold increase over current network resources will be needed within five years.

Extrapolation from experience with local area networks also projected need for a thousandfold increase in wide area network capacity over the next five years. A remote supercomputer access scenario was used to suggest how network transparency can increase the speed and accuracy with which engineering decisions can be made. Two orders of magnitude increase is needed to create a nationwide distributed file system on an existing 56-Kbit/s network; another order of magnitude is needed to accommodate expected increases in computer speeds. Thus a 45 Mb/s communication speed is indicated.

The community of users who will need to be networked together in the year 2000 will be distributed over the more than 3000 academic campuses, national laboratories, and other research facilities. Six classes of traffic were defined, which captured most of the sort of activity expected. Voice telephony was deliberately excluded on the grounds that these resources will continue to be procured by other non-education/research departments, and because voice telephony is based on completely different bit rate, line quality, and other requirements, and is of such a volume as to completely distort the design point of any reasonable research computer network.

The six classes of traffic are:

Class 1: Video and teleconferencing requires 50-Mbit/s peak bit rates, 1 Mbit/s average;

Class 2: Closely coupled "supercomputers". Examples might be a Connection Machine and a Cray, each executing different steps of a joint program job, requiring 3-Gbit/s burst rates;

Class 3: Workstation-to-host, closely coupled. The workstation user must interact with the supercomputer's execution stream in real time. To do this, the user must see one million picture element (pel) frame every 30th of a second. As a result, a peak rate of 720-Mbit/s is needed;

Class 4: Workstation-to-host, loosely coupled. One million pel frame per second results in a requirement for a peak rate of 24-Mbit/s.

Class 5: Fast packet switching may require 1-Mbit/s peak bit rate.

Class 6: Everything else. This includes packet switching as we now understand and use it, incidental voice for order-wire purposes, facsimile, modem traffic, and 64-kbit/s leased or circuit switched data. As a result, a 64-kbit/s peak bit rate is required.

Estimates of typical numbers of concurrent users who might be active within each traffic class, and the total aggregate bit rate generated by these users provides a network-wide estimate of total ongoing traffic requirements. The analysis yields total bit rates of nearly 1000 billion bits/second (1 Terabit/s). This is the aggregated bit rate distributed geographically over the network, a way of giving an approximate upper bound on demand.

One final requirement, the ability to accommodate inhomogeneity, is also important. The research community has particularly strong needs for its members to use systems whose characteristics are not forced into the same mold just so they can become parts of a communicating community. This requirement highlights the need for open systems and clearly-defined standards.

The above analyses estimate load increases for existing network topologies. An important additional need is to extend network service to the smaller universities throughout the nation; this would add another factor of 2 to 3 to the above estimates. Since by definition these research sites are not currently connected to an existing wide area network, there will be a demand for more communications lines rather than an increase in line speeds. Similar arguments can be made for international networking.

An analysis was also made of existing utilization of wide area networks used by scientists to access unique remote facilities

(supercomputers, accelerators, analysis software, and databases) and for communication and coordination among the large geographically distributed U.S. and international scientific collaborations.

High-speed local area networks are being connected to low-speed wide area networks throughout the research community. Communication speeds of 1.5 Mbit/s, digital data service (DDS), and packet networks have been introduced to wide area networks, and their use has become widespread. Nevertheless, wide area networking capacity has not kept up with the capacity of local area networks. Some wide area networks handle both high data volume and highly interactive traffic over the same communications links. This results in suboptimal performance. At the functional level, wide area network user interfaces have not kept up with their counterparts in local area networks.

The principal trunks, or backbones, of the major networks are similar in topology, and existing network links throughout the community are generally fully utilized. Some of these networks are severely overloaded, resulting in significant performance degradation. Additionally, more ubiquitous access is needed by the university research community, especially at smaller institutions. For example, there is a need for nationwide, high-speed access to large scientific databases.

4. REQUIREMENTS

Based on these demand estimates, today's networking resources are not adequate to support the needs of future U.S. researchers. Existing network links throughout the research community are generally low data rate (i.e., at most 56 Kbit/s) and fully utilized. Some of these networks are severely overloaded, resulting in significant performance degradation. Additionally, more ubiquitous access is needed by the university research community, especially at smaller institutions. By 1992, U.S. researchers will need access to wide area networks that are one thousand times more capable than those available today.

By 1992, a large number of these campuses will have local area networks running at 10 Mbit/s; many will have 100-Mbit/s local area network backbones. These campuses will be interconnected by long-haul networks organized in a variety of ways. Agency and discipline networks will serve the needs of user communities with a common orientation or mission. Consortium networks will provide for efficient access to shared resources, such as supercomputers, by their biggest users. Geographic networks will provide for the general interconnection of campuses or users without special needs of affiliation. One or more backbone networks will carry transit traffic between geographic networks.

Remote high resolution interactive workstations will be essential for using computer graphics techniques which enable researchers to visualize and simulate two or three dimensional structures.

Molecular biology, space exploration, medical imagery, ship and airplane design, engineering of new materials, and energy research applications are some of the research areas that would benefit from increased speed of data transfers. Higher speeds are also needed to allow sharing of large databases produced by distributed research enterprises and to keep pace with future high performance computers.

A minimum of 64 kbit/s-to-user workstations will be needed; some applications, such as workstations interacting with supercomputers may require high speeds such as 1.5 Mbit/s or greater for one user. In addition, groups of experimental researchers will, before 1992, require upwards of 1.5 Mbit/s for data file transfer and for sharing of programs and databases among the computing facilities at their home institutions. One implication of these data rates is that each campus will need at least 1.5-Mbit/s capacity into the Internet, since this bandwidth must be shared between campus users.

Other future requirements relate to interoperability and security. Some networks are not compatible, because they were developed according to design goals that did not include consideration of uses and technologies unrelated to the job at hand. Many networks are overloaded with traffic. Authentication procedures and security are not uniformly good from network to network or from host to host.

Although Integrated Services Digital Network (ISDN) switched and non-switched circuits ranging from 64 Kbit/s to 1.5 Mbits/s will be available in the larger metropolitan areas of the U.S. within the next five years, these services will fall short of the requirements for research networks which serve to connect campus area networks (CANs) operating with advanced capabilities (100 Mbit/s). Wide area networks operating at 56 Kbit/s to 1.5 Mbit/s cannot handle the expected high data volume.

Longer-range estimates vary, but it seems clear that, by the year 2000, the Nation's research community will be able to make effective use of a high-capacity national network with one hundred thousand times more capacity than that available today, and with speeds measured in billions of bits per second. Without improved networks, speed of data transmission will be a limiting factor in the ability of future researchers to carry out complex analyses and to share unique scientific resources. Presenting computer generated images that appear to move requires 30 frames per second; each frame represents about 10 million bits per second (Mbit/s) of information. This presentation thus requires a transmission speed of 300 million bits per second of information. To support thousands of scientists simultaneously (even using advanced compression technology) would require backbone speeds of 300 billion bits per second (Gbit/s).

5. TECHNOLOGY CONSIDERATIONS

Barriers

There are several technological problems associated with advanced networks, involving scale, scope, and complexity. The first problem is availability of high-speed packet switches. The majority of switches available today support data rates of 64 kbit/s, with a few high-performance switches supporting a small number of 1.5-Mbit/s circuits. The 1992 Internet will need packet switches capable of operating at 1.5-45 Mbit/s. The hardware and software technology necessary to build these switches exists today, but product development lead times and uncertain markets for such switches may impede their availability.

The second problem is routing of packets in this Internet. Existing routing algorithms for large networks are based on hierarchical topologies. It may not be possible to impose a hierarchical structure on the 1992 Internet. In addition, constraints on routing must be imposed to reflect organizational realities. Mission-oriented networks need to continue to meet their mission-oriented needs and must be protected from excess transit traffic. Existing routing algorithm technology does not fully address these needs.

The third problem is one of robustness. Safety features must be installed to prevent hardware or software failures from propagating. Without these "firewalls", each increase in scale will result in a decrease in internet availability. In addition to concern over hardware and software failures, some attention must be given to securing the network from malicious users.

The fourth problem is one of performance. As recent experience has shown, the performance of internetworks constructed out of overloaded networks and overloaded gateways can be poor. The scale of the 1992 internetwork will aggravate these problems. These problems could be alleviated by the installation of backbones of sufficient capacity between strategic points of the Internet, following network engineering studies to determine the optimum backbone locations. In addition, more technology is needed in controlling congestion and providing efficient and fair allocation of network bandwidth within desired policy guidelines.

Common Carriers

The position of the common carriers is rapidly changing, particularly in North America, due to deregulation, plans for ISDN, and voice/data integration. Less visible, but in this context more important, is the rate at which buried optical fiber is being installed and the operating costs for it. Communication costs (e.g., cents/bit/second/kilometer), as a function of time over the last few decades, shows a steady reduction as fiber installation has increased. No corresponding revolution in

switching technology to match that in transmission technology has occurred, but there has been progress. Slow-switching (digital cross-connects or "DACS: units) equipment at T1 (1.5 - 2 Mbit/s) and recently at T3 (45 Mbit/s) rates are being rapidly installed, and switching at the raw fiber bandwidth of 0.5 to 1.7 Gbit/s is on the horizon.

Fiber is being installed first in intercity trunks and in local area networks; by the year 2000, fiber access between local premises and the central office (the "last mile") should be widely available.

Bandwidth

At least two dozen important communication enterprises are installing buried single mode optical fiber, and, over the next few years, ten of them will have significant national coverage. For added robustness, the more ambitious buried fiber carrier networks are two-connected (two fibers bundles installed) between nodes (and probably eventually three-connected).

Each installed fiber, although now being used at a single wavelength to send digital bitstreams at synchronous rates of 1.7 Gbit/s maximum, ought to be able to support 10 Gbit/s by the year 2000. The fibers are today usually installed in bundles and are typically 12x12 = 144 fibers in a bundle. One might get a capacity estimate for the year 2000 by noting that these numbers add up to 1 Tbit/s per bundle, and that when spatial redundancy and the multiplicity of carriers are included, most large cities should in the year 2000 be interconnected by terabits of raw digital capacity.

There are two wild cards to this prediction, whose realization could increase the capacity greatly even beyond these figures. The first is Wavelength Division Multiplexing (WDM). The intrinsic passband of the already installed single mode fibers is over 100,000 times the 10 Gbit/s that has been quoted above as the bandwidth of each fiber. In order to use more than today's one wavelength at a time, further advances in multispectral lasers and receivers (typically based on diffraction gratings) will be required. Operational WDM systems today use 2 wavelengths; figures up to 12 wavelengths characterize today's laboratory experiments. By the year 2000, the number of wavelengths simultaneously usable over fiber that was installed in the 1980s should be somewhere between 100 and the support limit of 100,000.

The other wild card is coherent optics: the use of the familiar heterodyne form of transmission and reception but at optical frequencies, rather than incoherent on-off energy detection. This should at least increase the signal-to-noise ratio and thus reduce the repeater spacing and may have other capacity increasing consequences.

Satellites are not expected to play a major role in research communication networks. Their major usage niches are expected to be broadcast and program distribution and access to hard-to-reach places not served by fibers.

Switching

Today's DACS (Digital Automatic Cross-Connect systems) frames, which are controlled by Telco operators on request from subscribers, will, under "software defined network" and ISDN plans of the major carriers, become subscriber-actuatable over the next few years. These provide switchover times of the order of seconds at a bandwidth granularity of DS-0 (64 kbit/s) and of DS-1 (T1; 1.5 Mbit/s). DS-3 DACS equipment 45 Mbit/s) is expected to be installed beginning next year. DACS switching speeds of the order of milliseconds appear to be no problem. Switching of entire per-fiber bitstreams is not available yet, but electronic GaAs-based switching or pure photonic switching is progressing and should become available in 100 x 100 configurations by the year 2000.

Today's switchover times of on the order of a millisecond may also characterize the photonic switching of 2000. Larger switches can be built by the usual concatenation of smaller switching elements.

Local Processing

There is always the question whether the growth of local processing power will lead to a reduction rather than an increase of the communication bandwidth required. One projection, for example, is that workstation MIPs will increase from today's 4 to a 1000 by the year 2000. However, the need to intercommunicate may increase substantially, simply due to the nature of research as an enterprise that requires large and apparently increasing amounts of intercommunication with colleagues, and with computing and shared information resources. No meaningful prediction is possible on whether the increase in local processing MIPs will have a significant effect, either positive or negative, on the communication capacity required.

Conclusions

The technology of fiber communication will produce by the year 2000 a better than 1:1 ratio of the number of communication channels of all speeds available to the number of users that have a need for these channels. (This contrasts with 1:100 to 1:1,000,000 in today's networks.)

The traditional packet switching approach, whose main purpose is to save on bandwidth by line sharing, may not be the right approach for many of the requirements of 2000. The majority of the bandwidth requirements may be best served by circuit switching. If this prediction is wrong and packet switching is

widely needed in the year 2000, very fast packet switching, now only in the early prototype stage, will be required.

There will always be some requirement for packet switching service, including very rapid time multiplexing of messages for different destinations (e.g., many copies of the same short document to different addressees). Packet switching provides speed matching and allows for better management of highly dynamic connections as well as supporting the need for server resources (such as databases) to respond to many requests nearly simultaneously. The homogeneity/transparency requirement also argues for a clear-channel circuit switch approach. The optimum research network of the future could be thought of as a homogeneous network of inhomogeneous systems.

6. NSF PLAN

This section describes activities and plans for the NSF that are aligned with interagency planning.

The sharing of agency networks and linking them in an Internet is the major activity. The purpose of this activity is to reduce unneeded redundancy, and to reduce total cost to the Government, while maintaining or improving service levels. For example, several agencies (including NSF, NBS, DARPA, and DoE) maintain transcontinental leased lines operating at 56 thousand bits per second (kb/s) as part of their operational networks. Some of these circuits are fully utilized and their agency networks correspondingly congested. Yet, because the long-haul communications market is highly competitive and has excess capacity, for a figure approximately equal to the sum of those now being spent on 56 kb/s circuits the agencies could jointly fund and share circuits providing the same connectivity at 1.5 million bits per second (Mb/s) - nearly thirty times the speed and capacity. NSF Networking Program Officers are negotiating with their counterparts in the other agencies to implement this improvement, which will achieve the trunking speeds of the second tier network described earlier, although it will reach fewer research campuses.

NSF funding will go primarily to activities which assist the development of regional networks, enhance the Internet backbone, and support the required research and development for advanced network services. The requested budget for networking in FY1988 is $12.M. This meets needs for the tier 1 and tier 2 networks described above, (but with reduced coverage), and initiates research toward the tier three network.

Regional networks are being initiated on a cooperative basis with confederations of campus networks via awards for switches and connections to the transcontinental NSFNET high-speed backbone network. These awards will "phase down" support for intercampus links over a three year period, but support connections to the backbone for up to five years.

NSF has procured professional network management to operate the NSFNET backbone and to provide information services to all connected campuses. About $20M over five years is budgeted for these activities.

Enhancement of the educational process in the U.S. has traditionally been a Foundation concern. Since the three-tier plan focuses on research institutions, it is accordingly natural that the NSF look to "the capillary structure" of the national network, i.e., the part of the network that should reach the more than 2000 other institutions of higher learning. These are primarily teaching institutions, but experience gained by NSF with CSNET indicates that there are valuable educational payoffs from connecting them to research institutions. This is accomplished at a modest level through the participation of the Networking program in NSF's broad activity of supporting research in undergraduate institutions, and by supporting the development of low cost, entry level network technology.

NSF plans to continue the activities described above. This includes additional research to move toward use of ISO protocols, very high speed switches and circuits, and additional support for basic research in switching algorithms, routing and traffic modelling.

Management Issues

The principal management problem that is exacerbated by the uncertainties of interagency planning for transition from a multiplicity of agency networks to a national research network is that of funding models for connections to the network. Thus, the problem is that end-users of networking, and perhaps campus administrators will perceive some networks to be "free" while others "cost money"; this misperception may hinder the development of networks that support the general research enterprise. Mission-oriented agencies typically fund an investigator or a cohesive group of researchers on a research campus, and pay in full both the initial and continuing costs of installing and operating a connection to the agency's network. NSF-sponsored campus connections on the other hand are intended for the use of all researchers at the institution - those supported by the several NSF scientific divisions as well as those supported by other agencies.

Central funding of campus connections and their continuing costs would severely distort the NSFNET budget, hence the NSF has elected to initiate procedures that will result in usage charges being levied against campuses by the mid-level networks that connect them to the transcontinental NSFNET backbone. (It will of course be up to each campus to devise a funding strategy to pay the levy; a partially subsidized service, consistent with OMB Circular A-21 and patterned upon the way campus telephone service is charged, seems likely to be adopted on some campuses.)

As NSF and the other Federal agencies expand their collaboration in providing network services to the scientific community, the issue of management for the interconnected agency networks becomes more important. At present, coordination of the several network management and operation organizations, each funded by its responsible agency, is achieved informally by expanding existing procedures and mechanisms that grew out of experience in the DARPA Internet. With increasing scale of collaboration (e.g., shared trunks of higher bandwidth, more shared connections), the informal methods will inevitably prove inadequate and will need to be supplanted by a more structured form, perhaps including funding of a single management and operation organization. Although several models exist for such interagency projects, including the "lead agency" concept and the establishment of a jointly-funded quasi-public corporation, each has disadvantages, and there is no clearly dominant choice.

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

February 3, 1988

nsf

OFFICE OF THE
DIRECTOR

Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
Committee on Science, Space and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Walgren:

Enclosed is a report on Knowledge and Technology Transfer from NSF-supported Centers and Laboratories to Smaller Businesses. This report was requested by the FY 1988 NSF Authorization Act (HR 2330).

The report is the outcome of a study of the activities of current centers that was carried out by an NSF task group. It discusses a range of potential options for the future. It should be noted that any steps to expand the role of NSF centers in this arena will depend upon future budgets for NSF and these center programs.

Either my staff or I will be available to discuss the report and its recommendations with you or your staff.

Sincerely,

Erich Bloch
Director

Enclosure

Knowledge and Technology Transfer
from NSF-supported Centers and Laboratories to Smaller Businesses:
Report to the U.S. Congress from the National Science Foundation

January, 1988

This report reviews the transfer of scientific and engineering knowledge from NSF Centers to small businesses and recommends actions to further such transfer in the future.

Although in the past there has been limited attention paid to small business connections by most NSF centers, a survey of center directors and NSF center monitors specifically on this topic has turned up a wide variety of small business involvements. Such activity varies enormously from center to center and from NSF program to program. The recently established Engineering Research Centers [ERC's] have the most active involvement with smaller businesses but significant connections are also reported by many other types of laboratories and centers including a majority of the nine Materials Research Laboratories [MRL's], and many of the 39 Industry-University Cooperative Centers [IUC's]. The potential for small business contacts was also noted by Supercomputer centers and by the newly formed Minority Research Centers of Excellence[MRCE]. Even basic research centers such as the three NSF-supported astronomy facilities were able to note some types of small business connections.

Center orientation to tech transfer and to small business involvement varies with type of program and the ground rules under which different centers were developed. Some centers such as the ERC's and IUC's are encouraged to attract industry support. Others are not. Some subjects also lend themselves to small business opportunities more readily than others. For example, the field of biotechnology currently appears to be attracting a very large number of small start-up enterprises. The further centers proceed toward the applied end of the research-development continuum, the more potential there will be for transfers especially to smaller firms.

Involvement of NSF centers with smaller businesses take place in five categories: [1] direct affiliations, [2] information sharing and educational activities, [3] joint projects, [4] involvement through third parties acting as mediators, and [5] special arrangements. Strengths and weaknesses of each approach as presently configured can be summarized as follows.

1. Formal center affiliations usually require annual fees in excess of $25,000, which limits small business participation. Consortia arrangements and dual fee structures give some access to small business, but these arrangements are not yet widespread. IUC's in particular count on industrial affiliate fees as a major source of support and are therefore understandably reluctant to grant full participation to any firms at reduced rates.

2. Information sharing takes several forms including print, meetings and workshops, facilities access, and visits. All centers contribute substantially to the scientific and engineering literature which is ultimately available to all. However, some of this literature may be too technical and require considerable interpretation and reworking before industrial applications become evident. By being close to the research and knowing the researchers, industrial affiliates are better able to reach this level of understanding. Small working conferences and workshops where substantial transfers of technical knowledge can take place are also often reserved for affiliates. However, all ERC's and many other centers hold some open conferences or other events which are attended by small businesses. Some centers also have research facilities and costly equipment such as supercomputers whose use can be of significant value to small firms. Most centers also entertain a stream of visitors throughout the year and some give special consulative assistance to small businesses on an ad hoc basis.

3. Small businesses sometimes develop joint projects with center researchers, thus gaining informal or indirect access to the center's capacity. Patents and licensing arrangements may also emerge from such joint efforts. Every ERC has at least one joint project with a small business, and some have several in the works. The potential for this mechanism seems great.

4. Third parties often serve as catalysts or underwriters for small business linkages. Among these are state and local agencies, trade associations, larger firms, and other federal agencies. There has been a substantial increase in the activity of state and local economic development organizations in the last decade. NSF has been able to leverage a great deal of state and local government support especially for IUCs. Most ERCs also have such connections. Many of these agencies give special encouragement to small business development and thus represent a very promising conduit for their involvement. Large numbers of small businesses can also be provided access through trade association involvement with or affiliation in NSF centers. More than half the ERC's have such ties, but the type of transfer which results for small business members is likely to be of the "awareness" variety. Some small firms also may get to share technology from NSF centers through subcontractor relationships with larger firms or through special centers subsidized by larger firms with a particular interest. Various other federal agencies also may be available to encourage small business involvements with centers in areas of application relevant to those agencies.

5. Some NSF centers have units or officials designated to provide special knowledge or technology transfer services. A few are specifically oriented to small businesses. Another trend of the 1980's has been the growth of special organizations to assist entrepreneurs in the early stages of business development. Many of these "small business incubators" have a high tech orientation and many have university affiliations. Some foster the formation of new firms by researchers.

Recommendations

Mechanisms for technology transfer are continuing to expand nationwide at the federal, state, and local levels and within the private sector. Many NSF centers are taking advantage of these new developments, often to the specific benefit of small business. However, there are additional actions which can be taken to enhance small business involvement with the NSF-supported centers and laboratories. They are of three kinds.

Recommendation #1: Administrative Encouragement

NSF will encourage more activities through suggestions and administrative measures which do not require augmentation of center budgets, e.g.

- specific center reporting requirements on small business participation;
- encouraging inter-center information sharing on small business transfer strategies;
- encouraging more cooperative efforts within the local environment.

Recommendation #2. A Joint Project Incubation Program

If additional financial resources can be made available, NSF will consider providing special new incentives for specific joint projects between small businesses and centers.

Recommendation # 3. An Innovative Transfer Stategies Program

If additional financial resources can be made available, NSF will consider the initiation of a program to encourage new efforts by NSF-sponsored centers to interact with smaller businesses. Competitive proposals would be invited from existing centers to achieve such ends through a variety of mechanisms such as:

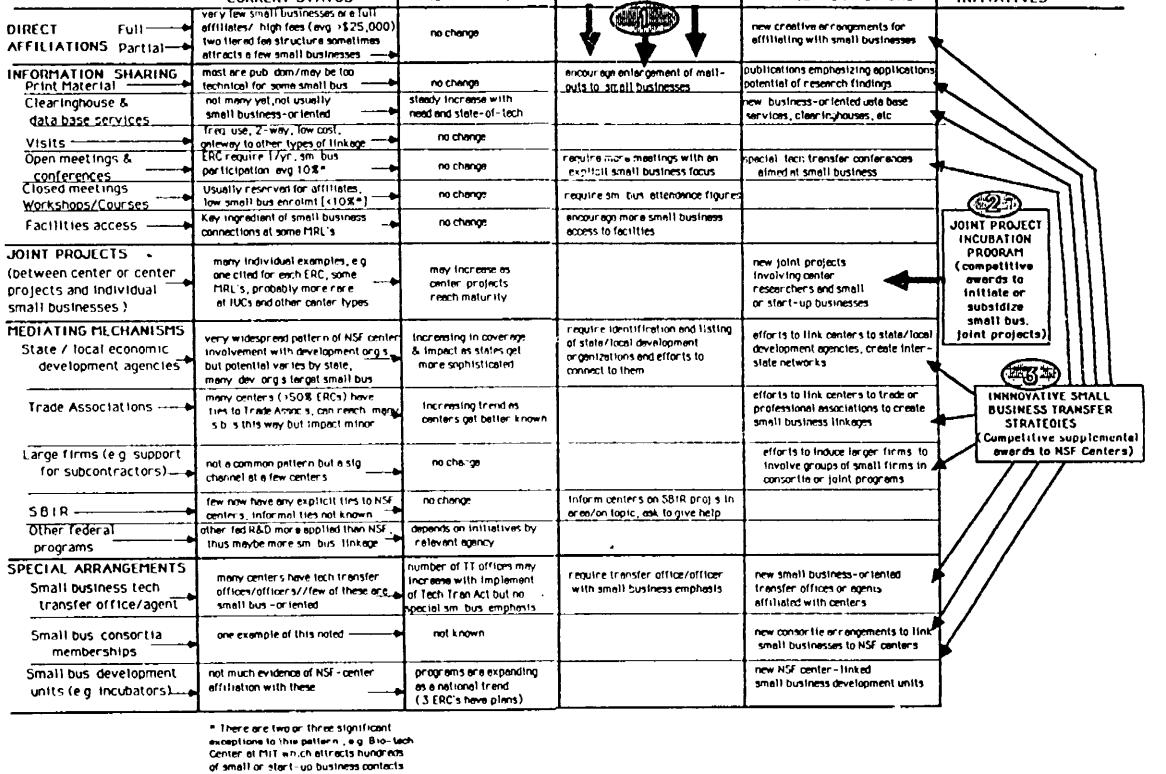
- special conferences for small business;
- new programs to support small business-oriented technical data base services, clearinghouses, and specialized publications;
- installation of small business-oriented tech transfer agents or offices;
- establishment of center-linked development units such as small business incubators.

Figure 1 [attached] summarizes current efforts and NSF recommendations in matrix form.

Figure 1:

SMALL BUSINESS INTERACTIONS WITH NSF CENTERS

MECHANISMS OF KNOWLEDGE AND TECHNOLOGY TRANSFER



* There are two or three significant exceptions to this pattern, e.g. Bio-tech Center at MIT which attracts hundreds of small or start-up business contacts

Knowledge and Technology Transfer from NSF-supported Centers and Laboratories to Smaller Businesses:

Report to the U.S. Congress
from
The National Science Foundation*

January, 1988

Objectives and Scope

In recent years the National Science Foundation has given an increasing number of long-term awards to universities to establish interdisciplinary laboratories and centers. The primary purpose of these awards has been to strengthen our national capability to perform certain types of large-scale research that cannot be performed by single investigators or small teams with limited resources. Additional purposes have been to facilitate interdisciplinary research, to foster university-industry interactions, and to build a stronger knowledge base in certain areas critical to industrial competitiveness or clear national need. Many of these centers have also sought advice, participation and support from private industry since it is assumed that private industry in general benefits greatly from applications of the scientific knowledge which is being developed. It is less clear how these benefits are distributed, i.e., which industries benefit and in what ways. Such questions fall under the general heading of "knowledge or technology transfer."

The U.S. Congress has now asked the NSF to report specifically on how the various NSF-supported centers and laboratories transfer scientific and technical information to businesses, with emphasis on small and medium sized businesses. The Congress also want to know what can be done in the future to enhance such transfer activity. This report has been prepared in response to this request and has three purposes:

1. to indicate the context for NSF activity in this area;

2. to indicate the ways in which NSF and its centers now promote knowledge transfer or technology transfer to smaller businesses; and

3. to indicate what further efforts could be undertaken in this direction.

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*Prepared by the NSF Task Force on Technology Transfer,
Lynn Preston, Chairperson, Ronald G. Havelock, Consultant/writer

It should be made clear at the outset that the charge to the Technology Transfer Task Force was limited to a summary review of current center activities. It does not represent a full accounting of the numbers of small businesses involved with NSF centers and the impact that such contacts have had on business success, employment, and technological advance, even though it appears that the impact may be quite substantial. Nor did the study extend to a systematic assessment of the most effective means to transfer knowledge from centers to small businesses. Rather, what is provided is a framework for such an assessment and an indication of areas of strength and weakness in current efforts. A more extensive and systematic effort to collect such information is prerequisite to the formulation of sound policy in this area and is recommended.

I: Context for NSF Activity in the KnowledgeTransfer Arena

"Knowledge or technology transfer" refers to a rather broad area of concern which touches on the basic and applied sciences but is clearly distinct from them. It is necessary at the outset of this presentation to set down some definitions which limit the scope of this report.

A. Definition of Terms

Four key terms require definition. These are: [1] knowledge or technology, [2] transfer, [3] NSF-supported centers and laboratories, and [4] smaller businesses.

1. Knowledge or technology is defined as:
   all knowledge products derived from scientific and engineering research.

Any outputs from basic science which have potential value for industry could fall within this definition. These might include technical knowledge pertaining to processes, methods, designs, and products.

2. Transfer is defined as:
   transmittal to new users and transformation into new products or processes with different and/or more widespread applications.

NSF's prevailing mission is to support the generation of knowledge and experimentation with its use. This report seeks to determine an appro-

priate role for NSF in facilitating the transfer of knowledge to industrial users. Such facilitation involves a partnership among NSF, academic researchers, and industry. Responsibility for development of new processes and products derived from scientific knowledge rests with these other partners and lies outside the NSF purview.

Transfer may occur by any and all channels including publication, distribution, patent licensing, demonstration, teaching, training, consultation, collaboration, etc. A key aspect of transfer is level of impact. Low-impact transfer events create user awareness of or interest in the technology but little more. High-impact transfers lead to substantial changes in the user's situation including innovation, improved productivity or efficiency, and increased profitability. High-impact transfers are most likely to occur when researchers and users work closely together on mutual interests for long periods of time. Many special efforts to improve technology transfer are aimed at increasing such higher-impact transfers.

3. NSF-supported centers and laboratories are defined as:
organizations supported by NSF awards in which numbers of scientists and/or engineers work together on research programs of long duration.

For the purpose of this report we have included centers with a wide variety of program objectives from several different NSF divisions. In some instances, the award has been made primarily to support the acquisition of equipment and facilities which are then made available to individual researchers or research programs. As will be noted subsequently, these centers and laboratories differ widely in their orientation to industrial affiliation and to technology transfer either to small or large business.

4. Smaller business is defined as:
any technically-oriented business with fewer than 1,000 employees.

This definition includes the standard definition of "small" businesses as those firms employing fewer than 500 employees, and "medium-sized" businesses as those employing between 500 and 1,000 persons. The definition also assumes that the enterprises are independently owned and unaffiliated with any other company whose employees would bring the combined total employment to more than 1,000.

"Technically-oriented" signifies those businesses which might be expected to benefit directly from the application of advanced NSF center research. There are at least three distinct types of small business which

fit this category. One is the start-up business in which researchers take a leading entrepreneurial role. Often the founding members of such enterprises are university professors or former professors. They are fully imbued with a basic understanding of the technology and what it can do, but may not have a strong grasp of such issues as marketing and business management. A second type is represented by small businesses which have established markets and/or manufacturing capabilities but might benefit greatly from an infusion of new technology related to their product line or their manufactring process. Such companies may be short on in-house technical expertise and may have a difficult time appreciating the significance of new scientific and engineering developments from which they could profit substantially. This is the group that stands to benefit the most from active transfer efforts by the research community. Yet a third group represents the suppliers to the scientific community of specialized materials and customized equipment in lots too small to interest larger companies. This class of businesses has a strong motivation to stay in close contact with laboratories and centers which is somewhat different from the other two.

B. The NSF Role in Knowledge/Technology Transfer

The primary function of the NSF is the support of fundamental scientific and engineering research. Traditionally, the NSF role in knowledge transfer has centered on the provision of support for undergraduate and graduate training so that U.S. industry is continuously supplied with a highly skilled and technically sophisticated work force. Where work of an applied nature is supported, NSF funding tends to be restricted to the generic aspects of that work, i.e. research which does not lead directly to marketable products and services without considerable additional applied R&D on prototyping, testing, and manufacturing processes well beyond the scope of NSF support. This does not mean that there has been no transfer from NSF programs. On the contrary, NSF research has led to major technological advances in many fields which have contributed in a significant way to economic growth and national security. Such high impact transfers usually do not occur because of any deliberate effort by NSF to manage the transfer process. Rather, they occur through through pre-existing channels and mechanisms and through private sector initiatives.

During the 1970's NSF did develop an approach to transfer through the program entitled "Research Applied to National Needs" (RANN). Many RANN projects were designed to bring universities and industry together in joint activities, and although almost all the RANN programs were phased out by the late 1970's and early 1980's, they provided experience on what can be done in this arena. The current program of Industry-University Cooperative Centers is based on that experience. The 39 IUC's currently in operation give ample proof that NSF can act as a catalyst to leverage substantial industry support for research in many fields.

NSF's Small Business Innovation Research Program [S.B.I.R] is an important example of a program designed to promote technology transfer. Under authority of the Small Business Innovation Development Act of 1982 [P.L. 97-219], NSF sets aside a fraction of its budget for competitive awards to small businesses to conduct research on new technologies with a defined market potential. This program requires applicants to structure their work in three phases, the first two of which are eligible for NSF support and the third requiring full funding from other sources. In 1987 there were 152 new Phase I awards and a smaller number of Phase II awards. There have been numerous cases of commercially successful innovations emerging as a result of this program.

The S.B.I.R. program serves as an example in at least two respects. First, it establishes the fact that there is considerable small business interest in exploiting research opportunities, often in some form of collaboration with university faculty [about half of all S.B.I.R. awardees make use of university faculty as consultants performing fundamental research in the same field as the application]. Second, it sets a firm precedent for the use of public funds to leverage substantially greater amounts of private funding for technology-based commercial ventures.

A third case where NSF support has a technological orientation is in the Engineering Research Centers Program [ERC's]. The intent of this program is to provide substantial support for fundamental engineering research and education in selected areas critical for the competitiveness of U.S. industry. The ERC's have been structured in such a way as to encourage substantial industry involvement in the direction of research and education programs of each center as well as providing substantial financial support to that center. The ERC's thus far established have been very successful in attracting such industry involvement and support. However, since the first centers established are now only in their third year, it is too early to tell how well these arrangements will work in providing substantial high impact transfers.

II: How NSF Centers Now Promote Transfer to Small Business

Although NSF centers have not been focused on encouraging small business involvement, a survey of center directors and NSF center monitors specifically on this topic has turned up a wide variety of mechanisms whereby such involvement is already taking place. These activities vary enormously from center to center and from NSF program to program. Inquiries were made of most center-laboratory programs including the following:

- Engineering Research Centers [ERC's] of which there are now 14; six were entering their third year of operations in the fall of 1987;
- Industry-University Cooperative Centers [IUC's] of which there were 39 as of November, 1987;
- Materials Research Laboratories [MRL's] of which there are now nine;
- National Center for Atmospheric Research [NCAR];
- Supercomputer centers;
- Three astronomy facilities including the National Astronomy and Ionosphere Center [NAIC], the National Radio Astronomy Observatory [NRAO], and the National Optical Astronomy Observatory [NOAO].

A. Types of Centers and General Level of Activity Re Small Business

Center orientation to knowledge/technology transfer and to small business involvement varies with type of program and the ground rules under which different programs were developed. These differences result in varied approaches to transfer, affect the level of transfer activities, and even determine which types of activities are feasible or appropriate. Five types of differences should be noted: [1] explicit industry affiliation, [2] subject, [3] placement on the basic-applied continuum, [4] purpose, and [5] age.

1. Explicit Industry Affiliation

A major distinction should be made between centers which are encouraged to attract industry support and those which are not. The IUC's are actually structured in such a way that industry and other non-federal support will predominate, with NSF funding completely phased out over a five year period. ERC's are also expected to attract industry affiliates who will contribute a substantial but not necessarily a majority share of financial support. In contrast, MRL's, astronomy laboratories, and the NCAR receive the great bulk of their funding from NSF, and there is no

particular expectation that they reach out to the private sector for additional support.

2. Subject

The NSF centers and laboratories obviously differ widely in subject matter. It is likely that some subjects lend themselves to more private sector interest than others. For example, materials research would appear to have more industrial applications than astronomy research. It also may be that some subjects lend themselves to small business opportunities more readily than others. For example, the field of biotechnology currently appears to be attracting a very large number of small start-up enterprises. Such patterns may reflect the state of the technology as well as the subject matter per se. They may also reflect the extent to which an industrial infrastructure has already developed in relation to the application opportunities. In established materials areas such as steel, polymers, and ceramics, there are large-scale fully developed industry users with a major and long-standing stake in new developments. This does not rule out small business participation but it changes the nature of the game for the smaller actors.

3. Placement on the Basic-Applied Continuum

The application-orientation of the research field is also a factor which is likely to affect industry interest and potential for technology transfer in major ways. It is customary to think of R&D as a continuum from very basic research to applied research and product-oriented development. The primary NSF mission is support of the basic end of this continuum. Nevertheless, many of its centers do conduct some applied research which includes the development of prototypes or proof-of-concept demonstrations of new processes and materials. For example, the ERC's are intended to perform generic research in areas that are important for technological advancement. The further centers proceed toward the applied end of the continuum, the more potential there will be for transfers to both large and small business.

Opportunities for small business participation may be greatest at the most applied end of the continuum where application possibilities are most obvious and where return on investment is likely to come quickly. On the other hand, some small businesses may be in a better position to take advantage of early-stage findings because of greater flexibility, a greater

willingness to take risks, and a higher interest in exploiting small markets.

4. Purpose

The purpose of the laboratory or center is also an important factor affecting the ways in which it is likely to interact with small business. Some centers are established to conduct specific types of research, but others are organized as facilities which are then made available to the research community as a whole. A major NSF mission is to make available certain kinds of facilities and equipment which cannot easily be acquired in other ways. This includes various kinds of expensive and elaborate scientific equipment, very high speed computers, and so forth. Usually facilities are placed on university campuses and are intended primarily for use by university researchers, but use by R&D personnel from the private sector is also allowed because these facilities are intended for the general benefit of the society as a whole. Thus, facilities use was considered as a major category of potential small business involvement with certain types of centers.

5. Age

Finally, it may be important to consider the age of centers and center programs in viewing their potential for involvement with business in general and small business in particular. The newest centers are likely to be preoccupied with getting organized and getting their core research program going. For some of these newest centers, outreach to small businesses which offer little in the way of resources may be seen as an unwanted distraction. On the other hand, some older established centers may have difficulty taking on a new transfer role to small business, especially where they have already developed strong and long standing relationships with a few major industrial sponsors. Thus, the most promising candidates for small business activity may be those centers which are in their early established years, when they have developed a certain self-confidence and stability but are still open to developing new ways of relating to different types and sizes of industrial organizations.

