“Constructing a National Scalable Information Infrastructure”

Plenary Talk

National Electrical Engineering & Computer Engineering Department Heads Association (NEEDHA 2000) Annual Meeting

New Orleans, LA

March 18, 2000

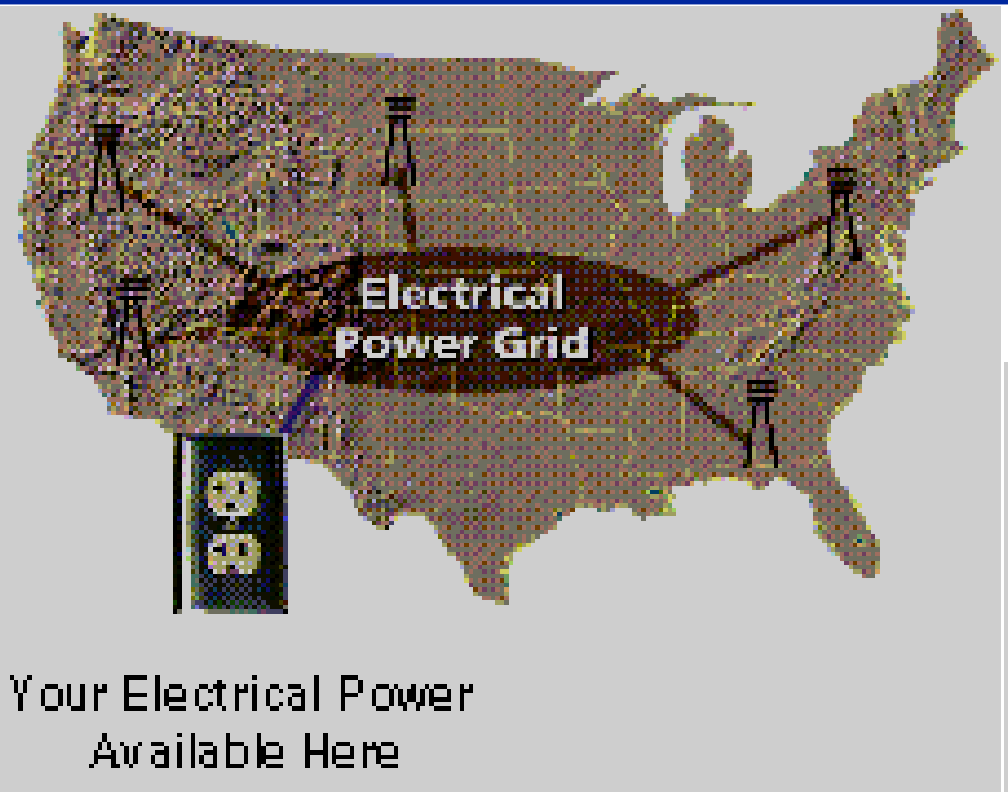
Dr. Larry Smarr

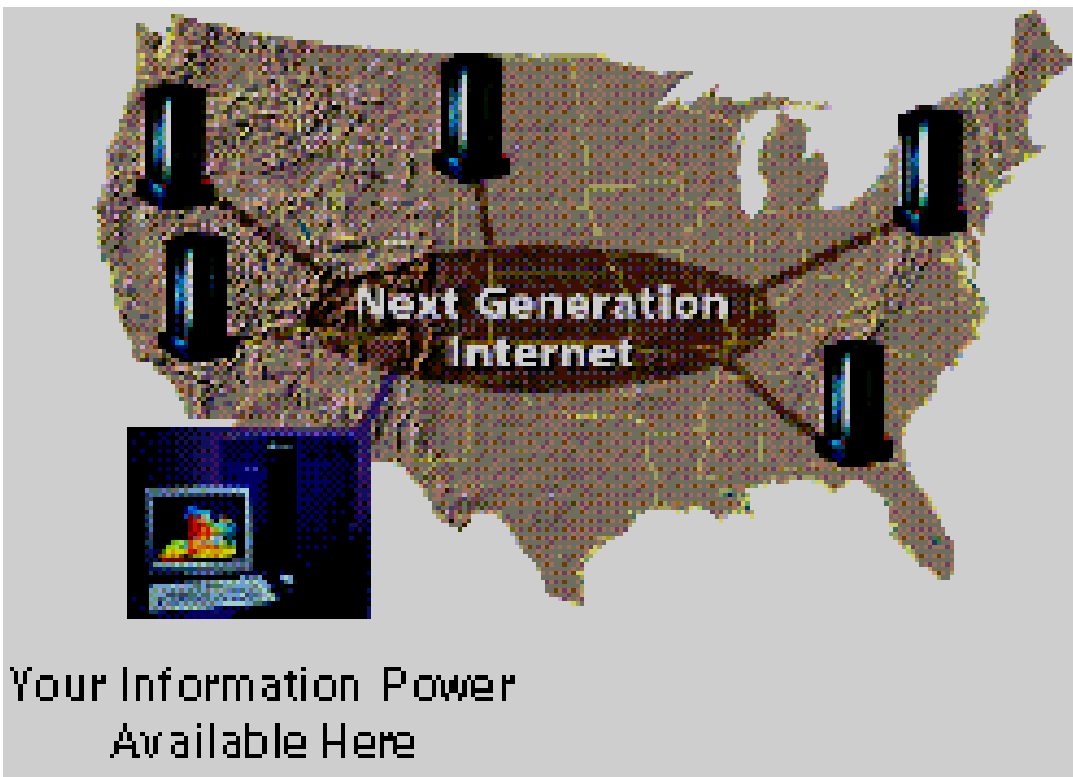
Director, National Computational Science Alliance and the National Center for Supercomputing Applications