B. Overview of Smaller Business Involvements by Type of Center

1. Engineering Research Centers [ERC's].

All ERC's must strive to involve industry in their research and educational activities. Such involvement takes many forms. Industrial personnel sit on advisory boards and help to set research and education goals. They are sometimes involved in joint projects. Some also teach courses and help guide the research of students. Although NSF has made no stipulation regarding how industry affiliations are to be organized, all ERC's have evolved fee structures for industrial affiliation which provide a substantial amount of financial support. Some charge a flat fee of between $30,000 and $50,000. which entitles the firm to a seat on the industrial advisory board, involvement in the research, and early access to findings. Other ERC's have tiered membership structures in which annual dues of $100,000 to $200,000 entitle participants to board membership, placement of technical personnel in residence, and joint projects which lead to early access to findings. Affiliates who pay fees in the range of $25,000 to $50,000 get a lower level of access and have somewhat less direct influence on programs. Affiliates at the lowest level may pay from $2,000 to $10,000 annually for publications, attendance at various meetings and workshops, and access to special briefings.

Unfortunately, such fees are sometimes prohibitive for some small businesses. Even when provisions for tiered affiliations as described above, few small businesses feel they can justify such outlays. One major exception is the MIT Bioprocess Technology Center which has strong ties to many small business and start-up enterprises.

Despite the small number of formal ERC affiliations with firms in this category, ERC's have many and diverse linkages with small businesses, and all of them will eventually have a potential for strong impact in this area. Each ERC is currently required to hold at least one open industrial meeting annually. This event represents one obvious access opportunity for smaller enterprises. However, connections to the small business world are also formed through a wide variety of mechanisms which are detailed in the next section of this report. Prominent among these are connections through state economic development programs and through various types of ad hoc joint endeavors.

2. Industry-University Cooperative Centers [IUC's]

Even though there are 39 IUC's with a seemingly large potential for involvement with small business, it is very important to recognize that IUC's are largely dependent on dues-paying industrial affiliates which are mostly very large companies. IUC's are reluctant to allow any special access to small businesses which might undercut the special relationship with major sponsors although some have sliding scale membership fee structures. There are a few instances in which smaller businesses have been helped by IUC's. This help is most likely to come either through informal channels or through the encouragement of state development agencies which are major contributors to some IUC's [e.g. the New Jersey Institute of Technology's Hazardous and Toxic Waste Management Center].

3. Materials Research Laboratories [MRL's]

The MRL's were originally established by the Department of Defense in the early 1960's in response to what was then seen as a major national need for improved materials science capability. However, in part because their work was of a very fundamental nature, oversight responsibility was transferred to the NSF in the early 1970's. The primary concern over the years has been to develop interdisciplinary materials research programs of high quality without regard to specific applications. These facilities are entirely supported by the NSF, and there has been little emphasis on formal industrial participation or co-sponsorship, either large or small. Access to MRL research is provided through collaborative research with MRL faculty members and groups, open meetings, and the published literature. In response to an inquiry from the Task Force, MRL directors were able to cite many instances of small business involvement. Collectively they report 145 visits from small businesses over the last year and involvement by about 75 small firms in meetings. Five MRL's report joint projects involving smaller companies. Four have ongoing relations with state development agencies through which many kinds of small business linkages can be made.

4. Supercomputer Centers

Recently, facilities were established to provide supercomputer access to university-based researchers. Involvement with small business has not been an objective of this initiative. Nevertheless, some activity involving smaller businesses has been reported, much of it encouraged and

facilitated by state economic development agencies. This includes visits and workshop attendance and some participation in joint projects with universities in which the smaller firm has some limited access to super-computer usage. All these Centers also have technology transfer offices, but these are not particularly oriented to small business. On the whole, the balance of such activity is on the larger business side.

5. The National Center for Atmospheric Research

In accordance with provisions of the Stevenson-Weidler Act of 1980 and the Technology Transfer Act of 1986, NCAR has created a full time position for a technology transfer officer. It also has an ongoing project with one small business and purchases equipment and services from a number of other small businesses.

6. Astronomy and Other Basic Science Facilities.

Very little direct interaction with small business is reported by any of the centers surveyed. Although small businesses generally have little interest in the output of these centers, relationships often develop in which particular small businesses are important developers and suppliers of specialized equipment needed in such research. Smaller firms are often in a better position than large firms to provide customized items in low volume. For example, the National Radio Astronomical Observatory estimates that 40-50% of its purchase awards are to small businesses. They also note two instances of start-up company spin-offs from their research.

7. New Centers and New NSF Center Initiatives

NSF has still more center-type initiatives either launched or in the planning stage. Among these are the previously mentioned Minority Research Centers of Excellence, and a new program of Science and Technology Centers. When initiated, the S&T centers will incorporate some of the same features of linkage to the industrial community as were required of the ERC's including industrial fellows, visitor programs, and other mechanisms for knowledge transfer. It is clear that many of these institutions have considerable potential for small business linkages of one kind or another, and they should be considered in the evolution of an NSF policy regarding overall center involvements with small business.

C. Mechanisms of Smaller Business Involvement with NSF Centers

There are a wide variety of ways in which involvement of NSF centers with smaller businesses can take place. In our review of these activities, we tried to develop a comprehensive listing of these mechanisms, dividing them into five types: [1] direct affiliations, [2] information sharing and educational activities, [3] joint projects, [4] involvement through third parties acting as mediators, and [5] special arrangements. It should be emphasized that these mechanisms are not all available to every center. Furthermore, most mechanisms are not mutually exclusive; a single instance of transfer might have involved several mechanisms. For example, a small business membership might be arranged through a special consortium arrangement facilitated by a state economic development agency, allowing access to print material, attendance at advisory board meetings, and leading to joint projects.

Some discussion of each of these categories follows.

1. Direct Affiliations

The most obvious way in which private industry can take part in NSF center activities is through paid membership in affiliate programs. Such programs have become increasingly frequent in the 1980's and have become a very successful way to leverage substantial amounts of industry support for fundamental as well as applied research programs. For example, ERC's and IUC's invite industrial participation through affiliate arrangements in which each industrial member pays an annual fee. In return for this fee, the company is awarded a seat on a research advisory committee and is given special and early access to the center's knowledge output in a variety of ways including publications, workshops, visiting fellowships, etc. This level of access can cost up to $100,000 or $200,000. Affiliation fees are almost always set at a much higher level than small businesses are willing or able to pay. Thus, with a few notable exceptions, small businesses not have gained much access to centers via this route.

Some ERC's and a few IUC's have set up two tiered memberships in which smaller businesses can participate in a more limited set of activities for a lower fee, usually one half of the full affiliation. Such reduced fees are still too high to attract large numbers of small businesses. A very few centers have arranged for more substantial fee reductions for small business. For example, the Ohio State University ERC

offers a $2,000 small business membership which gives access to programs and publications but no affiliate voting rights. The MIT ERC has developed a consortium relationship especially to encourage small business access on an equal footing with larger businesses. However, it should be recognized that the success of NSF centers in leveraging industry funding depends in part on the promise of special opportunities for commercial exploitation of the research. Free or reduced cost access by small firms is seen by many centers as potentially undermining this leveraging strategy.

What a company gets for its affiliate dues is a package of linkage opportunities. Full membership always includes a seat on an advisory board and a vote on the direction that the research program will take. This provides the opportunity to steer research programs into areas of highest interest to those particular member companies, even though the work supported is of a generic nature. Full affiliates also have the opportunity to closely monitor research progress to the proof-of-concept stage.

Another offering included in the affiliate package is the live-in industrial fellowship which allows industrial personnel to get seriously involved in the research program. This would seem to be a potent conduit for technology transfer, but this option is rarely taken because companies are reluctant to "lose" their most competent people for such a long period. Other offerings include license-free use of patented technology (few patents are generated from such generic research in any case), pre-publication access to research findings, and invitations to attend closed workshops and conferences.

Perhaps the most important benefit to industrial affiliates is having a window on the talent that is represented in the students and faculty in the centers. Simply by being there, reviewing research proposals, listening to results, industry people become aware not only of the leading edge research that is going on but the people who are doing it. These people may later be hired as consultants or full-time workers on company projects of a more applied and directly profitable nature. In any case, the evaluators of IUC's report that industrial board members express very high levels of satisfaction with the programs and full contentment that they remain at the generic level.* Small business entrepreneurs might not be quite as content supporting work with only long term pay-off.

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*Gray, Denis O., Hetzner, William, Eveland, J.D., & Gidley, Teresa. "NSF's Industry-University Cooperative Research Centers Program and the innovation process," in D.O. Gray, T. Solomon, & W. Hetzner (editors) Technological Innovation-Strategies for a New Partnership. North-Holland: Elsevier Science Publishers B.V., 1986

2. Information sharing

There are a number of ways in which small and medium-sized businesses can receive information from NSF centers. While the numbers of smaller firms served in this way may look fairly impressive, it should be pointed out that information sharing usually leads to low-impact transfers such as awareness, interest, and some technical understanding. On the other hand, such information sharing is often the first step towards more serious forms of collaboration.

About one third of the ERC's are already able to report considerable information sharing with small and medium sized businesses through a variety of channels. Such involvement varies depending on the field of research and on length of time the center has been in existence. The ERC's which report the most information sharing to industry in general are those that have been in existence the longest. Since even these centers are very new, we would expect the rates of industrial participation to increase still further in the ensuing years.

Regarding the focus area of the research program, some topics seem to be more attractive to small business than others. It is clear, for example, that biotechnology is seen as a major opportunity area for small start-up enterprises, and high participation rates at the MIT Bioprocess ERC reflect this. Centers focussed on fundamental technologies in a number of other areas may be of most initial interest to larger firms which have the capacity to do their own parallel application-oriented research. Opportunities for smaller firms may only become apparent when the research programs have led to full proof-of-concept demonstrations and prototypes. University-based research does not usually extend as far as prototype development.

a. Publications and other print distribution

All NSF-supported centers make most of their publications available to any interested parties as part of the general body of publicly accessible scientific literature. Many centers also have newsletters which are distributed to affiliates and others. For newsletter mailing lists, the MIT ERC reports about 50% small business, for the Ohio State ERC, 40%, and for the Maryland ERC, 25%. Other ERC's report small business representation on their mailing lists between 5 and 10%. Two MRL's also report significant distribution of their newsletters to small businesses.

Access to technical publications may be very important for some types of small firms but not be very helpful for others. Some small start-up

enterprises are founded and staffed by highly skilled researchers with an entrepreneurial bent and with a view to a market niche which is highly technical and highly specialized. Such entrepreneurs really have a colleague status with the university researchers and many are former or part time academics. In some cases they will value the research being developed in a center to such an extent that they will pay for full affiliate status. For another and probably much larger group of small businesses, having access to the published research will not be enough for intelligent and profitable utilization. Many small businesses which might have relevant production capabilities and entré to markets may lack the scientifically-oriented technical personnel who can read and interpret the findings in ways which will benefit the firm. This is a general problem with publications oriented to the scientific community, but it falls most heavily on many small firms with limited internal resources to absorb and interpret the knowledge as given.

b. Clearinghouse and special information service functions

To overcome some of the problems inherent in the practical utilization of knowledge from scientific publication, it is possible to create various kinds of information services to select and interpret such information in user-relevant categories. Providing such services can be expensive and time-consuming; few examples of this kind of activity can be cited.

Two ERC's specifically mentioned clearinghouse activities as an area which could give special advantage to small businesses. The UC-Santa Barbara ERC Director noted that small businesses need adequate access to information sources more than do large companies. For that reason the UCSB ERC provides information services for a nominal fee. The Maryland Center Director reported that his ERC is also developing a special clearinghouse function which should help small businesses. The IUC's provide special information access to their major industrial sponsors and are very reluctant to develop arrangements for more general information access as early access is one of the incentives for membership.

c. Visits

Visits represent the most frequent type of direct contact between centers and smaller businesses. For the most part, visits are informal events involving one or two persons. We should also include in this category the reverse phenomenon of center researchers or staff visiting small business sites.

Three ERC's report a substantial volume of small business visitors, led by Purdue with about 500 individuals from 200 companies. MIT's Bioprocess ERC reports 150 visitors from about 60 companies, representing 60% of total visits. Two other ERC's report that about 30% of their visitors are from small businesses.

MRL's also report a stream of visitations from small businesses, estimated at 145 over the last year for eight MRL's. No estimate was provided of what percentage this represents of total visits.

Five ERC's also report a significant number of visits by faculty and students to small businesses in their region. Lehigh leads in this catogory with visits to 45 firms. The Purdue ERC reports visits to 20 and the Maryland Center to 15. The MIT and Ohio State ERC's each report about 10 such field visits.

d. Open meetings and conferences

Each ERC holds one open informational meeting for industry each year. All ERC's report some small and medium sized business participation in such meetings.. At MIT's Biotechnology Center a majority of participants are in this category, some 500 individuals representing 150 companies. The Maryland ERC estimates small business attendance at about 100 persons from 40 companies, 25% of their total. The Lehigh ERC indicates that 90% of their industrial meeting attendees are small businesses. Two other centers report small business attendance rates between 30 and 35% and the remainder indicate rates of 5 to10%. Five MRL's also reported a significant presence of small firms at industrial meetings with an estimated total of 75 companies represented or an average of 15 per meeting.

e. Workshops and courses

For those with industry affiliation programs, participation in workshops or courses may be one of the members-only privileges. The most small business activity in this category is reported by the same three ERC's which lead in other categories of information sharing. The MIT Bioprocess ERC's workshops draw roughly half their attendance from small or medium sized businesses, about 80 persons from 20 firms. Likewise about 35% of that Center's courses have small-business enrollees, about 200 persons from 60 companies. The Maryland Center reports 40% of course enrollees in this category, estimated at about 100 persons from 30 different firms. Purdue reports about 10% small business participation in

both course and workshops. The UCLA Center estimates that as many as 100 small businesses are served through their educational extension program.

f. Facilities access

Being able to make use of expensive testing, computing, or analytic tools and facilities can be a very important resource for the small technically-oriented firm. In principle all such equipment and facilities funded by NSF are available to any legitimate users in the private sector although access is controlled by the university centers in which they are located. This may be problematic for many small firms since universities reserve primary access to university research and are more likely to provide private sector access to larger firms, especially those with which they have affiliate status. Several small businesses are reported to have time allocations at one or another NSF supercomputer center and others can gain access through procedures established by each center. In general, however, centers such as the MRL's which do have well established facilities are understandably reluctant to open their gates to all and sundry users because they have neither the time nor the space to accommodate large numbers.

3. Joint projects with small and medium-sized businesses

The most likely way in which small businesses will receive sustained and substantial transfers from NSF centers is through joint projects. At least 10 centers within the ERC group already have such joint projects under way with one or more firms in the small business category, and all ERC's are actively considering such possibilities. While the actual numbers are small so far, it is clear that all centers have this capability. We would also expect that small business joint project opportunities will mushroom as technologies mature and as some students and professors who have worked on successful projects begin to perceive market opportunities related to their discoveries.

Among other types of centers, joint projects are less commonly cited as typical forms of interaction. Three MRL directors reported such activity as ongoing and two others indicated that some such projects were being initiated. Some MRL research has also led to patents which have been licensed to small businesses.

4. Involvement through mediating agencies

NSF center-small business interactions take place in a larger social environment which has become markedly more complex in the last decade. Many new organizations have come into being with the explicit purpose of aiding or promoting economic growth or productivity in one sphere or another. Some are governmental, some private, and some represent a mix of private and public cooperative efforts. There are a number of ways in which these new organizational forms can facilitate small business development. Many NSF centers have made use of more than one of these facilitating mechanisms to increase small business participation, and ERC's have been particularly active in this category of involvement. There are at least four important types of third party facilitation organizations. These are [a] state and local economic development organizations, [b] trade associations, [c] large businesses acting as umbrella organizations, and [d] other federal programs.

a. State, county or other local economic development organizations

The 1980's has seen a tremendous growth in regional, state and local development agencies, many with an R&D emphasis, and many with a mandate to concentrate some of their efforts on the creation and support of small businesses. Because of their high technology emphasis, many state programs gravitate to NSF centers and are sometimes instrumental in the founding of such centers. State and local government funding has been particularly important for the continuance and growth of the Industry-University Cooperative Centers which now receive three times as much of their support from these sources as they receive from the NSF. Although ERC's do not depend on state funding, nine have already established some relationship with a state or local government development agency and four more are actively considering developing such ties. Four MRL's report such ties and three others have them under active discussion. The states of Illinois, California, and Pennsylvania actively promote and coordinate visits to their supercomputer centers, but the total of such visits is estimated at under five per year per center. Thus, state and local development agencies are important partners in NSF center activity and a significant potential avenue for technology transfer.

The fact that such ties are common does not mean that they are important as far as the intensity of small business involvement is concerned. In spite of heavy state involvement, the IUC's have had relatively few small business interactions in a direct sense. Thus, IUC

staff often interact with small businesses but do so through state or university-state programs not directly connected with the IUC. The availability of such organizations as well as their emphasis also varies from state to state so that their potential in relation to small business involvement will sometimes be great, sometimes only marginal. Some states such as Indiana and Pennsylvania have development organizations with a strong small business orientation. The ERC's in those states tend to see a high potential for using this mechanism to enhance small business participation. For example, the Purdue ERC estimates that some 200 small firms have become involved through Indiana's small business-oriented Technical Assistance Program (TAP). Overall, MRL and ERC directors rate the potential of these state-local relationships for the enhancement of small business contacts as moderate to high.

b. Trade or industry associations

Trade or industry associations which have a large small business membership should in theory be a good vehicle for widespread sharing of new technologies, but most NSF centers have minimal contacts in this direction. IUC's do not encourage trade association affiliations for fear that they would minimize the incentive of larger companies to have separate memberships. Only one of the nine MRL's has considered trade association affiliation, and the astronomy centers have no such ties. The ERC's present a distinctly different picture. Six centers reported that they have established ties to one or more trade associations, and three more have discussed the possibility of ties. Four others have not yet considered this option.

For those ERC's which have developed such relations, the numbers of small businesses reached thereby seem rather impressive: in one case more than 500, in another more than 150, and in another about 50. On the other hand, the types of involvement engendered may not be very intense. In some cases the association tie provides companies with "awareness" of what the ERC is doing. In other cases it leads to workshop attendance, distribution of ERC reports, the donation of company equipment to the center, and at one or two centers it has also led to joint projects. Future potential of this mechanism was rated by four directors as "high," by four others as "medium," and by one as "low."

c. Large businesses as facilitators of small business involvement

Another potential avenue for small business involvement is through connections to larger businesses who are members and who may want to pass on the technology through subcontracts, joint ventures, and other means. Some centers in each category noted such relationships but few ascribed any importance to them. For example, five ERC directors affirmed that such connections do exist, but five others reported that they were not aware of any such indirect ties involving small businesses. The Purdue Center reports several such connections, and the Ohio State University Center notes that two of its major affiliates now encourage their subcontractors to join the ERC. Nevertheless, none of the center directors was ready to rate this path to small business involvement as having high future potential. Four rated it "medium," three, "low;" two were not sure and four gave no rating at all. MRL's gave this mechanism similar marks. Two were aware of such connections, four were not. One rated the potential as "high", three "medium" and one "low."

d. The Small Business Innovation Research Program [S.B.I.R.]

Grant awards under the Small Business Innovation Research Program represent yet another potential avenue for indirectly supporting small business involvement with NSF centers. There is nothing to prevent either SBIR awardees from affiliating with centers or center scientists from allying themselves with small businesses to pursue such awards.

e. Other federal programs

There are a large number of R&D programs sponsored by other agencies of the federal government which to some extent overlap NSF center programs. In sum total, such programs actually dwarf NSF in total dollar funding. Because most of these other initiatives are more applied in nature, they may represent an additional bridge for industrial involvement and technology transfer. Although such interactions are rarely mentioned by NSF center directors or monitors, it seems very likely that they are ubiquitous and that they offer special opportunities for small business. This is an uncharted region.

5. Special Transfer Arrangements Targeting Small Businesses

Because knowledge and technology transfer is a complex process both in a social and a technical sense, it is supported in many fields by a complex infrastructure of special roles arrangements. U.S. agriculture probably has the most elaborated transfer system in the Cooperative Extension Service but transfer structures have also been established for aerospace technology [the NASA TU Program], for education , and for some other special areas. In the early 1970's NSF also experimented with new facilitative arrangements and mechanisms oriented to various public needs and a few of these continue to exist long after NSF support has been withdrawn. The Technology Transfer Act of 1986 endorses much of this infrastructure development and specifically sanctions the Federal Laboratory Consortium to take a lead role in furthering the dissemination and use of R&D emanating from federally-funded programs.

Without taking a position on the pros and cons of any particular mechanism, we have attempted to lay out some alternatives within this realm which might have some relevance to facilitating transfer of technology from NSF-supported centers to small business.

a. Special technology transfer role

The major innovation in this arena has been the special technology transfer office or officer for whom the archetype is the agricultural "county agent." Some of the NSF centers have taken the step to appoint an individual to carry forward the transfer mission. NCAR, as a national laboratory, is required to have a tech transfer agent on staff. The supercomputing centers also have technology transfer agents and one of the three astronomy facilities has one. However, none of these is designated to pay special attention to small business. Among the MRL's, one has a full time transfer agent and two others have part time agents. The remaining six have not considered the possibility of having one. Similarly, most IUC's have incorporated no such role because their member companies have not asked for it.

Nine of the 14 ERC's now have a staff member assigned specifically to tech transfer duties. At four ERC's this is a full time position. For the five others it is a significant part of someone's dutics. Two additional centers have such a role under active consideration, and two have not yet considered having one. Of those eight who have a tech transfer officer, three have thus far put special emphasis on small and medium-sized business involvement.

Two ERC's indicated that the tech transfer officer was engaged in setting up arrangements with state development organizations, trade associations, and special programs within the region which would involve a number of small businesses. Others indicated that the tech transfer officer developed innovative educational and communication mechanisms, set up meetings, and performed miscellaneous other tasks designed to stimulate more active dialog with affiliates and others generally.

Having a tech transfer officer was seen as a mechanism with "high" future potential for advancing transfer to small and medium-sized businesses by four ERC directors, whereas five thought it had "medium" potential and two others were uncertain. Among MRL's only one gave this option a "high" rating and four others a "medium."

b. Small business consortia and consortia-center affiliations

If smallness as such is a problem, an obvious solution might be to combine forces to make a larger entity. Simple as that concept seems, it has not been a common path to small business involvement in NSF-supported centers. However, there are a few examples of small business consortia such as one developed by MIT's Bioprocess Technology ERC. The consortium arrangement provides a group of small businesses the same level of access usually accorded large firms which are assessed large membership fees. The MIT case suggests that models of collaboration in this form will work if given the right situation and a modicum of encouragement. Acceptance of these special arrangements may also hinge on the type of knowledge/technology being developed, the competitive structure of the field, etc. Some such collaborations are facilitated by state development programs, some by trade associations, and some by larger companies.

c. Small business development organizations

Another phenomenon of the 1980's has been the growth of new organizations specifically designed to assist the start-up and early nurturing of new businesses. These include consulting services, small business incubators, venture capital locating services, and so forth. Many of these are located on or adjacent to university campuses or established as special university units. Many are supported directly or indirectly by the state development agencies already discussed above. NSF asked center directors if they had ties to such organizations, and found that both formal and informal connections were widespread. Among MRL's, five reported

formal ties, another had informal ties, and two more were considering ties. Five ERC's also reported formal ties to at least one such entity. Two others reported informal ties while three more have been discussing the possibility of developing such ties. The potential of such mechanisms was rated "high" by two ERC's and one MRL. Three other ERC's and three MRL's rated such mechanisms of only "medium" potential.

This list does not exhaust the possibilities for special arrangements to help small businesses benefit from NSF-supported laboratories and centers. What should be emphasized is the variety of efforts that have already emerged and the clear willingness of many centers to experiment with innovative modes of industry and small business involvement to maximize the impact of their programs.

III: Recommendations

The preceding limited review serves to point out two facts. First, there is already a considerable amount of ongoing activity linking NSF centers and laboratories to small and medium sized businesses. Second, the ways in which such linkages take place are extremely varied. In proceeding to make recommendations, it will be important to keep both of these facts in the foreground. It is desirable to build on what has come before and to take advantage of trends which are already apparent.

In making recommendations, we should also note the fact that not all centers have equal potential for transferring knowledge to small business. Some are better positioned by subject matter, size, and program maturity to play an important role in this area. The ERC's are the most actively involved with small business users for a variety of reasons: they have an engineering rather than a basic science focus; their substantial NSF and state funding base frees them from heavy dependence on large industry contributions [in contrast to IUC's which have a smaller funding base and are clearly dependent on industrial contributions]; their status as a young program brings a certain amount of flexibility and willingness to experiment with organizational forms and arrangements. Other types of centers share some of these attributes and a few may have some special advantages in regard to relating to small businesses which ERC's do not have. Nevertheless, there is a roughly definable scale of applicability of any new measures that might be developed to encourage small business interactions.

A. Current trends

It is useful to start the recommendation process with consideration of what would happen without any additional initiatives from NSF. It is clear that the nation as a whole is mobilizing in various ways to meet the challenge from other industrialized countries. More and more businesses, large and small, are coming to realize that more effective ways must be found to utilize basic knowledge for industrial innovation. Many firms have banded together in new R&D consortia, and many states have begun to invest substantial sums in economic development efforts. State efforts are often implemented through universities which are also the recipients of NSF center support. Various branches of the federal government other than NSF are also actively involved in supporting new mechanisms, some of which are advantageous to the development of smaller businesses. The Congress has also passed legislation which explicitly encourages transfer activities including those of the Federal Laboratory Consortium.

In short, there is an emerging technology transfer infrastructure which will continue to expand with or without active NSF participation. Many of the existing centers are taking rather creative advantage of these developments to enhance their transfer capabilities and a significant fraction of these benefit small business directly. Even without specific NSF encouragement, these trends will continue for the next few years at least. Nevertheless there are specific steps that can and should be taken to strengthen the connection to smaller businesses.

The following proposal for increased NSF encouragement of knowledge/technology transfer from centers to smaller businesses rests on three observations. First, such firms have a strong role to play in innovation and technical employment. Second, effective transfer to a broad spectrum of firms will require special measures on the part of NSF and its centers. Third, such initiatives were not envisaged when current center funding levels were set. Thus, only modest enhancements of linkage to small business can be made within existing budget limits. A significant extension of the center role into this realm would require augmented support. It should also be re-emphasized that any NSF initiatives on transfer must be of a catalytic nature, designed to enhance the partnership among centers, state and local governments, and the small business community.

B. Additional Administrative Encouragement [Recommendation #1]

NSF will encourage many kinds of activities through suggestions to centers or through other administrative measures which do not require augmentation of center budgets by NSF and do not in any way subvert the basic scientific and engineering missions of the centers.

- reporting requirements

NSF center programs will now put knowledge and/or technology transfer requirements in proposal guidelines and request more extensive and detailed routine reporting on activities in relation to transfer to small business. At present the ERC program has these requirements for technology transfer in general. A number of small business contacts have evolved out of these activities and as a natural consequence of centers' evolution. More such activities will be encouraged by adding a regular reporting requirement on small business transfer activity per se.

- inter-center information sharing

Because many centers have experimented in one way or another with different mechanisms of involvement of smaller businesses, it is now time to start sharing these experiences, heightening cross-center awareness of alternatives, and developing a support network among centers for further initiatives, as the ERC program now has started to do through its annual center directors' management meeting.

- encourage cooperative efforts within the local environment

Most NSF-supported centers are located on university campuses where there is a great deal of activity going on in support of large and small business interactions. Some NSF centers are much more active in linking to these activities than others. NSF will encourage more active linkage by requesting annual reporting on what specific activities have been undertaken. Such encouragements will also be made informally by NSF center monitors.

- encourage linkage to other local/state/national networks and resources

There is an evolving national infrastructure for supporting technology transfer generally and within specific fields. Every trade association in a

technology area represents such a network as does the Federal Laboratory Consortium, the IEEE and its many affiliated interest groups, and numerous state and regional entitities. Many of these actively encourage small business involvement and others represent low-cost channels of access to technical information which are compatible with small business capabilities. Centers will be encouraged to become more aware of opportunities of this type and to establish links to those networks that are especially relevant to their own fields.

C. Special Financial Incentives [Recommendation #2]

NSF will consider providing special financial incentives to promote smaller business involvement with NSF centers or to promote their use of research output. Such action might include support for: [a] full or limited industrial affiliate memberships, [b] small business participation in workshops or courses, [c] trade associations, large businesses or other third party entities to encourage consortia-type small business affiliations with centers or [d] joint projects.

Direct support for industrial affiliate memberships is not recommended because of the potential high costs and difficulties involved in determining eligibility requirements. It is also difficult to determine a priori what small businesses would truly benefit from affiliate status or from attendance at what sorts of workshops and conferences. Supporting larger entities like trade associations or major companies is probably inappropriate for NSF, especially since some of these entities have shown that they are capable of supporting their own initiatives. This is also an area in which state programs are active, and there is no reason for NSF to duplicate state efforts. On the other hand, NSF can provide encouragement and applaud the efforts of centers which make the most of such opportunities [as indicated in Part 'B' above]

The one type of support which seems to have high potential is for specific small business cooperative projects. It is therefore desirable to establish a special fund for joint projects with small and start-up businesses which want to exploit the commercial possibilities emanating from NSF center research. Such projects would be funded by NSF on a competitive basis and would have to meet with the approval of the industry advisory boards of each center. However, no such program of incentives can be provided unless NSF has additional financial resources made available for this purpose.

D. A New NSF Center Program for Innovative Linkages to Small Business [Recommendation #3]

It is clear that there have been a number of creative efforts undertaken by particular centers to enhance small business involvement. In order to encourage more such efforts and to take full advantage of this diversity, NSF will consider a new program of supplemental awards to centers which propose special arrangements or mechanisms for this purpose. Within fairly broad guidelines this program will be field-initiated. The nature of each proposal will be the responsibility of the proposing center, reflecting their diversity and the diversity of opportunities available to them by reason of geography, topic, etc. Proposals can cover any of the areas reviewed previously in this report under "mechanisms" and might include:

- special types of publications, technical data base services or information clearinghouse activities targetted to small business,
- special conferences or workshop series for small business
- special forms of program participation for small businesses,
- installation of small business-oriented technology transfer agents or offices,
- programs for center-linked small business development units such as business incubators or consulting services.

The awards program would be competitive across all center programs. Individual projects and the program as a whole would be cast in an experimental mold with built-in evaluations at specified intervals. Projects would also be required to build in graduated cost sharing with other sources to the point where self-renewal without NSF funds is projected. This recommendation, like recommendation #2, cannot be implemented unless additional financial resources are made available.

In summary, we envisage a three-pronged initiative to enhance small business involvement with NSF-supported centers and laboratories. First, with no significant budget increase, we will encourage increased collection and sharing of information on small business interactions among centers. Second, with a significant budget increase, NSF will consider initiating a program for center-oriented small business collaborative projects. Third, with the same proviso, NSF will consider initiating a new program of competitive supplemental awards to centers for innovative mechanisms to enhance their interactions with small business in order to facilitate knowledge and technology transfer and use.

APPENDIX II

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550



May 20, 1988

Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space
and Technology
2319 Rayburn Building
House of Representatives
Washington, DC 20515

Dear Mr. Walgren:

Enclosed are answers to the questions on a number of NSF activities submitted to Dr. Schmitt and me following the March 23 hearing. I appreciate your interest in our programs. Should you have any further questions, please do not hesitate to contact me.

Sincerely,

Erich Bloch
Director

cc: Honorable Sherwood Boehlert

QUESTIONS SUBMITTED TO MR. BLOCH FOR THE RECORD BY DOUG WALGREN

NATIONAL SCIENCE FOUNDATION (NSF) AUTHORIZATION HEARING
March 23, 1988

Question: In the FY 1988 budget request, NSF indicated that one or more plant science centers would be started with joint support from NSF, the Department of Agriculture, and the Department of Energy. What is the status of this plant science initiative?

Answer: NSF, USDA and DOE requested $3.3 million each to initiate a program for plant science centers in FY 1988, for a total of $9.9 million. The FY 1988 budgets for the agencies, as appropriated, permitted a total of $5.2 million to be allocated for plant science centers. The amounts by agency are: NSF - $2.0 million; USDA - $2.0 million; DOE - $1.2 million. An Interagency Program Announcement was prepared and issued.

Fifty-six proposals were received by the March 1, 1988 deadline. The proposals reflect significant cooperation between institutions: approximately 900 collaborating scientists from universities, from the Agricultural Research Service (of USDA), from the National Laboratories (of DOE), and from industrial firms described joint research programs.

The merit review process of these proposals has begun and is expected to continue throughout the spring. It will include site visits to those judged most competitive. Awardees will be selected from these. Final deliberations will conclude during the summer. Awards will be announced by the three agencies on or about September 1, 1988. Agencies will make award decisions jointly, but each awardee will be funded by a single agency.

Question: Does NSF have a goal for the eventual number of Science and Technology Centers? If the FY 1989 budget request is approved, do you anticipate additional new starts for Science and Technology Centers in FY 1990?

Answer: The original plan was to develop a program of perhaps as many as 75 STCs by FY 1992, with the first 10-20 STC awards in FY 1988. This plan was based on the Administration's FY 1988 proposal to double the NSF budget by FY 1992. However, the disappointing outcome of the FY 1988 budget process caused the Foundation to reevaluate its plans and propose a different approach to STC funding for FY 1989. The Congressional budget process is only now considering the proposed new approach that would provide up-front funding for five years for the first set of STCs. We do not yet know how that approach will be viewed, what the outcome of the budget process will be, or what the budget climate will be at the time a decision needs to be made on future STC competitions. Therefore, although the early stages of

review of STC proposals suggest there are a large number of exceptional proposals that could be funded, the Foundation will not be in a position to decide about future competitions until we have a better sense of the FY 1989 budget outcome and the likely climate for the future.

Question: What criteria will be used to choose among the Science and Technology Center proposals that receive the highest ratings for scientific merit?

Answer: The same eight criteria are being employed at all stages of the review process. These were published in the original program solicitation and include: the intrinsic merit of the intellectual focus and research; the research performance competence of the principal investigators; the utility and relevance of the research; the appropriateness of the center approach; the appropriateness of institutional and management plans and arrangements; the effect of the center on the infrastructure of science and engineering; the quality and appropriateness of the educational and training components of the Center's activities; and the form, appropriateness, and strength of linkages and knowledge transfer efforts to other sectors and groups.

Question: The NSF's precollege curriculum development programs have been criticized as being too meek, having too little involvement by scientists, and being too biased toward the largest publishers. How would you response to these criticisms?

Answer: NSF's current approach to precollege materials in science and mathematics is strong and innovative. The program already is receiving substantial support and acceptance from educators and from the other sectors involved in the preparation, production, adoption, and utilization of educational materials.

The Foundation's support is intended to make available:

1) new and effective instructional materials adoptable and adaptable for the basic science education of <u>all</u> elementary and secondary students;

2) improved disciplinary materials that will raise standards and be more attractive and effective for <>students who show unusual interest in science and mathematics; and

3) special materials and programs that are responsive to individual talent in science and mathematics, whenever and at whatever grade level it may appear.

The success of this effort hinges on a combination of factors and circumstances: the quality of content must be high; implementation and adoption must be on a broad scale, so that

these innovative materials do in fact reach a large fraction of students nationwide; teachers must be confident of the "usability" of the new materials, and helped to prepare for their introduction into the classroom.

Current efforts for materials development are taking place in three stages. Elementary school materials development projects are under way. During FY 1988 and 1989 several middle school materials development projects will be started to extend this pattern. In FY 1989, several high school level projects will be initiated; their completion will yield new science and mathematics curricula covering grades K-12.

These materials will provide an array of alternatives for consideration by school systems that want to provide a strong science education for all students.

The Foundation is insisting on and supporting the collaboration in these projects of proven academic developers of instructional materials, well known cognitive and disciplinary scientists, active and experienced school teachers (and their institutions), and strong marketing organizations. The marketing organization, usually a publisher, invests heavily in the project, is deeply involved in the development from the very beginning, and commits its own resources. Selection of these participants has been through an intense open competition, publicized with the cooperation of The Association of American Publishers to every size and type of marketer. The awards cover a wide range of business styles and marketing organizations, including large publishers and small publishers as well as educational marketers who might not be considered "publishers" in the conventional sense of the term.

Question: How would you rate NSF's education programs of the 60's? Are there models to be followed or examples to be avoided?

Answer: There were (and are) two major components of the NSF's precollege education activities: one focused on improving the subject matter competence of teachers at all levels, the other on the development of new and better instructional materials.

The teacher education programs of the 60's are widely acknowledged to have been successful. The best evidence for this is the continuing reference to their impact by students, teachers, school officials, and concerned citizens over nearly three decades.

Clearly, the experience of the 60's and 70's has provided useful models. These models cannot be followed precisely, however. We dealing now with a different group of professionals, working under greatly changed conditions with a vastly different student body. NSF's programs must be adjusted continuously to

meet changing circumstances.

Today, the Foundation's precollege activities emphasize the science and mathematics education of all students. Given the complexity of our educational system, we do not hope to find an ultimate, perfect model. Rather, we seek to develop a variety of models that serve different needs and that can be adopted on a wide scale.

Question: Recent articles in the press have called attention to alleged environmental abuses by NSF in the Antarctic. We also note that the 1987 National Science Board report on "The Role of NSF in Polar Regions" included a recommendation that "...environmental protection practices for polar research programs, especially the Antarctic Program, be studied and upgraded where necessary." Could you comment on NSF environmental protection practices in the Antarctic: are they in need of improvement and, if so, what are your current plans to implement changes?

Answer: The evolution of environmental awareness at U.S. facilities in Antarctica in many ways parallels that seen in our country over the last twenty years.

Antarctic environmental protection practices of the National Science Foundation follow the Code of Conduct for Antarctic Expeditions and Station Activities. The Code, adopted in 1975 at the Eighth Antarctic Treaty Consultative Meeting, was approved by the United States through passage of the U.S. Antarctic Conservation Act of 1978 (Public Law 95-541) [Sections 6(b)(6)and 6(b)(7)]. Compliance with the Code and these sections of the Act were further implemented through a directive promulgated by the Director, Division of Polar Programs, National Science Foundation, that USAP participants comply with an amended version of the Code (United States Antarctic Program, Directive No. 84-1).

The National Science Foundation, and other interested agencies and organizations, believes that despite U.S. Antarctic Program compliance with the above mentioned Code, Act, and Directive, more can be done to further environmental protection and conservation in the Antarctic. Recently, the Program has embarked on an aggressive campaign to reassess approaches to environmental protection.

Environmental policy and planning

The United States Antarctic Program is picking up clutter remaining from the early days of the program; this cleanup has accelerated in the past few years.

The program has developed an environmental protection plan that includes environmental assessments and impact studies; rational site planning and waste management strategies; and is

developing an environmental awareness program for participants and visitors. The initial focus is McMurdo, the largest and most active antarctic station.

The United States enforces its Antarctic Conservation Act prohibiting U.S. citizens from interfering with biota except for valid scientific purposes; even then, interference is allowed only under a restrictive permit system.

The United States seeks equitable ways to limit adverse environmental impacts associated with tourism in Antarctica.

Energy

Waste heat from diesel-powered electrical generators is used at McMurdo Station to distill all freshwater needs from seawater, at Amundsen-Scott South Pole Station to supply freshwater from ice and to heat the station's facilities, and at Palmer Station to heat buildings. As a result, fuel usage is lessened, and atmospheric emissions are reduced.

Solar and wind power are used where possible, as for automated scientific observations in the field, and to power communications relay sites. These technologies are not yet capable of supporting entire stations.

Liquid wastes

Sewage at McMurdo Station is treated by maceration, dilution, and dispersion with brine from the water desalination process; a subsurface outfall is being installed. These steps minimize biological impact.

McMurdo sewage is not otherwise treated. Treatment chemicals would have greater impact on the biota than the relatively small amount of untreated sewage released to the sea. The program works to remain aware of better alternatives for handling liquid wastes.

An oil separator at McMurdo prevents garage lubricants and other waste oils from entering the sewage treatment system. Such waste is shipped back to the United States.

Reactive chemicals are neutralized prior to disposal. All radioactive waste is retrograded to the U.S.

Upgrading

Old stations are being cleared. At McMurdo, utility lines are being consolidated, sprawl is being reduced, energy efficient buildings are replacing old ones, and site cleanup has been in progress for several years.

McMurdo's dump site at Winter Quarters Bay is being cleared.

The material will be shipped back to the United States. Work is slow and dangerous.

Metal scrap from Palmer Station is given to ships of nations near Antarctica for recycling.

Assessment of McMurdo Station's solid waste production, and alternatives for its management, has begun. The aim here is development of an environmentally protective waste management system.

Retrograding

Solid waste generated at field camps is taken back to stations. If, as in the McMurdo Dry Valleys, liquid waste cannot be deposited in deep snow trenches, it is hauled to stations for proper disposal.

Each year, thousands of kilograms of materials--waste lubricants, drums, packing materials, scrap metal, construction waste, broken tools, tires, batteries, vehicle parts, and scientific equipment no longer needed in Antarctica--are shipped back to the United States. During the 1986-1987 season the cargo ship M/V Greenwave took 1.7 million kilograms of retrograde materials out of Antarctica. At the conclusion of the 1987-1988 summer research season clean up activities at McMurdo Station accounted for the retrograding of: 1) sixteen 20 foot containers of scrap metal (each weighing about 20,000 pounds); 2) sixty 20 foot containers of materials no longer needed at the station; and 3) over 500 drums of waste oil and other petroleum products.

Question: The recent National Science Board report on Centers and Individual Investigator Awards" indicates that the annual faculty turnover rate in NSF-support research is 10-15%. The report recommends that NSF seek to raise this rate to at least 20% of the overall research budget per year. Will NSF seek to implement this recommendation?

Answer: We are studying the impact of this recommendation, as well as several others such as increasing grant size, numbers, and duration. To a large degree, the rate of increase of the NSF budget will determine how fast we can move on any one or combination of these goals.

Question: What percentage of proposals receiving favorable reviews are funded currently and what is the trend over the past few years.

Answer: In fiscal year 1987, 32.4% of all research proposals from academic institutions were funded. This compares with 33.6% in FY1984 and 34.2% in FY 1985 (no comparable data is available for FY 1986). This is a Foundation-wide average, with considerable variation among divisions.

If "favorable" is defined as being at or above the median combined rating, 57.4% of proposals in that category were funded in FY 1987, 54.3% in FY 1984 and 58.0% in FY 1985. The median combined rating in FY 1987 was 3.7 on a scale of one to five, and it was up slightly from 3.64 in FY 1984.

Question: Price-Waterhouse conducted a management review of three research consortia which operate some of the NSF facilities: UCAR, JOI, AURA. One finding of the study was that the consortia do not have policies in place regarding potential conflicts of interest by their boards of directors. The report went on to recommend that specific actions be taken to correct this situation. What are the plans regarding implementation of these recommendations?

Answer: Recommendations:

- The consortia should adopt policy statements to forbid Board member participation in potential conflict of interest situations.

- The consortia should exclude from their key subcommittees (i.e., with decision making responsibilities regarding financial or contract performance issues) any member representing an institution with a significant direct financial relationship with the centers or any member whose institution is in competition with a consortium for major project funding.

Actions and Plans to Date:

All three of the consortia in the review agreed in principle to implement the recommendations.

To date the AURA and UCAR Boards have developed and issued policies concerning the conflict-of-interest issues. The JOI Board has developed a draft statement on this issue. It is expected that the JOI policy will be issued by the end of July.

Question: What percentage of the FY88 appropriations did NSF allocate in the first quarter of the fiscal year? What is the rate of spending for the second quarter and what is the estimated rate of spending for the remaining two quarters in FY88?

Answer: The rate of obligations as a percent of the FY 1988 NSF appropriations, is shown in the table below:

Actual Obligations Projected

	1st Q	2nd Q	3rd Q	4th Q
R & RA	22.0%	48.7%	76.3%	100.0%
SEE	10.8%	27.4%	48.6%	100.0%
USAP	38.9%	66.6%	87.3%	100.0%

Question: What did NSF initially request of OMB for Science and Engineering Education?

Answer: NSF's request to OMB was made in September 1987. At that time the FY 1988 Appropriation amount from Congress was not known. Consequently, NSF gave OMB two scenarios for the SEE 1989 request, depending on the estimated amount allocated to SEE for FY 1988. These were:

If SEE's Current Plan amount for FY 1988 were $115 million, then FY 1989 Request would be $134 million.

If SEE's Current Plan were to be $145 million for FY 1988, then the FY 1989 Request would be $165 million.

Question: For Research and Related?

Answer: The OMB Request for Research and Related was $1.877 million. However, this amount included $69 million for S&T Centers.

Question: For Antarctic?

Answer: The OMB Request for the U.S. Antarctic Program was $147 million.

Question: For S&T Centers?

Answer: The OMB Request amount for S&T Centers was structurally part of each of the Research Directorate's Budget Request. The total amount was approximately $69 million.

Question: In volume 89, number 4, of the American Anthropologist, there appeared an article written by Dr. Stuart Plattner (Director, Cultural Anthropology Program, National Science Foundation) and two co-authors. In this article, 15 universities were identified as having "elite" PhD programs in anthropology. The combined success rate of NSF proposals submitted by their graduates during fiscal year 1980-86 was computed.

Please provide the following additional information:

a. The number of proposals submitted by graduates of each of these universities, listed by university;

b. The number of proposals funded, out of those submitted by graduates of each university, listed by university;

c. The average size of awards made to graduates of each of these universities, listed by university.

Answer:

	Institution	Number Proposals	Number Funded	Average Award Amount
1.	UC Berkeley	51	11	$33,043
2.	Michigan	49	19	44,342
3.	Chicago	55	13	39,804
4.	Pennsylvania	13	4	21,453
5.	Arizona	8	1	71,331
6.	Yale	21	4	38,904
7.	Stanford	37	19	33,260
8.	Harvard	62	26	49,022
9.	UCLA	26	4	46,653
10.	CUNY	8	3	46,121
11.	New Mexico	8	1	14,410
12.	Northwestern	16	4	28,649
13.	Illinois	27	6	34,877
14.	UCSB	9	3	36,101
15.	Columbia	61	18	50,437

Question: Please review for the Committee the original schedule proposed by NSF for the Very Long Baseline Array (VLBA) construction and annual operating costs, as well as the delays, causes for delay, and current status of the project.

Answer: The NSF FY 1985 Request to Congress included $15.0M to start construction of the Very Long Baseline Array (VLBA) on a 4-year schedule. The implied out-year profile at that time was:

	FY 85	FY 86	FY 87	FY 88	FY 89	Total
VLBA Construction	$15.0M	$16.3M	$17.1M	$17.9M	--	$66.3M
VLBA Operations		0.5	1.9	3.4	4.9	6/yr

The NSF FY 1985 appropriation bill specified $9.0 M for VLBA construction and the start of construction was delayed from 4/1/85 to 5/15/85 at the request of the chairman of the House Appropriations Subcommittee on HUD-Independent Agencies.

The NSF FY 1986 Request to Congress included $11.5M for VLBA construction introducing a stretch out, possibly to 6-years. This request was reduced to $9.0M by Congressional action and subsequently to $8.6M by Gramm-Rudman-Hollings sequestration.

For FY 1987, NSF requested $9.4M for VLBA construction in anticipation of Congressional instructions. However, the FY 1987 NSF appropriations bill was silent on the level for VLBA and NSF sought permission for reprogramming within Astronomical Sciences to a level of $11.4M in FY 87, sufficient to permit purchase of 2 antennas and a speed-up of the pace set by the $9.0M level in FY 85 and FY 86.

The FY 88 request of $11.9M was reduced to $11.6M because of the overall reduction for the NSF as a whole.

The current plan is:

	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	Total
VLBA Const.	$9.0M	8.6M	11.4M	11.6M	12.0M	12.5M	13.0M	3.0M	--	81.1M
VLBA Oper.	---	---	0.2	0.5	1.0	4.0	5.0	6.0	7.0	7/yr.

All delays have been the result of changes in the funding schedule. The VLBA is progressing well on the current schedule. Six antennas have been ordered and are being installed. Two additional ones will be ordered in FY88 and in FY89. The project is beginning partial operations as individual antennas become available. The Array Operations Center is under construction in Socorro, NM, with funding advanced by the State of NM.

Question: Does NSF plan to lease a research platform with icebreaking capability for the Antarctic Program?

Answer: Yes. However, the vessel will be chartered (leased) by the NSF's prime contractor, ITT Antarctic Services.

Question: Has your service contractor, ITT Antarctic Services, received proposals regarding this platform?

Answer: Yes. The procurement process began on February 19, 1987 with an announcement in the Commerce Business Daily; subsequently a request for proposals was released September 3, 1987. Proposals were due November 9, 1987.

Question: How many proposals were received? How many of those were from U.S. operators with U.S. shipyards?

Answer: Twelve proposals were received. Three proposals were from U.S. firms proposing construction in U.S. shipyards.

Question: Of the proposals from U.S. firms that were rejected by ITT, how many were rejected on technical grounds?

Answer: As of April 20, 1988, all proposals rejected by ITT have been on technical grounds.

Question: I also understand that the Government Accounting Office is in the process of responding to certain bid protests filed by U.S. companies. Has GAO's investigation been completed? When is it due?

Answer: Three protests were made to the GAO two from U.S. firms and one from a partnership of U.S. and foreign interests. One of these protests has already been declined. Reports on the other two investigation are due on June 7 and July 13.

Question: Mr. Bloch, on March 16th, you appeared before the House Appropriations Subcommittee on HUD and Independent Agencies. Did you agree then to notify the Subcommittee before awarding any contracts that would adversely affect the U. S. shipbuilding industry, If so, would you also please notify the Science, Research and Technology Subcommittee at the same time?

Answer: We have agreed to keep the House Appropriations Subcommittee on HUD and Independent Agencies (and the Senate Appropriations Subcommittee as well) informed of our progress in obtaining a research vessel with icebreaking capability. We would be glad to keep the House Science, Research and Technology Subcommittee informed also.

QUESTIONS SUBMITTED TO DR. SCHMITT FOR THE RECORD
BY REP. DOUG WALGREN

Question: What role is the NSB playing in assuring that the Engineering and Computer Science Assistant Director vacancies are filled expeditiously?

Answer: As Chief Executive Officer of the National Science Foundation, the Director is responsible for the recruitment and appointment of Assistant Directors and has been conducting an intensive search to fill the current vacancies. The National Science Board has approved the following procedures to govern his actions:

"In the process of appointing NSF assistant directors, the Director of the Foundation will request nominations of candidates and advice on potential candidates from the members of the National Science Board. At such time that a preliminary selection has been made, the Director will inform the Executive Committee, and if possible the NSB, and seek relevant comments and advice prior to final action. However, in exceptional circumstances when the absence of immediate action would result in the loss of an outstanding candidate, the Director should proceed with necessary actions and inform the NSB as expeditiously as possible." The Executive Committee and individual Board members have consulted with and aided the Director in his search.

Question: Currently the House Budget Committee has recommended nearly the full increase requested by NSF for FY89. However, the Appropriations Committee is not bound by these recommendations. If we see lower appropriations in FY89 as we have been seeing since 1984, what role will the NSB play in deciding priorities in 1989?

Answer: The National Science Board urges the Congress to fully fund the President's request of $2,050 billion in new obligational authority for the Foundation's programs in FY 1989 as an important installment toward doubling the Foundation's capacity to invest in the Nation's scientific and engineering research and education enterprise. Should the Congress provide less than the amounts requested, the Director of the Foundation, after consultation with the National Science Board will allocate resources, consistent with the Foundation's priorities and Budget Request.

Question: Has the NSB ever discussed whether or not it is in the best interest of NSF to have an Inspector General?

Answer: The National Science Board is well aware that the Foundation does not have a statutorily empowered Inspector General. This matter has been the subject of discussion in both the Executive Committee and the Audit and Oversight Committee. These Committees have assured themselves that the Office of Audit

and Oversight, whose functions are analogous to an Inspector General's, has adequate independence and access to records and personnel. The Director of that Office deals directly with the Director of the Foundation and with the Board's Committee on Audit and Oversight. The current arrangement is well-suited to meeting the Foundation's responsibilities regarding public accountability.

Question: Was the NSB consulted with or in any way involved with the budget levels set in the FY89 budget? Can you explain the strategy in the distribution of growth between FY89 and FY93? What role did the NSB have in the 5 year appropriation request for the S&T centers, in this FY89 request?

Answer: The National Science Board met in June 1987, to assess the opportunities and needs of science and engineering research and education and to chart the course toward a doubling of the Foundation's budget by 1993. At that time, considerations were centered on the three major themes subsequently presented to the Congress: education and human resources, disciplinary research programs and supporting facilities, and science and technology centers and groups. More detailed components of the FY 1989 Budget were addressed in a special meeting of the Executive Committee and subsequently approved by the full Board. It is expected that specific details of succeeding annual budgets will be developed in a similar fashion in future years. The concept of a five-year appropriation for science and technology centers arose in discussions between the Director and the Office of Management and Budget and was heartily endorsed by the Board upon presentation by the Director.

Question: On January 28, 1988, the Director of NSF issued a memo to all staff announcing that effective January 31, 1988, the Division of Audit and Oversight was renamed the Office of Audit and Oversight and the staff formerly of that Division would report straight to the Director. What does the NSB see as the impact of this change?

Answer: While the NSB Audit and Oversight Committee has assured itself that the Office of Audit and Oversight had adequate independence and freedom of access under the previous organization, the change makes this authority more visible.

Question: The draft authorization bill which NSF submitted proposes an amendment to the rotator program that would in effect provide relief with respect to calculating the salary and benefits rotators are entitled to. This leads to the general question as to whether or not you are experiencing any difficulty in recruiting and retaining high quality scientific personnel? What information do you have that describes the situation?

Answer: We are experiencing increasing difficulties in recruiting scientists and engineers to NSF. These difficulties, their causes, and proposed solutions are summarized in a

recent analysis by NSF's Division of Personnel and Management. This analysis is attached.

Question: The National Science Board recently passed a resolution calling for balance between centers and individuals, but provided no guidance on how to do that. Why was this resolution so open-ended? How can balance be assessed and maintained?

Answer: The NSB resolution on the balance between centers and individuals recognizes the importance of providing a range of funding strategies in order to assure the vitality of the scientific and engineering enterprise and contribute to the furtherance of national goals. This recognition is based on the key role played by the individual in scientific and engineering research and education, the need for large, broadly shared experimental facilities, and the growing importance of new organizational arrangements such as groups and centers.

The committee report on which the NSB resolution was based in fact developed a set of principles intended to assist the Foundation and its organizational components in achieving effective balance in its future programs of research and educational support:

Each research and educational activity supported by the Foundation should be carried out at the lowest level of organization consistent with the maximum generation of creative new ideas, discoveries, and knowledge; with scientific or engineering requirements; and with sound management practice.

The Foundation should provide resources through a range and balance of funding modes that correspond to the actual requirements of the research and educational activities supported.

In order to meet fully its broad responsibilities, the Foundation will undertake the support of research and educational programs directly relevant to the solution of societal problems and the attainment of specific national priorities.

The Foundation must continue to support academic research through grants to individual investigators and to support centers and large facilities when it is clear that there is added value in doing so.

There is no magic algorithm for specifying <u>a priori</u> the proper balance among support strategies for the Foundation overall. The complexity, scope, and variability of the research and educational activities supported by the agency preclude a simplistic approach. Rather, management and program officials, with the assistance and support of advisory committees and the peer review system, should develop appropriate support strategies for each intellectual area as part of the NSF long-range planning and budgeting process. Thus, balance must ultimately be determined by the unique requirements and opportunities of each

scientific or engineering field, the quality of the research and educational activities proposed, and the level of resources available to the Foundation for the funding of such activities.

Question: Could some of the cost of a new vessel be reduced through international cooperation? Would other nations be willing to contribute to the cost of buying or leasing a ship? Do any nations share such costs now?

Answer: In addition, the U.S.A.P. has a full-time requirement for such a vessel; sharing time with other nations would severely restrict the U.S. program.

There is a considerable amount of international cooperation with regard to sharing the use of facilities, which generally serves in place of direct cost sharing in Antarctic activities.

It is unlikely that other nations would be willing to make a major contribution to the cost of a new ship as most already have such a capability of their own.

Question: The National Science Board report on polar programs recommends limitations be placed on tourism in the Antarctic. How serious a problem is this? Is it growing? What other activities are leading to environmental degradation? Do the areas under the control of other nations fact these same problems?

Answer: Unmanaged or unregulated antarctic tourism is serious in that it: 1) may impact the environment or biota of the Continent and its surrounding waters; 2) may contravene the requirements of the Antarctic Treaty, the U.S. Antarctic Conservation Act of 1978, or the U.S. Antarctic Program's (USAP's) policies relative to pollution control and private expeditions; 3) may pose significant negative impacts to the conduct of antarctic scientific research; and, 4) may have a potential to strain the logistic support and resource systems, and compromise the safety of personnel, (in connection with potential search and rescue activity). These tourism engendered problems are expanded upon below:

Environmentally-related Effects and Problems. Tour operators and tourists entering the antarctic area bring with them residuals (i.e., waste materials or substances) that if not properly handled by individual tourists or by commercial tour operators may degrade antarctic environments and harm protected species. Examples include human wastes and other refuse associated with tour activity (e.g., film wrappers, plastic wastes), and fuel spills. Tourists landing on accessible portions of the Antarctic coast or on islands may disturb critical breeding areas, impede the normal progress of resident fauna, or destroy limited plant habitats. All of these actions run counter to the requirements of the Antarctic Treaty and the Act.

Historic sites and monuments in the Antarctic may experience substantial disturbance or damage due to the recurrent congregation of tourists at these sites. That such sites receive only occasional maintenance by the national programs that established them serves to heighten the problem.

Science-related Effects and Problems. Residuals (as mentioned above) brought by tourists or tour operators may significantly compromise the conduct of science by altering habitats and subsequently the nature, population dynamics, or health of resident biota. While on tour, tourists may also disturb established research sites or arrogate potential biological or geological scientific specimens as souvenirs.

Effects and Problems Related to Logistical Demands. Travel in the Antarctic is never on a business-as-usual basis. The extreme climate of the area constantly holds the potential for individual or group mishaps that would involve the use of resources of the USAP (and other national programs). Resource allocation among the various organizations and needs of the USAP are strictly limited and always subject to prior commitment. Use of human resources, for example, search and rescue capability involves a high level of risk.

Specialized types of assistance requested of the USAP (and other Treaty members) by commercial tour operators as well as private expeditions have been:

Cruises. Requests for assistance in determining current local weather and ice conditions. Requests are also made to view (and to learn about through lectures) field research activities, scientific laboratories, and living conditions. Cruise participants are also eager to purchase souvenirs;

Overflight Assistance. Requests for the provision of air navigation, radio communications, and in-flight information. Should the popularity of overflights (within air space regularly used by national research programs) increase, detailed flight planning closely coordinated with the national programs will be necessary;

Aircraft Landings. Essentially the same types of assistance requests made by overflights. Landings and takeoffs being the riskiest segments of air travel require that emergency ground crews and equipment be, at least, "at-the-ready" should an accident occur during a landing near a station. In addition, landings at USAP stations carry a risk as none have runways, heliports, airfields or navigational aids and landing systems that are certified for general or commercial use.

Diversions of resources to provide requisite humanitarian rescue and relief in the event of some mishap involving tourists would seriously impact U.S. Antarctic Program activities as they have in the past.

Antarctic tourism, by all indications gathered by the USAP, is growing.

The increased incidence of tourist visits to Antarctica may be directly attributed to: 1) better access to the antarctic area; 2) increased awareness among travellers of the unique character of Antarctica; and, 3) promotion of such tourism by the private sector (or in some cases governments).

Early indications to the USAP suggested that as many as 6700 tourists might visit the Antarctic Peninsula during the 1987-1988 austral research season. More up-to-date estimates, following actual tour ship visits to Palmer Station placed that number at approximately 1000. The reduction resulted in part from cancellation of trips of one cruise ship capable of carrying over eight hundred passengers and crew and in a limitation on the number of visits per ship to Palmer.

While complete elimination of human impacts is impossible, the United States actively pursues environmental protection in its antarctic activities and policy decisions:

The United States Antarctic Program is picking up clutter remaining from the early days of the program; this cleanup has accelerated in the past few years. The evolution of environmental awareness in Antarctica in many ways parallels that seen in our country over the last twenty years.

The program has developed an environmental protection plan that includes environmental assessments and impact studies; rational site planning and waste management strategies; and is developing an environmental awareness program for participants and visitors. The initial focus is McMurdo, the largest and most active antarctic station.

The United States enforces its Antarctic Conservation Act prohibiting U.S. citizens from interfering with biota except for valid scientific purposes; even then, interference is allowed only under a restrictive permit system.

The United States seeks equitable ways to limit adverse environmental impacts associated with tourism in Antarctica.

The USAP believes that many other parties to the Antarctic Treaty face very similar problems related to tourism and to environmental degradation. Some other nations however, do not place the same high priority on management of tourism for minimization of environmental degradation as does the USAP. The efforts and practices of USAP in these areas could serve as models.

The USAP has undertaken the following activities to address the issue of antarctic tourism:

Preparation of a position paper in conjunction with the U.S. Department of State in preparation for the next Antarctic Treaty Consultative Meetings. The paper identifies workable approaches to the management of antarctic tourism;

Inclusion of consideration of tourism- and private expedition-generated safety issues in the task of the USAP Safety Review Panel;

Dissemination of a statement of "U.S. Policy on Private Expeditions in Antarctica" to parties within and outside of the USAP;

Initiation of tourism management discussions among the Managers of National Antarctic Programs;

Assignment of a National Science Foundation (NSF) Liaison Representative for Tourism to its most actively visited station (Palmer Station in the Antarctic Peninsula) to coordinate tour activity, and to effectively communicate Program policy on tourism; and

USAP effected operational restrictions on tours proposing to land passengers at Palmer Station during the 1987-1988 research season.

APPENDIX III

Whither Science, Engineering, and Technology in America?
Peter Likins
President, Lehigh University
AAAS Annual Meeting
11-15 February 1988

I was invited to discuss the controversial subject of the NSF Science and Technology Centers from the perspective of the universities. I should have declined the privilege.

There is of course no such thing as "the perspective of the universities." The pluralistic system of higher education in America has produced a great variety of institutional perspectives, and within any single university there are as many points of view as there are professors. Moreover, I must acknowledge that university presidents inevitably see the world from a different aspect than they themselves did as professors. So who dares to speak for the universities?

Moreover, the Science and Technology Centers to be established this year by the National Science Foundation should not be isolated for debate in a meeting of the American Association for the Advancement of Science. These centers are part of a larger movement that deserves thoughtful consideration in this forum, and in the various science policy advisory committees that guide our nation's efforts in science and technology. We should try to understand the specific arguments swirling around the NSF Science and Technology Centers in the broadest possible context.

It is natural and proper for an artist to believe in art for its own sake, and not as an alternative to agriculture or medicine. We must expect to find in any meeting of the AAAS a deep commitment to science for its own sake, and that is how it should be. In the United States Congress, in the White House, and in the corporate boardrooms of America one can also find individuals who see art and science as having inherent value, but these people must make decisions based upon comparative value. This is not a revelation, of course, but a reminder of a fundamental reality of American life. The people who actually make science policy in the United States are ultimately our elected politicians and corporate executives, and we must couch our arguments in terms that make sense in the context in which these people operate.

The decision-makers in America today are preoccupied with thoughts about the economy. In my personal opinion, this concern is well-placed, and in fact much belated. But my opinion doesn't matter here; whether you like it or not, the uncertainties of the global economy as they affect the United States are so dominant in their influence on key decision-makers in our society that all other considerations are driven into the background.

Even such fundamental issues as world peace, human health and education are being debated today in economic terms. The

disarmament debate has a newly important economic dimension; not only is the cost of weaponry an issue, so also is the advocacy of world trade as a deterrent to war. The struggles against AIDS and alcoholism are increasingly justified by calculations of the costs of these diseases to the economy. Illiteracy is increasingly perceived as an economic liability. Fellowships for graduate study are justified as investments in the American economy, or not justified at all.

In this context, no one should be surprised to find the debate about science and technology policy presented in economic terms. It is very important in the present forum to remind ourselves that this is not the only justification for science. When we fail to make this point we damage not only our own future credibility; we also undercut our colleagues in the arts, who suffer more than we do in times of economic stress. But after we register our concern about the current pre-occupation with the economic aspects of science and technology policy, we are well advised to face current reality, and think this way ourselves, if only for strategic purposes.

The choice of topic in this AAAS meeting session suggests that the issue is the comparative merit of research by individual principal investigators and research by multidisciplinary teams. An underlying theme is the tension between "pure" and "applied" research. If we think seriously about the context of the debate, however, it begins to take quite a different form. If our sole (or principal) reason for investing in research is to harvest a financial return, and we're willing to accept the notion that the return may be greatly delayed in time and need not be guaranteed except in probabilistic terms, then we frame the debate in terms of the comparative merit of "targeted" and "untargeted" research. By these euphemisms we mean to distinguish research directed toward fields that show promise of economic reward from research directed toward resolving questions that happen to be of interest to the most capable scientists and engineers seeking funds for research. In either case, the research may be fundamental or applied; that's not the basis for the distinction at issue here.

I submit that the science and technology policy phenomenon of these times in America is the shift toward more clearly targeted research. Because the National Science Foundation has been the primary locus of funds for untargeted research nationally, the policy shift has been most dramatic in that agency. Because the research center concept has been the primary vehicle for this shift in policy, we tend to focus on these centers. But that's not the real issue. The real struggle is between targeted and untargeted research.

I have no difficulty accepting intellectually an argument against targeted research. It's not such a dumb idea to leave the choice of research topics to the most brilliant researchers in the

land, and to finance their investigations on the strength of our confidence in their instinct to use their energies in important ways. This argument won't win many budget debates in Washington today, but that doesn't make it wrong.

Much less credible, in my view, is the twisted logic that accepts the premise of economic justification for research, and then defends whatever we want to do in economic terms. I realize that this is the kind of "political logic" that seems to work in Washington today, but I think it's very dangerous. The credibility of the scientific establishment has been very high in America, and we can put this achievement of several decades in jeopardy by stretching too far the protective cloak that we call "strengthening industrial competitiveness in the global economy." Better justification than this can be found for the superconducting supercollider and the space station, to cite two quite different examples of megaprojects often defended with economic arguments of dubious merit.

If the debate is between targeted and untargeted research in science and technology, and the forum for the debate is anywhere off campus, then in the current era in America the struggle will be brief. Moreover, I believe that this mood will persist for at least a decade, and much longer if a general sense of prosperity is not restored in that time. We cannot simply close our eyes and hold our collective breath, hoping that the "good old days" of government support for peer-approved science will return. We must ask and answer what I will call THE FUNDAMENTAL QUESTION.

If we were to accept genuinely the premise that America cannot now afford to finance very much science for its own sake, and focus our attention on the effort to deliver the best economic return possible on the nation's science and technology investment, where would that take us?

Each of us will answer this question differently. My own response is as follows:

* Total expenditures for research in science and engineering would exceed those available with any other premise.

* Expenditures would be skewed significantly within every field of science and engineering.

* The national economy would be significantly strengthened.

Obviously not everyone will agree with my answers to what I have called the fundamental question. There are those who fear that expenditures would be skewed without any significant beneficial effects on total research expenditures or the national economy. My purpose here is not to resolve the debate, but merely to reframe the terms of the argument. If we can begin talking in

the academic community about the issues raised by the fundamental question, then we might be able to communicate more effectively with the people in government and industry whom we rely upon for understanding and support. I believe that this is the question that is uppermost in the minds of the decision-makers in America. It behooves us to try to answer the question they are asking, instead of talking to each other about issues beyond their field of view.

Finally I can open up the subject of research centers generally, and the NSF Science and Technology Centers specifically. I do so in the context of the fundamental question posed above, influenced by my own sense of the answers as noted.

It is my impression that the concept of the research center has been advocated primarily on the grounds that it will contribute to the quality of the research investment in economic terms. This is at least the argument that has been used most extensively (and most effectively) in Washington and in the state capitals of the land. In the academic community, we often hear instead the argument represented above as my first answer to the fundamental question, namely that the centers will increase total expenditures for research ... increase the size of the research pie. In order to establish a position in the debate about research centers, we must examine these arguments.

So let us consider the question: Is a research program more cost-effective in economic terms when conducted by a large number of independent principal investigators or by a smaller number of research teams? When the question is posed in this way, it becomes obvious that the correct answer depends on a number of variables, such as the field of investigation and the nature of the teams. It may not be very satisfying to answer an important question by saying "It depends," but this is an entirely operable answer. Translated into policy, this answer means that the science and technology research program in America should be a mix of individual and group-centered research projects.

Untargeted research is best pursued in the spirit of laissez-faire, with individual principal investigators chosen by their peers to pursue their own interests.

It follows that the shift in policy from less to more targeted research should involve an increase in the number and importance of group projects evaluated by diverse criteria and diverse constituencies. This is exactly what is happening in America today.

The Engineering Research Centers established by the National Science Foundation a few years ago provide a model illustration of the center concept at work. The fields in which these centers have been established are all areas of great economic significance;

manufacturing, construction, microelectronics, and biotechnology provide examples. The research is thus targeted, but not necessarily applied; in many cases the time horizon for the anticipated economic pay-off is quite distant. In some cases these centers have brought together into collaborative research investigators who have previously been confined by limited funding opportunities to projects of more narrow disciplinary focus. They have also attracted attention, collaboration, and financial support from industry, serving an important role in technology transfer. Finally, they have altered the culture of our universities, and influenced not only the research but the teaching and learning experience on our campuses.

The NSF Engineering Research Center projects are differentiated from other academic research projects in their motivation more than in their execution. ERC projects are "problem-driven," not "discipline-driven." The boundaries that separate academic disciplines are not respected by the kinds of problems that challenge industry, so the ERC's become cross-disciplinary or multidisciplinary by necessity, and not by dictum. Nor are the boundaries that separate scientists from engineers on campus respected by industrial problems, so the ERC's are (despite their names) places where engineers assemble with mathematicians and physical and social scientists as required to meet the challenges presented by the problems in the field.

My personal experience with the NSF ERC concept relates principally to the ERC at Lehigh University for the Advanced Technology of Large Structural Systems. This experience is broadened by my service as chair of a committee on "New Directions in NSF Engineering" for the National Academy of Engineering, and by participation in National Research Council reviews of the program. Although it is too soon for final evaluation, I believe on the basis of my own observations that the Engineering Research Center concept will be perceived historically as a major success.

Of course the ERC's are merely the latest in a long line of research centers sponsored by The National Science Foundation and other agencies of the federal government; NSF centers go back as far as 1952. These initiatives have not all been uniformly successful. The RANN program (Research Applied to National Needs) had its detractors, and perhaps for that reason it suffered from "boom and bust" funding patterns. The Materials Research Centers represented a major federal initiative that survived the test of time. The Industry-University Cooperative Research Centers at NSF represent a modest commitment of federal funds, because most of the money comes from industry, but this program too is generally regarded with favor. There are thirty-nine such centers nationally, of which two are at Lehigh University: The Center for Innovation Management Studies and the Center for Chemical Process Modeling and Control.

But what about the new Science and Technology Centers? Will they truly serve the advertised objective of strengthening the national economy? Will they serve the subordinate objective of increasing the federal budget for research, or at least the NSF budget? Will they drain support from individual scientists who prefer to work only with graduate students and postdocs? Or might the centers actually carry individual scientists with them to a higher plane of research support from the federal budget? ("A high tide lifts all boats," they tell me, but nobody talks about the inevitable low tide. Is it true that "a low tide beaches whales?")

When President Reagan included the announcement of the NSF Science and Technology Centers in the 1987 State of The Union Address, a general celebration in the academic community seemed in order. I personally heard the President announce in the White House a plan to double the NSF budget in five years, as part of a plan to preserve America's industrial competitiveness in the global economy. The President's budget as revealed a year ago showed about a 17% growth in the NSF budget, with only about one-fifth of the requested growth of $270 million going to the new centers. In this rosy scenario, even when the NSF budget doubled in 1992 all NSF centers together were to represent only 7.7% of the total budget. Clearly the plan was to permit everyone to win, in the great American tradition.

In the opening days of 1988, reality seems to have intruded into the American consciousness. Even the politicians seem to have discovered that there's no free lunch, even in Washington. The NSF budget increase looks like 5.8%, and with a 40.6% growth in the Science and Engineering Education component and a 6.7% growth in the U.S. Antarctic Program that leaves a mere 3.3% growth over FY87 in the critical Research and Related Activities budget component that normally funds both research center and single investigator proposals. The total growth in this category is $47 million, compared to the $30 million originally slated for the new Science and Technology Centers. What will they do now? What should they do?

The answers can be approached at several levels, but the political realities are inescapable. The NSF Science and Technology Centers are a Presidential Initiative, and I can't believe that they will be abandoned because of budgetary stringencies. In fact, the arguments used to advocate these centers in 1987 have an even greater urgency in 1988. The Science and Technology Centers will surely have a prominent place in next year's budget too. An appeal to preserve the privileges of the academic research community would be counterproductive. Economic justification is now the only game in town. How should we play it?

Let's not forget the basic premise, which is that more research centers will better serve the objectives of strengthening the economy. The debate must now center on the subordinate

question, "How many more?" For those who favor a high ratio of single investigator funds to center funds, I recommend recourse to that old sports adage: "The best defense is a good offense." Surely we can marshall abundant evidence that single investigator research projects have strengthened the economy in the past, and will do so again in the future, particularly with a little "targeting" applied to this funding category as well. The recent breakthrough in superconducting materials research is illustrative.

Generalizations are difficult, but it might be possible to identify fields and subfields in science where advantage lies with a large number of independent individual investigators, even if the objective is a financial return on investment. It seems to me to be plausible to argue that this situation is more likely to prevail in certain domains of science than in most fields of engineering, where the closer proximity to industrial application suggests a stronger argument for cross-disciplinary research and education. Does it follow that the ratio of center to single investigator funding in the Engineering Directorate of NSF should exceed the comparable ratio in the science directorates?

Amidst all the uncertainties of these times, one thing seems clear. Any NSF Science and Technology Centers established in the first round had better succeed in terms that can be demonstrated within three years, when the first of two possible three-year renewals is contemplated. In view of the premises underlying the program, the first centers should be genuinely Science and Technology Centers,and not merely a repackaging of scientific research that could as well have been supported in the conventional ways. Creating research partnerships between academic scientists and engineers may be a prerequisite for the initial centers, and on most campuses that will be difficult.

In my personal opinion, the Science and Technology Center concept should be recognized as experimental, and the first few centers viewed as pilot programs. They should be monitored carefully, and studied as experiments in research management. Even in the absence of budgetary stringencies, there should be comparatively few centers (relative to the Engineering Research Centers, for example, or as a share of the science research budget.) The scientific research community should stifle its skepticism, and support this innovative concept vigorously. This is no time to be quarreling among ourselves about how we should be supporting scientific research in America. Unless we make the case for the economic value of our work in all its guises, we will suffer enormously in the budgetary squeeze that almost certainly lies ahead. No matter how the election goes, the financial pressures two years from now will be more severe than they are today, in my opinion.

If we seize the opportunity that underlies this and every period of adversity, however, the science and technology community can emerge from this difficult period in American history with an even stronger position in our society. World War II was of course a tragedy of staggering proportions, but it thrust science and technology onto center stage in America. The Soviet Sputnik presented the United States with a major setback in the eyes of the world, but it stimulated a renewed commitment to science and technology in America. Now the challenge is in the arena of global economics. If the science and engineering research communities meet this challenge with our full energies, we can play a critical role in the preservation of our society as we know it. In the long run, such a response will serve every segment of the research community in America.

AMERICAN ASTRONOMICAL SOCIETY
Office of the President
Department of Physics, 26-335
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Bernard F. Burke
President

(617) 253-2572

21 March 1988

The Honorable Doug Walgren
Chairman, Subcommittee on
Science, Research and Technology
2319 Rayburn House
Washington, DC 20515

Dear Mr. Walgren,

I enclose a copy of my written testimony, as President of the American Astronomical Society, to be included as part of the record in the authorization hearings that you are holding 22 March 1988 on the National Science Foundation budget for FY 1989.

Very truly yours,

Bernard F. Burke

cc: Grace Ostenso

Testimony of Bernard F. Burke
Wm. A.M. Burden Professor of Astrophysics, MIT and
President, American Astronomical Society

Submitted to the House Subcommittee
on Science, Research and Technology

21 March 1988

The American Astronomical Society, an association of professional astronomers with over 4000 members, was founded 89 years ago to foster the growth of astronomy. I currently have the honor of being President of the Society, and in that capacity I must communicate concern for American ground-based astronomy, whose future development is placed in jeopardy by recent trends in the National Science Foundation budget.