Professor in the Departments of Physics and Astronomy

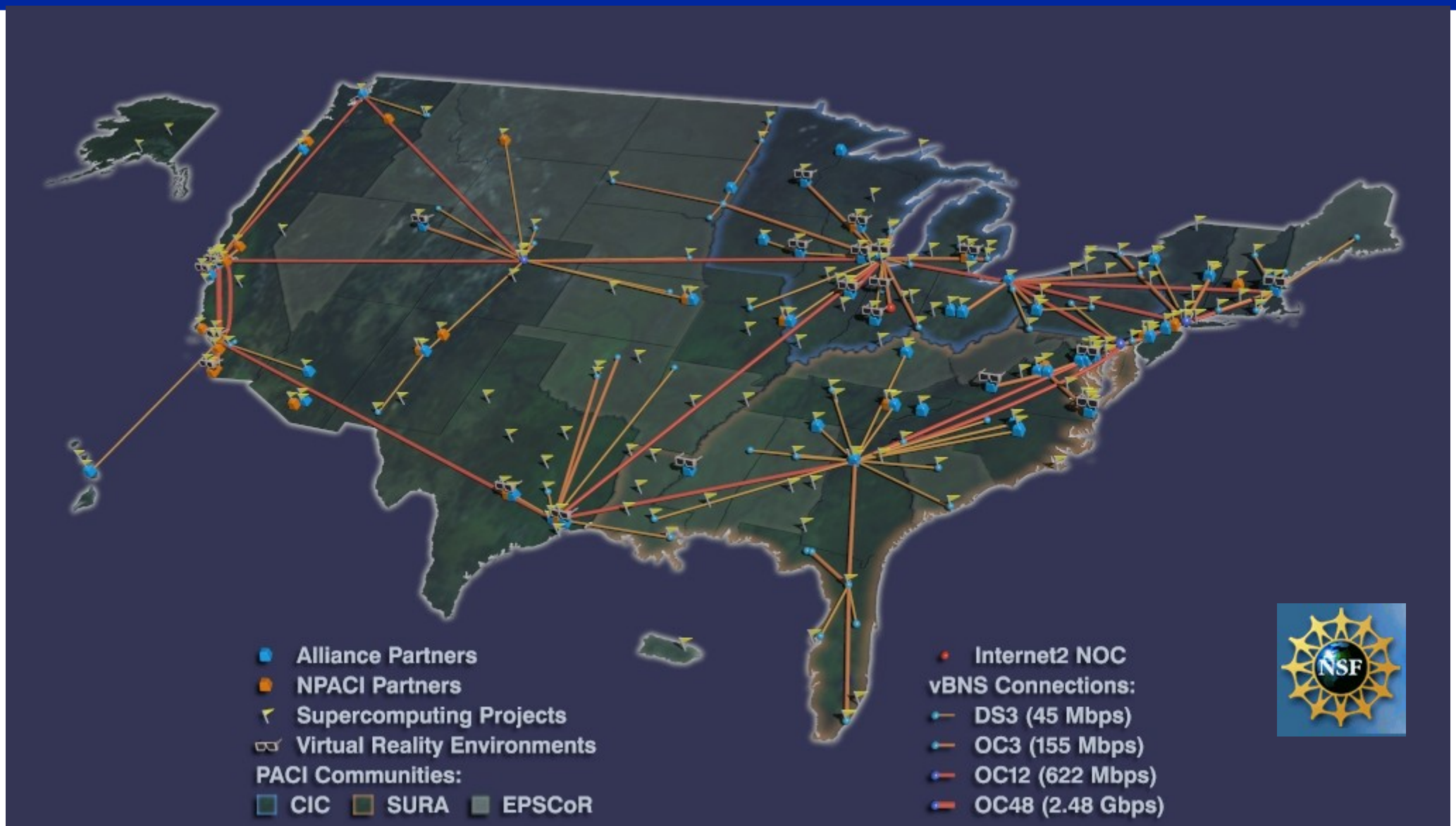
University of Illinois Urbana-Champaign

The Emerging Concept of a National Scale Information Power Grid





Prototyping America's 21st Century Information Infrastructure



NSF's PACI Enabling the Grid

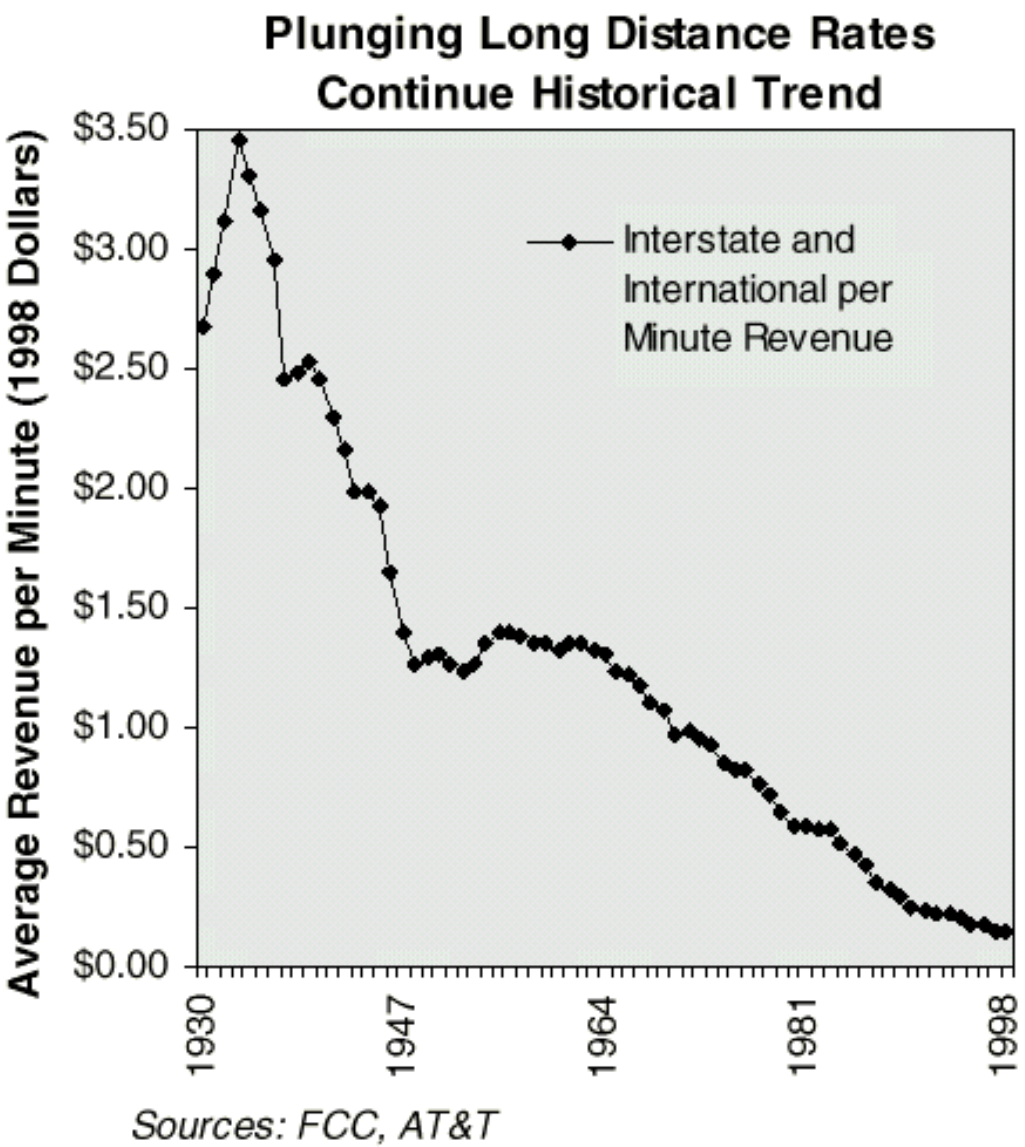
PITAC Recommended Increasing Federal IT R&D Investment by $1.4 Billion/Year

- **Four Priorities for Long Term Basic IT Research**
  - **Software**
  - **Scalable Information Infrastructure**
  - **High-End Computing**
  - **Socio-Economic Impacts**

Area	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Software	112	268	376	472	540
Scalable Information Infrastructure	60	120	180	240	300
High End Research	180	205	240	270	300
High End Acquisitions	90	100	110	120	130
Socioeconomic	30	40	70	90	100
Total	472	733	976	1192	1370

Recommending Funding Increases for IT R&D
($ in millions)