In order to gain a broad overview of the problem, it is useful to review the record of excellence that has been established by American astronomers. Within this century, since the American Astronomical Society was founded, the United States moved from a minor position in world astronomy to being the unquestioned world leader. The roster of fundamental discoveries by American astronomers is most impressive: the discovery of the expansion of the universe and the subsequent discovery of the cosmic microwave background that establishes the "big bang" cosmology, the development of methods to classify stars and describe their evolution, the discovery of quasars, the discovery of cosmic masers, the discovery of neutron stars within the crab nebula, the discovery of cosmic radio noise and the founding of radio astronomy, the discovery of cosmic x-ray sources and the founding of that new astronomical discipline also, the use of large computers to understand how stars evolve, the development of electronic devices that increase the power of telescopes nearly a hundred times, and the development of Very-Long-Baseline Interferometry, which increases the astronomer's sharpness of vision a thousand-fold, to cite only a few. The list is much longer, but this outstanding record of American achievement stands clearly in history.

Two general characteristics stand out as contributors to these successes. The first is the vigor and boldness with which American observatories built the largest and finest telescopes in the world. The second key factor was the way in which American astronomers aggressively extended and adapted the newest technologies to astronomical practice. In addition, both traditions were followed as the U.S established its national observatories, both radio and optical. These, in their

excellence, have been admired by astronomers all over the world.

Now, as the Congress examines the national budget for Fiscal Year 1989, I must report that this preeminence is under a real threat. Both the grants program to the universities and the operating budgets of the national observatories have undergone four years of successive cuts (in real terms, when corrected for inflation). The problems are reaching a critical stage this year, as research workers of real distinction are seeing their research support cut drastically or terminated, and the national observatories are being forced to cut back their highly skilled work forces. This steady attrition can be contrasted with a newly aggressive posture in Europe, where our astronomical colleagues are building and planning impressive new facilities. Competition is good in science, but it does not seem to be a prudent national policy to yield preeminence without discussion and debate.

American astronomers have been justly proud of their accomplishments, but the experience of the last several years, coupled with the weak prospects for next year, must raise serious questions about the national will to sustain these achievements. The most serious concern of all must be for the coming generation of young astronomers and physical scientists. A field that is perceived to be static, cannot be expected to be attractive to the young scientists of greatest promise. Astronomers as a whole are idealists, interested in extending knowledge first of all, but even the most committed idealist cannot be expected to show enthusiasm if there is neither the opportunity for advancement and recognition nor the prospect for building and using the instruments of the future. The current policy directions that will be dictated by the static or declining National Science Foundation support for astronomy is a reversal of those attributes that led to our progress, the building of superb forefront astronomical instruments and the close interplay between technology and astronomy. Unfortunately, such initiatives are stifled in the present climate.

These comments are not made in a spirit of special pleading. Astronomy is one of the physical sciences, and the physical sciences as a whole are being discouraged from advancement by the dismal budget situation for FY 1988 and the proposed budget for FY 1989. The physical sciences are truly the foundation-stone on which the broader intellectual structure of science rests, and astronomy is part of that foundation. It is my earnest request that the Congress examine the soundness of that foundation, and encourage the corrective actions, in the form of appropriate augmentations, where such aid is indicated.



Advancing psychology as a science, a profession, and as a means of promoting human welfare

STATEMENT OF

Leonard D. Goodstein, Ph.D.

Chief Executive Officer

And

Executive Vice President

American Psychological Association

on behalf of

THE AMERICAN PSYCHOLOGICAL ASSOCIATION

before the

UNITED STATES HOUSE OF REPRESENTATIVES

Committee on Science, Space and Technology

Subcommittee on Science, Research and Technology

on the subject of the

NATIONAL SCIENCE FOUNDATION AUTHORIZATION

Fiscal Year 1989

March 22-24, 1988

The Honorable Doug Walgren, Chairman
2319 Rayburn House Office Building

1200 Seventeenth Street, NW
Washington, DC 20036
(202) 955-7600

On behalf of the American Psychological Association (APA), I am pleased to submit our views on the reauthorization of the National Science Foundation (NSF) for Fiscal Year 1989. APA represents the concerns of 90,000 psychologists, many of whom conduct important scientific research with the support of NSF. In this statement, we comment on the Administration's proposed FY 1989 budget for NSF, focusing on areas of particular concern to psychologists and other behavioral and social scientists.

NSF FISCAL YEAR 1989 REAUTHORIZATION

APA appreciates this opportunity to strongly endorse the Administration's proposal to increase the National Science Foundation budget by 19 percent for FY 1989 to a total of $2.05 billion. Moreover, we applaud the President and NSF Director Erich Bloch for their foresight in proposing that the NSF budget be doubled over the next five years to $3.2 billion in FY 1992. These proposed increases signify a commitment by this Administration to invest in basic scientific research as part of this nation's goal to become more competitive internationally. We appreciate the Subcommittee's understanding of the need to support enhanced basic scientific research, which provides the requisite foundation for improving economic growth, productivity and competitiveness. We assure you of our active efforts to encourage the Congress to approve the public resources needed to rebuild our scientific base and to ensure ongoing support for innovative basic scientific research.

BEHAVIORAL AND SOCIAL SCIENCES

There are many important contributions to be made by the behavioral and social sciences in addressing the critical current concerns of our nation. An excellent review of some of the areas of research that have a great deal of promise in the years to come is contained in the recently (March 1988) released and extensive report of a committee of the National Research Council (NRC). In this report, "The Behavioral and Social Sciences: Achievements and Opportunities", the committee recommends a "new national commitment to the behavioral and social sciences" and that the federal investment in the behavioral and social sciences be increased by $240 million annually to capitalize on wide-ranging opportunities for scientific advances.

Among the research priorities identified by the NRC committee are studies on basic processes linking the mind, brain and behavior; motivational and social contexts of behavior; theoretical analyses of choice, information, incentives and behavior in markets and other organizational contexts; cross-national studies on cultures and institutions; and the development of large scale data bases.

The additional investment recommended by the NRC is urgently needed to reverse declining federal support for the behavioral and social sciences. Between FY 1972 and FY 1987, according to the report, federal support in constant dollars for behavioral and social research declined by 25 percent, while federal support for other fields of science research increased by 36 percent.

APA strongly endorses the authorization of additional funding through the National Science Foundation for research and research training in the behavioral and social sciences. While APA commends the Administration for its proposal to increase funding for all of NSF's Research and Related Activities by 10 percent to $1.6 billion, we remain concerned that NSF support for the behavioral and social sciences continues to lag behind that for other sciences. Within the $1.6 billion proposed for Research and Related Activities, $288.7 million is allocated to the Biological, Behavioral and Social Sciences (BBS) Directorate, an 8.6 percent increase. Still less favorable increases are targeted for the Behavioral and Neural Sciences Division (8.1 percent) and the Social and Economic Science Division (6.2 percent) within BBS.

This continues a trend in which percentage increases for the behavioral and social sciences research budget are disproportionately below such increases for the NSF research budget as a whole. The result is that although the total NSF budget has been significantly increased (in absolute dollars) over the past few years, the share of the NSF research budget allocated to behavioral and social sciences has diminished markedly, ignoring the rich scientific yield and practical benefits to be gained from supporting such research. In FY 1980, 6.1 percent of NSF's Research and Related Activities budget was allocated for behavioral and social sciences research. In contrast, only 4.9 percent of the FY 1989 Research and Related Activities budget is earmarked for the behavioral and social sciences. This consistently disparate treatment of the behavioral and social research programs is troubling in view of the rich research menu identified in the NRC report and its recommendation that federal support for such research be significantly boosted over the next three to four years. APA recommends that Congress target at least 6 percent of the Research and Related Activities appropriation towards the behavioral and social sciences.

In recent years, much national attention has been focused on the inability of our nation to compete effectively in global markets. Basic research in the behavioral and social sciences has a critical role to play in efforts to revitalize the nation's economic and technological base and helps to ensure, over the long term, that our nation has new knowledge needed for economic growth. Our international competitors have long recognized the value of principles derived from research in the behavioral and social sciences and have implemented policies that incorporate an understanding of human behavior that these sciences contribute. The United States could benefit from the behavioral and social sciences in similar fashion, especially with regard to increases in productivity, if critical

areas of research on organizational structures, social and motivational, and decision-making processes do not continue to be overlooked.

While hardware-related technological advances are important, of no less importance is an understanding of behavioral processes that can contribute to new social and institutional approaches to revitalizing the nation's industrial base. Following are just a few examples of areas of behavioral and social research that are relevant to this quest.

- Using rapidly developing results in experimental psychology, artificial intelligence, cognitive science, and the computer and information sciences, psychological scientists are engaged in cutting-edge research on the fundamental aspects of thinking and learning. The research concentrates on modeling the complex processes of human cognition. Unified theories of human cognition will be the fruit of these efforts, and these in turn will serve as the basis for more effective modes of training and education and more effective designs in robotics applications.

- The management structure and processes of American industry are often based on behavioral science research, especially with regard to productivity. This research includes studies of the relation between the factors of employee morale and job satisfaction to employee productivity; the nature of employee resistance to changes in management practices; the effect of instituting employee profit-sharing plans; and the relation between styles of leadership to group productivity. All of these areas in turn have relied upon fundamental research on human motivation, emotion, cognition, and social perception.

- The field of psychology has made great strides increasing our understanding of how to maximize productivity by revealing the importance of and methods for effectively matching specific types of jobs with specific types of persons; personnel selection test validation; and utility analysis. The field is now addressing such issues as quality of work-life; retraining for technological change; and the development of employee work values and attitudes. All these areas of research and research application have relied significantly on basic research on attitude formation and attitude change, item response theory in testing and assessment research, computerized adaptive testing techniques, development of social values, choice behavior, personality development, and social and cognitive development.

- Related to these cutting-edge research areas are new integrations of basic findings in experimental psychology with basic and applied human factors research. This multidisciplinary integration has contributed important understanding of basic biomechanical and human perceptual/cognitive functioning that in turn have permitted practical recommendations in designing efficient interfaces between humans and machines; optimizing human performance by designing work-station

elements in accord with human capabilities and by designing architectural environments in accord with basic principles of human perception and behavior; determining optimal parameters of lighting on roadways; determining the nature and likelihood of risk-taking behavior of drivers operating vehicles under hazardous conditions; and identifying efficient aircraft cockpit display arrangements.

SCIENCE EDUCATION

APA is concerned about the future of science education at the pre-college, undergraduate, graduate and postdoctoral levels. We recognize that much improvement is needed in our nation's science education activities, and we endorse the President's request of $156 million for the Science and Engineering Education (SEE) Directorate. This represents an increase of nearly $17 million (or 12 percent) over and above the FY 1988 appropriation which in itself was a large increase over previous funding levels. Increased funding for science education is needed to restore a priority to science education programs which were drastically reduced in the early 1980's. Without adequately trained scientists and engineers today, the benefits of scientific research will not be realized tomorrow. The importance of the education of our nation's future scientists is properly reflected in NSF's proposed budget.

Equally important is the need to attend to the scientific and technological (e.g., computer) literacy of the American public for reasons that include the need to facilitate efforts to retrain displaced American blue-collar workers, the need for the public to properly understand the potential contribution of science and technology to an enhanced quality of life, and the need for Americans to be informed consumers of the benefits deriving from science and technology.

Additionally, APA is pleased with the Administration's proposal to enhance overall spending for education and human resources activities throughout NSF by $45 million in the FY 1989 budget request. This increase would raise the total spent on pre-college (K-12), undergraduate, graduate and professional development (e.g., visiting professorships) programs to nearly $266 million. In keeping with NSF's effort to augment educational support for scientists and engineers, the Administration has proposed to increase spending levels for undergraduate programs by $25 million and graduate and postdoctoral programs and other related activities including professional development and programs for minorities and women. APA is particularly supportive of efforts to enhance research experiences at the undergraduate level, enabling psychology students greater opportunities to participate in behavioral science research projects supported by NSF.

NEW INITIATIVES

The benefits of a multidisciplinary approach to advance knowledge and stimulate scientific innovation have been amply demonstrated in scientific research. In order to accelerate scientific advances that will help to improve our nation's competitive posture, the FY 1989 NSF budget invests significant resources in new science and technology centers. APA supports the establishment of these new multidisciplinary centers which will include centers in the behavioral and social sciences.

One such center for psychobiological research could expand research in important areas of psychology. For example, proposed psychobiology centers could provide support for research on the underlying mechanisms of learning, memory, and cognition. The study of the neuro- and psychobiology of learning and memory is fast becoming the most active and promising research area within the neurosciences today. For example, important research now being conducted on the disorders of learning and memory will form the basis for a better understanding of Alzheimer's disease and cerebrovascular disorders. Research to investigate cellular mechanisms underlying neural plasticity, which serves as the basis of learning and memory, is also part of significant ongoing efforts in this field. Other studies are examining brain systems that participate in the establishment and retrieval of memories. This research will lead to a greater understanding of human cognition and how the nervous system processes information. The benefits to be reaped will be in many areas including education and training, which significantly affect the competitiveness of America's workforce.

Many cutting-edge research areas within the behavioral and social sciences require cross-disciplinary cooperation in order to effectively address the complexities of specific research issues. For example, there are enormous methodological and technical complexities, as well as conceptual complexities, involved in performing research on the psychobiological basis of learning and memory. Consequently, APA supports the multidisciplinary center concept as an appropriate approach to research in the behavioral sciences. In addition, APA supports the NSF proposal to expand support for small multidisciplinary research group awards.

While APA is encouraged by these initiatives to establish and support new centers in the behavioral and social sciences, we are concerned about continued support for field-initiated research at NSF. We hope that expanded support for the centers will not drain needed resources away from independent investigator research, which has been the foundation of innovative basic scientific research at NSF. APA recommends that support for field-initiated research be enhanced as funding and resources within NSF are increased.

APA appreciates the Subcommittee's consideration of our comments and recommendations during its deliberations on the FY 1989 authorization for NSF. Behavioral and social science research makes important contributions to enhancing our nation's intellectual and human capital, and is key in

developing new behavioral, social, and institutional approaches to revitalizing the nation's economic and technical base. We urge Congress to approve the proposed spending increases and program initiatives for NSF in FY 1989.

The American Society of Mechanical Engineers

Suite 218
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202-785-3756

March 30, 1988

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On behalf of a task force of the Council on Education of the American Society of Mechanical Engineers (ASME), I am pleased to submit the enclosed statement regarding the engineering-related activities in the FY 1989 proposed budget of the National Science Foundation. ASME is a nonprofit technical and educational organization with 118,000 members, including 22,000 students.

The task force endorses the Administration's plan put forward in FY 1988 to double the NSF budget in five years. In particular, we support the major priorities of the budget for the Engineering Directorate and endorse the Foundation's commitment to develop and sustain a high level of federal support for both engineering research and education.

We hope the Subcommittee finds the comments useful, and we respectfully request that the statement be included in the written record of hearings on the NSF FY 1989 budget authorization.

If you have any questions or comments concerning our statement, please feel free to contact Brenda Sanders of the ASME Washington office at 785-3756.

Sincerely,

Alex Dybbs

Alexander Dybbs, Ph.D.
Chairman
Task Force on the NSF Budget

AD/BSS:cae

Enclosure

The American Society of Mechanical Engineers

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202-785-3756

Statement of the

Task Force on the National Science Foundation

of the

American Society of Mechanical Engineers

on the

National Science Foundation

FY 1989 Budget Request

Submitted to

Subcommittee on Science, Research and Technology

Committee on Science, Space and Technology

U.S. House of Representatives

March 30, 1988

Mr. Chairman and Members of the Committee:

We appreciate the opportunity to submit our views on the proposed fiscal year 1989 budget of the National Science Foundation. The American Society of Mechanical Engineers (ASME) is a nonprofit educational and technical organization with 118,000 members, including 22,000 students. This statement was prepared by a task force of the Council on Education of the American Society of Mechanical Engineers. It represents the considered judgement of the task force, a group of experts in the field, rather than an official position of ASME.

ASME continues its vital interest in the successful implementation of the full range of NSF programs. The task force endorses the Administration's plan put forward in FY 1988 to double the NSF budget in five years. These comments, however, focus primarily on those aspects of the budget request affecting the contributions of engineering research to national goals.

We are in an age of technology. To a great extent, the future economic strength of the United States will depend on maintaining superiority in technology. Most of the spectacular technological advances of this century, from radar to nuclear power, from the transistor to the laser, from computers to optical communications, have been critically dependent on the basic scientific and engineering research that has been typically supported by NSF. Unless we continue to advance this base, the ability of the U.S. to continue to be a leader in the development of new technology will be impaired.

OVERVIEW: NSF ENGINEERING BUDGET

The FY 1989 budget request for the NSF Engineering Directorate is $194.96 million. This is an increase of $23.48 million or 13.7 percent over the current FY 1988 plan of $171.48 million. We are disappointed that this increase is smaller than the proposed increase of 19 percent for NSF overall. Even if the request is approved in full--an unlikely prospect based on the experience in recent years--it is modest when one considers that there has not been a significant increase in the NSF basic engineering programs for the last three years. If, as has been the case recently, the budget eventually is trimmed below the request, the NSF engineering program runs the risk of ending up with a seriously inadequate budget. This will make it

difficult if not impossible for NSF to balance its support for programs that foster economic vitality with those that ensure the long term health of basic engineering research.

In FY 1985, NSF supported a larger fraction of engineering research at universities than any other federal agency. In FY 1986, this was no longer true. This is an unwelcome trend which will probably continue. Thus, it is important to provide significant growth in engineering research at NSF as we do not want U.S. universities' engineering research to become solely mission oriented and DOD dominated.

The Engineering Division of NSF has programs in two broad areas, basic or disciplinary engineering research, and more targeted or cross-disciplinary engineering research. In FY 1989, 65 percent or $15.3M of the proposed $23.5M increase will be in the targeted or cross-disciplinary areas of engineering research. These include the Engineering Research Centers (ERCs), a proposed $7.03M increase or 30 percent of the total increase; the Emerging Engineering Technologies Division, a $2.85M increase or 12 percent of the total increase; the Critical Engineering Systems Division, a proposed $3.15M increase or 13.4 percent of the total increase; and the Design, Manufacturing, and Computer-Integrated Engineering Division, a proposed $2.28 increase or 9.7 percent of the total increase.

The proposed increase for the basic engineering programs is $8.17M. The Chemical, Biochemical, and Thermal Engineering Division, a proposed increase of $3.0M or 12.8 percent of the total increase; the Mechanical Structures and Materials Engineering Division, a proposed $3.27M or 13.9 percent of the total increase; and the Electrical, Communications, and Systems Engineering Division, a proposed $1.9M or 8 percent of the total increase. It should be noted that even within these divisions, the largest increases are in the more focused or cross-disciplinary programs.

We are concerned that only modest increases are proposed for the basic engineering programs. If the same budgeting constraints prevail as in the last two years, the total request will be trimmed, and those portions of the program for which only modest increases were proposed will actually end up with a decrease. The soundness of the total program depends on a strong engineering science base. Historically, we

have seen time and time again major programs suffer because of an inadequate engineering science base.

The technological advances of this century required a sound foundation in engineering science. Many of the R&D programs receiving strong emphasis now, within and outside NSF, as well as some NSF programs slated for increased emphasis in FY 1989, will not fare well unless they are backed up by increased emphasis on the relevant engineering science base.

For example, the Strategic Highway Research Program (SHRP), which is being carried out by the National Research Council under legislation passed by Congress last year, is an important program. Without it our huge investment in highways, which forms such a critical infrastructure for our whole way of life, would be in jeopardy. The program itself is aimed at short term solutions of some of the most critical problems. Somebody, presumably NSF, should be looking at the longer range solutions. In our judgement, these solutions cannot be achieved without strengthening the engineering science base critical to understanding. For instance, what are the factors that provide greater durability in reinforced concrete structures? How can we carry out meaningful non-destructive evaluation of these structures, and how can we develop better specifications in this area?

As another example, the only clearly identifiable support of the critical area of lifetime cost of products is the proposed increased emphasis on "computer modeling for life-cycle engineering." While this increase is laudable, it addresses only a very small element of the total need. Both the military and civilian economy are beginning to recognize the urgent need of strengthening the methodologies required to design for maintainability. These cover some sophisticated and complex technologies, from adaptive control to expert systems. The need for stronger research support in these areas is critical to national defense and to reestablishing our country's industrial competitiveness.

CONCLUSIONS AND RECOMMENDATIONS

We support the major priorities of the FY 1989 budget for the Engineering Directorate and endorse the Foundation's commitment to developing and sustaining a high level of federal support for both engineering research and education. Given the impact that

engineering can have on U.S. economic competitiveness and the importance of NSF to many areas of basic and focused engineering research, we feel that it is, indeed, essential that Congress approve the proposed increase for FY 1989. These budget increases will help NSF balance its support for programs that foster economic vitality with those that ensure the long-term health of basic engineering research.

In the event that Congress finds it necessary to reduce the NSF request, we recommend that the first priority should be to provide meaningful increases to the basic engineering science programs. These programs are the ones that will provide the resources of intellectual talent for the next generation of innovative technological advances. For the most part, these areas have received no funding increases in the last three years. There is much catching up to do in these areas so that a proper balance can be restored between basic and targeted engineering research.

It is our hope that the Subcommittee will see the budget as an important investment in the nation's economic and industrial future, the rewards of which the nation will reap many times over.

American Chemical Society

OFFICE OF THE
PRESIDENT

Gordon L. Nelson
President-Elect, 1987
President, 1988
Immediate Past President, 1989

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April 1, 1988

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space, and
Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

The Nation's technological competitiveness depends significantly upon continued long-term support for basic research and education at our universities and colleges. Without such support, the U.S. cannot extend the knowledge base of the basic sciences and engineering, which lays the foundation for innovation and new product development. Nor can the U.S. train and educate the next generation of scientists and engineers who will be needed to develop products, to perform research, and to restore scientific literacy. To provide the necessary support for a healthy academic system and to ensure a continuing supply of scientifically trained employees for industry's needs, the American Chemical Society (ACS), recognizing the existing bipartisan support for these goals, strongly urges the Subcommittee to begin a five-year doubling of the National Science Foundation's budget in FY 1989.

The research disciplines have lost valuable ground due to budget constraints over the past three years. A healthy discipline is built on research conducted in the core fields and at the frontiers of science; it depends upon adequate instrumentation and facilities. For fifteen years, U.S. investment in civilian R&D as a percentage of GNP has lagged far behind that of West Germany and Japan, and the difference is growing. Now France has passed the U.S.

The Society is pleased that there are proposed increases for the NSF Divisions of Chemistry, Materials Research, and Chemical, Biochemical, and Thermal Engineering. ACS is supportive of the new and continuing interdisciplinary research thrusts, as well as the cross-directorate human resource and education initiatives that are funded in them. However, after three years of budget constraints, the underfunding of base research programs is growing and must be rectified.

The individual researcher and established research groups are hard-pressed for funding. They are looking to the FY 1989 budget for funding to address the research opportunities before them. With this in mind, the American Chemical Society makes the following recommendations:

- In order to exploit the enormous research potential in the chemical sciences and technologies, the ACS recommends that $4.5 million be added to the budget of the Chemistry Division, and that an additional $3.0 million be added to the budget of the Materials Research Division, as a first step towards providing adequate support for individual investigators. The funding level proposed for the Chemical, Biochemical, and Thermal Engineering Division should be viewed as the minimum level necessary in the fields supported.

- The Society supports the Science and Technology Centers program, at the requested level of $150 million, as a viable method of funding research. However, should budget constraints occur, funding for the S&T Centers should not come at the expense of the Foundation's requests for individual investigator research. The program also should be monitored closely by the Office of Science and Technology Centers in order to measure its contribution to the health of the sciences and its impact on the research base.

An effective system of science and engineering education is vital to the long-term interests of the United States. The Nation is falling behind developed and developing countries in the quality of scientific education. Science literacy is declining. Our prosperity and national security depend on having enough well-trained scientists and engineers to respond to national needs. Therefore, the American Chemical Society recommends:

- An increase of $50 million in FY 1989 be allocated to the Science and Engineering Education (SEE) Directorate to address the problems of teacher retraining and recruitment, instrumentation needs, and minority and female recruitment into the sciences. SEE is the primary focal point for NSF's educational activities. Since its reinstatement in 1985, the Division has labored to match its past levels of effort. This increase will begin a steady march toward that goal. The additional funding requested by ACS is $33 million above the budget proposed by the Administration and should be new monies added to the Foundation's budget proposal.

The accompanying Appendix provides greater detail on the Society's recommendations. The ACS believes that the work accomplished by the Foundation contributes to the economic well-being of our Nation. Thus, it is imperative to provide increased support to the National Science Foundation even in a time of budget constraint.

Sincerely yours,

Gordon L. Nelson

Appendix

cc: Other Members, House Subcommittee on Science, Research and Technology

APPENDIX

The Nation's future research capability depends upon the teaching and education afforded to our students through government-sponsored research. Our industry's ability to compete rests upon the technological advances made through basic research. Central to these activities is the National Science Foundation, which funds research and education activities at all levels, and is the principal funding source for nonmission-oriented basic research. Recognizing the existing bipartisan support for improving these areas, the American Chemical Society strongly supports a five-year doubling of the NSF budget beginning this year.

While the Foundation's budget is slated to increase 19 percent in FY 1989, the Research and Related Activities (R&RA) category, however, is scheduled to increase by only 10 percent. Nearly 60 percent of the funding within R&RA will support individual investigators--a single researcher in a laboratory with graduate students. Much of our national scientific advancement has grown from these roots. The funding received by these individual investigators benefits not only the research and the student, but the institution as well, strengthening and improving the U.S. education enterprise nationwide.

Individual investigators are aware of NSF's attempt to begin doubling its budget in FY 1988. They also are painfully aware that that goal was not achieved. For FY 1988, R&RA received a 3 percent increase, somewhat less than inflation.

The health of academic research and education in chemical sciences, materials science, and chemical engineering is essential to continued U.S. economic competitiveness, particularly in the chemical and allied industries; a sector of the economy that has a growing positive trade balance. This strong showing is related to the academic infrastructure that supports it.

NSF is a primary player in assuring continued competitiveness through its funding of: (1) 40 percent of all the academic chemistry research sponsored by the federal government; (2) 84 percent of all the federally-funded academic chemical engineering research; and (3) about 50 percent of all the academic materials research conducted with federal funds.

The ACS is discouraged that modest increases are proposed for these fields in NSF's FY 1989 budget request. The 5.2 percent increase in the Chemistry Division and the 7.2 percent increase in the Materials Research Division will not allow researchers to exploit the opportunities before them. The Society is pleased that the Chemical, Biochemical, and Thermal Engineering Division does receive a 10.4 percent increase. Synergism exists among these fields, and extends to joint initiatives at the research frontiers. The comments that follow focus on the individual NSF divisional activities first, then on the synergistic relationships.

Chemistry Division

The FY 1988 budget for the Chemistry Division increased one-half of one percent (0.5 percent) over FY 1987. Although the dollar amount of the Division's awards are equal to the FY 1987 level, fewer awards actually will be made. For those who received awards or renewals of current grants early in FY 1988, the dollars received were less than expected. Programs are being operated at reduced levels--inorganic,

Bioinorganic, and Organometallic Chemistry; Organic and Macromolecular Chemistry; Physical Chemistry; and Chemical Instrumentation are below the FY 1987 level of support. Chemical Instrumentation, in fact, is operating at less than the 1984 support level. Given the current funding level, it is unlikely that the Chemical Instrumentation Program will be able to continue to fund maintenance of large-scale instrumentation, a plan that just began this year. The Society strongly urges the Foundation to take every effort to bring the Chemical Instrumentation Program back to the equivalent level of funding that was available in FY 1987. State-of-the-art, shared-use equipment in our Nation's university laboratories is crucial to the health of the U.S. research enterprise. It is essential that NSF continue its strong support in this area.

The FY 1989 budget request includes a 5.2 percent increase for the Chemistry Division. While the FY 1989 budget increases support for new, interdisciplinary research initiatives in materials chemistry, the ACS is concerned that these initiatives are being pursued at the same time that disciplinary research is being underfunded.

Finally, the Society commends NSF for its initiation of the Postdoctoral Fellowships in Chemistry awards. These are three-year awards that may be converted, in their final year, to academic starter grants. The ACS regrets, however, that this program was only able to move forward in 1988 at one-half its intended level. The American Chemical Society supports the $1.5 million FY 1989 increment for this program and hopes to see continued emphasis within the Division for these awards.

Materials Research Division

In the Materials Research Division a similar pattern of erratic funding is found. While the proposed FY 1989 budget increases 7.2 percent, that increase follows three years of small but variable increases. In FY 1986, the budget decreased due to sequestration under the Gramm-Rudman-Hollings law. In FY 1987 and FY 1988, the budget increased 4.3 percent and 2.1 percent, respectively, yet this represents only one-third and one-fifth of the increases requested to meet the Division's needs, due to increased academic research proposals in this area.

The FY 1988 budget increase is below inflation and only permits operation of some programs at their FY 1987 level or below. The Materials Research Groups program will fund one of the three to four additional groups originally planned in 1988. The Materials Research Instrumentation Program was cut 18.5 percent in FY 1988, bringing instrumentation funding to below 1984 levels. As with instrumentation funding in the Chemistry Division, ACS urges that every effort be made to restore this program at least to levels equivalent to FY 1987.

The Materials Research Division supports numerous activities that are on the forefront of high technology, notably, solid state chemistry, polymers, and ceramic and electronic materials. NSF is, in fact, the predominant source of federal funding in solid state chemistry since the Department of Defense funding for basic research has declined. The seriousness of this situation in the Materials Research Division is evidenced in the lost opportunities that are stymieing polymer research.

During the past twelve years, the number of academic investigators has risen from about 200 to over 850; yet individual investigator proposals funded during the same period have declined from 94 to 92. Funding needs in basic polymer research are not being met.

ACS is pleased that the Materials Research Groups program is slated to receive a 20.3 percent increase in FY 1989. The proposal pressure in this program has been increasing since its inception in FY 1985. That year, NSF received nineteen proposals and funded five groups. In FY 1986, the Foundation received thirty-one proposals and again funded five new groups as well as one Materials Research Laboratory that had been down-graded. In FY 1987, thirty-two proposals were received, but only three new groups were funded, along with another down-graded Laboratory. Only one additional group will be funded in FY 1988, out of twenty-six that have sent in proposals. On an average, a Materials Research Group supports six investigators, and six to eight graduate and undergraduate students. The FY 1989 increase slated for the Materials Research Groups program will enable the Foundation to continue support for existing groups while funding three to four new additional groups.

Chemical, Biochemical, and Thermal Engineering Division

After Gramm-Rudman-Hollings sequestration occurred in FY 1988, the budget for the Chemical, Biochemical, and Thermal Engineering (CBTE) Division did not increase substantially: the FY 1987 budget maintained programs at the FY 1986 level. Because of the late action on the FY 1988 budget, CBTE programs again increased very little, leaving investigators working near FY 1986 levels of support. The impact of these funding patterns becomes more worrisome when one considers that 84 percent of federal support for basic research in chemical engineering conducted at universities and colleges comes from NSF.

Research initiatives within CBTE focus on areas important to our manufacturing technologies. The research supported impacts on biotechnology, electronic materials, pharmaceuticals, polymers, specialty chemicals, semiconductors, and ceramics. It is imperative that these funding levels be given priority in this and future NSF budgets.

ACS is pleased to see the Foundation's emphasis on combustion processes relating to the incineration of wastes. Novel concepts that will lead to advances in the thermal destruction of dangerous compounds are needed. Current research on uniform deposition of thin films for microelectronic chip production are being supported, as well, by CBTE. Research in this area can ultimately benefit our high-technology industries by eliminating the need for elaborate control systems, thereby reducing ultimate production costs.

Interdisciplinary Research

Chemistry is a central science that leads and supports research in numerous fields--from biotechnology to microelectronics. Chemistry's contribution to high-

technology industries is wide-spread. A synergistic relationship exists among chemistry and other fields, notably with materials research, biology, physics, and engineering. These relationships are manifested in interdisciplinary efforts.

The Materials Chemistry Initiative, for example, is supported by the Chemistry; Materials Research; and Chemical, Biochemical, and Thermal Engineering Divisions, with a total combined funding of $19.6 million in FY 1989, a 24.8 percent increase. Included as part of this initiative is superconductivity research, materials with designed properties, and chemical processing of advanced materials and devices for information storage and handling.

The American Chemical Society commends the long-term support that the Materials Research Division provides in the field of superconductivity. Fourteen years of continuous support enabled Dr. Paul Chu's research team at the University of Houston to make the advances in superconductivity that made international headlines. However, much remains to be done. ACS supports the emphasis placed on superconductivity in FY 1989--a $2 million increase for that area to $14.5 million in the Materials Research Division. Overall, the Foundation will provide $20.1 million for superconductivity research, including $0.75 million in the Chemistry Division, $2.5 million in the Physics Division, and $2.2 million in the Engineering Directorate. Some funding will be part of the Materials Chemistry initiative, supplemented with individual investigator grants.

Superconductivity has captured the imagination of the American people and it has demonstrated the need for long-term support of basic research. However, the Society is concerned that the small increment in the Chemistry Division will not be sufficient to permit in-depth studies on the characterization of superconducting materials. The Society hopes that this increment will increase substantially in FY 1990.

The ACS supports the additional research thrust within Materials Chemistry on "Chemical Processing of Advanced Materials and Devices for Information Storage and Handling." This initiative will be managed jointly with the Chemical, Biochemical, and Thermal Engineering Division, and possibly other divisions. Among the important research areas to be explored are the preparation and characterization of thin films used in making electronic, optical, and magnetic devices that store and handle information. Interfacial phenomena studies will help us understand the layering formations important to high-quality materials. Other studies will enable us to further our knowledge of available materials and to make more compact structures for information storage and handling.

The Society also notes the continued emphasis on another initiative, Chemistry of Life Processes, which was proposed in a 1985 National Academy of Sciences/ National Research Council report, Opportunities in Chemistry. Research in Chemistry of Life Processes is conducted by the Chemistry Division in conjunction with the Biological, Behavioral, and Social Sciences Directorate. Areas supported include the chemistry of the senses and studies of large-molecule/small-molecule binding and recognition. The Chemistry Division supports additional single-investigator projects that complement these collaborative projects.

Benefits of Research and Future Research Directions

Opportunities in Chemistry emphasized five broad areas of research that require priority funding--understanding chemical reactivity, chemical catalysis, chemistry of life processes, chemistry around us, and chemical behavior in extreme conditions. Chemistry has been and continues to be underfunded to meet new research directions. Although the Society can cite discoveries, we can only wonder at the opportunities lost due to a lack of adequate funding.

Dr. Donald Sawyer at Texas A&M has discovered a new chemical method that destroys polychlorinated hydrocarbons, such as PCB's. The most environmentally persistent of these usually contain the most chlorine, yet Dr. Sawyer's new method would destroy these compounds more easily. His discovery has a broad impact on environmental chemistry.

Professor Donald Cram, UCLA, received the 1987 Nobel Prize in Chemistry for his research on "host-guest" chemistry. His research focuses on the ability of large molecules to recognize and capture small molecules. These large molecules mimic naturally-occurring substances called enzymes that influence chemical and physical reactivity. This landmark research, which will impact on technologies such as separations, catalysis, and molecular biology, would not have been possible without the thirty years of continuous support received from the Foundation's Chemistry Division, among others.

In June 1988, the National Research Council is scheduled to publish a report, similar to the 1985 Opportunities in Chemistry report, that will address the needs in the field of chemical engineering--"Frontiers in Chemical Engineering: Research Needs and Opportunities." This Report will identify areas of research that can provide the U.S. with a technological lead in the next decade and beyond. Areas of emphasis for NSF include:

- electronic, photonic, and recording materials;
- polymers, ceramics, and composite materials;
- separation and purification research;
- environmental protection, process safety, and hazardous waste management;
- surface and interfacial engineering;
- biotechnology and biomedicine;
- computer-assisted process and control engineering; and
- processing of energy natural resources.

Because of the large proportion of support provided for basic research in chemical engineering by NSF, the Foundation must play a leading role in the advancement of these research areas.

Recommendations for Research Divisions

Research support in the chemical sciences and engineering is central to our Nation's economic growth. The research performed is beneficial to our leading

industries--pharmaceuticals; organic, inorganic, and specialty chemicals; resins; rubbers; fertilizers; and plastics. The Chemical and Allied Products sector has consistently maintained a positive trade balance with foreign nations. Last year, Chemical and Allied Products exported $9.3 billion more products than were imported.

These industries are research intensive. They rely not only upon the innovations made in our Nation's universities and colleges, but also upon educated scientists and engineers who can bring fresh insights and experiences to these industries. More than ever before, it is essential to maintain and improve the research base in the chemical sciences, and the Foundation must play the key role in this area.

The ACS is pleased that there are proposed increases for the Divisions of Chemistry; Materials Research; and Chemical, Biochemical, and Thermal Engineering. The Society is supportive of the new and continuing interdisciplinary research thrusts in these Divisions, as well as the cross-directorate human resource and education initiatives that are funded in the research divisions. These research initiatives and foundation-wide programs have a justified claim on increases proposed in the FY 1989 budget. However, after three years of budget constraints, the critical base research programs are underfunded and the individual researcher and established research groups are hard-pressed for current funding.

- ACS recommends that an additional $4.5 million be added to the budget for the Chemistry Division, to enable NSF to program additional funds to the core disciplinary research areas and instrumentation, which are underfunded.

- Considering the great research strides emanating from the Materials Research Division, ACS recommends that the Division receive an additional increase of at least $3 million above the FY 1989 request. The Society recognizes that additional monies would advance basic research in this area and strongly urges the Foundation to consider the importance of this field in its preparation of the FY 1990 budget.

- The research areas outlined in the soon-to-be-released National Research Council report present the Chemical, Biochemical, and Thermal Engineering Division with the opportunity to move into critical new avenues of study. To the extent possible, ACS recommends that funding be made available for these promising research areas, through internal readjustments within the confines of the proposed FY 1989 budget. Future budgets should be prepared with these needs in mind. In FY 1990, an increment of $12 million will be necessary to begin implementation.

Science and Technology Centers

The American Chemical Society believes that it is appropriate that a separate line item be created for the S&T Centers. The request of $150 million will provide support for twelve to fifteen centers in FY 1989 and assure continued funding for up to five years. To date, the National Science Foundation has received 325 proposals totaling $4.1 billion for the total five year period.

ACS commends NSF for the creation of the S&T Centers Coordinating Office, which will enable NSF to monitor the program carefully. Questions relating to the evaluation and lifetime of the centers must be addressed. The separation of the S&T Centers from the research divisions will enable NSF to measure the impact of the Centers on other modes of research funding, especially individual investigators and groups, a task in which NSF must be especially diligent.