Long Distance Phone Calls Have Almost Dropped to Zero Cost

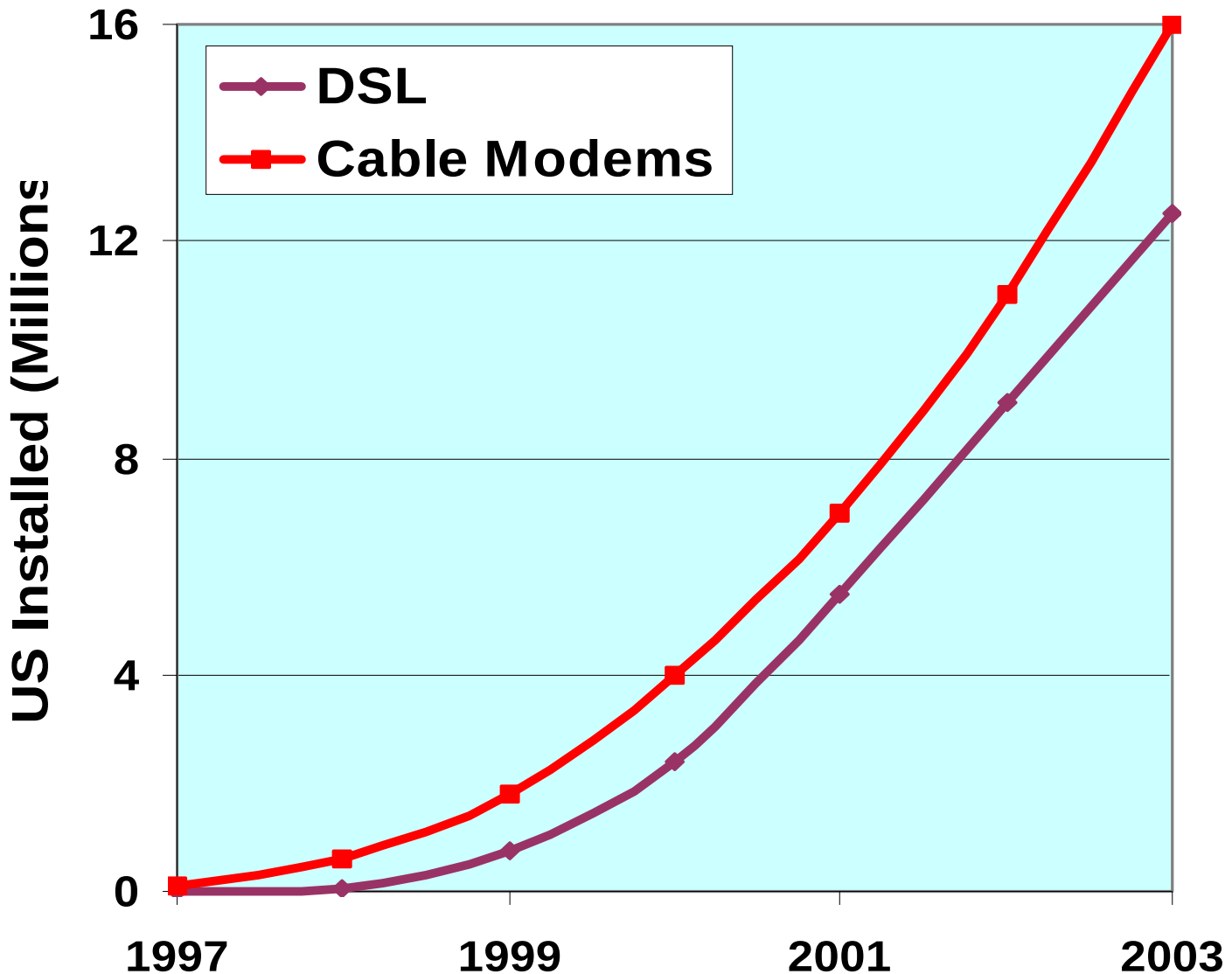


- **Implies Telecoms Will Need Alternate Revenue Streams**
  - **Cable TV**
  - **Broadband Internet Access**
  - **Wireless Telephone and Internet Access**

The National Bandwidth Divide

- **Current Situation-Islands of Bandwidth**
  - 100x Drop in Network Speed Moving
    - Off-Campus
    - Off-Corporation
  - Ethernet Speeds versus Modem Speeds
- **The Commercial Broadband Revolution**
  - Cable Modems
  - Fiber to the Curb (DSL)
  - Fiber to the Home
  - Satellite Dish
  - Broadband Wireless

Both Cable Modems and DSL Installations are Growing Rapidly



Source: Kinetic Strategies Inc.,
Glider Technology Report
Pioneer Consulting

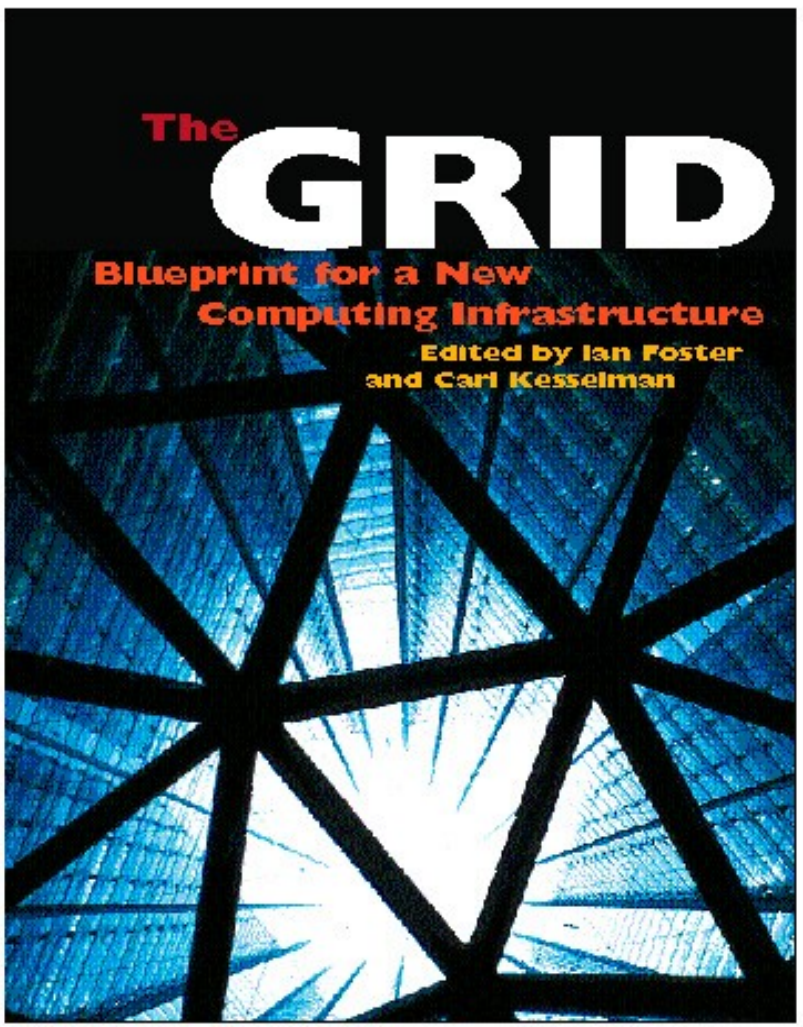
Extending the Grid to Wireless Devices, Embedded Sensors, and Processors

- **Emerging Internet of Embedded Devices**
  - Today 12 Billion Embedded Devices
  - Sun's JINI Provides Software Connectivity
  - Wireless Technologies on Steep Curve
  - Miniature GPS and Sensor Devices
- **Future Possibilities for New Applications**
  - Biocomplexity/Environment Deployment of Sensor Arrays
  - Precision Agriculture Water Management
  - Biomedical Readouts of Vital Health Factors
  - Untethered Education and Research
  - Early Warning of Complex Machine Failures (EMC, Cat)

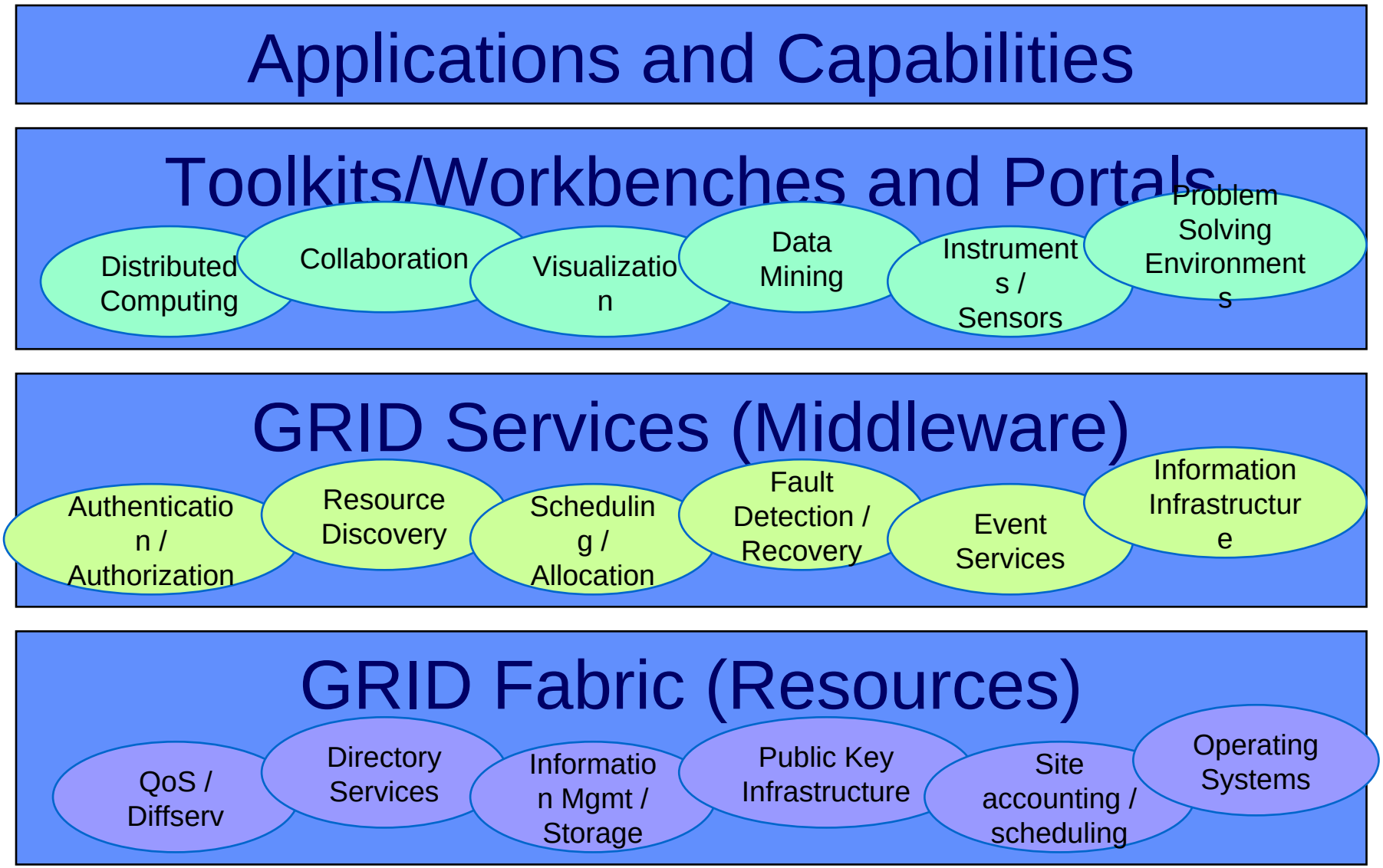
From Metacomputing to the Information Power Grid Blueprint for a New Computing Infrastructure

- **Ian Foster, Carl Kesselman (Eds), Morgan Kaufmann, 1999**
- **22 chapters by expert authors including:**
  - **Andrew Chien,**
  - **Jack Dongarra,**
  - **Tom DeFanti,**
  - **Andrew Grimshaw,**
  - **Roch Guerin,**
  - **Ken Kennedy,**
  - **Paul Messina,**
  - **Cliff Neuman,**
  - **Jon Postel,**
  - **Larry Smarr,**
  - **Rick Stevens,**
  - **and many others**

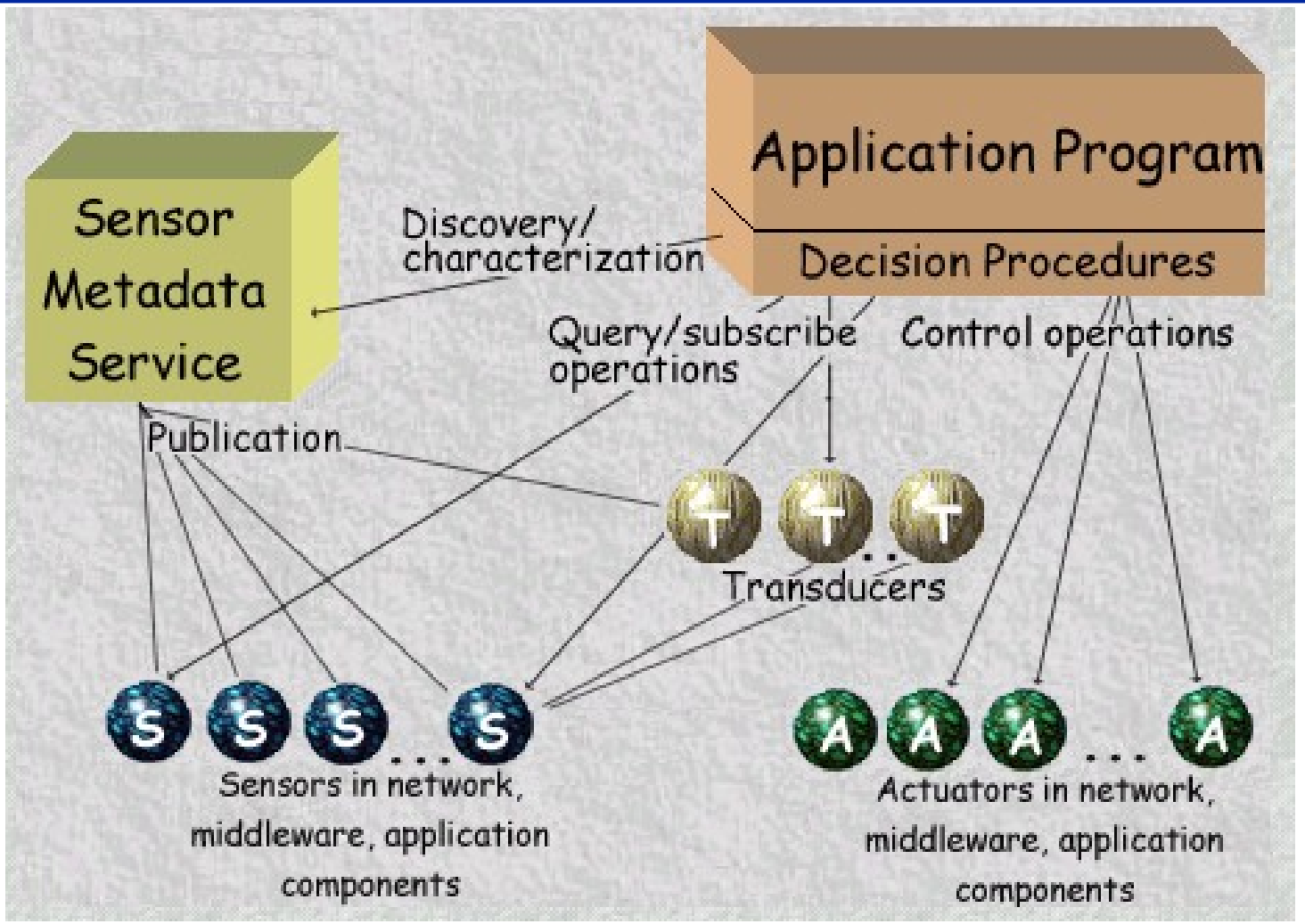
"A source book for the history of the future" -- Vint Cerf