ACS agrees with the finding of the National Science Board, the Foundation's advisory board, that the balance between centers and individual investigators should be determined by the requirements of the science and engineering enterprise. Although ACS firmly believes that the individual investigator is the appropriate mode of support in most fields of endeavor, the Society recognizes that the center concept may provide long-term support in some areas that demand additional funds. The centers concept may contribute to the number of investigators entering cross-disciplinary fields by encouraging students to complete doctoral studies in these emerging fields.

These centers may provide the incentive for creative interactions that can lead to scientific discovery. ACS supports the requested budget of $150 million; however, should budget constraints occur, funding for the S&T Centers should not come at the expense of the Foundation's requests for individual investigator research.

Science and Engineering Education Directorate

Given the continuing need for strengthening our national commitment to science and mathematics education, the Society is disappointed with the small increase in the Administration's FY 1989 request for the SEE Directorate. The proposed amount can not maintain the current momentum of Directorate programs, nor can it allow for the establishment of new programs vital to the success of NSF's congressionally chartered mission.

The well-documented crisis in U.S. science, engineering, and mathematics education is still with us. No one should assume that a few years of concern will compensate for many years of neglect. Nor should it be assumed that the problems now facing science, engineering, and mathematics education are in any way less serious than the problems of science and mathematics education in the mid-1960's. As stated in the 1988 report of the International Association for the Evaluation of Educational Achievement, the United States lags significantly behind many other countries in student achievement in the sciences for 5th, 9th, and 12th grades. In chemistry achievement, for example, the United States was ranked eleventh out of thirteen countries; 48 percent of U.S. high schools scored lower than the lowest schools in the highest ranking countries (England, Hong Kong, and Singapore). This situation is a shocking indictment of what was once the model school system, admired and emulated by the rest of the world.

If the U.S. does not solve its current educational problems and ensure that they do not recur, the Nation faces critical shortages of scientific manpower that

will seriously impair economic productivity and destabilize its security well into the next century. Yet the level of support for SEE Directorate programs under the FY 1988 Current Plan is only one third of the level of support, in constant 1988 dollars, for education in the FY 1968 NSF budget--and there are 50 million more Americans to educate (See Attachment). As Congress itself has noted, the NSF education programs have been "short changed" for almost twenty years and there is an urgent need to "catch up".

In view of the Nation's precarious position, the American Chemical Society recommends that, for FY 1989, the SEE Directorate be authorized at a much higher level than the Administration request. An increase from FY 1988 to FY 1989 of at least $50 million is needed. Further, in concurrence with recommendations from two National Science Board reports, Educating Americans for the Twenty-First Century and Undergraduate Mathematics, Science, and Engineering Education (the "Neal" Report), the Society believes that the total effort of the SEE Directorate should rise to $600 million over the next four years, as part of the planned increase in the NSF budget.

The ACS heartily supports the efforts of the SEE Directorate to devise programs that address the full spectrum of science literacy concerns, as well as the more traditional science career programs. Science cannot flourish in a society where the majority of its citizens do not understand either the scope or the limitations of science as a solver of societal problems; and have neither the knowledge, nor the comfort level, necessary to address science and technology issues that impact upon the community.

The SEE Directorate's emphasis on materials development and informal science education at the elementary and middle school levels is very appropriate given the established importance of successful science experiences in the early years. Such experiences contribute to a greater appreciation of the nature of science, and to a larger available talent pool from which the scientists of the future will emerge.

However, programs planned for FY 1989 do not appear to be funded well enough to address the issues of teacher retraining and shortages. Given the aging population of current science and mathematics teachers, and the very few science and mathematics students electing to join the teaching profession, the ACS recommends that additional funds be made available to tackle these particular problems. To encourage entry into the profession, one approach would be to develop a Presidential Young Teacher's Award, analogous to the Presidential Young Investigator's Award, to support the training of undergraduates electing to become science and mathematics teachers. Such a program would do much to recognize that new, well-educated, highly motivated teachers are just as important to science as are new, well-educated, highly motivated researchers. The Presidential Awards for Excellence in Science and Mathematics Teaching recognize the contributions of current teachers but are not a sufficient motivator to attract new teachers into the profession.

The Society is pleased that the College Science Instrumentation Program is being administered for instructional as well as research purposes. The ACS reaffirms its previously stated position that this competition should be conducted each year, and that each year it should be open to two-year colleges, four-year colleges, and research universities. The need for this program is evident given the large

number of unfunded proposals in FY 1988. All institutions of higher learning have need for undergraduate instrumentation. The proposed level funding for FY 1989 of $11.5 million is clearly inadequate. It should be noted that the Neal Report recommends an annual outlay of $30 million for instructional instrumentation and equipment.

The American Chemical Society supports the expansion of undergraduate programs to more than $60 million in FY 1989. However, the Society notes that only $4.5 million in new money is assigned to the SEE Directorate for a total of $23.5 million in FY 1989. The Society again would like to cite the Neal Report which recommends a $100 million budget for undergraduate education in FY 1989 and designates the SEE Directorate as the lead organizational unit. The current coordinating function of the Office of Undergraduate Science, Engineering, and Mathematics Education does not meet the intent of that Report.

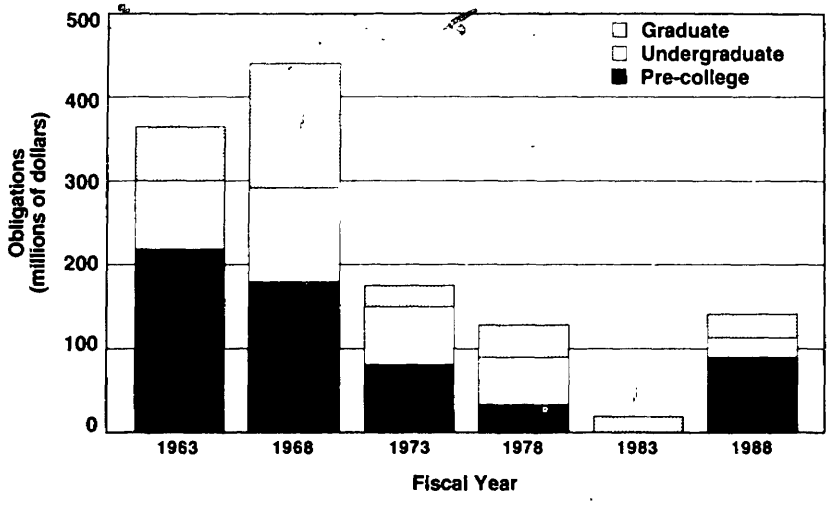
The ACS has learned that even with a decrease in proposed funding being planned, an additional 100 Graduate Fellowships will be awarded in 1989 through a change in accounting procedures. The Society notes that the SEE budget will have to increase in subsequent years just to meet these current obligations.

Finally, the Society fully supports the special emphasis of the Foundation on minority and female recruitment into the sciences. However, given the high exodus of minorities from the educational pipeline before 12th grade, and the disastrous pattern of mathematics and science coursetaking by minorities in high school, intervention should most effectively be targeted at the elementary and middle school levels. Support at the graduate, or even undergraduate, levels is well-meaning but probably too late to substantially increase the population of currently underrepresented minorities in science, engineering, and mathematics. Because of demographic projections into the next century, increasing the representation of these minorities in the quantitative disciplines pool goes beyond equity issues to the very survival of the scientific enterprise as it is recognized today.

April 1, 1988

Science and Engineering Education

Obligations by Level of Education (in constant FY88 dollars)



AMERICAN SOCIETY OF CIVIL ENGINEERS

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April 6, 1988

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research, and Technology
2319 Rayburn House Office Building
Washington, DC 20510

Dear Chairman Walgren:

On behalf of the 100,000 members of the American Society of Civil Engineers (ASCE), I urge your support for the Administration's $2.05 billion fiscal 1989 budget request for the National Science Foundation (NSF). Understandably, concerns about the federal budget deficit may call into question NSF's proposed $330 million (19%) increase, however, the nation's commitment to enhancing U.S. competitiveness underscores the importance of preserving this budget increase.

Engineering Directorate funding would rise by $23.5 million (13.7%) to a level of $195 million. ASCE is particularly encouraged by increased support for Mechanics, Structures, and Materials Engineering of $3.3 million (13%) to a level of $29 million, and by increased funding for Critical Engineering Systems of $3.15 million (12.5%) to a total of $28.3 million. The Engineering Research Centers (ERC) program will increase from $33.2 million in FY 1988 to $40.0 million in FY 1989, an increase of $6.8 million, or 21 percent, which continues support for existing centers and allows two new centers to be started, bringing the total number supported by NSF to 19 centers. The ERC's expedite the transfer of research results from the lab to America's application in the global market place.

Computer and Information Science and Engineering would be boosted by $25 million (20%) to a level of $149 million. In addition, NSF's important commitment to Science and Engineering Education would rise 12 percent, to a level of $156 million. This funding will support important and expanded education efforts at the precollege, undergraduate, and graduate levels.

We commend and share the Administration's commitment to substantially increase the NSF budget over five years. Historically, technological breakthroughs have been a key factor in increasing U.S. economic competitiveness and raising the standard of living. NSF's growth in research and education activities will contribute significantly to technological development and economic growth at home, and U.S. competitiveness abroad. Given the widespread support in Congress for improving U.S. competitiveness the NSF budget should be viewed as an investment in talent, and our future. This $2.05 billion budget request, though a small fraction of the Federal Government's $1.1 trillion budget, is a big cog in the basic research and educational activities which will ultimately fuel the economic engine of the United States. NSF support, indeed, plays a major role in the Federal funding of civil engineering research.

During the 1970's the United States lost ground in the area of economic competitiveness to several industrialized countries. This FY 1989 budget, as part of the five year plan to increase the Engineering Directorate budget to $500 million by FY 1992, will help us to begin making up for lost ground. ASCE strongly supports the fiscal 1989 budget request for NSF and urges your approval of it.

I respectfully request that this letter be entered into the hearing record.

Sincerely,

Albert A. Grant, P.E.
President

April 7, 1988

Hon. Doug Walgren
Chairman
House Science, Research & Technology Subcommittee
2318 Rayburn HOB
Washington, D.C. 20515

Dear Mr. Chairman:

On behalf of the Engineering Education Task Force, representing the American Society for Engineering Education (ASEE), The National Society of Professional Engineers (NSPE) and the National Association of State Colleges and Universities (NASULGC), I would like to submit the enclosed testimony for the record on the FY 1989 National Science Foundation budget.

As you will see from our statement, we are supportive of the NSF proposed budget, but are concerned about the implications of the reduced request from FY 1988 for the engineering research directorate. We also believe that two areas in the NSF undergraduate education initiative would benefit particularly from enhanced investment: the curriculum revitalization program and faculty professional development.

Individual representatives on the Task Force are Donald Glower, dean of engineering at the Ohio State University and Task Force chairman (NSPE); James John, dean of engineering at the University of Massachusetts (NASULGC); David Waugh, University of South Carolina (ASEE Engineering Deans Council); Donald Weinert, Executive Director of NSPE; and myself.

Thank you for your consideration of our views. If we may provide you with additional information, please call on us.

Sincerely

F. Karl Willenbrock

F. Karl Willenbrock
Executive Director

FKW:rd







Statement of

The Engineering Education Task Force of

American Society for Engineering Education
National Society of Professional Engineers
National Association of State Universities and
Land Grant Colleges

on the

National Science Foundation
FY 1989 Budget Request

April, 1988

STATEMENT OF THE ENGINEERING EDUCATION TASK FORCE
ON THE
FY 1989 NATIONAL SCIENCE FOUNDATION BUDGET
APRIL 1988

Dear Mr. Chairman:

We appreciate this opportunity to share our views on the National Science Foundation budget for Fiscal Year 1989. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society group working together to address major issues in engineering research and education. Member organizations are the American Society for Engineering Education (ASEE) and its Engineering Deans Council, the National Society of Professional Engineers (NSPE) and the National Association of State Universities and Land Grant Colleges (NASULGC).

ASEE is a membership society of more than 10,000 individual members as well as schools of engineering and engineering technology and engineering-oriented industrial companies. NSPE is a professional society representing 75,000 professional engineers in industry, construction, private practice, government, and education. NASULGC is a higher education association whose member public colleges and universities educate more than two million of the nation's students each year.

85-344 - 88 - 25

The Engineering Education Task Force believes the increases in education and engineering research proposed in the FY 1989 NSF budget are inadequate: the need is considerably greater. As our economic competitiveness and quality of life become increasingly dependent on technological advancement, we must strengthen our investment in technological education and research. It is the high quality education and research achievements of young engineers and scientists today that will lead the nation into the high technology future of the 21st century. Moreover, with technology tightly linked to political and economic decisions, our nation's citizens must achieve greater technological literacy.

The National Science Foundation's role in this effort is not only to support basic research and education, but to provide national leadership and leverage resources from industry, state and local governments and academic institutions in addressing these challenges.

ENGINEERING RESEARCH. Members of the task force believe that engineering research in NSF historically has been underfunded. The proposed increase for FY 1989 fails to continue the previously proposed and broadly supported plan to correct this deficiency. A request for the engineering directorate of $10 million less than last year's request is not persuasive evidence of commitment to this goal.

The inadequacy of the proposed funding is illustrated in the NSF's Engineering Research Centers (ERC) program. The academic and industrial communities have overwhelmingly proved they are capable of working together in industrially-relevant research, updating engineering

curricula and transferring technology from engineering schools to cooperating industrial companies.

Rather than recognizing the successes of this experiment in academic engineering research and education, NSF has slowed development considerably. Two new centers for FY 1988 have yet to be designated and the Foundation is proposing only two new centers for FY 1989. This total of 18 centers is well below the 25 centers recommended in the original National Academy of Engineering proposal. This is particularly unfortunate in light of the fact there are superb technical proposals that are not being funded.

THE STUDENT PIPELINE. We would like to focus our remarks on the greatest long-term challenge to engineering education: the student pipeline. As you know, between now and the 21st century, the nation's college age population will drop by 25% and become increasingly Black and Hispanic, groups which have traditionally been underrepresented among engineering students. This demographic fact is particularly important to engineering because unlike many other fields, most engineering students are full-time, of traditional college age. Moreover, recent gains in attracting nontraditional students to engineering have begun to lag. Although the number of women engineering graduates rose by ten-fold and the number of underrepresented minority engineering graduates tripled between 1975 and 1985, since then those numbers have been dropping. If we are to maintain our engineering workforce, we must find stronger means to attract these students into engineering.

Given the seriousness of this challenge, the ASEE Engineering Deans Council, which is comprised of the deans of accredited U.S. engineering schools, earlier this year organized a task force, funded with an NSF grant, to examine what the deans of engineering could do individually and collectively to open up the engineering student pipeline. Among their recommendations, the deans agreed they should join or form regional consortia whose goals are to increase the numbers of minority and women graduates in engineering, and should re-focus the engineering school environment from one that "weeds out" the less-prepared students to one that identifies and nurtures a broad range of students. The deans also agreed they should set for themselves specific goals for recruiting and retaining underrepresented students. ASEE will soon make available to you a full copy of the deans' report and recommendations.

NSF has recognized the growing challenges of the engineering and scientific student pipeline and we endorse its increasing investment in addressing these issues through both the education and research directorates.

PRECOLLEGE. At the precollege level, the Foundation supports a number of high-leverage activities designed not only to engage early-on those students who may become engineers and scientists, but to raise the technological literacy of all Americans. We strongly support these programs in teacher training, classroom materials development and informal education, and applaud the strong Congressional leadership in this area. NSF has been supportive of such efforts as the Junior Engineering Technical Society (JETS) sponsored jointly by NSPE and ASEE.

UNDERGRADUATE EDUCATION. A key section of the student pipeline for engineering is undergraduate education. In contrast to the sciences where the principal point of entry into the profession is the doctorate, about 70 percent of all engineers begin their careers with a baccalaureate degree. This makes it particularly critical that undergraduate engineering education be an up-to-date and effective educational experience.

Since the 1970's, undergraduate education -- the vital bridge between high school and professional careers or graduate study -- has been sorely neglected at the Foundation. In response to a 1986 report of the National Science Board, however, the Foundation has reintroduced support for undergraduate programs. While FY 1988 funding has been less than expected, we commend the agency for systematically reintroducing undergraduate activities and creating a new office of undergraduate education in the education directorate to coordinate Foundation-wide efforts. For FY 1989, NSF proposes spending about $65 million on undergraduate education and research, about two-thirds of which will be funded through the research directorates. This will support research opportunities for undergraduate students, women and minorities, instrumentation for the improvement of undergraduate teaching, curriculum development and faculty enhancement.

We strongly endorse these activities and believe NSF could effectively spend more than the $100 million per year on undergraduate activities recommended by the National Science Board report. There are two areas in particular we believe would benefit in FY 1989 from enhanced investment. Major curriculum revitalization projects were

initiated in FY 1988 by NSF for both calculus and engineering. For calculus, this effort was recognition of the fact that as the basis for all physical sciences, the calculus curriculum needed to be updated. For engineering, it was recognition that with the rapidly changing nature of engineering practice and the impact of new instructional technologies, new approaches were needed in the undergraduate curriculum.

Although NSF had proposed spending $6 million on these programs in FY 1988, budget limitations reduced actual spending by half, to $3 million. The Foundation proposes to spend only $4 million for all curriculum revitalization in FY 1989. In light of the strong response NSF is already receiving from the academic engineering community alone, as well as the importance of systematically introducing new materials and methods into engineering and scientific curricula, we believe significant funding above the $4 million request would be a valuable investment.

At the same time, technological change has been so rapid in recent years that many engineering faculty cannot keep up with developments outside their own areas of expertise. NSF-supported experimental short courses and conferences with colleagues in industrial and academic research can enable faculty to catch up on technological developments and incorporate them into their teaching. Once again, we believe that funding above the $3 million request for faculty professional development would be an important investment.

OTHER STUDENT PIPELINE ACTIVITIES. An area of great importance is NSF's program in the education directorate to create regional centers

in which minority students would be tracked and nurtured in mathematics, science and engineering from elementary school through college. We believe this program has significant potential for addressing the varied factors that limit entry of underrepresented minorities into engineering and scientific careers. We also commend the Foundation for its initiatives in promoting research opportunities for women, minorities and the disabled. These programs help create the role models that are vital for increasing the flow in the student pipeline.

GRADUATE EDUCATION. One of the biggest challenges facing engineering education is attracting greater numbers of U.S. students to engineering faculty careers. According to a recent report by the National Academy of Engineering (NAE), nearly 50 percent of all engineering assistant professors age 35 years or younger are foreign-born.

The failure to attract U.S. students into engineering faculty careers is a result of several factors, including the availability of jobs in industry for BS graduates at salaries that make graduate study relatively unattractive. However, we believe prestigious NSF fellowships and research opportunities offer useful incentives for the brightest students to consider academic engineering careers. We strongly endorse the Foundation's plan to increase the number of Presidential Young Investigator awards and graduate research fellowships in FY 1989. We also believe that graduate fellowship stipends should be increased for fields such as engineering and computer science where market forces keep baccalaureate salary levels high.

We also recognize the importance to the academic pipeline of NSF research grants. Only 12 percent of the graduate students supported by NSF participate in the graduate research fellowship program. Most of the nearly 15,000 NSF-supported graduate students are research assistants funded through faculty research grants.

If we hope to attract more U.S. students to academic engineering careers, additional steps must be taken to remove financial barriers to graduate study. Federal grant stipends should be raised to equal one-half the average starting salary of an engineering graduate. For NSF, that would mean raising graduate research fellowship stipends in engineering from $12,300 to about $15,000. At the same time, full tax deductibility should be restored for both graduate student stipends and tuition remission. To attract more students into faculty teaching careers, the federal government should consider offering forgiveness on student loans to those who undertake careers in teaching.

SUMMARY. Through the Foundation's role as a catalyst for academic activity and its ability to leverage resources, we believe NSF programs can make a significant difference in promoting the nation's economic well-being. By helping educate the engineers and scientists who will keep us at the forefront of technological achievement and competitiveness and by sponsoring cutting-edge research and technology transfer, NSF is contributing directly to the nation's engineering and scientific strength.

The Engineering Education Task Force supports substantial increases in NSF research funding for FY 1989, particularly in engineering research. We also urge you to consider increases above the

budget request for faculty development and curriculum revitalization programs. We believe the Foundation's education and research programs represent a sound investment that will benefit the nation for decades to come.

AAES
AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES
415 SECOND STREET, NE • SUITE 200 • WASHINGTON, DC 20002 • (202) 546-2237

DANIEL DE SIMONE
EXECUTIVE DIRECTOR

April 8, 1988

The Honorable Doug Walgren
Chairman
Subcommittee on Science, Research
and Technology
Committee on Science, Space, and
Technology
U.S. House of Representatives
2319 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman:

I am pleased to enclose the statement of the American Association of Engineering Societies on the FY 89 National Science Foundation appropriation.

We respectfully request that this statement be incorporated in the written record of the Subcommittee's hearings on this subject.

If additional information is needed, please contact me or Janis Fritts of the AAES staff.

Thank you.

Sincerely,

Daniel De Simone
Executive Director

Enclosure

AAES AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES
415 SECOND STREET, NE • SUITE 200 • WASHINGTON, DC 20002 • (202) 546-2237

Statement

of the

American Association of Engineering Societies

on the

National Science Foundation

FY 1989 Budget Request

Presented to the

Subcommittee on Science, Research and Technology

Committee on Science, Space, and Technology

U.S. House of Representatives

April 8, 1988

Mr. Chairman and Members of the Subcommittee:

The American Association of Engineering Societies (AAES) is a multidisciplinary organization of engineering societies dedicated to advancing the knowledge, understanding, and practice of engineering in the public interest. The member societies of AAES, which represent over a half million engineers in industry, government, and education, include:

- American Society of Civil Engineers
- American Institute of Mining, Metallurgical and Petroleum Engineers
- American Society of Mechanical Engineers
- Institute of Electrical and Electronics Engineers
- American Society for Engineering Education
- American Institute of Chemical Engineers
- National Institute of Ceramic Engineers
- Institute of Industrial Engineers
- Society of Women Engineers
- Society of Fire Protection Engineers
- American Institute of Plant Engineers
- American Nuclear Society
- American Indian Science and Engineering Society

AAES endorses the NSF budget request for fiscal year 1989 of $2.05 billion. This request, which is a 19 percent increase over FY 1988, is an important step forward in NSF's effort to strengthen its research and development activity and is part of a long-term, sustained move toward improving its base for education and university basic research. AAES supports these measures.

Introduction

The NSF mandate in engineering is divided among three directorates: Engineering, Computer and Information Science and Engineering, and Science and Engineering Education. Each of these directorates is important to the nation's engineering enterprise, and we are pleased that in its budget request the Foundation has recognized the vital role of engineering education and research

in strengthening U.S. economic competitiveness and quality of life. It is the educational and research opportunities presently open to our young engineers today that will allow the United States to meet the challenge of high technology in the twenty-first century.

Before discussing the specifics of the NSF budget, it is important to define the nature of engineering research. Engineering research is the pursuit of new knowledge about the technical processes and systems of the man-made world. It is closely related to scientific research, which seeks to understand the fundamental theories and systems of the natural world. While engineering research uses the foundation of scientific knowledge about the natural world, it has its own rules and laws and takes into account factors beyond science such as economics, aesthetics, and law.

Engineering and scientific research, while distinguishable, are mutually supportive in important ways. Information uncovered in the process of scientific research can lead to solutions to problems in engineering research, while advances in engineering stimulate scientific research.

Like scientific research, engineering research can be characterized as both "basic" and "applied." Basic engineering research seeks to provide a theoretical foundation for engineering principles and applications. For example, although ironmaking has been known for sixty centuries, only recently have the complex scientific and engineering principles underlying this process been revealed. While the ancient metalsmith could improve his craftsmanship through experience and trial and error, he lacked the knowledge of thermodynamics, heat transfer, and fluid mechanics that would have enabled him to guide his experimentation.

Applied engineering research builds on basic research, both in engineering and science, to find answers to specific technical problems. Applied engineering research may be viewed as the link between basic engineering and the development of new or improved products and services. Applied engineering research employs basic research in metallurgy to develop steel alloys to meet prescribed specifications. Applied engineering research is nearly always cross-disciplinary: in trying to solve engineering problems, it draws heavily

upon knowledge developed in several engineering and scientific disciplines.

The Engineering Directorate

The work supported by the Engineering Directorate -- in both basic and applied engineering -- is the foundation of technological advances in computers, communications, manufacturing processes, and space technology, all areas that are vital to the nation's productivity and economic well-being. As more than half of the gains in U.S. productivity since World War II are the result of technological innovation, engineering research is clearly essential to further productivity gains.

We support the Administration's proposal to increase the budget of the Engineering Directorate by 13.7 percent in FY 1989, to $195 million. In recent years, the U.S. has been losing ground to its competitors. One contributing factor was the reduced emphasis on engineering research during the 1970s. The U.S. is now fourth among industrial countries -- behind Japan, West Germany, and France -- in the portion of gross national product invested in civilian research and development.

The multidisciplinary Engineering Research Centers (ERCs) merit continued strong support. While it is yet too early to gauge all the benefits that will come from the ERCs, they have already prompted significant intellectual activity, financial commitment, and cooperation in the academic community and gained strong financial support from industry. These centers reflect the trend toward interdisciplinary collaboration in addressing complex and urgent problems. They also provide unique opportunities for education and technology transfer. We believe that many exciting projects being developed through the ERCs could lead to major breakthroughs in telecommunications, robotics, biotechnology, and the development of composite materials.

While we approve the administration's emphasis on programs to enhance the nation's competitive position in world markets, we believe it is also important that NSF maintain its traditionally strong support for its basic engineering programs that support individual principal investigators involved with engineering research that is important for the long term vitality of

engineering. Several engineering disciplines rely heavily on NSF grants for engineering research. In FY 1986, NSF supported 77 percent of all federally sponsored civil engineering research and 74 percent of all federal research in chemical engineering at universities and colleges. More importantly, NSF is the only agency whose purpose is to support both basic and applied long-term engineering research across all fields. This includes areas that may not appear to have immediate technological payoffs but may lead to breakthroughs in the future.

The Computer and Information Science and Engineering Directorate

Because of their revolutionary impact on communications and information processing, computers have changed the conduct of science and engineering in a host of ways: from modifying methods of research and redefining the meaning of state-of-the-art procedures, to reshaping the ways in which students are taught in the classroom and participate in laboratory practice. Thus, continued progress in computer science and engineering is vital not only for the development of newer, more sophisticated computers and applications but as a key element in other engineering disciplines.

AAES supports the Foundation's proposed 20.3 percent increase in the Computer and Information Science and Engineering Directorate budget to $149 million for FY 1989. We also support NSF's two-pronged initiative to support research into the fundamental understanding of computer and information science and engineering and to expand the availability of advanced computing systems and encourage participation in their use.

The Science and Engineering Education Directorate

Fundamental to engineering and computer research is engineering education. Without talented and well-educated individuals conducting first-rate research projects and teaching young engineers, the system will falter. For that reason, AAES strongly supports the expansion of educational and human resources programs envisioned by the Foundation.

Continued support for NSF precollege mathematics and science programs is vital. Our high school graduates must be well-prepared and highly motivated or the nation will soon face a serious shortage of engineers and scientists to meet the ever more demanding needs of government, industry, and academia. Over the past several years, NSF has considerably upgraded its precollege activities and we support NSF's role in this area.

Of special significance to the engineering community is the Foundation's initiative in undergraduate education. In the 1970s and early 1980s, undergraduate education was barely addressed at the Foundation. However, since FY 87 NSF has begun to redress this imbalance and this year plans to spend up to $65 million on undergraduate education. The measures the Foundation has initiated are designed to improve undergraduate engineering curricula and faculty development, as well as expand educational instrumentation and undergraduate research programs. Unlike the physical and life sciences where most practitioners in the field are required to have advanced degrees, more than two-thirds of the nation's 1.5 million engineers have received only a bachelors degree. Their four years of college education provide an essential basis for professional development programs throughout their careers.

NSF support for undergraduate engineering education also serves as a catalyst for colleges and universities to revitalize their curricula and to modernize engineering laboratories. Programs to foster experimentation in faculty development permit faculty members to update their technical knowledge and enhance their teaching skills. Greater undergraduate participation in research exposes students to the benefits of an academic career.

Expansion of graduate programs at NSF forms another key link in the system. The NSF has maintained its graduate fellowship programs over the past several years. Creation of one hundred additional graduate fellowships and two hundred new Presidential Young Investigator awards are the types of incentives that will encourage promising young graduate students to remain in academia and join the ranks of permanent faculty.

In addition to these measures, support for undergraduate and graduate education is carried out indirectly through Foundation funding for research projects. For example, most of the nearly 15,000 NSF-supported graduate students and research assistants are funded through faculty research grants.

Summary

Overall, we in the engineering community support the major outlines of the FY 1989 budget for the National Science Foundation and praise the Foundation's strong commitment to engineering and scientific research and education. Accordingly, we urge the Congress to carry through with substantial increases in the Foundation's budget over the next several years. This increase will help NSF balance its support for programs that foster economic vitality with those that ensure the long-term health of basic engineering research. It can make a real contribution to the nation's economic well-being.

We appreciate the opportunity to present AAES' views on the FY 89 National Science Foundation budget.

CONSORTIUM of SOCIAL SCIENCE ASSOCIATIONS
1625 I STREET, N.W., SUITE 911, WASHINGTON, D.C. 20006 • [202] 887-6166

STATEMENT OF THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS
(COSSA)

Howard J. Silver, Ph.D.
Acting Executive Director

on the

FY 1989 BUDGET FOR THE NATIONAL SCIENCE FOUNDATION

Prepared for the
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The Honorable Doug Walgren, Chairman

April 8, 1988

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association
American Psychological Association • American Sociological Association • American Statistical Association
Association of American Geographers • Association of American Law Schools • Linguistic Society of America

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral science disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Member associations, Affiliate societies, and Contributor institutions is attached.

COSSA would like to take this opportunity to express its appreciation for the Subcommittee's past strong support for the social and behavioral science disciplines at the National Science Foundation. What follows are comments on the proposed FY 1989 budget for the NSF and some of the issues raised by that budget.

We strongly support the proposed overall increase of 19.4% in the FY 1989 budget and the continued commitment to doubling the Foundation's resources. The $333 million increase represents an incremental step for investing in the future greatness of this nation. In this era of budgetary restraint, the administration's advocacy of increased support for America's scientific endeavors reflects an understanding that more basic research today means greater scientific and technological achievement tomorrow. Reducing that commitment will decrease the nation's ability to compete in the interdependent world of the Twenty-first century. We urge the Congress to accept the full NSF increase.

The 10% increase for Research and Related Activities is also welcome. We strongly urge the maintenance of that increase during the Subcommittee's deliberations. The 8% increase for the Social and Economic Science Division and the 6% increase for the behavioral programs of the Behavioral and Neural Sciences Division, while not as large as necessary, reflect continued NSF support for these programs.

A recent report of the National Research Council, The Behavioral and Social Sciences: Achievements and Opportunities, notes that the decline of federal support for these disciplines in the last fifteen years has been 25% in constant dollars. By contrast, during the same period, federal support for other fields of scientific research has grown by 36%. Funding for the National Science Foundation has increased significantly in the past eight years, yet the share of those funds going to social and behavioral science research has continued to decrease (from 6.1% in FY 1980 to 4% in the proposed FY 1989 budget). In calling for new federal funding of $240 million for the social and behavioral sciences, the report asks that NSF contribute $60 million. Spread over three years and including support for new fellowships, this request could be met by increasing funding so that 5% of the FY 1989 Research and Related Activities budget goes to social and behavioral science research. This would mean adding $16 million to the FY 1989 proposed funding in these disciplines. We believe this is a justifiable goal given the intellectual vitality and ferment of these sciences and their importance to the nation.

The NRC report presents a significant picture of the

vitality, ferment, and contributions of these disciplines. Although meant to be illustrative and not exhaustive, the report identifies five fundamental areas where researchers face extraordinary challenges and opportunities to develop their work in multidisciplinary fields and activities if they are given sufficient support. These areas include:

1) research linking behavior, the mind, and brain focusing on seeing and hearing, memory, cognition, decision making, and language acquisition;
2) research on the motivational and social contexts of behavior focusing on affect and motivation, health and behavior, crime and violence, and social interaction;
3) research on choice and allocation looking at agenda setting, voting behavior, organizational design and change, markets and economic systems, bargaining and negotiation, and jobs, wages, and careers;
4) research on institutions and cultures, investigating the evolution of human society, demographic behavior, family and religion, science, technology, and public policy, internationalization, and international conflict; and
5) research to improve the methods of collecting and analyzing data, examining data collection designs, formal models, and statistical inference and analysis.

All of these would benefit from increased interdisciplinary cooperation and increased federal support.

The proposed FY 1989 NSF budget for the social and behavioral sciences further reflects the emphasis on multi-disciplinary activity. The new National Center for Geographic Information and Analysis (NCGIA) will provide greater access to the products of digital remote sensing, geographic information systems, computer cartography, and computer graphics, which will form the basis for major advances in geographical analysis, spatial statistics, and expert systems. The enhanced information-portrayal and decision making capacities resulting from such theoretical advances will enable scientists and policy makers more effectively to resolve the complex environmental and social issues the nation faces now and in the future. This center will involve expertise in disciplines including geography, information science, computer graphics, political science, remote sensing, risk analysis and many others. Commercial vendors, government agencies, and research universities will share in the services that will be provided by the NCGIA.

The Decision, Risk, and Management Science Program (DRMS) will continue to strengthen its efforts to encourage collaborative interdisciplinary research across the decision sciences. Three broad problem areas remain the focus for exploration: 1) risk perception, communication, and management; 2) group decision making; and 3) artificial intelligence approaches to problem structuring and model building for decision support. Here too the number of disciplines involved is large: from artificial intelligence and expert systems to political

science, psychology, and sociology to organization design and general systems theory.

In the behavioral sciences the major initiative in the neurobiology of learning and memory will continue to include increased support for multidisciplinary research teams, and the establishment of a small number of multidisciplinary research and resource centers. Greater elucidation of the neural structures and processes which underlie the phenomena of learning, memory, and information utilization continues to be the goal of this research.

Studies of organizational effectiveness are another major cross-disciplinary effort needing enhanced support. Research on structural constraints to effective use of human resources, management decision-making, small group interactions, and organizational evolution will produce information to help America respond to the many economic productivity questions it faces, e.g. organizational resistance to high-tech innovation adoption and the impact of organizational morale on productivity. An attempt will be made to create a data base from a national sample of organizations which will allow for tracking over time of changes in structure and effectiveness. Sociologists will be able to conduct cross-level analyses comparing individual-level data with organizational-level data. Economists will pursue the development of a conceptual paradigm to explain organizational effectiveness through the use of game theory models, institution design mechanisms, and public choice models. Payoffs from this basic research can already be seen in deregulation activities and in acceptance by businesses of worker profit sharing as an incentive for low unemployment and greater productivity. (The latter also became a major plank in a presidential campaign this year.) Interdisciplinary studies of behavioral theories of business firms will also lead to better understanding of organizational performance.

These initiatives in geography, decision, risk and management science, psychobiology, and organizational effectiveness are significant indications from NSF that the social and behavioral sciences are an important part of the Foundation's agenda for economic competitiveness. All were adversely affected by the reduction from the FY 1988 request in the FY 1988 appropriations. Granting the full increment for Research and Related Activities for FY 1989 will allow these important research initiatives to go forward without curtailing ongoing projects in the social and behavioral science disciplines, including support for large scale, multi-user data bases such as the Panel Study of Income Dynamics, the General Social Survey, the National Election Studies, and the Supreme Court Data Base, which provide researchers and public policy makers enormous amounts of useful information.

In addition, the proposed budget provides for increased support for social and behavioral science research on global change. A major international effort to expand our understanding

of this phenomenon is underway. Groups such as the American Association for the Advancement of Science, Sigma XI (The Scientific Research Society), the International Conference of Scientific Unions, and the International Social Science Council, are involved in seeking answers to this worldwide challenge. Social and economic research in this area will enhance comprehension of the effect of public policies, regulation and industrial and agricultural policies on the biology, chemistry, and geology of the earth. This is also an area where the social and behavioral sciences will interact with the natural and physical sciences to produce significant solutions to an important problem. Support for NSF's full FY 1989 request will sustain this effort.

COSSA also supports increased funding for the Studies in Science, Technology, and Society program in the new Division of Instrumentation and Resources. Interdisciplinary research on history, philosophy, social, and ethical issues of science and technology reveals where we have been, how we got where we are, and the methods we can live with to get where we are going.

Concern has been raised in many places about NSF's move to encourage the development of science and technology centers, often perceived at the expense of individual investigator-initiated research. COSSA is concerned as well. For many of the social and behavioral science disciplines, the individual investigator remains the key to significant basic scientific research. Yet there is a place for centers in these disciplines as well. The Foundation has received 325 proposals for its Science and Technology Centers program. A number of these are in the social and behavioral sciences, and a significant number is in the multidisciplinary fields of cognitive science and artificial intelligence. We ask the Subcommittee to fund the Centers at the requested level so the Foundation will not have to sacrifice the individual investigator to save the Centers program or vice-versa. We also still believe the Subcommittee should keep a wary eye on this situation since the long-term effects of support for such centers is unknown.

This is one of the reasons we would continue to support an ongoing role for the authorization committees in their relationship with NSF. Congressional oversight through the authorization process remains an important check on the agencies of the executive branch. Checks and balances should be reinforced. The Subcommittee should act with caution in moving to a five-year authorization for the Foundation.

COSSA also supports the 12% increase proposed for the Science and Engineering Education Directorate. It represents a further step in the reinvigoration of that directorate. The proposed increase in the number of graduate fellowships will enhance the development of a new generation of scientists and researchers to produce the knowledge of tomorrow. We agree with NSF's strategy to provide resources for undergraduate education within the disciplines. This is the best means for the

integration of research and training for undergraduate social and behavioral scientists. We also applaud the increase for research in teaching and learning, an arena in which behavioral scientists play an important role.

The significant research achievements of social and behavioral scientists are well known to this Subcommittee. You have demonstrated time and again your belief that these accomplishments are important to the scientific enterprise within the United States. The Congress continues to call on us to present the results of our research to provide the information that will help policy makers make decisions. In the first 3 months of the 2nd session of the 100th Congress close to 80 university-based social and behavioral scientists have been witnesses before Congressional committees. We cannot continue to offer this expert advice without support for the basic research we carry out. We ask you to support our future efforts by giving NSF its full FY 1989 budget request.

Thank you this opportunity to present our views.

Consortium of Social Science Associations

Members

American Anthropological Association
American Economic Association
American Historical Association
American Political Science Association
American Psychological Association
American Sociological Association
American Statistical Association
Association of American Geographers
Association of American Law Schools
Linguistic Society of America

Affiliates

American Assembly of Collegiate Schools of Business
American Association for Public Opinion Research
American Educational Research Association
American Society of Criminology
Association for Asian Studies
Association for the Social Sciences in Health
Eastern Sociological Society
Federation of State Humanities Councils
Gerontological Society of America
History of Science Society
International Studies Association
Law and Society Association
Midwest Sociological Society
National Council on Family Relations
National Council for the Social Studies
North Central Sociological Association
Northeastern Anthropological Association
Operations Research Society of America
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Regional Science Association
Rural Sociological Society
Social Science History Association
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Society for Research on Adolescence
Society for Research in Child Development
Society for the Scientific Study of Religion
Southern Sociological Society
Southwestern Social Science Association
Speech Communication Association
The Institute of Management Sciences

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Tulane University
University of Virginia
University of Washington
University of Wisconsin, Madison
University of Wisconsin, Milwaukee
Yale University

CONSORTIUM of Social SCIENCE ASSOCIATIONS

1625 I STREET, N.W., SUITE 911, WASHINGTON, D.C. 20006 • [202] 887-6166

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral science disciplines, functioning as a bridge between the research world and the Washington community. COSSA was initially established as an informal coalition of the major disciplinary associations in the social sciences. Member associations, which govern the Consortium, are shown below. At the present time, 53 universities or independent research institutes are also contributing to COSSA, and 30 scholarly associations are COSSA affiliates.

Responding to the severely disproportionate cuts proposed in 1981 for federal research budgets in the social and behavioral sciences, COSSA established a Washington office to organize and coordinate a response on behalf of the social science community. Its initial focus was largely on restoring the budgets for social and behavioral science research in the National Science Foundation. In this endeavor COSSA has met with success: today the budgets for social and behavioral science research at NSF are nearly restored to their 1980 level, at least in current dollars.

Since the beginning of 1982, the Consortium has moved beyond NSF and beyond budgets. COSSA now monitors research and research funding in most federal agencies where externally granted, competitively awarded research and research-related funds form a significant portion of the portfolio. It also concerns itself widely with research management and policies affecting good practice in the conduct of federally funded research. Increasingly, COSSA also serves as a source of information and guidance for social science groups -- professional, interdisciplinary, subdisciplinary -- that do not have a ready understanding of or a 'presence' on the Washington scene. With them, COSSA identifies and monitors issues of long-range importance.

One of the primary missions of COSSA is to inform and educate Members of Congress, congressional staff, and officials in the administration and in federal agencies about recent research in the social and behavioral sciences, its importance, and the need to maintain adequate financial support for it. To this end, COSSA conducts congressional seminars and briefings on important current and emerging research in the social and behavioral sciences, particularly in areas of congressional interest and responsibility.

In order to keep social and behavioral scientists informed about legislative actions and federal policies that bear directly on the conduct of social and behavioral science research, COSSA issues a biweekly newsletter, the COSSA Washington Update, which is sent to more than 1,100 social scientists, research managers, and policy-makers and is circulated widely to many more. In late 1986, with partial support from the Russell Sage Foundation, COSSA published the comprehensive Guide to Federal Funding for Social Scientists. COSSA also stays closely in touch with the science and general press.

For more information about COSSA, contact Howard Silver, Acting Executive Director; Simon Cordery, Executive Associate; or Brian Daly, Executive Associate.

February 1988

IEEE **WASHINGTON OFFICE**
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC
1111 19th STREET, N.W. WASHINGTON, DC 20036-3690, U.S.A. TELEPHONE (202) 785-0017

May 16, 1988

Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
House Committee on Science, Space and Technology
Room 2319 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Walgren:

Technology and its growth and application are particular interests of the IEEE. We are the largest technical professional society in the world, with over 232,000 members in the United States who are engaged in advancing the froniers of knowledge and supporting the public with a broad and growing range of electrotechnologies. As you would expect, we have a special interest in U.S. government programs which support the advance of technology, so vital to the nation's competitive position. We are therefore eager to address the National Science Foundation (NSF) budget which affects electrical and computer engineering science and technology, and request that these comments be included with the Record of your Budget Hearings.

I am writing on behalf of the Engineering Research and Development Committee of the IEEE. In past years this committee has provided detailed comments on various aspects of the NSF budget. While they would be happy to provide a detailed critique of this year's budget at your request, our position is that it is basically sound. We choose instead to focus our comments on what we feel are two critical problems regarding the NSF budget: ensuring an adequate overall level of funding, and providing for adequate support of engineering research and development.

The Congress has expressed great concern recently at the continuing decline in the United States' international economic competitiveness. We share your alarm, and we wish to make clear our firm belief that in order to reverse this trend the Federal government must increase spending in a number of critical areas, among them the National Science Foundation's programs in engineering research and development. The total amount needed is a tiny fraction of the Federal budget, but that action will play a significant role in determining the future economic well-being of this nation. We predict that the Federal budget dilemma will grow progressively worse unless our national technology base recovers a healthy status through sustained, adequate funding levels for activities such as the NSF.

Within the Foundation's budget, it is our firm belief that a strong emphasis on engineering research and development is critical to the issue of international technological competitiveness. Accomplishments of the United States in science are a matter of national pride and thus we urge continued high levels of support for academic science. However, scientific research does NOT automatically result in technology development. Funding for engineering research within the NSF (programs supporting Engineering, Computer and Information Science and Engineering, and Science and Technology Research Centers) represents only about a fourth of the Foundation's budget. It is essential that engineering cease being the poor cousin of science and become a stronger participant in matters of policy and budget, if the U.S. is to regain technological pre-eminence. A copy of the IEEE U.S. Activities Board policy statement on Engineering Research also is attached in further support of this position.

Since a leading position in technology internationally is required for national economic well-being, an adequate budget for technology research and development, sustained over the years, is an essential part of a sound economic policy. We urge the Congress to support the President's budget levels for the NSF in Fiscal Year 1989. We further stress that within the National Science Foundation the proposed increases for engineering research and the Science and Technology Centers be accorded the highest priority in order to protect the future economic well-being of the United States.

Sincerely,

Russell C. Drew

Dr. Russell C. Drew
IEEE President

Enclosures



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Statement of the Institute of Electrical and Electronics Engineers, Inc.
On The
FY 1989 Budget of the National Science Foundation
Before the Subcommittee on Science, Research and Technology
House Committee on Science, Technology and Space
May 16, 1988

It is a pleasure to submit the views of the Institute of Electrical and Electronics Engineers (IEEE) on the proposed budget for the National Science Foundation (NSF) for Fiscal Year 1989. The IEEE is the world's largest technical professional society, with some 232,000 members in the United States alone. Our membership consists primarily of engineers and scientists in the electrical, computer and communications disciplines, so we have a very great interest in the programs of the NSF.

Today, the United States economy faces the greatest competition from offshore manufacturing than any time since the 1930's. This is largely a result of other nations rebuilding formidable post-war industrial capacities, and often employing technologies that were originally developed in the United States to drive us out of both foreign as well as our own domestic, marketplaces. To a large extent, the ability of the United States to forestall further erosion of our economic well-being will relate to our ability to prepare the next generation of highly skilled technical manpower, and our ability to set a rapid pace of technological innovation well beyond that of our economic competitors. We believe that the NSF will play an essential role in this mission.

Although this is necessarily a time of austere funding for Federal programs, we believe that the NSF's budget represents the "seedcorn" from which the U.S. economy can grow, by advancing our national human technical base in science and technology. Thus we feel that the Administration is fully justified in proposing $2.05 Billion for the NSF, an increase of 19% as part of the overall plan to double the NSF budget in a five-year period. We see these requests as recognition of the key role played by basic research and engineering education in the health of the U.S. economy and our competitive posture internationally.

We fully concur with the proposal to broaden the earlier NSF initiatives on Engineering Research Centers to include Science and Technology Centers, particularly in Computer and Information Sciences and in Material Sciences and Engineering. The proposed new research programs in materials processes and interfaces, cognitive science and architecture, large scale systems engineering, and supercomputer applications are excellent choices as areas that have great potential impact on the future productivity and competitiveness of the nation.

As we have expressed in previous testimony, we recommend an approach which balances support for such centers with support for individual investigators in disciplinary programs, and thus, also balances support for basic and applied research. Thus we also strongly support the proposal to increase the average grant size to individual investigators, largely to correct the decline in real dollars for support of graduate students during the last ten years, and the equally important proposal to increase substantially the funding of Engineering Research Centers, so as to permit these exemplary units to function as originally envisioned. We would like to see further attention paid in future years to basic research in areas, such as telecommunications, which have not received significant increases to date.

With respect to the two general styles for supporting research activities, through centers on the one hand and individual investigators on the other, we recommend that a third approach between these two extremes should also be employed by the NSF. Because of the magnitude of funding necessary for research centers, very few can be funded. On the other hand, there are many engineering schools of small to medium size across the country, which taken together, contribute a large fraction of the total number of engineering graduates in the United States each year. There is an urgent need to harness this important national resource, if we are to maximize U.S. industrial competitiveness. It is not feasible to operate centers at most of these schools, although many of them have first-class faculty investigators. We suggest that the NSF consider the possibility of initiating a program to support research teams which would not necessarily be either large or cross-disciplinary. Although such teams could, in principle, be supported through either the centers program or the disciplinary programs, it is in fact extremely difficult to compare small group efforts with the other categories. The review process for either of the existing categories tends to eliminate efforts involving three to five investigators. They are clearly too small to qualify as centers, and Disciplinary Program Managers tend to break small team proposals into parts for separate review, which eliminates the synergism available through group efforts.

We would also like to point out that shorter-term, goal oriented research would be one particularly fruitful way of applying such smaller group grants, which could maximize their beneficial impact on productivity in U.S. science and technology. A great deal has been said and written recently about the relatively short-term focus of U.S. industry, which contrasts sharply with the long-term focus of academia. We observe that scientists and engineers from these two critical resource groups in our country are frequently most productive when working together, sharing a focus that is long enough for the results to be competitive internationally, but short enough to give a high likelihood of productive results. Government has had the wisdom to sponsor some such efforts. The NSF Centers are an example, on a larger scale; work sponsored by the Defense Advanced Research Projects Agency (DARPA) is another. DARPA sponsors a full range of team sizes, and in many cases insists on cooperative university-industry efforts in order to bring together the best of theory and practice.

We would like to encourage the NSF to provide grants to small teams of academics, including some for the purpose of working cooperatively with industry. We

believe that engineering faculty members would particularly benefit from the practical experience gained in such work. At the same time a much-needed influence would be applied to U.S. industries, drawing them toward products and manufacturing methods more advanced than their current short planning horizon allows. This approach is consistent with the forward-looking management of research funding which we associate with the NSF, and hope to see it implemented under an expanding budget for the Foundation.

In summary, we support the NSF budget with the recommendation that the NSF fund small groups of researchers in intermediate sized centers. We feel strongly that our nation should maintain a position of world leadership in the development of science and technology. These agencies are keys to achieving this goal. The few tenths of one percent of our federal budget that are needed to achieve that leadership will be recovered many fold in the prosperity that will result from this investment in our future.

ENTITY POSITION STATEMENT

U.S. ENGINEERING RESEARCH & DEVELOPMENT

1111 19th STREET, N.W. WASHINGTON, DC 20036-3690
(202) 785-0017

The objective of engineering research is the ultimate application of experimental and analytical results to public needs. It is not undertaken merely for the sake of knowledge, nor is it necessarily focused on an immediate product or service. Basic research must take place in engineering as much as it does in science. Neither "always comes first". The two complement each other, and both are necessary to the continued technological and industrial growth of the U.S.

Since the industrial revolution, engineering research and development (R&D) has provided fuel for industry, the engine which propels the economy of the United States. This is clearly demonstrated by reflecting upon the history of technological advances such as the steam engine, the telephone, the transistor, and the computer. These are specific examples of fundamental engineering R&D achievement in the U.S. which have established the economic stature of the country in the world community, have provided our citizens an unsurpassed quality of life, have enhanced the national security of the United States and other free nations, and have contributed to our position of international leadership. These benefits have derived significantly from a national R&D effort which has historically been perceived to provide an adequate balance between quality, quantity, and direction.

A National Policy for Technological Competitiveness

Since the late 1950's, the international economic situation has experienced major and dramatic changes. Thirty years ago, the U.S. enjoyed a secure technological position and superior industrial competitiveness in the world. Since that time, key industrial segments have been lost due to intense competition from other countries. The automobile, steel, textile, shoe and consumer electronics industries are specific examples where the dominant U.S. economic position has been lost to international competition. The semiconductor and integrated circuits industry has recently fallen into jeopardy, while many other industries are threatened with erosion of home markets and have great difficulty competing in foreign markets. Our industries must be concerned with global competitiveness if they are to survive. The fundamental role of engineering R&D in facing this international challenge must be recognized.

United States Activities Board — Approving Entity

11/20/86 — Date

U.S. Engineering Research & Developoment

Our country's critical economic position in international markets has been caused by a combination of factors, important among which has been a deemphasis of engineering R&D in the United States, and accentuation and focus on it by our competitors. Short-range goals emphasized by industry managers and executives have directed our attention away from correctly assessing the impact of engineering R&D on competitiveness. Investments in R&D and technological innovation have pronounced positive long-term effects on productivity and economic growth. Although support for research in basic science has increased somewhat, U.S. R&D investments for technology have declined, both in constant dollars and relative to our competitors.

Our nation's ability to face broad international competitiveness issues will determine our economic future and impact our national security and our way of life. A basic goal must be to ensure that the national policy of commitment to an R&D effort is adequate in quality, quantity, and direction.

To achieve this goal will require a new, positive climate for engineering R&D. This climate must increasingly encourage and support joint ventures, partnerships, and cooperation among the R&D components in our nation. These components include industry research, government laboratory research, single investigator, and cross-disciplinary research teams at the university. They include both scientific and engineering R&D.

The Federal government should assume the dominant role in developing and implementing the national policy and a change of climate for U.S. R&D. Industry has demonstrated willingness to collaborate with universities and the government because economic advantages are clear and urgent.

National policy must include a clear understanding of engineering R&D, with an awareness of what the Federal government should do, what industry should do, what the universities should do, and what the states should do in the national R&D climate. A central focal point is needed within the government which will allow a strong national commitment to R&D in technology to be articulated, advocated broadly, and implemented. The existing focus is inadequate. This policy will help ensure economic stability and long-term viability of the competitive industrial enterprise of the United States.

Problems of Implementation

The importance of investments in R&D activities is well understood and has been widely discussed. Our international competitiveness crisis is clear. There should be more direct investments throughout the U.S. R&D infrastructure, including industry, government, and the academic community. However, some changes will be required in order for industry and universities to effectively absorb and adequately cope with well-directed increases in R&D investments.

Expanding technological pressures cause industries to rely on the universities to supply highly skilled engineering manpower. Yet the universities cannot supply needed engineering talent without adequate resources. The universities must produce future faculty members as well as engineers educated for industry, and there must be a balance between the professional attractiveness of academic and industrial careers.

U.S. Engineering Research & Development

Universities cannot properly educate engineers if they are saddled with obsolete equipment and facilities. Technological advances in engineering, especially electrical, electronics, and computer engineering occur rapidly, often over a period as short as three years. However, amortization of equipment investments for teaching and research within the university occur over a much longer period, often a decade or more. This perpetuates obsolete university equipment.

Enrollments in engineering have increased dramatically in the last five years. This is especially true in most electrical engineering departments. Thus, many universities are confronted by an inadequate complement of faculty members, and these faculties are often stressed by the teaching loads arising from increased enrollments, leaving little time for conducting research and interacting with industry. Development of curricula in areas important to technological competitiveness, such as manufacturing engineering, quality control, and robotics, has been neglected. This imbalance in teaching and research, when coupled with a divergence in salary scales between industry and the university, has caused some faculty members to abandon academic careers for industrial positions. It is encouraging to note that progress has been made in eliminating the imbalance between industry and university salary scales, but more effort is needed to make academic careers attractive to the brightest engineers.

All the problems discussed above tend to aggravate one another and perpetuate the problems faced by both industry and universities. These problems have been discussed in other forums and, fortunately, they are becoming more widely recognized by industry and university administrations. Unless these problems are addressed together, the situation for engineering R&D will continue to deteriorate. It must be clearly understood that joint investments by government and industry for engineering and science are required to modernize and upgrade facilities and to support the development of strong faculty with long-range academic careers.

Turning to industry, the principal problem here is that management and stockholders currently inhibit investment in long-range R&D which may fail to show profits for many years. Industry must face this problem and change its policies regarding long-range research. Research support for universities and university/industry collaboration can alleviate the problem. The role of government in encouraging and strengthening this collaboration must be pursued aggressively. A continued reluctance to face this issue is a not-very-tacit declaration of a national policy dedicated to making the United States a second-rate nation in technological competitiveness.

Recommendations

Based on the above discussions of issues of technological competitiveness and problems in implementing a national policy of commitment to strong, balanced R&D programs in science and technology, we recommend the following:

- o The role of engineering R&D in national policy must be recognized by the Congress and the Executive Branch.
- o A focal point within the government must be designated for advocating and implementing this policy. We reaffirm our previously stated position that a Department of Science and Technology is needed in the Federal government.

- o A concerted effort by government, industry, and the universities to orient their enterprise to conform with the resulting policies must be formulated, coordinated, and launched aggressively.

- o The Federal government must strengthen its direct support of innovative high risk, and long term, engineering research.

- o Government and industry must increase their support for maintaining strong engineering faculties, modern facilities for research and education, and basic engineering research, and maintain a balance between individual investigators and the Engineering Research Centers on university campuses.

- o The university community must increase its activities in establishing effective industry/university collaboration in engineering research. They must take concerted action to acquire expertise and develop accreditable curricula in developing areas of importance to industry.

APPENDIX IV

Additional Comments of

[redacted]

Dr. Arthur B.C. Walker
NSF Authorization Hearings
March 22, 1988

Question 1. In FY86, the Congress was informed of the intent of NOAO to close the Sacramento Peak Observatory in Sunspot, New Mexico due to budgetary constraints. As this facility had been identified as critical to the Solar Astronomy community, including the Air Force, Congress requested more fair analysis of the intent to close this facility. In the FY 86 appropriations, a provision was incorporated to require that "no funds shall be expended toward the closure of a national facility without appropriate scientific review including review by the National Science Foundation's appropriate advisory committee or committees and the National Science Board."

Are we now at the point, given the budget constraints in Astronomy, to initiate this review? In your view, is Sac Peak in trouble?

Unfortunately, even if the FY 1989 budget projection is at a level no lower than the modest 4.7% increase projected for astronomy, NOAO will be forced to make, as expressed by Dr. Goetz Oertel, President of AURA, "Long-term curtailments or elimination of programs to reduce the NOAO budget to the level of funding scheduled to be available in FY 1989". AURA has not yet made any recommendations to the NSF on what steps would be taken, but severely curtailing or shutting down operations at one of the remote sites (Sacramento Peak and Cerro Tolodo Observatories) shutting down a major instrument at Kitt Peak, reducing the size of the scientific staff, or curtailing the NOAO research program are all options which must be very seriously considered. Therefore, Sacramento Peak, as well as other major NOAO facilities are indeed in jeopardy. I assume that if AURA recommends to NSF that a major closure should occur, then NSF will ask the Advisory Committee to review that recommendation and concur or offer alternatives..

Question 2. Dr. Walker, as a Solar Astronomer, can you tell this Committee where the U.S. is with regard to the international solar community in terms of scientific capabilities, facilities, etc. What role does Solar Astronomy play in the overall field of Astronomy. What is the significance of this subfield to the Space Program? to the plans for Space Telescope and Space Station?

In regard to our status with respect to the international solar community we are, at this moment still very competitive, and in fact, still leading in several areas although several European Nations have placed very fine new solar facilities in operation recently. However, a consortium of European nations is planning a new telescope called the Large Earth Based Solar Telescope (LEST) which will become the premier instrument for solar observations from the ground. The High Altitude Observatory is a member of this consortium, but with the present funding situation for astronomy, I am concerned that the US may be unable to participate should the consortium decide to go forward with the project in the near future. If the US is left out of this major new project, then US facilities for solar research will become inferior to those available to other nations. Our astronomers have been very active in developing the technologies of adoptive optics which are necessary to build the LEST instrument, but unless we can secure a reasonable level of funding to support this important new international project, our technology will be exploited elsewhere.

Solar Physics plays a very critical role in Astronomy, because the sun is the only star that we can study in sufficient detail to allow us to observe the detailed physical processes which underlie such stellar phenomena as flares, the hot corona, sunspots, magnetic structure and convection which carries heat to the solar surface. We have discovered over the last several years, that all these phenomena are present on many other stars, but we cannot study any other star in sufficient detail to understand the basic physical mechanisms which underlie them. The Sun is, therefore, fundamental to our understanding of stellar atmospheres, as well as our understanding of stellar interiors (I have discussed the latter aspect of solar studies in the response to Question 8 of the list of Republican Questions).

In regard to the space program, solar astronomy is equally significant. I have enclosed a copy of a plan to develop a comprehensive space-borne solar observatory, the Advanced Solar Observatory ASO). Many of the phenomena that we observe on the sun, such as the solar activity cycle, solar flares, and solar magnetism, will be studied on other stars by Space Telescope (and by AXAF as well). The studies of these phenomena on the Sun, and in a variety of stars both similar to and different from the Sun by Space Telescope (and AXAF), will be highly synergistic, and will lead to a much greater understanding of stellar phenomena. In regard to the Space Station, the report I have enclosed on the Advanced Solar Observatory (ASO) was written with the assumption that this observatory would utilize as its primary component the Solar Optical Telescope now called the High Resolution

Solar Observatory and would be mounted on the Space Station. Unfortunately, the uncertainties surrounding the Space Station and its final design and capabilities, and the impact of the Shuttle Challenger accident has caused NASA to cancel HRSO, and to very greatly restrict funds for planning ASO.

Question 3. One response which NSF has provided to justify the low rate of growth in Astronomy is the decision of the community that the VLBA is the number one priority of the 80's and therefore growth in other Astronomy projects and at other facilities would be curtailed until VLBA is completed. As Chairman of the NSF Advisory Committee, do you concur with this view? Has the Advisory Panel submitted budget estimates to NSF for FY 89-92? If so, please submit this and any long-term plans, for the record.

I do not concur in the view that the Astronomy Advisory Committee has advocated that support for other astronomy projects be reduced until VLBA is completed. The issue is not one of growth, but one of maintaining a viable research program in astronomy.

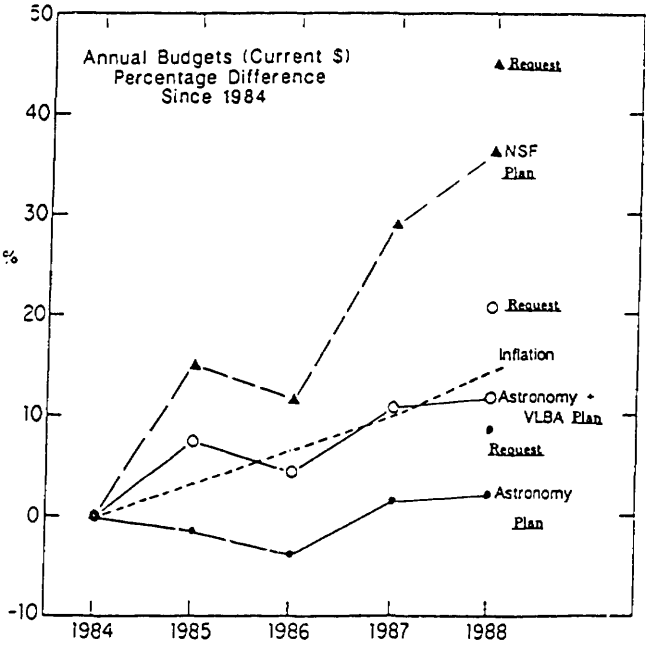


Figure 10

As Figure 10 of my prepared statement shows, support for astronomy research, not including VLBA construction, has declined by more than 10% in terms of current purchasing power. To raise the issue of growth in relation to the

VLBA, is, therefore, extremely misleading. What the Advisory Committee did recommend two years ago was that if any additional funds, above an inflationary budget increase and a very modest growth of 1 or 2% could be found, then the VLBA should have priority for this additional funding. Completion of the VLBA does indeed remain the highest priority for astronomy.

In response to your second question, the Advisory Panel has reviewed the estimates prepared by the NSF. I will forward these to you under separate cover.

Question 4. At any point during the preparation of the Science and Technology Centers program was the Astronomy community and/or the Advisory Committee consulted by NSF as to the appropriateness of "S&T centers" approach in the astronomical sciences?

In FY88 NSF requested $92.56M for Astronomical Sciences (based on the appropriation, the FY88 operating level is $86.02 million, less than $1 million above the 1987 levels.) The FY89 request is lower -- $90.04 million. Can this possibly be attributed to NSF predicting that Astronomy will have an S&T Center? How would you explain this downward trend?

The astronomy community was informed of the plans for the Science and Technology Centers, however, I am not aware that any representatives of the community were asked to present their views during the planning process. Dr. William Press, of the Harvard University Departments of Physics and Astronomy, and Dr. Larry Smarr, of the Department of Astronomy of the University of Illinois, were members of the Panel in Science and Technology Centers chaired by Dr. Richard Zare of Stanford University.

In regard to the impact of any expectations that there will be S&T centers devoted to astronomy on the decision that the 1989 FY request for astronomy be made lower than the 1988 FY request, I have no direct knowledge of this subject. In my prepared remarks, however, I do point out that since astronomy already uses the center concept more extensively than any other NSF supported discipline, it appears likely that astronomy will benefit less than other disciplines from this new initiative.

I can find **no justification** for this downward trend in the budget.

Question 5. It is been a continuing interest of this Committee to distinguish between and identify the complimentary roles of land-based and space-based observations. Could you kindly expound on this for the benefit of the Commitee?

I have discussed the complementary role of land-based and space-based astronomical observations in depth on pages 9 - 15 of my prepared statement. I have enclosed a copy of these remarks as Attachment 1 for your convenience.

Question 6. In the submission of the President's request for FY89, NSF provided the overall total authorization targets for FY 90-93. They are asking for a 4% growth in FY90, and a 12% in each of the remaining years. What impact with a 4% grown have on Astronomy? What will be the effect on the VLBA construction and operational costs?

A 4.7% growth in the astronomy budget for FY1989 will have a devastating effect on the National Astronomy Centers as I have indicated on pages 5 - 8 of my prepared statement. I have enclosed these remarks as Attachment 2. A second small increase in 1990 would only contribute further to the disintegration of the basic infrastructure of astronomical research at each of the national centers, and the research programs supported by the grants program. This small increase will mean that the construction of the VLBA will continue to proceed very slowly, and that the staffing for the portion of the VLBA network which is now operational will continue to be inadequate. Finally, it will mean that many grant proposals which receive very high marks, and which merit support will be turned down. This is particularly serious, because most of the support for graduate students comes from these grants.

Attachment 1

The Appropriate Role for Land-Based Astronomical Operations in View of the National Space Agenda: I am especially pleased to be able to address this topic as an astronomer whose own research (on the x-ray emission of the sun) is carried out almost exclusively in space. I believe I am able to offer an objective opinion on the importance of land-based astronomy. My willingness to serve two terms on the Astronomy Advisory Committee of the NSF, which, of course, deals with land-based astronomy, demonstrates my conviction that *virtually every major question in astronomy* requires both space-based and land-based observations for *its resolution*. In many cases, it is obvious that a particular capability can only be carried out (given the limitations of present technology) in one milieu or the other. X-ray astronomy, for example, must be carried out from space, since x-rays cannot penetrate our atmosphere. The Advanced X-Ray Astrophysics Facility (AXAF)* remains the highest priority for space borne astronomy (after the successful launch and operation of the Space Telescope). An indication of the importance of x-ray observations is the discovery that the enormous volume of space between the galaxies bound in vast clusters on scales of millions of light-years, is filled with a very diffuse but hot (100,000,000 K) gas, which apparently contains as much matter as is contained in all the stars in the galaxies themselves. This matter was undetectable from the ground. I might point out that because of the long delay in funding the AXAF project, American x-ray astronomers who pioneered the field of x-ray astronomy, must now use Japanese, European, or Soviet x-ray satellites as guests, since the U.S. has no operational x-ray satellite.

In contrast, radio facilities, such as the Very Large Array and the Very Long Baseline Array, can provide resolution and sensitivity which can be matched by no other technique. These facilities are best deployed on the ground. The power of these new technologies is shown in Figure 7. The resolution of 0.001 arcsecond can be achieved by no other technique at present. In this field, the U.S. still leads the world, but the serious funding problems at NRAO hold very serious and negative indications for the future.

Another example, in this case referring to the study of a single object, the sun, is shown in Figures 8 and 9. Figure 8 is a graphical illustration of the fact that the sun oscillates in many modes. These oscillation modes are very analogous to the modes of oscillation of the Earth, after an earthquake. Just as the models that geologists have developed of the Earth's interior structure are based principally on the study of earthquake data, the sun's oscillation modes can provide a model for the solar interior. This is a critical matter for all of astrophysics, since our theory of stellar interiors and evolution is based solely on observations of stellar masses, surface temperatures, and radii. The only direct data on stellar interiors comes from the detection (by detectors located in mines deep underground) of high energy solar neutrinos generated by thermonuclear reactions in the sun's core by Dr. Raymond Davis and colleagues. This

* *Astronomy and Astrophysics for the 1980's*, Volume I, National Academy Press, 1982

NATIONAL RADIO ASTRONOMY OBSERVATORY

IMAGE DESCRIPTION, NRAO FILE NUMBER. 80728

CREDIT LINE. Courtesy NRAO/AUI ACKNOWLEDGMENT. (Statement(s) Quoted Below

DESCRIPTION: 3C 120 Montage.

3C 120 is another of the superluminal sources that has been studied since the early 1970's. The radio source is in a galaxy, usually classified as a Seyfert, at a redshift of 0.033. As such it is the closest of the superluminal sources and is therefore the one that allows the most detailed studies of the environment This montage shows the radio structure of 3C 120 on all scales from a parsec to hundreds of kiloparsecs. It demonstrates that a continuous structure connects the superluminal features and the large scale, one-sided jet. It also shows that 3C 120 has a lobe (or outer part of a counterjet) on the side opposite the jet and complicated structure on the largest scales. The brightness of the jet evolves simply over the entire length showing that the basic physical parameters are established on the parsec or sub-parsec scales and evolve in a relatively simple manner as the jet travels from the galactic core to outside the galaxy.

TECHNICAL INFORMATION:

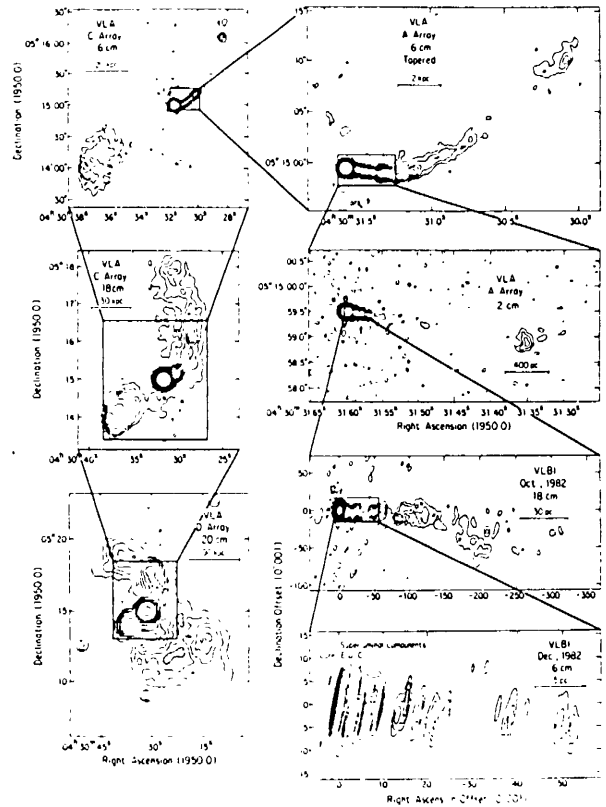
Source: 3C 120 (Seyfert Galaxy at Z=0.033)

Instruments: VLBI - U.S. VLBI Network plus EVN.
VLA - Several configurations.

Frequencies: i.e. 1.6, 5.0 and 15 GHz.

REFERENCES

Walker, R.C.
Benson, J.M.
Unwin, S.C.
1987, ApJ., 316, 549.



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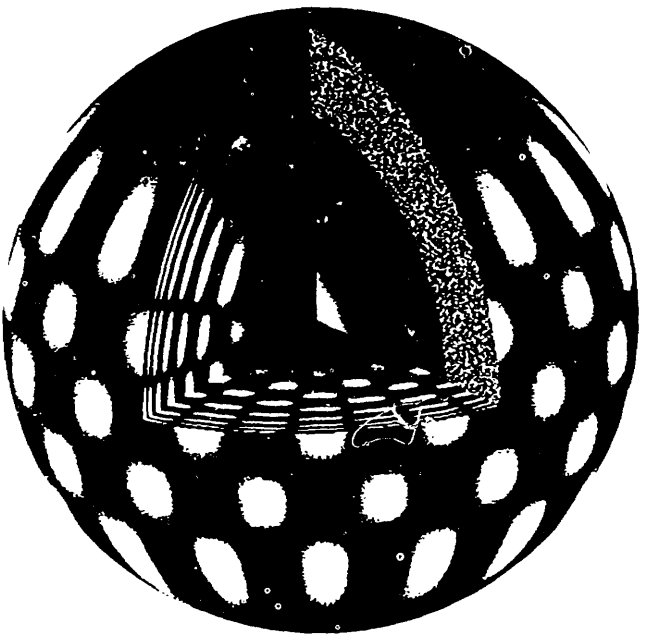
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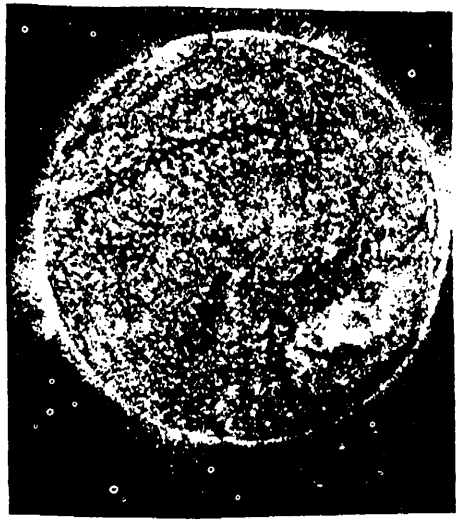
National Optical Astronomy Observatories

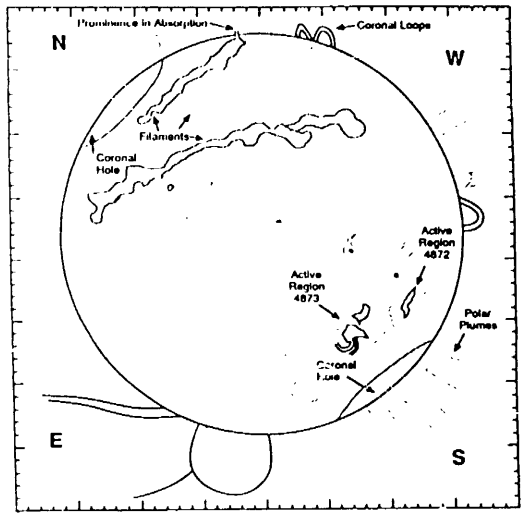
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4103 — A computer representation of one of nearly ten million modes of oscillations of the Sun shows receding regions in red tones, approaching regions in blue. By measuring the frequencies of many such modes, and using theoretical models, solar astronomers can infer much about the internal structure and dynamics of the Sun. This novel technique, called helioseismology (for its resemblance to terrestrial seismology), is at the heart of a new NOAO program to develop an international network of instrumented stations that provide continuous measurements of such oscillations, and a greatly extended understanding of our nearest star.







THE SUN AT 1,000,000 K

Stanford/MSFC Rocket X-Ray Telescope, Flight 27.002, Oct. 23, 1987, 18:08 UT
Center for Space Science and Astrophysics, Stanford University
NASA, Marshall Space Flight Center
Lawrence Livermore National Laboratory

Arthur B. C. Walker, Jr., Joakim F. Lindblom, Richard B. Hoover, Troy W. Barbee, Jr.

This image represents the first high resolution image of the sun in the soft x-ray/extreme ultraviolet light obtained with a normal incidence Cassegrain multilayer telescope. The image was recorded above an altitude of 100 miles during a sounding rocket flight launched from White Sands Missile Range on October 23, 1987. The telescope mirrors were coated with a Mo/Si multilayer surface, allowing the telescope to operate in a spectral regime not previously accessible with traditional Cassegrain configurations. Multilayer coated optics is a powerful new technology which promises to significantly enhance laboratory and astronomical imaging in the soft x-ray/extreme ultraviolet. The bandpass of the telescope is 171 - 175 Å, where the solar emission is dominated by Fe IX and Fe X lines produced by coronal plasma at 0.95 - 1.3 million degrees K. This 200 second exposure was recorded on a special soft x-ray/extreme ultraviolet sensitive T Grain emulsion recently developed by Eastman Kodak.

This research was sponsored by the National Aeronautics and Space Administration.

experiment demonstrated that our model of the solar interior must be revised, perhaps in a major way, since the measured high energy neutrino rate from the solar interior is only one-third of the rate expected on the basis of our best models. (Ironically, although the discovery of neutrinos and the first detection of neutrinos from the sun were achieved by U.S. scientists, the next step in the study of solar neutrinos will be taken by a team of Soviet and German scientists who will study low energy solar neutrinos. Funding for this experiment, which uses a different type of neutrino detector than used by Davis and his colleagues, could not be provided by the NSF.) The study of solar oscillations is an innovation developed by U.S. scientists. The major new instrumental initiative currently under development at NOAO, is a network of ground based observing stations, the "Global Oscillations Network", for the study of this phenomena. Unfortunately, as I pointed out above, the FY 1989 plan will further delay the implementation of this important project.

Figure 9 is an example of the unique role that space observations can play in the study of the sun. It is an image of the solar corona, which is sensitive to material at ~1,000,000 K, obtained by myself and three of my colleagues. It is the first high resolution image of an astronomical source using a new technique for imaging x-rays developed by Dr. Troy Barbee of the Lawrence Livermore Laboratory (Dr. Eberhard Spiller of the IBM research laboratories independently developed the same technology). Before the advent of space observations, the corona could only be studied during solar eclipses, and then only at the limb of the sun. The technique utilized to obtain Figure 9 will provide higher resolution images of the sun's corona, and other sources of celestial x-rays, than can be achieved by other techniques. This image also illustrates the interaction of astronomy and technology, since this new technique of x-ray imaging will have applications in medicine, biology, and materials science and technology.