"The Grid" Integrates Many Technical Projects



Network-Aware Middleware Introduces Measurement and Control to the Grid

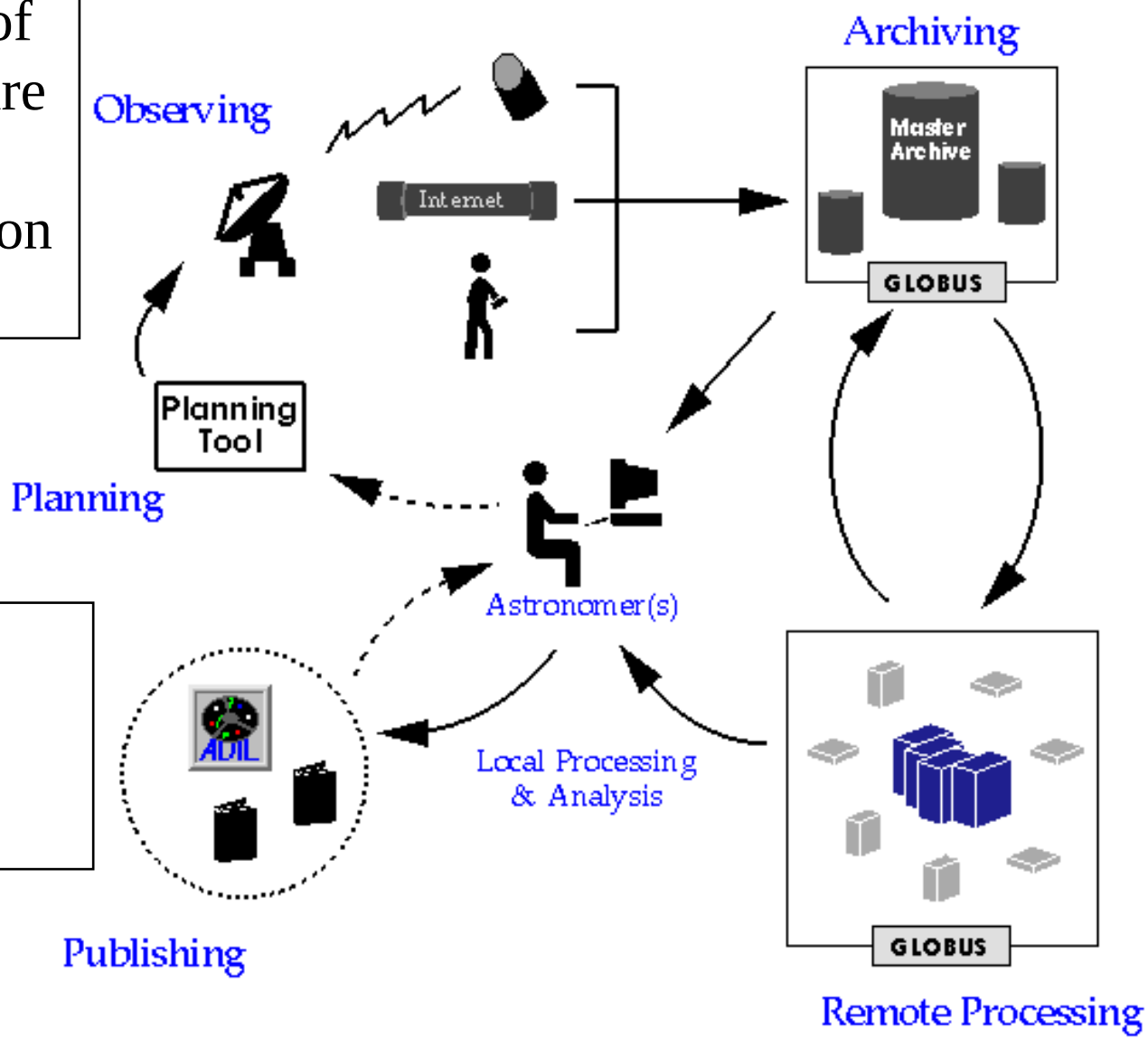


- Pablo and Autopilot performance analysis toolkits
- PPFS2 adaptive file system
- Globus wide-area computing infrastructure

Source: Dan Reed, UIUC (www-pablo.cs.uiuc.edu)

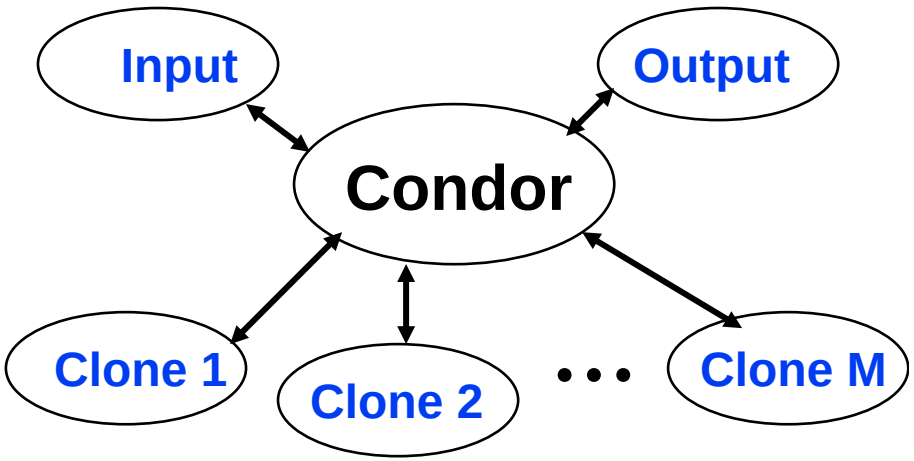
The "Virtual Telescope" Vision
Next Generation Scientific Instruments

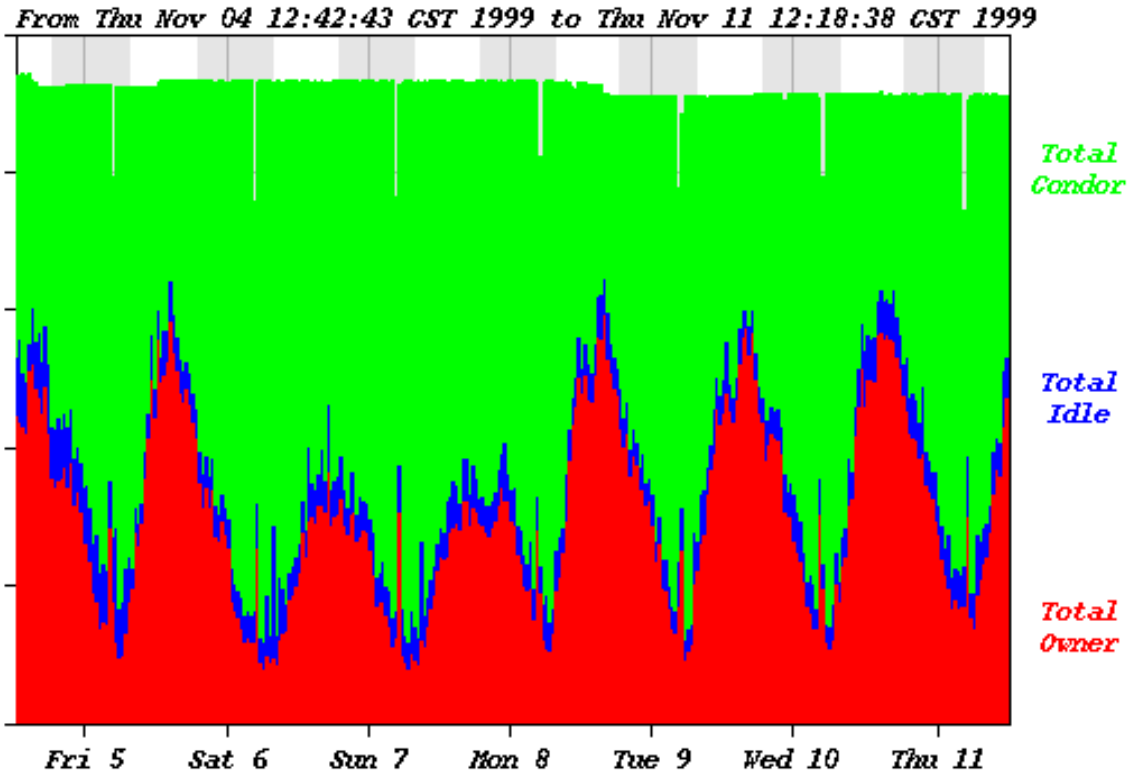
NRAO's AIPS ++ on Top of Globus Provides All Software for End-to-end Data Processing in Next Generation Networked Telescope



Astronomy Digital Image Library
(imagelib.ncsa.uiuc.edu)
One million hits!

Grid Computing (Condor) For Quantum Monte Carlo Materials Codes



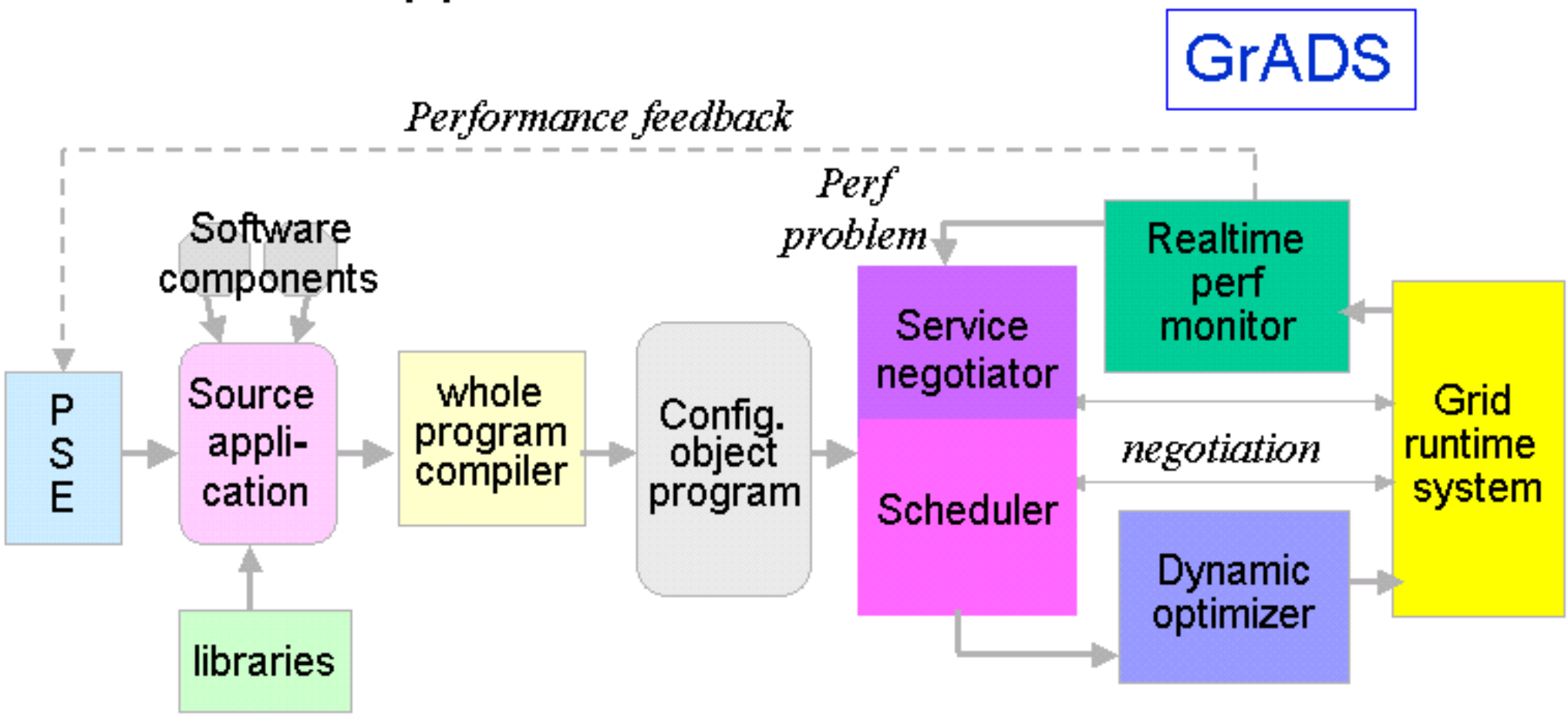


- Pool of Workstations: Condor Carries Out the Management, Distribution, Monitoring and Checkpointing
- Very Coarse-Grain Parallelism: Parameter Scans, Independent Searches, Monte Carlo
- Each Clone: Independent Random Number Streams - "Grand Averages" Evaluated at the Very End

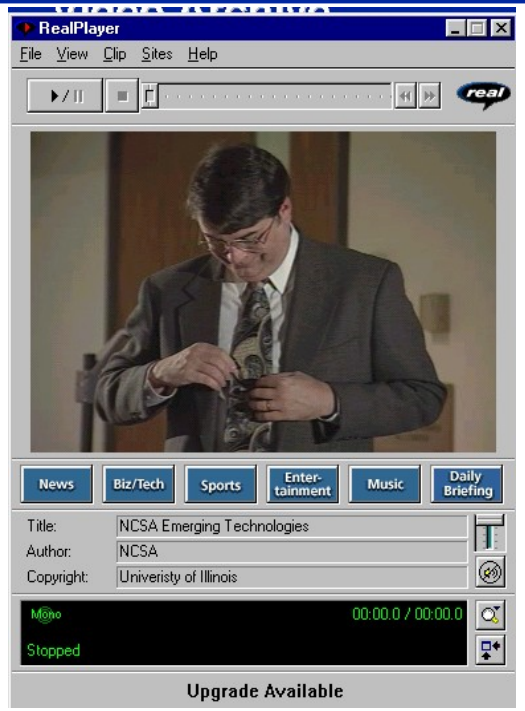
- UW Pool ~ 800 Workstations Www.Cs.Wisc.Edu/condor
- NCSA/BI Pool ~ 40 Workstations - Capable of Providing Free 9000 SGI CPU- Hours Per Month

Computer Science of Distributed Computing

- Vision: applications use computer cycles the way household appliances use electrons



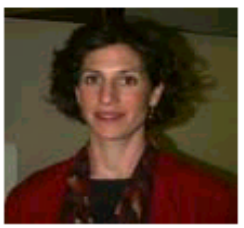
The Emergence of Web Based Lifetime Learning and Distance Education





Smarr, Larry *smarr@ncsa.uiuc.edu*

History and Introduction to NCSA 1/22/98
- Video Abstract
- Slides from presentation
- Video of presentation
- Biography



Kanfer, Alaina (Instructor)
alaina@ncsa.uiuc.edu

Evaluation Research Methods & Results 1/29/98
- Slides from presentation
- Video of presentation



Oakley, Burks II *oakley@uiuc.edu*

UI-OnLine: The Realization of the 21st Century Land-Grant University 2/12/98
- Video Abstract
- Slides from presentation
- Video of presentation



Plante, Ray

Radio Astronomy Instrumentation 4/16/98
- Video Abstract
- Slides from presentation
- Video of presentation

- **> 800 Video Files Downloaded During Semester (2/3 Outside)**
- **> 300 Video Files Downloaded Month After Class (2/3 Outside)**