Perhaps one more example is appropriate, involving the Space Telescope. The Space Telescope will achieve a resolution of 0.06 arcseconds, a 3-fold increase in resolving power over that which can be achieved at the best land-based sites. This will enable the Space Telescope to detect fainter objects than can be observed on the ground, greatly expanding the volume of the universe that we can sample, and will allow us to observe objects in the ultraviolet, at wavelengths that cannot penetrate our atmosphere. In view of the enormous advances that the Space Telescope is expected to achieve, some have asked why astronomers still wish to build optical telescopes on the ground. In fact, as Table 4 shows, the last several years have witnessed the greatest period of planning and fund raising for large land-based telescopes in history. Recently, the European Southern Observatory (ESO) has been given the authority to precede with the development of the VLT telescope (to consist of four 8 meter telescopes) with an equivalent aperture of 16 meters) by its member nations. The Japanese National Telescope with 7.5 meter aperture, which will be placed in Hawaii, is very near approval, raising the possibility that the largest publicly owned telescope on U.S. territory will be owned by Japan! The reason that so many nations and universities wish to build large land-based optical telescopes is that the collecting area of the space telescope is only 4.7 meters, about 2.5% of that of the proposed National New Technology Telescope (NNTT). To determine the spectra of a very distant galaxy, which is essential to determine its distance and many other characteristics, it would require 40 times as much observing time with the Space Telescope as with the NNTT. Clearly, carrying out this type of observation with an expensive and unique instrument such as the Space Telescope, rather than with a more efficient land-based telescope such as the NNTT would be a very inefficient use of a unique resource. Viewed in another way the NNTT can be 400 times as cost effective for certain types of observations as the Space Telescope. Of course, only the Space Telescope can make the many essential observations of very faint objects, observations at very high resolution and observations in the ultraviolet portion of the spectrum to which the Earth's atmosphere is opaque. Clearly, land-based and space-based observations are highly complementary to each other. A *scientifically productive and cost effective* program *must have both capabilities* in the *correct proportion*. I was privileged to have participated in the last National Academy of Sciences Astronomy Decade Study, chaired by Dr. George Field*. I believe that the plan presented by the Field Report contains a balanced program of

* Astronomy and Astrophysics for the 1980's, Volume I, National Academy Press, 1982.

Table 4: Existing and Planned Telescopes with Apertures >= 2.5 M
Apertures in Meters, Areas in Square Meters

Apert.	Name	Mountain	Area	$M		Leader	Owner
2.5	Dupont	Las Campanas	4.9	10		MWLCO	US
2.5	Newton	La Palma	4.9			Royal Greenwich	UK
2.6	Byurakan	Yerevan	5.3			Byurakan	USSR
2.6	Crimean Shajn	Simeiz	5.3			Crimean	USSR
2.7	McDonald	Mt. Locke	5.7	5.9		U Texas	US
3.0	IRTF	Mauna Kea	7.5	10		NASA	US
3.0	Shane/Lick	Mt Hamilton	7.1	3		U California	US
3.5	German-Spanish	Calar Alto	9.6			GS Astron. Obs.	FRG
3.6	CFHT	Mauna Kea	10.2	30		Canada et al	CAN
3.6	ESO 3.6	La Silla	10.2			ESO	INT
3.8	UKIRT	Mauna Kea	11.3			Royal Greenwich	UK
3.9	Anglo Australian	Siding Spring	11.9			UK et al	UK
4.0	CTIO 4 meter	Cerro Tololo	12.6	10		NOAO	US
4.0	Mayall	Kitt Peak	12.6	11		NOAO	US
4.2	Herschel	La Palma	13.9			Royal Greenwich	UK
4.5	MMT	Mt Hopkins	15.9	7.5		C f A et al	US
5.1	Palomar-Hale	Mt Palomar	20	6		Cal Tech	US
6.0	Special Astr. Obs.	Zelenchuk	28			USSR Academy	USSR
		Total:	196.9				
3.5	ARC	Apache Peak	9.6	10		U Washington et al	US
3.5	ESO 3.5	TBD	9.6			ESO	INT
3.5	Iraq 3.5	TBD	9.6			Iraq Government	Iraq
3.5	WIN	Kitt Peak	9.6	12		U Wisconsin et al	US
6.0	USSR 6	TBD	28.3			Leningrad U	USSR
6.5	MMT Upgrade	Mt. Hopkins	42			C f A et al	US
7.5	Japan NLT	Mauna Kea	44			Tokyo Observatory	JAP
7.6	Penn	Mt. Locke	45			Penn State U.	US
8.0	Magellan	Las Campanas	50			Carnegie	US
8.0	NOAO North	Mauna Kea	50	50		NOAO	US
8.0	NOAO South	TBD	50	50		NOAO	US
10.0	Keck	Mauna Kea	76	87		Cal Tech	US
11.3	Columbus	Mount Graham?	88			U Arizona	US
12.0	German 12	TBD	90			German Universities	FRG
16.0	NNTT	Mauna Kea	176	200		NOAO	US
16.0	VLT	Cerro Vizcachas	200	250		ESO	INT
19.6	UK 20	TBD	300				UK
25.0	USSR 25	TBD	490				USSR
		Total:	1,767.7				
		Total:	1,964.6				

Based in part upon material provided by Jean Goad and Jacques Beckers

both space- and land-based research. Unfortunately, very few of the major recommendations made by the Field Committee have been carried out. Indeed, several of the programs assumed to be approved and ongoing in the report, namely the Solar Optical Telescope and the Space Infrared Telescope Facility, are not yet begun. The major recommendation for land-based optical astronomy, the 16 meter NNTT, seems at this point many years in the future. The only major initiative recommended by the Field report which has been started, the Very Long Baseline Array (VLBA), is proceeding at a depressingly slow rate.

The concepts and technologies for the new generation of land-based optical telescopes were developed largely in the U.S. It appears now that U.S. astronomers will be forced to watch their European, Japanese and Soviet colleagues utilize our concepts and technologies to forge ahead of us in optical astronomy. It is interesting to note that the director of ESO recently commented that approval of the VLT project by the ESO member countries would not have been possible without the enthusiastic support of the high technology industry in those countries, who saw important advantages in the technology of the VLT for themselves. The importance of science at the very frontier of knowledge for a nation's economic health is clearly accepted by these nations.

In summary, the program proposed in the Field Report is a well balanced program which uses both space- and land-based facilities. Clearly, the European, Japanese and Soviet astronomical programs have learned the lesson that U.S. astronomers were the first to emphasize, that there is great synergism between these two ways of viewing the universe. Presently, we are in danger of falling behind (or have actually fallen behind) in certain aspects of both arenas; the danger; is most urgent, however, in regard to land-based astronomy because of the severe budget restrictions I have already discussed.

Priorities Within the National Science Foundation: The very slow growth of funding of the RRA budget line for the physical sciences in the NSF is a very serious matter of concern. I am aware that the NSF has been given new responsibilities, and that a major expansion of the NSF budget is planned to allow the NSF to effectively address these new responsibilities. Unfortunately, the pace at which these responsibilities have been, or are scheduled to be implemented,has clearly exceeded the rate at which the NSF budget has grown. It appears that this imbalance between responsibilities and resources has struck most deeply in the area of support for the basic programs of research in the physical sciences. For example, the FY 1989 proposed astronomy budget of $90.04 million, is actually $2.5 million **below the original** FY 1988 request of $92.56 million. Figure 10 shows how funding for astronomy has fared over the past 4 years, compared to the overall NSF budget. The situation, especially in astronomy, has now reached the point that the basic infrastructure of the national observatories, and of university based research groups has begun to crumble, and may, if the situation is not addressed immediately, suffer damage that will require years to repair. If this occurs, the competitive situation in which we find ourselves, with loss of leadership having already occurred in a few fields, about to occur in others, and with our leadership being strongly challenged almost everywhere, may deteriorate very rapidly. I urge you to address the question of the low priority accorded the physical sciences in the NSF budget, over the past four years especially, immediately in the FY 1989 authorization.

The Erosion of Our National Position of Scientific Leadership: One of the most depressing aspects of the budget restrictions in astronomy in the last several years is the loss of scientific leadership in the areas that were pioneered by U.S. astronomers. An example is the field of millimeter wave (mm wave) astronomy. At these wavelengths, it is possible to study the interstellar gas clouds that are the birthplace of stars. One the most startling discoveries made in this wavelength interval is the ubiquitous presence of *organic molecules* in interstellar gas clouds, raising the possibility that the raw materials for living organisms may have evolved in interstellar space, and then been "seeded" onto planets. Approximately 10 - 12 years ago, U.S. astronomers proposed that the NSF build a 25 meter diameter mm wave antenna, in order to exploit the observational techniques that were pioneered here. Unfortunately, the project, although once included in President Carter's budget, was not approved and started in a timely manner. Before the U.S. could exploit this new technology, German astronomers secured approval to construct a 30 meter antenna and Japanese scientists secured approval to construct a 45 meter antenna. Both of

Attachment 2

The Impact of the Size of the New Science and Technology Centers Program on Other Centers and Large Facilities: The fiscal problems of the three national centers supported by the Division of Astronomical Sciences [NOAO, NRAO and NAIC (HAO, as part of NCAR is supported by the Division of Atmospheric Sciences)] are extremely severe. Figures 3a and 3b illustrate the impact of the very restricted budgets of the last four years on the actual purchasing power of the NRAO and NOAO budgets. In spite of the decrease in purchasing power of their budget, the national observatories have supported the research of a growing number of astronomers, as Figure 4 illustrates. They have achieved this remarkable record with a declining staff, as reductions in force have become an annual ritual (Figures 5 and 6). Despite the disruptive effect of these layoffs, all of the national observatories have maintained an almost constant level of high quality service, leadership, and research. This has been achieved by the dedication of the staff, the reduction of services which has been compensated by increased efforts by the users, and by postponing critical maintenance and the development and implementation of critically needed new capabilities. The impact of the 1988 budget has been especially severe, because of the mandated reductions which occurred after the fiscal year was well under way (Table 2). The result of this has been that both observatories must cut drastically into very basic programs in 1988 and utilize all reserves, since even more drastic measures are necessary than would have been required if the amount planned for 1988 had been announced earlier. For 1989, the picture is equally daunting. Table 3 shows the budget levels proposed for 1989. Note that the FY 1989 budget request is below the original FY 1988 budget request, by $2.5 million!

The President of AURA, the consortium of universities which operates NOAO, has stated; "Long-Term curtailments or elimination of programs to reduce the NOAO budget to the level of funding scheduled to be available in FY 1989 [are necessary]. Continued operation of all sites at the current level plus the scheduled [increase] in [expenditures] for the Global Oscillations Network requires $3 million more than has been requested in the budget submitted by the President to Congress."

NRAO has been forced to lay off 19 employees, reduce 2 full time employees to part time, and cancel 15 open positions to meet the cost limitations imposed by the 1988 budget. In 1988, NRAO is operating the unique and powerful Very Large Array Telescope (VLA) on an operations budget, which is the same, in terms of purchasing power, as the operations budget before the VLA was placed into operation. The proposed FY 1989 budget level will not allow the many urgent problems which have developed as a result of chronic under funding of the observatory to be addressed. These include, according to the President of AUI (the consortium of universities which operates NRAO):

- The staff is overburdened and underpaid;
- Investment in future instrumentation is at an unprecedented low level;
- Deferred maintenance threatens the vitality of major facilities;
- Urgent computing needs remain unaddressed;
- The operational needs of the Very Long Baseline Array are not being met;
- The technology development program that has been so important to the success of radio astronomy in the U.S. is in danger of being lost altogether.

Clearly, the impact of the FY 1989 plan on the national astronomy centers is devastating. After studying the 1989 NSF budget plan, it is difficult to avoid the conclusion that one of the major factors driving the severe budget crisis in astronomy is the allocation of funding to start the Science and Technology Centers program at so high a level.

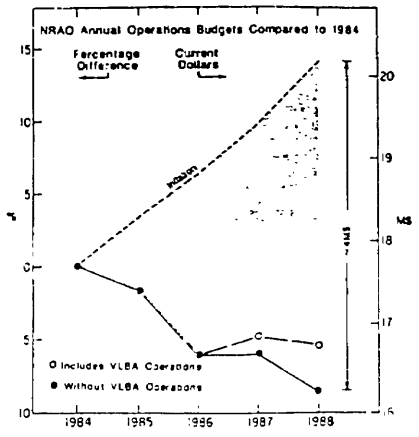


Figure 3a

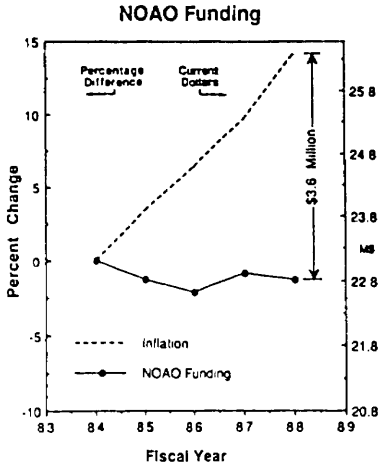


Figure 3b

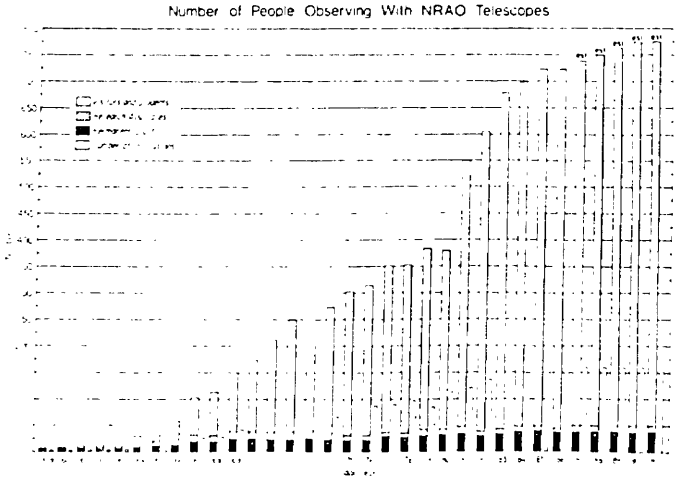


Figure 4. The number of NRAO permanent staff, research associates and visitors who use NRAO telescopes for each calendar year. The number of institutions represented by the visitors is also shown. The significant increase in visitor use in 1981 reflects the increased use of the VLA. A similar increase can be anticipated when the VLBA is fully operational.

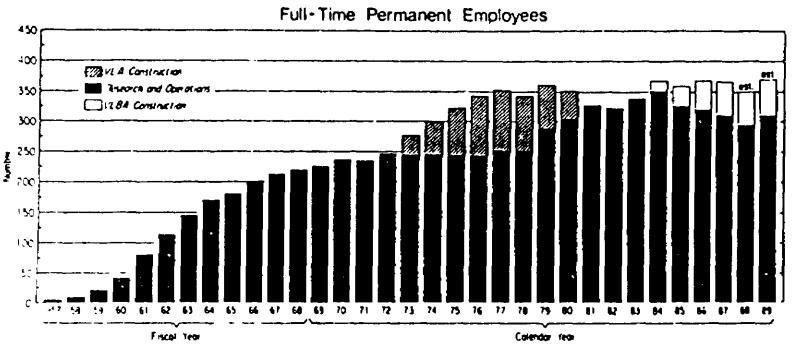


Figure 5. This figure shows the total number of NRAO full-time, permanent employees at the end of each year, projected into the future.

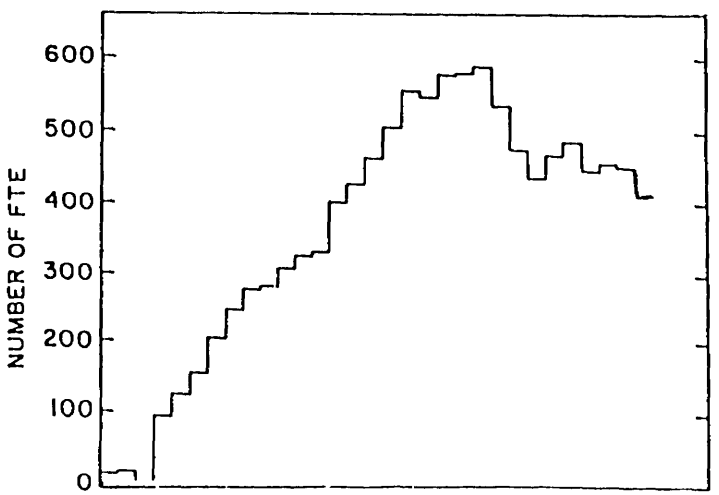


Figure 6. Employment for NOAO base programs (not including the Global Oscillations Network and the New Technology Telescope Development).

Table 2

CHANGES BETWEEN THE FY 1988 BUDGET AND THE FY 1988 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1987 Actual	FY 1988 Request	FY 1988 Current Plan	Change Dollar	Change Percent
Astronomy Project Support	$27.66	$29.51	$27.89	$-1.62	-5.5%
National Astronomy and Ionosphere Center	5.88	6.30	5.93	-0.37	-5.9
National Optical Astronomy Observatories*	23.10	25.80	23.30	-2.50	-9.7
National Radio Astronomy Observatory*	28.40	30.95	28.90	-2.05	-6.6
Total, Subactivity	**$85.04**	**$92.56**	**$86.02**	**$-6.54**	**-7.1%**

Table 3

FY 1989 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1988 Current Plan	FY 1989 Request	Change Amount	Change Percent
Astronomy Project Support	$27.89	$29.2	$1.32	4.7%
National Astronomy and Ionosphere Center	5.93	6.33	0.40	6.7
National Optical Astronomy Observatories*	23.30	24.40	1.10	4.7
National Radio Astronomy Observatory*	28.90	30.10	1.20	4.2
Total	$86.02	$90.04	$4.02	4.7%

* Includes construction and development (Global Oscillations Network and Future Telescope Technology Initiative at NOAO, Very Long Baseline Array at NRAO).

Additional Comments of

[redacted]

Dr. Arthur B.C. Walker
March 22, 1988

Question 1. It has been reported that industry helped convince European governments to approve the world's largest telescope for construction in South America on the grounds that it will help Europe become more competitive. The NSF is seeking to make the US more competitive but has apparently decided to accomplish this by giving less, not more, emphasis to basic research such as astronomy. Who do you believe is right?

Astronomy is a very technology intensive activity. Large high resolution optical telescopes require a large number of technologies involving precision fabrication of mirrors, sophisticated control problems, the development of new materials, and the development of array detectors as well as many other technologies which once mastered, will have important industrial, military and commercial applications. I believe that European industry is correct in their assessment that solving these problems will make important contributions to their technology base, and make their industrial sector more competitive. I suspect that were their opinions solicited, many research directors in US industry would agree. I believe that we must do more to insure that basic scientific discoveries, in which US science still leads the world, are developed as rapidly as possible to exploit their industrial and commercial applications, and that the NSF has an important role to play in this endeavor. Weakening US basic research in order to achieve more rapid development of basic discoveries is, however, counter-productive.

Question 2. You mention that there are obstacles to turning US basic research into inventions and competitive products. What are some of these obstacles, and to what extent can they be overcome through NSF funds?

I believe that there are two kinds of obstacles:

i) legal and other barriers to the formation of consortia by competing groups in order to utilize a larger fraction of the nation's expertise to address scientific or technological problems,

ii) inadequate resources from federal research agencies (NSF, DOD, NASA, DOE) to support advanced technological developments which have immediate scientific application, but industrial or commercial applications which are not as immediate.

In regard to the first obstacle, I recall that when NASA solicited proposals for experiments for the High Energy Astrophysics Observatory about 15 years ago, after the initial evaluation of competing proposals, NASA encouraged those submitting the strongest competing proposals to form consortia, which would allow the best features of each proposal to be incorporated into the instruments built. Several groups did form consortia, and that resulted in a better research satellite. I believe this approach should be utilized more often for large research programs.

In regard to the second obstacle, let me cite an example. The charge coupled detector (CCD) is a solid state imaging device which has found widespread use in television cameras and in video recorders. The potential commercial impact of these devices is very large. Astronomers were among the first to apply these devices to scientific research and the exacting requirements of astronomy have motivated a number of important improvements in the technology of CCD's. Although NASA was able to fund development of these devices for some of its space missions and the 10 meter Telescope Consortium (California Institute of Technology and University of California) is currently funding a modest program, in general, most of the development funds for these important devices have been commercial. This is an example where the very sophisticated requirements of astronomy can encourage US manufacturers to develop advanced devices which can be exploited commercially. Unfortunately this has not occurred to the extent that astronomers would have liked, in fact, RCA, which at one time produced one the the best CCD's has left the business, and non-US companies are now ahead in the commercial exploitations of these devices.

Question 3. During these times of a Federal budget crisis, what would it take to pursue an effective astronomy program under the "Research and Related" category?

As Figure 10 from my prepared statement (reproduced below) illustrates, the recent history of funding for the ongoing astronomical research program of the NSF, which includes research in the universities, and the operation, maintenance, and improvement of the existing facilities at the National Astronomy Centers is one of

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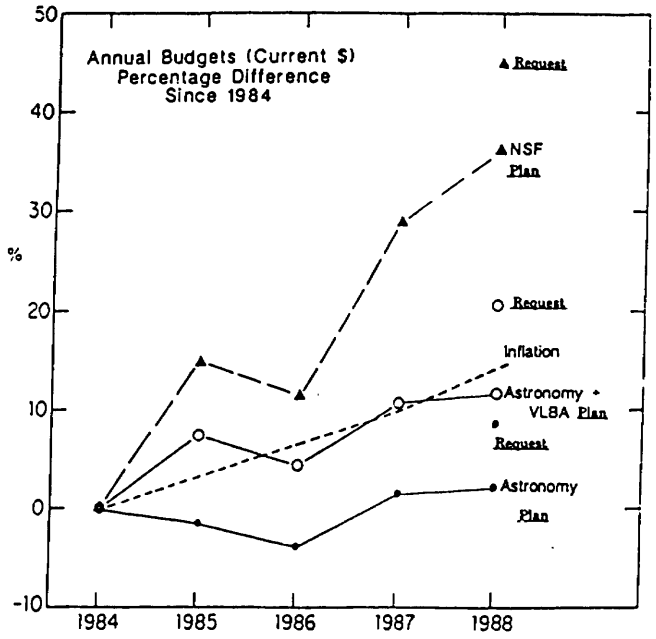


Figure 10

declining resources. Funding for the core research program in astronomy has fallen more than 10% behind inflation since 1984. Even including the construction of the Very Long Baseline Array, NSF support of astronomy has failed to keep pace with inflation. I believe that most astronomers feel that the funds available for the ongoing research program in astronomy should have at least kept pace with inflation, and ideally would share to a significant extent in the proposed increases in NSF support which are projected to double the NSF budget over 5 years. There are many urgent needs in US astronomy, including the need to remain competitive with Europe, Japan and the Soviet Union in optical astronomy by constructing the NTT, the need to join in the international collaboration to build a high resolution "Large Earth Based Solar Telescope", and the need to strengthen the base program of research as recommended in the Field Report. The pace of construction of the VLBA has been somewhat slower than optimal, however I believe astronomers would accept that as perhaps necessary in these times of budget problems, provided that the ongoing research program had remained vital. I emphasize that astronomy is in an era of new opportunities for land-based observation and theoretical research, stimulated in large part by discoveries with space-borne instruments, and by new technologies such as the fabrication of light weight mirrors which make the building of telescopes of 7.5 meters and greater aperture possible.

Question 4. Does astronomy play a role in attracting students to study, and perhaps take up careers, in science and technology?

I believe that astronomy does play an important role in attracting students to study, and take up careers in science and technology. In my own case, it was an interest in Einstein's discoveries, and their implications for our understanding of the universe that first attracted me to science in junior high school. Today, astronomical discoveries are in all likelihood, covered in the press and in the electronic media more extensively than discoveries in

any other area of science, with the exception of medicine. In my own teaching, which often involves undergraduates who are still formulating their career goals, I find that my astronomy laboratory course provides many students with their first experience in scientific observing. Astronomy is able to communicate to young people a sense of the excitement of scientific research and discovery more effectively than other disciplines, perhaps because the subject matter of astronomy, the Sun, the planets, stars and galaxies is already familiar to them.

Question 5. Does astronomy play a role in training engineers and technologists and does it help prepare them for careers in other areas?

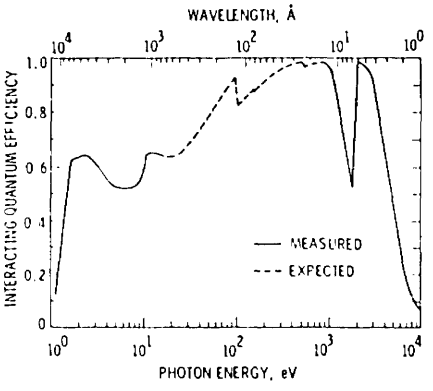
The work of talented and innovative engineers and technologists is an integral part of astronomical research. In fact, the dividing line between astronomers who develop new technologies for astronomical applications, and engineers who work on astronomical instrumentation is quite arbitrary. In the case of my own Ph.D. students, who have worked principally on adapting x-ray imaging technology to astronomy during their Ph.D. dissertation research, their current employment is summarized below:

- one is currently engaged in research and instrumentation in synchrotron radiation, which, of course, has wide applications in materials science, biology and medicine.
- one is currently engaged in infrared instrumentation research at a large aerospace corporation
- one is a former astronaut who is currently engaged in problems relating to arms control and disarmament
- two are currently engaged in astronomical research.

I suspect that most faculty who have trained students in astronomical instrumentation and research might find a similar variety of careers among their former students. In this regard, astronomy is similar to high energy physics research, providing well-trained scientists who can function in a variety of technology areas.

Question 6. Can astronomy profit from further improvements in detector efficiency or are larger telescope(s) needed to study fainter objects?

It is true that over the past decade astronomy has profited significantly from enhanced detector efficiency, as compared with photographic film, for which the efficiency was only a few percent. The Figure below, from a paper by Janesick, et al,* demonstrates that astronomical detector efficiencies can now reach 50 - 60 percent at visible wavelengths, and even higher efficiencies are possible in the ultraviolet. Further improvements in detector efficiency will be small. In order to study fainter objects, we must build larger telescopes.



* Optical Engineering 26 (8) 692-714 (1987)

Question 7. Does astronomy play a role in advancing technology? Which technologies?

Astronomy has played an important role in advancing a number of technologies. The National Radio Astronomy Observatory has prepared a brief report on the technological developments which have been fostered by radio astronomy, a copy of which I have enclosed. In addition, image forming and image recording technologies have been fostered at x-ray, visible and infrared wavelengths. I summarize a few of these developments below:

- The technique of aperture synthesis, which can achieve the resolving power of a large telescope, using an array of small telescopes was developed by radio astronomers, and is used in the VLA and VLBA. This technique is now used in may non-astronomical applications, such as synthetic aperture radar, and x-ray tomography of human tissue.
- Microwave thermography, a radio astronomy technique for measuring the temperatures of remote objects, is now used to sense the internal temperature of parts of the human body, in order to detect cancers.
- The Very Long Baseline Interferometry techniques, which are the basis for the VLBA, are now used by geologists to study the motion of the Earth's crust, and other seismic phenomena. One of the aims of this research is earthquake prediction.
- Radio astronomy has played an important role in the development of sensitive microwave receiving systems which have found application in the communications industry.
- The exaciting standards of astronomy for specialized high performance films has been an important motivation for Kodak in developing photographic technology. This partnership has been beneficial for both astronomers and Kodak.
- The Charge Coupled Detector Technology has been developed in part with NASA and NSF funding. These sensitive, high resolution imaging devices have wide applications in communications, and may replace or supplement photographic film in many applications.
- My colleague at Stanford University, Dr. Gethyn Timothy, has developed a high resolution astronomical detector called the Multi-Anode Microchannel Array (MAMA), which uses the multichannel plate, an image intensification device developed originally (and now extensively used) for military applications. Dr. Timothy's detector has attracted considerable attention in areas of scientific research outside of astronomy, and has potential applications in industry and elsewhere. The MAMA detector was selected by Industrial Research and Development Magazine as one of the "100 Most Significant New Technical Products of the Year" for 1981.
- Dr. Troy Barbee (working at Stanford University) and Dr. Gerhard Spiller (working at IBM Research Laboratories) have independently developed techniques to image x-rays using normal incidence mirrors. Astronomy was one of the principal motivations for these developments, and one of the earliest demonstrations of the power of this new technology has been an astronomical application, a high resolution image of the sun.* This new technology has potential applications in many areas of research and technology, including the manufacture of microelectronics.

Question 8. What are some of the scientifically most exciting areas in astronomy and other sciences?

One area of great excitement in astronomy is the nature of the material which constitutes the major constituent of our Universe. There is now very strong evidence which indicates that the matter which forms the Universe of planets, stars, and galaxies which we observe, only accounts for 10% or less of the mass of the universe. The remaining non luminous material may consist of particles of a type which has already been discovered by physicists, the neutrino, or some other as yet undiscovered type of particle. This question is closely related to the quest for a deeper understanding of the nature of matter on the very smallest scales, which is one of the focuses of the physics community. Questions such as this, and other questions concerning the evolution of the universe in the first microsecond of its existence provide an important link between cosmology, and elementary particle physics.

A second fundamental question of interest to astronomers is the nature of newly formed galaxies. It has been proposed that most galaxies were formed only a few billion years after the Big Bang event which marks the origin of our present Universe so that young galaxies will be very distant from our galaxy, and very faint. Observations with both the Space Telescope, and with large ground-based telescopes such as the proposed New Technology Telescope are essential to resolving this question.

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* Arthur. B. C. Walker, Jr., Troy. W. Barbee, Jr., Richard. B. Hoover, , Joakim. F. Lindblom, to be published in Science

A third question is the nature of the energy source of quasars, which are generally accepted as the cores of very distant galaxies. Many astronomers believe that black holes (objects so massive that any light emitted very close to these objects is trapped by the enormous gravitational field surrounding the black hole) accreting matter from the surrounding galaxy, are at the core of quasars. If this conjecture is correct, the physical phenomena occurring in quasars may be similar to phenomena which are responsible for many of the brightest x-ray sources in binary star systems containing ultra-dense stars in our galaxy. The study of quasars and of somewhat less distant galaxies which show similar phenomena in their cores, and of binary star systems will be a principal objecting of both AXAF and the VLBA. The study of ultra dense stars is of great interest to physicists, because the conditions in such a star, which can be 100,000,000,000,000 more dense than ordinary matter, cannot be reproduced in laboratories on Earth, and can only be studied in an astronomical context.

A fourth question of great interest to astronomers is the process by which stars and planetary systems form. An important by-product of an improved understanding of star and planetary system formation will be an ability to predict how many planetary systems there might be in our Galaxy, and how unique the Earth is.

A fifth question, on which the study of the sun has a very important impact, is the internal structure and composition of stars. Perhaps the most important and significant theoretical achievement of astronomy is the model of how stars evolve through the major stages of their life, from "ordinary" stars like our sun, to red giant stars like Betelgeuse, to white dwarf stars like the companion of Sirius, or exploding stars like supernova 1987A in the Cloud of Magellan. The weakest part of our understanding pertains to models of the internal structure of stars, which we have not been able to experimentally test directly. In the last several years, we have found that the Sun oscillates with many different frequencies and modes, and that the careful observation and interpretation of these solar oscillations can provide a direct test of our models of the solar interior. Direct tests of these models will have very profound implications for our understanding of all stars. The Global Oscillations Network, a distributed network of solar observing stations currently under construction by NOAO will be dedicated to the study of the solar oscillations. In addition, NASA is currently selecting experiments for a joint space observatory with ESA (the European Space Agency) which will study a different aspect of the solar oscillations.

A sixth question of great interest pertaining to our solar system is the nature and composition of comets. Comets are believed to represent "pristine" samples of the material from which our solar system was formed, and a spacecraft mission which could land on a comet and analyze its composition could provide a critical test of our present models of the formation of our solar system.

Finally, an intriguing question to both astronomers and biologists is the origin of life on Earth, and the possibility of life on other planets, both in our solar system and in other solar systems (provided other solar systems exist in our galaxy, as most astronomers believe). A very interesting area of research is the attempt to search for radio signals from other possible civilizations in our galaxy.

Question 9. What has been the significance of Supernova 1987A to astronomy and to our understanding of nature: What follow-up is needed?

Astronomers believe that in addition to representing the final event in the evolution of very massive stars, supernova are responsible for many other important phenomena in astronomy including:

- the triggering of the formation of new stars
- the production of all of the known elements heavier than helium
- the formation of super dense neutron stars, which are responsible for the pulsar phenomenon.

Among the very important and exciting results from Supernova 1987A are the following*:

- A burst of neutrinos was detected from supernova 1987A in 2 underground detectors (these detectors were constructed to search for proton decay, but are very efficient neutrino detectors as well), verifying that the core of the star which became supernova 1987A has collapsed into a neutron star.
- The detection of gamma rays from Cobalt 56, a nucleus with a half life of 78 days, which provides indisputable evidence for the production of heavy elements by the supernova, as predicted. The observations were made by Dr. E. L. Chupp and his colleagues using the Solar Maximum Satellite of NASA, and by Dr. W.G. Sandie and his colleagues using a balloon-borne instrument. Infrared observations by Dr. Harvey Moseley and others using NASA's Kuiper Airborne Observatory have found

* Science Magazine Vol 239 (29 January 1988) p. 460

evidence for the presence of other heavy elements which were most likely produced by the supernova explosion.

- The role of gamma rays from Cobalt 56 in providing the energy which appears at optical wavelengths in the weeks and months after the explosion has been confirmed.
- The star which exploded has now been identified as a very blue supergiant star, rather than a red super giant star as most models have predicted. Evidently the star shed its cool outer shell a few hundred thousand years before it exploded.

Supernova 1987A has provided confirmation of many of our ideas about supernovae, but it has also posed new challenges.

In regard to the follow up, it will be extremely important to observe the evolution of the remnant of the supernova at all wavelengths, from radio, to optical, to x-rays, to gamma rays, over the next decade. Much of what we know about supernovae comes from studying supernova remnants in our own galaxy (such as the remnants of the supernovae observed by Tycho Brahe and Johannes Kepler in the 17th century, and the Crab Nebula , the remnant of a supernova which exploded in the 11th century and was observed by Chinese Court astronomers). It will be important to relate our knowledge of the precursor star and the supernova event itself to the developing characteristics of the remnant. Our most powerful telescopes will be essential to the study of this unique event over the next several decades, including the VLA, the VLBA, the largest land-based optical telescopes available (including, hopefully, the NTT), the Space Telescope, x-ray observatories (including, hopefully, AXAF), and the Gamma Ray Observatory (scheduled for launch in 1990).

TECHNOLOGICAL DEVELOPMENTS FOSTERED BY RADIO ASTRONOMY

National Radio Astronomy Observatory

April 1987

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1

OVERVIEW

Radio astronomy is a science that is driven by the pace of technological improvements to its research instrumentation. Although the pioneering work in radio astronomy was conducted prior to 1940, the infant science did not fully blossom until after World War II. Major advances in the science came in the post-war era primarily due to the availability of the superb radar instrumentation developed during the war and also because of the interest of brilliant technologists who had excelled as radar and radio engineers driven by the war effort. It was clearly evident then, as it is today, that in order for a radio astronomer to work at the forefront of the discipline, his instruments needed to be at the forefront of the associated technology.

The communications industry has instrumental needs that are in many respects similar to those of radio astronomy, with the major exception that radio astronomers have no control over the natural radio signal transmitters that they struggle to detect. Consequently, radio astronomers have always been forced to develop antennas of the highest gain, receivers of the highest sensitivity, and in general instrumentation that defines the state of the art in signal reception and analysis. In many cases the required instrumentation was not available in other scientific disciplines or in industry and had to be developed specifically for radio astronomy. Oftentimes non-radio astronomy applications were discovered later. In other cases, a more symbiotic relation between the needs of radio astronomy and those of other sciences or of industry led to the development of instrumentation of value for each discipline. However, in all these circumstances the technical requirements of radio astronomy have directly or indirectly fostered technological innovations of wide applicability.

Engineering and software developments done principally for radio astronomy have contributed most to the five specific areas of technology that are described below:

- Sensitive microwave receiving systems, including
  - high gain antennas
  - low noise receivers
  - solid state oscillators and frequency multipliers
  - cryogenics
- Data correlation and recording technology
- Image restoration techniques
- Time and frequency standards
- Remote sensing, navigation, and geodesy

I. SENSITIVE MICROWAVE RECEIVING SYSTEMS

A. High Gain Antennas

Radio astronomers design and build antennas of the largest possible size and quality because celestial signals are extremely weak. This requirement has led to several major new technological developments that are just beginning to find commercial applications.

Homology Principle

One of the major limitations to the construction of large steerable antennas with precise reflecting surfaces is the gravitational deformations that change as the antenna is moved from one sky position to another. In 1967, S. von Hoerner published his Homology Principle in a paper addressed to astronomers[1] and in another to structural engineers[2]. An antenna with a design that incorporates homology will deform under changing gravitational stress--but it will deform into another paraboloid, albeit one with a different focal position and focal length. By tracking the focus the effect of the gravitational deflection is minimized and very large, accurate antennas are possible. In the strictest sense only radio telescopes have made full use of the homology principle, but nowadays all designs of large reflector antennas take advantage of homology at least to some degree. As the commercial antenna industry moves to ever higher frequencies, homology will become even more important. The Very Long Baseline Array (VLBA) antennas are examples of a modern design that has replaced an old 25-m antenna design providing a factor of four improvement in rigidity.

Holographic Antenna Metrology

Until recently the only techniques available for verifying the surface accuracy of an antenna were mechanical. Although radio astronomers helped develop these mechanical techniques, their greatest contribution to antenna metrology is the recent development of an electrical technique. This so-called "holographic method" uses the Fourier Transform relationship between the aperture illumination and

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[1] S. von Hoerner, "Design of Large Steerable Antennas," Astron. J., vol. 72, p. 35, 1967.

[2] S. von Hoerner, "Homologous Deformations of Tiltable Telescopes," Proc. ASCE - J. Struc. Div., vol. 93, p. 461, 1976.

the diffraction pattern of an antenna. Scott and Ryle[3] first used this technique to evaluate the antennas of the Cambridge 5-km array, following a suggestion of R. Hills. Bennett et al.[4] were the first to publish a discussion of the technique. The University of California, Berkeley radio astronomy group were the first to reset the surface panels of an antenna using this technique. It has been applied to the evaluation of virtually all major radio telescopes, and it is now part of the routine test and acceptance program of most new telescopes.