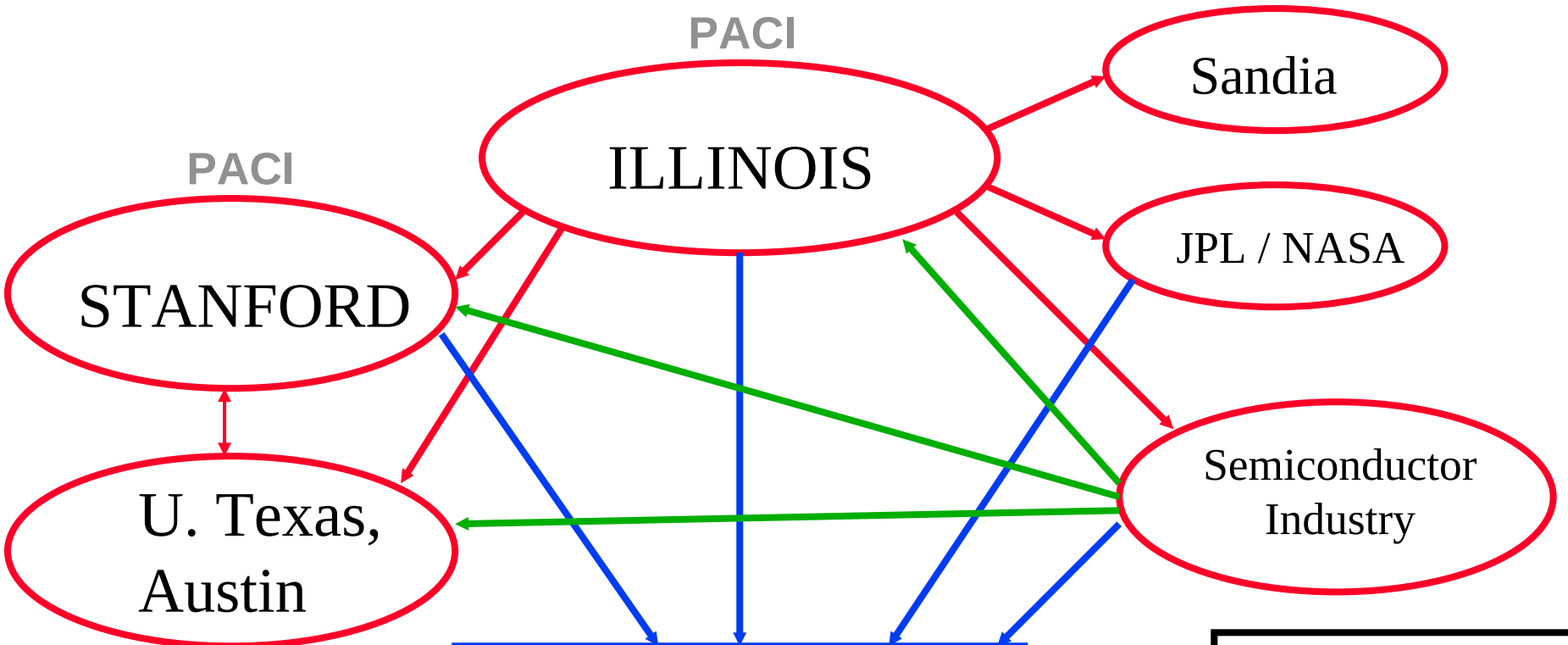
Access Grid Virtual Group Meeting Spaces Making IP Multicast Audiovideo Really Work

- **Access Grid Kits (ANL)**
  - Mural Displays
    - Multiple Front or Back Projectors
    - Software to Drive System
  - Audio
    - Stereo, Quad, 3-D
- **Installed on 3rd & 5th Floor BI**
  - Cost Effective
    - Base System < $50k
    - Driven by PCs
    - Desktop Accessible
  - 10 Sites in FY99
  - 20 Sites in FY00



The Nanomaterials Devices Grid

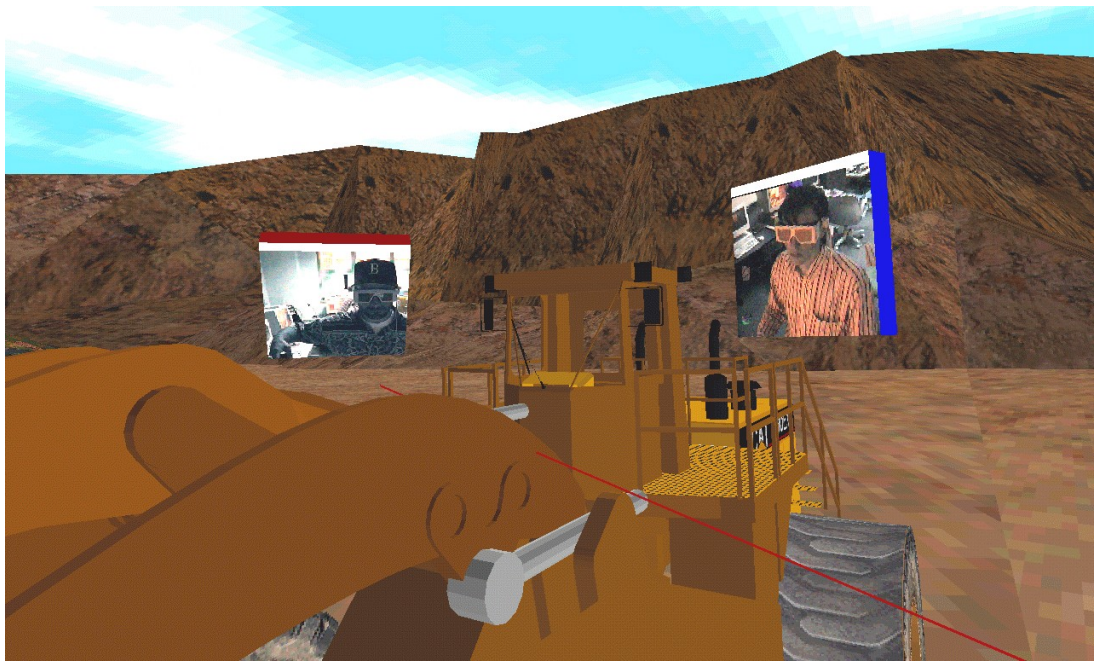
Focus on Collaborative Working Groups with Distributed Tools



NSF - Distributed Center for Advanced Semiconductor Simulation (DesCArtES): Illinois, Purdue, Stanford, Arizona State.