Holography is a valuable new method for measuring the amplitude and phase of the electric field in the aperture of an antenna and, as antenna standards are tightened, the antenna industry is expected to make increasing use of this technique. Two firms evaluate antennas holographically as a commercial service: a group in Sheffield, England, and Interferometrics, Inc., of Vienna, Virginia. NASA has adopted the technique as the standard for evaluating the quality of the antennas used in the Deep Space Network.

Correcting Subreflectors

An improved knowledge of the irregularities of the primary reflector has suggested methods for their compensation. In 1976, S. von Hoerner[5] published a procedure to correct for such errors by constructing a subreflector with compensating errors. Most radio telescopes employ multiple reflecting surfaces to bring radiation to the receiver system and Von Hoerner's idea was to improve telescope performance by dealing with a small subreflector rather than the large primary surface. The first application was the deformable subreflector on the NRAO 140-ft telescope which compensated for gravitational deflection of the primary surface by bending the subreflector.[6] More recent applications have fabricated optics to correct for specific surface errors revealed by holographically produced maps. The California, Berkeley radio astronomy group recently reported improvements to one of their millimeter-wave telescopes by use of an

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[3] P. F. Scott and M. Ryle, "A Rapid Method for Measuring the Figure of a Radio Telescope Reflector," Mon. Not. Roy. Astr. Soc., vol. 178, p. 539, 1977.

[4] J. C. Bennett, A. P. Anderson, P. A. McInnes, A. J. T. Whitaker, "Microwave Holographic Metrology of Large Reflector Antennas," IEEE Trans. Ant. & Prop., vol. AP-24, p. 295, 1976.

[5] S. von Hoerner, "The Design of Correcting Secondary Reflectors," IEEE Trans. Ant. & Prop., vol. AP-24, p. 336, 1976.

[6] S. von Hoerner and W-Y. Wong, "Improved Efficiency with a Mechanically Deformable Subreflector," IEEE Trans. Ant. & Prop., vol. AP-27, p. 720, 1979.

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error-correcting lens.[7] The University of Texas millimeter astronomy group has made dramatic improvements in the high-frequency performance of their 5-m telescope with error-correcting mirrors.[8,9] High performance telescopes of the future may well incorporate error-correcting optics as a standard technique for meeting specifications.

High Efficiency Antenna Feeds

In the 1960's, driven by the needs of radio astronomy, engineers and astronomers in the U.S. and Australia independently developed feeds which efficiently illuminate the main reflector. These circular-aperture hybrid-mode corrugated feed horns are widely used now in the communications industry and are essential to the operation of communications satellites. The history of this development has been documented recently by Thomas[10]. These horns are manufactured by many companies, including Rantec, Inc., TIW, and ERA Technologies, Ltd.

B. Low-Noise Receivers

Masers

Maser amplifiers were first used in the 1950's by the communications industry and radio astronomers for the reception of weak signals. Early communication satellites transmitted at a comparatively low power level due to the scarcity of on-board electrical power. (This is less of a problem these days since the advent of higher performance solar cells.) The interchange between techniques developed for radio astronomy equipment and for military/commercial equipment was especially true in the area of maser development. Following the pioneering work of Townes at Columbia University and others, AIL (Airborne Instruments Laboratory) built a number of maser systems for a wide range of applications. Each one advanced the understanding of this new technique; none were simply copies of previous units. Radio astronomy instrumentation was as much of a motivating factor as the pressure for improved satellite communications. Maser systems

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[7] J. Hudson, abstract, URSI (National Radio Science Meeting), June 1985 Vancouver meeting.

[8] H. Foltz, "Dual Subreflector Feeds," Technical Report No. 85-3, Elec. Engr. Res. Lab., Univ. of Texas at Austin, 1985.

[9] C. E. Mayer, "Texas 5-m Antenna Efficiency Doubled at 230-290 GHz with Error Correcting Secondary Optics," abstract, URSI (National Radio Science Meeting), January 1986 Boulder meeting.

[10] B. MacA. Thomas, "A Review of the Early Developments of Circular-Aperture Hybrid-Mode Corrugated Horns," IEEE Trans. Ant. & Prop., vol. AP-34, p. 930, 1986.

installed on the Parkes Radio Observatory antenna in Australia received data from the Giotto satellite during its closest approach with Comet Halley[11]. Although maser amplifiers have been largely superseded at lower frequencies, development is being continued by NASA/JPL for reception of weak signals from deep space probes and also by the radio astronomy community for use in the 20-50 GHz frequency range.

Parametric Amplifiers

Strongly supported by radio astronomy, companies like AIL (Airborne Instruments Laboratory) developed parametric amplifiers in the l te 1950's. Specifically, the radio astronomy community provided a major part of the driving force for higher sensitivity and wider bandwidth at higher frequencies. The satellite communications industry, both commercial and military, benefited in the 1960's and 1970's from this earlier work. In fact, a series of companies were formed on Long Island about this time to meet this need for high performance satellite communication systems. The entrepreneurs who started some of these companies (LNR, Comtech, etc.) had been actually involved at the bench level in building parametric amplifiers for the radio astronomy community.

GaAs FET

The push to develop GaAs FET (gallium-arsenide field effect-transistor) amplifiers came largely from the communications industry. These have replaced parametric amplifiers as the most commonly used low-noise amplifier for the reception of satellite transmissions. However, the radio astronomy community (NRAO and the University of California - Berkeley) have pioneered the development of cryogenically-cooled GaAs FET amplifiers for high sensitivity receiving systems. Berkshire Technologies was formed by former radio astronomers to meet NASA and industry requirements for cryogenic GaAs FETs.

HEMT

HEMT's (high-electron-mobility transistors) are recently developed semiconductor devices that have already found their way into both the computer and communication fields. Again, the radio astronomy community (NRAO) with help from NASA (JPL) has supported the development of HEMT devices by GE and Cornell University for use in cryogenically-cooled amplifiers. Since these developments are relatively recent, the full impact is not clear yet; however, the NASA/JPL DSN (Deep Space Network) is evaluating the use of these amplifiers to replace masers which are difficult to maintain in the

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[11] R. Reinhard, "The Giotto Encounter with Comet Halley," Nature, vol. 321, p. 313, 1986.

field. There are also early indications that there is interest by a company involved in defense work in a technology transfer from NRAO. These amplifiers are currently being installed on the Very Large Array (VLA) in order to obtain higher sensitivity for the reception of signals from Voyager II during the Neptune encounter during August 1989.

Schottky Mixers

Cooling reduces the noise of solid-state amplifiers. Weinreb and Kerr[12] pioneered the application of cryogenic cooling of GaAs Schottky mixers in order to improve their performance for radio astronomy. Although the cooling of mixers has not found wide commercial use, the engineering that has gone into the fabrication of cooled mixers has. The IEEE papers of Kerr and Archer have attracted world-wide interest from commercial and defense organizations. Kerr and Held were awarded the IEEE Microwave Prize for their papers covering conversion-loss and noise of microwave and millimeter-wave mixers[13,14]. Millitech was formed by a few talented radio astronomers and is now a major support firm for millimeter and submillimeter wave technology. The success of this company comes from having the right background at a time when the defense industry needs moved up into the millimeter range (battlefield radar systems, etc.).

Superconducting-Insulating-Superconducting (SIS) Mixers

Most major radio astronomy observatories making millimeter-wave observations are currently developing SIS mixers for low-noise receivers. Several observatories are successfully using these devices in receivers. Despite the few years that these devices have been in use, there is already a technology interchange in progress between NRAO and several commercial and government organizations (Hypress, NRL, NSA, etc.).

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[12] S. Weinreb and A. R. Kerr, "Cryogenic Cooling of Mixers for Millimeter and Centimeter Wavelengths," IEEE Journal of Solid-State Circuits, vol. SC-8, February 1983.

[13] A. R. Kerr and D. Held, "Conversion-Loss and Noise of Microwave and Millimeter-Wave Mixers: I - Theory," IEEE Trans. on Microwave Theory and Tech., vol. MTT-26, p. 49, 1978.

[14] A. R. Kerr and D. Held, "Conversion-Loss and Noise of Microwave and Millimeter-Wave Mixers: II - Experiment," IEEE Trans. on Microwave Theory and Tech., vol. MTT-26, p. 55, 1978.

Solid-State Oscillators and Multipliers

Phase-locked, millimeter-wave sources for use as broadly tunable local oscillators for radio astronomy are not readily available commercially. Consequently, the radio astronomy community has made substantial progress in the development of varactor multipliers[15] (Archer) and voltage-tunable Gunn oscillators[16] (Carlstrom, Plambeck, and Thornton). There has been considerable commercial interest in these devices and follow-up work at Millitech Inc. has led to their successful marketing.

Cryogenics

The low-noise amplifiers used on radio astronomy antennas are generally operated at cryogenic temperatures - 15K or 4K are commonly used. The closed-cycle refrigerators used are usually Gifford-McMahon refrigerators built by CTI (Cryogenics Technology, Inc.). The 4K system uses the same refrigerator type with an add-on Joule-Thompson circuit. Reliability of these cryogenic systems has always been important to the radio astronomy community, and radio engineers have worked closely with the manufacturer (CTI) to improve system performance and reliability. Some improvements to the compressors that were developed and evaluated by NRAO have been incorporated by the manufacturer. These systems have also had beneficial use in the semiconductor industry as the central component of low temperature vacuum pumping units.

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[15] J. W. Archer, "An Efficient 200-290 GHz Frequency Tripler Incorporating a Novel Stripline Structure," IEEE Trans. on Microwave Theory and Tech., vol. 32, p. 416, 1984.

[16] J. E. Carlstrom, R. L. Plambeck, and D. D. Thornton, "A Continuously Tunable 65-115 GHz Gunn Oscillator," IEEE Trans. on Microwave Theory and Tech., vol. MTT-33, p. 610, 1985.

II. DATA CORRELATION AND RECORDING TECHNOLOGY

A. Digital Correlation Techniques for Spectral Analysis of Broadband Signals

Many radio astronomical observations involve the spectral analysis of a broadband signal, the most common example being observations of an atomic or molecular spectral line. The frequency bandwidths that the astronomer needs to analyze, 10-1000 MHz, are extremely large for traditional techniques such as analog filters. Instead, radio astronomers have developed digital techniques involving coarse quantization (1-3 bits) and autocorrelation of wideband signals. The advantages of digital correlation are greater flexibility, reliability, and stability, with inexpensive components. The seminal work on digital techniques for spectral analysis in radio astronomy is that done by Weinreb[17] and Cooper[18].

Digital correlation is now used extensively in remote sensing applications (from earth satellites), oceanography, and oil exploration.

A contemporary digital spectrometer which provides the flexibility needed in radio astronomy to analyze signals of vastly different bandwidths (from 1.25 to 320 MHz) is described by W. Urry et al.[19]

Digital techniques employing coarsely quantized data also permit one to cross-correlate data rapidly from many separate signals. For example, the VLA radio telescope requires data to be correlated at a rate of 2×10^{12} multiplications per second. If this was to be performed with floating point numbers in a large computer then the power of 100 CRAY supercomputers would be needed. However, by using 3-level arithmetic, a special purpose digital correlator was built for this task at a cost of only 2 million dollars.

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[17] S. Weinreb, "A Digital Spectral Analysis Technique and Its Application to Radio Astronomy," M.I.T. Research Laboratory of Electronics, Tech. Report 412, 1963.

[18] B.F.C. Cooper, "Autocorrelation Spectrometers," Methods of Experimental Physics, vol. 12B, p. 280, 1976.

[19] W. L. Urry, D. D. Thornton, and J. A. Hudson, "Hat Creek Millimeter-wave Hybrid Spectrometer for Interferometry," Publ. Astron. Soc. Pacific, vol. 97, p. 745, 1985.

B. Wideband Tape Recording

The radio astronomical technique of Very Long Baseline Interferometry (VLBI) requires very wideband tape recording. Simultaneous observations are made at radio telescopes separated by tens to thousands of miles, and the tape recorded data are played back and cross-correlated at a latter time at a common location. Initially, radio astronomers used video cassette recorders, readily available in the consumer market at low cost, to record digital data. In addition, instrumentation recorders have been improved by more than an order of magnitude for high VLBI data rates. VLBI observations are recorded at a density of one million bits of information on each square inch of instrumentation tape.[20] The technique for doing so has attracted commercial interest.

C. Archival Mass Storage

The enormous data storage requirements of radio astronomical observations made conventional magnetic storage techniques uneconomical. To meet these requirements, astronomers have developed low-cost instrumentation recorders by using analog recorders to record digital data. One system in operation uses a Video Cassette Recorder for this purpose.

The NRAO has investigated whether the performance of these devices could be improved so that they might also be employed to store archive data. In the process of investigating the feasibility of using such a recorder for VLA archive data, the NRAO developed a prototype recorder suitable for high performance recording.

The new recorder resembles a streaming magnetic tape drive. It has a capacity of 2.5 gigabytes of user data and a data rate of 120 kilobytes per second. It employs read after write, error correction circuitry, and spatial multiplexing to achieve a rate low enough for high-performance recording.

The ability to place 2.5 gigabytes of data on a $4 cassette tape in an essentially error-free environment makes such a recorder very attractive for a number of fields. Disk backup, archiving of both scientific and business data, and medical electronics are but a few.

Ray Escoffier, the inventor and an AUI employee, has applied to patent the recording system and to provide for a life-long royalty free license to the United States Government. The first patent (Serial No. 870,305) is currently pending. Digi Data, an OEM manufacturer of magnetic tape equipment located in Maryland, has been licensed to

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[20] K. I. Kellermann and A. R. Thompson, "The Very Long Baseline Array, Science, vol. 229, p. 123, 1985.

manufacture the recorder. The company has further developed the recorder, taking it from a demonstration of feasibility to a product and plans to market it in late 1986.

III. IMAGE RESTORATION ALGORITHMS

A. Aperture Synthesis Techniques

The angular resolution of a radio telescope is proportional to the diameter of the dish antennas measured in wavelengths. Larger telescopes can more easily see fine scale details in cosmic sources. But, there is a limit to the size of an individual telescope that one can construct. To achieve still higher angular resolution, it is possible to synthesize a single telescope from an array of spatially separate antennas which simultaneously observe a position in the sky. The basic technique of aperture synthesis samples an electromagnetic wave front at many widely separated locations and then uses the Fourier transform of these data to stimulate the response that would have been obtained with a much larger, single antenna. The radio astronomer Sir Martin Ryle received the Nobel Prize in Physics for the conception and demonstration of this technique.

The principles of the aperture synthesis technique are directly incorporated in many non-astronomical image construction endeavors which are widely available commercially, such as the following,

- synthetic aperture radar
- X-ray tomography of human tissue.[21]

B. Self-Calibration Algorithms: Adaptive Optics

Distortion of an image by the atmosphere is a problem common to both radio and optical telescopes. This problem restricts synthesis array radio telescopes such as the VLA. The distortion manifests itself through collimation errors resulting from spatially and temporally varying refractivity of the atmosphere above the array. Years ago the radio astronomer Roger Jennison derived phase closure mathematical relations that could be applied to observations with telescope arrays in order to circumvent these effects and sharpen the radio images.[22] This technique, suitably refined and known as self-calibration, is now routinely employed in radio astronomy.[23]

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[21] R. N. Bracewell and A. C. Riddle, Ap. J., 150, 427, 1967.

[22] R. C. Jennison, "Fourier Transforms of Spatial Brightness Distributions of Small Angular Extent," Mon. Not. Roy. Astr. Soc., vol. 118, p. 276, 1958.

[23] F. R. Schwab, "Adaptive Calibration of Radio Interferometer Data," Proc. Soc. of Photo-Optical Instrumentation Engrs., vol. 231, p. 18, 1980.

To an optical telescope, the effect of the atmosphere is easily seen in, for example, the twinkling of stars. Atmospheric turbulence generates an irregular distortion of the wavefront across the telescope aperture. If it were possible to distort the shape of the telescope mirror in the same way, then one could cancel the atmospheric distortion and sharpen the image. This is precisely what is done. With an articulating mirror driven by pistons, the shape of the mirror is continuously deformed in real-time until the image sharpens. Such a technique for optical telescopes is called "adaptive optics," but it is in all ways analogous to the radio astronomical technique of self-calibration. Adaptive optics is also used in satellite cameras to improve their photographic capabilities.[24]

C. Maximum Entropy Algorithm

Synthesis array telescopes do not fully sample the incoming electromagnetic wavefront, and it is necessary to interpolate from the measured points so as to fill in the "missing" data. Such image processing by means of the maximum entropy algorithm, a technique first developed for the analysis of seismic data, has been greatly refined for application to radio astronomical problems.[25]

So successful has been this improvement that the astronomical software algorithms developed by radio astronomers are now used for problems of blurred photographic images in non-astronomical contexts (e.g., sharpening images for police work). Several commercial firms now market the maximum entropy algorithms for diverse applications. Maximum Entropy Data Consultants Ltd. is one such firm.

D. Astronomical Image Processing Systems (AIPS)

AIPS is an extensive integrated software package for manipulation of multi-dimensional images. Developed by the NRAO, AIPS is distributed without charge for use by hundreds of scientists worldwide. Designed to be machine independent, it runs on all classes and makes of computers, from minicomputers to supercomputers; it is routinely used in nonastronomical image analysis applications. Several hardware vendors advertise and promote the suitability of their equipment for AIPS support. Among these are the following:

CONVEX Computer Corporation, Inc.
International Imaging Systems, Inc.

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[24] R. Muller and A. Buffington, "Real-time Correction of Atmospherically Degraded Telescope Images Through Image Sharpening," J. Optical Soc. of America, vol. 64, p. 1200, 1974.

[25] S. Gull and G. Daniell, "Image Reconstruction from Incomplete and Noisy Data," Nature, vol. 272, p. 686, 1978.

IV. TIME AND FREQUENCY STANDARDS

A. Hydrogen Maser Frequency Standard

The technique of Very Long Baseline Interferometry (VLBI), in which tape-recorded data taken by telescopes thousands of miles apart are brought together and cross correlated, requires that each telescope maintain exceptional frequency stability. Specifically, the frequency at each station must be stable to better than one part in 10^{14} over a period of several hours. At the present time only active hydrogen masers can provide the required stability.[26]

Hydrogen masers, which produce the 1420-MHz hyperfine transition of atomic hydrogen as their fundamental output, were developed as an experimental time standard by the NBS. Prior to the needs of VLBI, there was no commercial maker for this laboratory device. Reliable field-ready hydrogen masers were subsequently developed by the Smithsonian Astrophysical Observatory and at NASA/Johns Hopkins Applied Physics Laboratory in order to supply each individual VLBI antenna with its own hydrogen maser frequency standard. These designs have been developed into a commercial product by Oscilloquartz S. A. in Switzerland and Sigma Tau Standards Corporation in Alabama, among others. The present market for hydrogen maser frequency standards is dominated by space communications and DOD needs. Finally, Hughes Research Laboratories is developing a space-qualified hydrogen maser for use on the NAVSTAR Global Positioning Satellites.

B. Time Standards and Time Transfer

A standard of time may have more than one appropriate definition. For a laboratory experiment a suitable time standard may be an atomic clock. For an astronomical observation, on the other hand, or a determination of the position (orbit) of an earth satellite "time" refers to the rotation of the earth on its axis. This rotation is not constant. Not all earth days are of the same duration owing to subtle wobbles of rotation of the earth.

The USNO relies heavily on the radio astronomical data for their daily determination of the earth's rotation periods. Using a worldwide network of optical telescopes augmented in an important way by radio astronomical observations with the NRAO interferometer in Green Bank, WV, the USNO constantly monitors the rotation of the earth relative to an astrometric grid of very constant radio sources (quasars). Unlike the optical determinations, the radio astronomical observations can be

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[26] A. Rogers and J. Moran, "Coherence Limits for Very Long Baseline Interferometry," IEEE Trans. on Instru. and Measur., vol. IM-30, p. 283, 1981.

made day and night, and they are affected by clouds or the weather to a relatively small degree. The USNO radio technique and its application is discussed by Winkler[27] and Matsakis et al.[28]

In order to transfer a single laboratory reference time to distant clocks with high accuracy, one must develop a synchronization method. The VLBI technique is routinely used in radio astronomy to synchronize telescope clocks to nanosecond accuracy worldwide. This method also has applications for very precise navigation and in other non-astronomical contexts.

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[27]G. Winkler, "Time Keeping and Its Applications," Advances in Elect. and Electron Phys., vol. 44, p. 33, 1977.

[28]D. Matsakis et al. "The Green Bank Interferometer as a Tool for the Measurement of Earth Orientation Parameters," Astron. J., vol. 91, p. 1463, 1986.

V. REMOTE SENSING, NAVIGATION, AND GEODESY

A. Microwave Thermography of the Human Body

Observations of cosmic sources of radio radiation made with a radio telescope are fundamentally measurements of the temperature of those objects. Instead of looking at the sky, one can use the same technique to scan the human body and, in so doing, measure precisely the distribution of temperature across the body. Since malignant tumors and regions of vascular insufficiency are thermally anomalous, these features are readily apparent on microwave scans of the human body.

Radio astronomers have adapted this technique for non-invasive measurement of the temperature of subcutaneous human tissue.[29] Although microwave radiometry has coarser spatial resolution than infrared thermography, it has a greater sensitivity to deep tissue temperature. Flesh is transparent at microwave frequencies. Clinically, in application to the detection of breast cancer, the combination of microwave and infrared thermographic data provides a true-positive detection rate of 96 percent.[30] Microwave thermography does not expose patients to harmful radiation.

B. Atmospheric Ozone Monitoring

The depletion of the protective layer of ozone (O_3) in the stratosphere is a matter of utmost current concern since potentially increased levels of solar UV radiation on the surface of the earth will result from a diminished O_3 concentration. For several years scientists have known that chlorine monoxide (CℓO) is a key tracer of the stratospheric ozone depletion cycle arising from natural and man-made injection of chlorine-containing compounds, particularly halocarbons, into the atmosphere. The reactions

$$O_3 + C\ell \rightarrow C\ell O + O_2$$
$$C\ell O + O \rightarrow C\ell + O_2$$

constitute the catalytic cycle by which chlorine atoms convert ozone to diatomic oxygen.

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[29] A. H. Barrett and P. Myers, "Subcutaneous Temperatures: A Method of Noninvasive Sensing," Science, vol. 190, p. 669, 1975.

[30] A. H. Barrett, P. C. Myers, and N. L. Sadowsky, "Microwave Thermography of Normal and Cancerous Breast Tissue," Proc. 3rd Intern. Symp. on Detection and Prevention of Cancer (Decker: New York), 1978.

Radio telescopes can directly measure and monitor the stratospheric abundance of ClO, and its diurnal and long-term variation. Radio astronomers demonstrated the efficacy of this technique by means of observations of the J = 11/2 - 9/2 and J = 15/2-13/2 rotational transitions of ClO at 204 and 278 GHz, respectively. Such ground-based observations provide a cost-effective way of monitoring potential damage to the ozone layer using existing radio astronomical instruments and techniques.[31]

C. Remote Sensing Satellites

One of the most economically significant applications of radio astronomy techniques has been to remote sensing satellites which carry passive imaging microwave spectrometers operating at wavelengths ranging from several centimeters to a few millimeters. Early successes in mapping atmospheric temperature and humidity fields, polar ice distributions, and other geophysical parameters, even in the presence of clouds, have led to the steady use of passive microwave temperature sounders on the operational NOAA and DOD weather satellites, and the anticipated primary use of a 20-channel imaging microwave spectrometer on operational NOAA satellites beginning in 1990. The following types of investigations are under way:

Operational Weather Monitoring - temperature profiles, water vapor distribution, and rain bands
Atmospheric Research - stratospheric and mesospheric temperature profiles, water vapor profiles, trace constituent profiles, and winds
Polar Ice Studies - ice pack evolution and navigability
Land and Ocean - sea surface temperature, sea surface wind, oil spill observations, soil moisture, and snow cover

Several references describe these applications.[32,33,34,35,36]

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[31] P. M. Solomon, R. de Zafra, A. Parrish, and J. W. Barrett, "Diurnal Variation of Stratospheric Chlorine Monoxide: A Critical Test of Chlorine Chemistry in the Ozone Layer," Science, vol. 224, p. 1210, 1984.

[32] D. Staelin et al., "Microwave Spectroscopic Imagery of the Earth," Science, vol. 197, p. 991, 1977.

[33] D. Staelin, "Passive Microwave Techniques for Geophysical Sensing of the Earth from Satellites," IEEE Trans. Ant. & Prop., AP-29, p. 683, 1981.

[34] Applications, Review Panel Report, "High Resolution Passive Microwave Satellites," D. H. Staelin and P. W. Rosenkranz, eds., Final Report, Contract NAS5-23677, Research Laboratory of Electronics, M.I.T., April 1978. Available from NTIS as NASA Accession No. N81-71117.

D. Earth Satellite Positions and Tracking

To determine the precise positions of artificial earth satellites, one needs not only a means of measuring the position but also a fixed reference frame to which one can refer those positions. The astrometric grid of cosmic radio sources, established over the whole sky by radio astronomers, provides the only truly "fixed" reference system, to which other moving objects may be referred.

The location of those artificial satellites which transmit a radio signal can be established to exceptionally high precision by the radio astronomical technique of Very Long Baseline Interferometry (VLBI). The technique has been verified on the Global Positioning System (GPS) satellites, which are the primary position reference beacons for the next-generation of military, commercial, navigational and geodetic applications.

E. Spacecraft Navigation

Earth-based radio interferometry, precisely as practiced by radio astronomers, has provided a straightforward means of "triangulation" for spacecraft navigation.

- To monitor the position of the Apollo astronauts on the moon during their explorations aboard the Lunar Rover.

- To precisely locate sounding balloons released into the Venusian atmosphere by the Soviet Vega spacecraft mission.

- To establish the relative position of the Vega pathfinder flyby of Comet Halley with respect to the radio astronomical reference system of cosmic radio sources. (Necessary for course corrections during the Giotto spacecraft's close nuclear approach.)

F. Geodetic Studies and Crustal Dynamics

Radio astronomical VLBI observations have become a valuable tool for geophysicists in their study of the motion of the poles of the earth, changes in the rotation of the earth, and the nature of lunar-induced tides in the solid earth.

Geophysical studies of the earth's crustal dynamics depend on high precision measurements spread over several years. The positional

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[15] P. Gloersen et al., "A Summary of Results from the First NIMBUS 7 SMMR Observations," J. Geophys. Res., vol. 89, p. 5335, 1984.

[16] Manual of Remote Sensing, vol. 1, R. N. Coldwell, ed. (2nd ed.), American Society of Programmetry, 1984.

accuracy obtained with radio astronomical VLBI observations is used to monitor the separation between geodetic radio telescopes to a few centimeters. Regional terrestrial deformations and global plate motions are thus measurable where the two telescopes span known fault lines and tectonic plates. The technique allows geophysicists to study pre- and post-earthquake seismic activity with the aim of earthquake prediction and a basic understanding of worldwide tectonic motions.[37]

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[37] A.E.E. Rogers et al., "Very Long Baseline Interferometry: The Mark III System for Geodesy, Astrometry, and Aperture Synthesis," Science, vol. 219, p. 51, 1983.

APPENDIX V

5/11/88

National NET'88

Public and Private Initiatives to Create a National Education and Research Network

Washington, D.C. April 19-20, 1988

Conference Report

CONSENSUS

- There is broad - essentially unanimous - support from education, industry, and government leaders for concerted action to create a high performance network to serve critical research and education programs in all three communities.

- Many of the requirements for the network - technological as well as managerial - already exist as a result of previous federal and institutional investments. What is most needed at this time is leadership, commitment, and stable funding.

- The network not only has the ability to catalyze and energize scientific advancements and applied product development in many fields, but it lies at the core of the nation's path to an "Information Age" economy with resultant benefits to employment and many broader social goals.

- Research for the future high performance network, which must serve a much larger population of users at very high transmission speeds, can use current networks and their applications - NSFNet, ARPANET, BITNET, CSNET, etc - as a base for development.

BACKGROUND

Sponsored by three higher education groups - EDUCOM Networking and Telecommunications Task Force, National Association of State Universities and Land Grant Colleges, and NYSERNET, and with partial support from the National Science Foundation, more than 350 representatives from higher education, government and industry participated in an executive conference - the first of its kind - convened to assess the needs for a national research and education computer network. The conference was called following a series of studies which concluded that a broadly accessible national network linking university campuses and government and industrial research sites would contribute significantly to improved U.S. research productivity and economic competitiveness. The most recent of these studies was commissioned by the Congress in 1986 and released by the White House Office of Science and Technology Policy in November, 1987 under the title, " A Research and Development Strategy for High Performance Computing."

RECOMMENDATIONS

Short Range

The NSFnet development is a significant step toward the national network. This effort, which includes support for the regional networks that further connect universities, needs to be supported at an increment (five to ten million dollars a year) over the currently allocated NSF budget. This will insure that the early operational phase of the network is properly supported.

Long Range

Colleges and universities anticipate development of a permanent financing mechanism for networking that is not totally dependent upon federal funds. However, the current federal role, supporting development of the network until it reaches a self-sustaining stage, is critical. That support is appropriate as a federal investment to meet national research objectives. In order to ensure effective development, there needs to be a strong Federal focus for the planning, management and development of the effort (such as using NSF as the lead agency) as well as careful exploration of the means of bringing the three key communities together—government, industry and higher education—so that the necessary collaboration is achieved.

ACTIONS

Working groups of the conference are continuing their support by:

- Identification and resolution of policy issues affecting implementation of the network;
- Study of successful network applications and the means to apply them more generally;
- Fostering collaboration among existing networks, including higher levels of participation by industrial laboratories and research groups;
- Communicating the needs and benefits of the network, in cooperation with industry, to gain Congressional support.

References

1. EDUCOM Networking and Telecommunications Task Force, *A National Higher Education Network Issues and Opportunities*, May 1987.
2. EDUCOM Networking and Telecommunications Task Force, *Building the Network Access, Connectivity, Technology, Services*, April 1988.
3. Arms, C. (ed), *Campus Networking Strategies*, Digital Press, 1988
4. OSTP, *A Research and Development Strategy for High Performance Computing*, November 20, 1987.
5. SIAM, *Report of the Panel on Research Issues in Large-Scale Computational Science and Engineering*, 1987.
6. NSF, *Report on Future Requirements for Advanced Scientific Computing*, February 10, 1988.

APPENDIX VI

HON. SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT
NATIONAL SCIENCE FOUNDATION AUTHORIZATION
March 22, 1988

MR. CHAIRMAN:

I'LL HAVE A STATEMENT ON THE NSF BUDGET AS A WHOLE TOMORROW. THIS MORNING I'D LIKE TO FOCUS ON THE SUBJECT OF OUR FIRST PANEL -- PRE-COLLEGE EDUCATION.

THERE IS NO TASK BEFORE US THAT IS MORE PRESSING -- OR MORE DAUNTING -- THAN REVERSING THE CURRENT ATROPHYING STATE OF AMERICAN EDUCATION. FIVE YEARS AFTER THE PUBLICATION OF "A NATION AT RISK," THE BAD NEWS CONTINUES TO ROLL IN.

TWO WEEKS AGO, FOR EXAMPLE, NSF RELEASED A STUDY SHOWING THAT THE PERFORMANCE OF AMERICAN FIFTH, NINTH AND TWELFTH GRADERS IN SCIENCE LAGGED BEHIND THEIR COUNTERPARTS IN EUROPE AND ASIA. IMMIGRATION HISTORICALLY HAS BEEN A PRIMARY PROPELLANT ADVANCING AMERICAN SCIENCE, BUT IT SHOULD NOT BE OUR ONLY HOPE FOR PROGRESS.

OUR COMMITTEE HAS BEEN GRADUALLY REBUILDING NSF'S PRE-COLLEGE EDUCATION PROGRAMS AS AN ANTIDOTE TO SUCH DETERIORATION. THIS MORNING'S HEARING IS A CHANCE TO STOP TO CONSIDER OUR METHODS AND HOW MUCH IMPACT THEY'VE HAD.

WE RECOGNIZE THAT IT'S EARLY TO GET A COMPREHENSIVE PICTURE; WE'RE STILL DEBATING THE IMPACT OF THE CONTROVERSIAL PROGRAMS OF THE '60S. SOME OF YOU MAY REMEMBER THE OLD TOM LEHRER SONG ABOUT THE "NEW MATH" WITH ITS REFRAIN, "IT'S SO SIMPLE, SO VERY SIMPLE, THAT ONLY A CHILD CAN DO IT."

WHAT HAVE WE LEARNED FROM THOSE EARLIER PROGRAMS? HOW EFFECTIVE ARE NSF'S TEACHER TRAINING INSTITUTES? ARE THEY THE MOST EFFECTIVE USE OF THE FOUNDATION'S MONEY? CAN NSF DO MORE TO BECOME A CLEARINGHOUSE FOR INFORMATION ON TEACHING AND A SOURCE OF MODEL TRAINING PROGRAMS? WHAT CHANGES ARE UNDERWAY IN CURRICULUM? GIVEN THE INFLUENCE A FEW LARGE STATES EXERT ON TEXTBOOK PUBLISHERS, CAN NSF EFFECT CHANGES IN TEXTBOOK CONTENT? HOW CAN WE MAKE TEACHERS MORE OPEN TO CHANGES IN CURRICULUM? HOW CAN WE ATTRACT MORE TOP STUDENTS INTO TEACHING?

THESE ARE JUST A FEW OF THE DIFFICULT ISSUES WE SHOULD EXAMINE TODAY. BUT BEHIND ALL THESE QUESTIONS IS A FIRM BELIEF THAT NSF, DESPITE ITS RELATIVELY SMALL EDUCATION BUDGET, CAN SERVE AS A BEACON, GUIDING AMERICAN SCHOOLS ALONG THE PATH OF PROGRESS. WITH ITS ENORMOUS PRESTIGE AND ITS CONTACTS THROUGHOUT THE EDUCATION ESTABLISHMENT, NSF HAS THE TOOLS TO ACCOMPLISH THIS GOAL. WITHOUT NSF, THERE IS ONLY A VACUUM.

EDUCATION IS AN INTEGRAL PART OF THE FOUNDATION'S MISSION AND A PREREQUISITE FOR THE LONG-TERM SUCCESS OF ITS OTHER PROGRAMS. WHAT H.G. WELLS OBSERVED ABOUT LEARNING IS EVEN MORE URGENTLY TRUE TODAY: "CIVILIZATION BECOMES MORE AND MORE A RACE BETWEEN EDUCATION AND CATASTROPHE."

THANK YOU.

HON. SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT
NATIONAL SCIENCE FOUNDATION AUTHORIZATION
March 23, 1988

MR. CHAIRMAN:

CIRCUMSTANCES HAVE CONSPIRED TO CONFRONT NSF WITH THAT MOST VOLATILE OF POLITICAL SITUATIONS -- A CRISIS OF RISING EXPECTATIONS.

RESEARCHERS MAY FEEL BETRAYED BY UNREALIZED PROMISES OF BUDGET GROWTH AND THREATENED BY NEW FORMS OF FUNDING. NSF OFFICIALS, FEELING STYMIED BY CONGRESS AND ACADEMIC CONSERVATISM, MAY RUSH EFFORTS TO START NEW INITIATIVES.

IN SUCH A CLIMATE, IT IS OUR JOB TO HELP PRESERVE BOTH BALANCE AND OPTIMISM.

WE CAN START BY DECLARING OUR UNSWERVING SUPPORT FOR THE PRESIDENT'S $2 BILLION BUDGET REQUEST. THIS FUNDING LEVEL RECOGNIZES THE IMPORTANCE OF THE FOUNDATION'S WORK, AND THE HOUSE BUDGET COMMITTEE'S ACTIONS HAVE SHOWN THAT IT CAN PRETTY WELL BE ACHIEVED DESPITE BUDGET CONSTRAINTS.

WE'RE OFF TO A PROMISING START, AND IF WE ALL WORK TOGETHER, THE FOUNDATION CAN BE BACK ON THE PATH TOWARD DOUBLING ITS BUDGET. IT'S WORTH REMEMBERING THAT EVEN LAST YEAR'S DISAPPOINTING APPROPRIATIONS WERE A SIGN OF SUPPORT FOR THE FOUNDATION, GIVEN THE AVAILABLE OPTIONS.

THE TRICKIER QUESTION, OF COURSE, IS HOW TO ALLOCATE THE MONEY. I WANT TO BE SURE THAT CURRENT PROGRAMS ARE FUNDED ADEQUATELY BEFORE WE EMBARK ON ANY NEW VENTURES. SUPERCOMPUTER CENTERS, FOR EXAMPLE, SEEM TO BE IN DANGER OF

STAGNATING AT CURRENT SPENDING LEVELS.

EVEN MORE VEXING IS DETERMINING THE PROPER BALANCE BETWEEN CENTERS AND INDIVIDUAL GRANTS. IT'S UTOPIAN TO BELIEVE THAT THIS QUESTION WILL EVER BE RESOLVED. I THINK THE BEST WE CAN EVER HOPE FOR IS THE UNEASY TRUCE WELL CAPTURED IN ONE OF WOODY ALLEN'S FRACTURED PROVERBS: "THE LION AND THE CALF SHALL LIE DOWN TOGETHER -- BUT THE CALF WON'T GET MUCH SLEEP."

THE ANALOGY IS ESPECIALLY APT. RESEARCHERS KNOW THAT THE LION, THOUGH DOCILE AT TIMES, HAS A GROWING APPETITE THAT CAN LEAD IT TO DEVOUR THE CALF. WE KNOW THAT ALTHOUGH THE LION IS CAPABLE OF GREAT STRIDES AND ATTRACTS MUCH ATTENTION, IT IS THE DEFENSELESS CALF WE DEPEND ON FOR OUR FUTURE SUSTENANCE.

WELL THAT'S IT FOR PLAYING AESOP FOR TODAY. DETERMINING PRECISELY WHAT BUDGET DECISIONS SHOULD FOLLOW FROM THAT MORAL MUST AWAIT THE CONCLUSION OF THESE HEARINGS.

IT'S IMPORTANT, THOUGH, THAT THESE SUBORDINATE DISTRIBUTION QUESTIONS NOT OBSCURE OUR UNITY ON THE PRIMARY TASK. A STRONG, HEALTHY, GROWING BASIC RESEARCH AND EDUCATION ENTERPRISE IS OUR GOAL.

I ONCE AGAIN PLEDGE MY SUPPORT FOR THE NATIONAL SCIENCE FOUNDATION, THE ONE FEDERAL AGENCY WHOSE MISSION IS, AT BASE, THE SEARCH FOR TRUTH.

THANK YOU.