National Center for Computational Electronics (NCCE) 1988-1999

Corporations Use the Grid For Virtual Prototyping



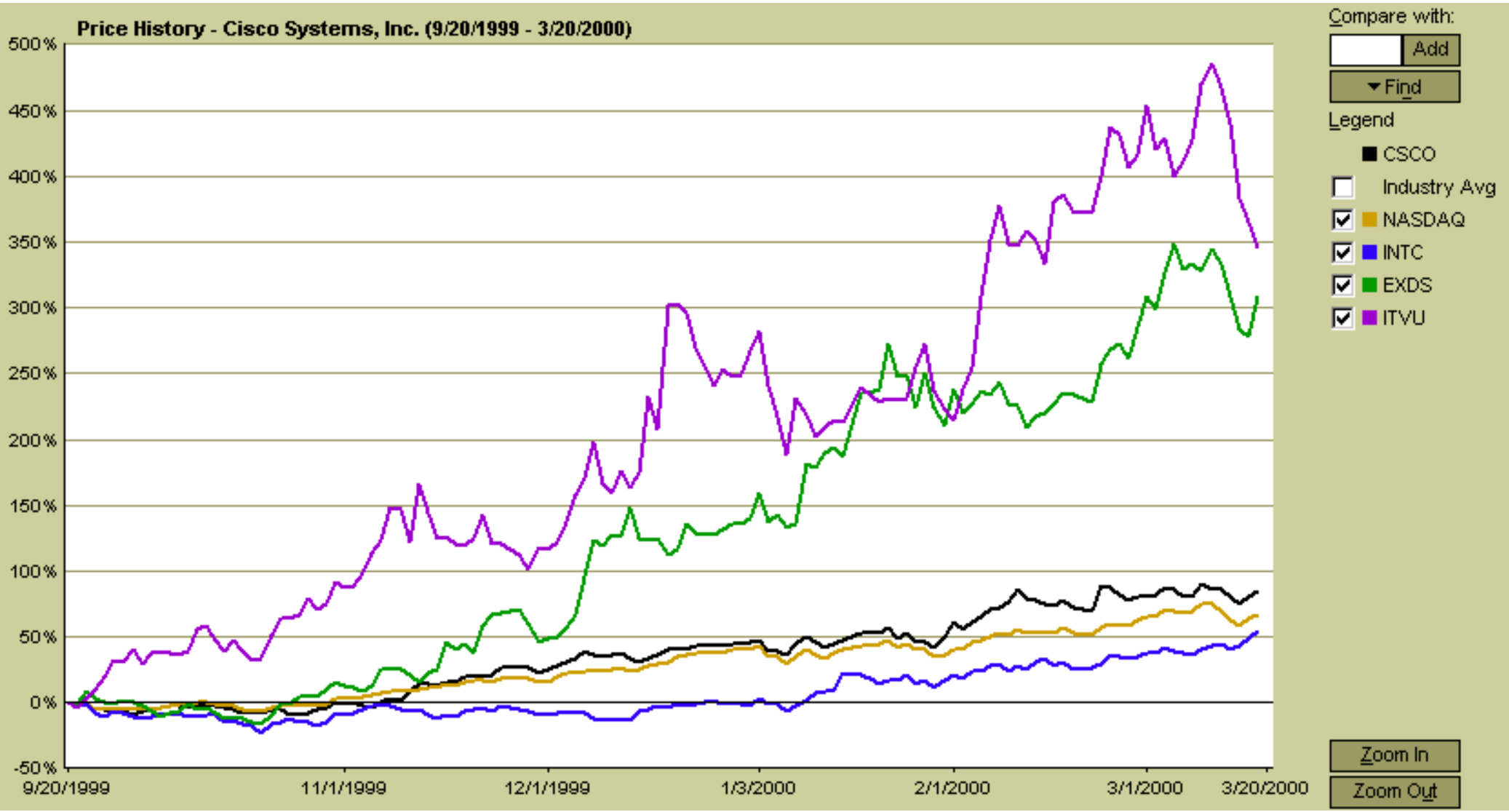


Real Time Linked Virtual Reality and Audio-Video Between NCSA, Peoria, Houston, and Germany

The New Grid Infrastructure Industries

- **Exodus**
  - 24/7 Server Warehousing
- **WamNet**
  - Storage Content Distribution
- **Akamai/InterVU**
  - Static and Streaming Content Distribution
- **WebEx**
  - Dynamic Content Distribution
- **Application Service Providers (ASPs)**
  - Application Execution Distribution
- **Entropia**
  - Computing Content Distribution

The Grid Industries are Growing Much Faster Than the Component Industries



Last Six Months, InterVU and Exodus vs. Cisco and Intel

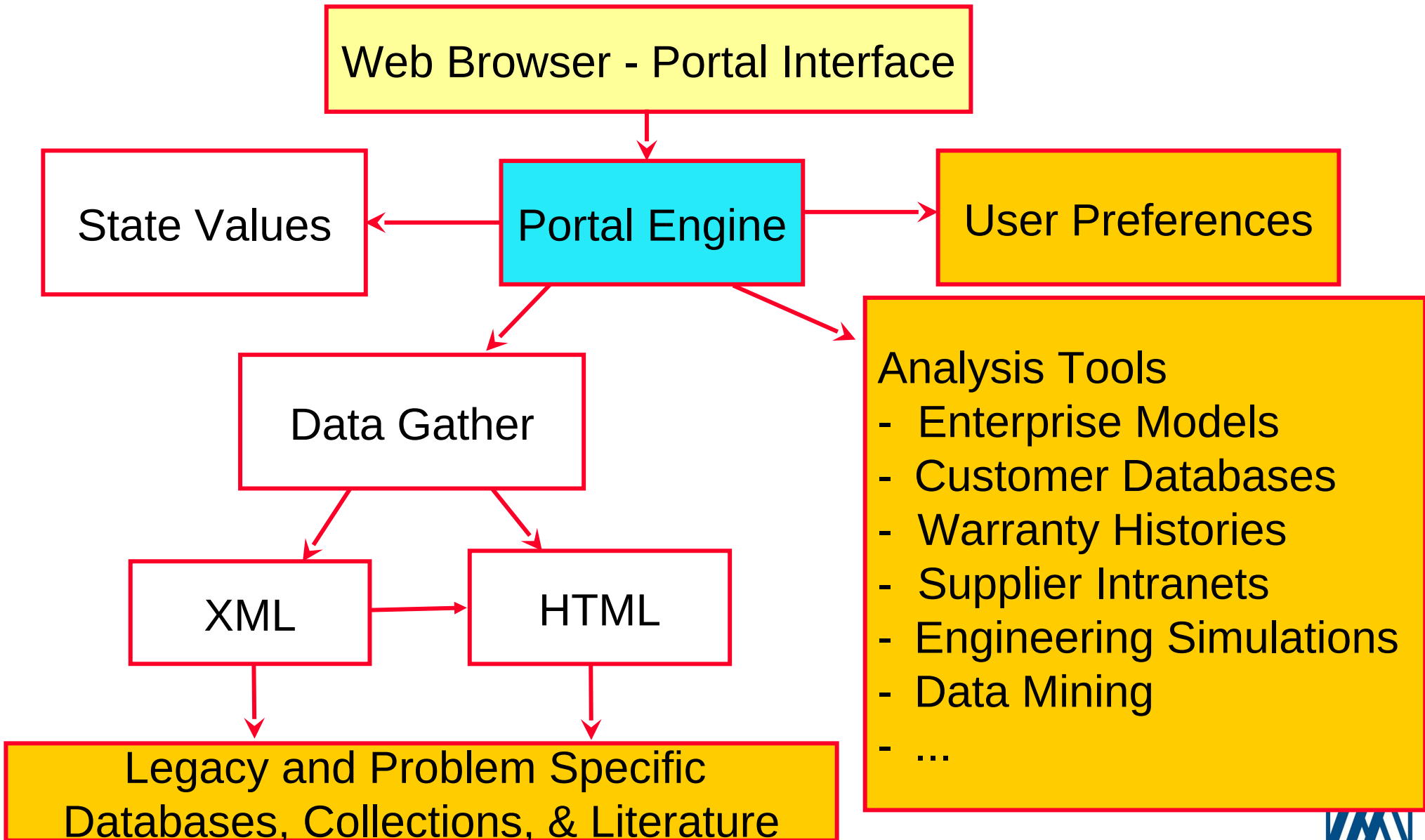
Akamai - the Largest Global Provider of Internet Content, Audio and Video Delivery Services

- **Akamai**
  - Has 3000 Servers
  - In Over 40 Countries
  - Directly Connected to More Than 100 Different Telecom. Networks
- **InterVU**
  - Serves 100,000 Streaming Media Requests/Day
  - 70% of the Most Hit Web Sites with Streaming Media Use InterVU (CNN, CNBC, MSNBC, House of Blues,…

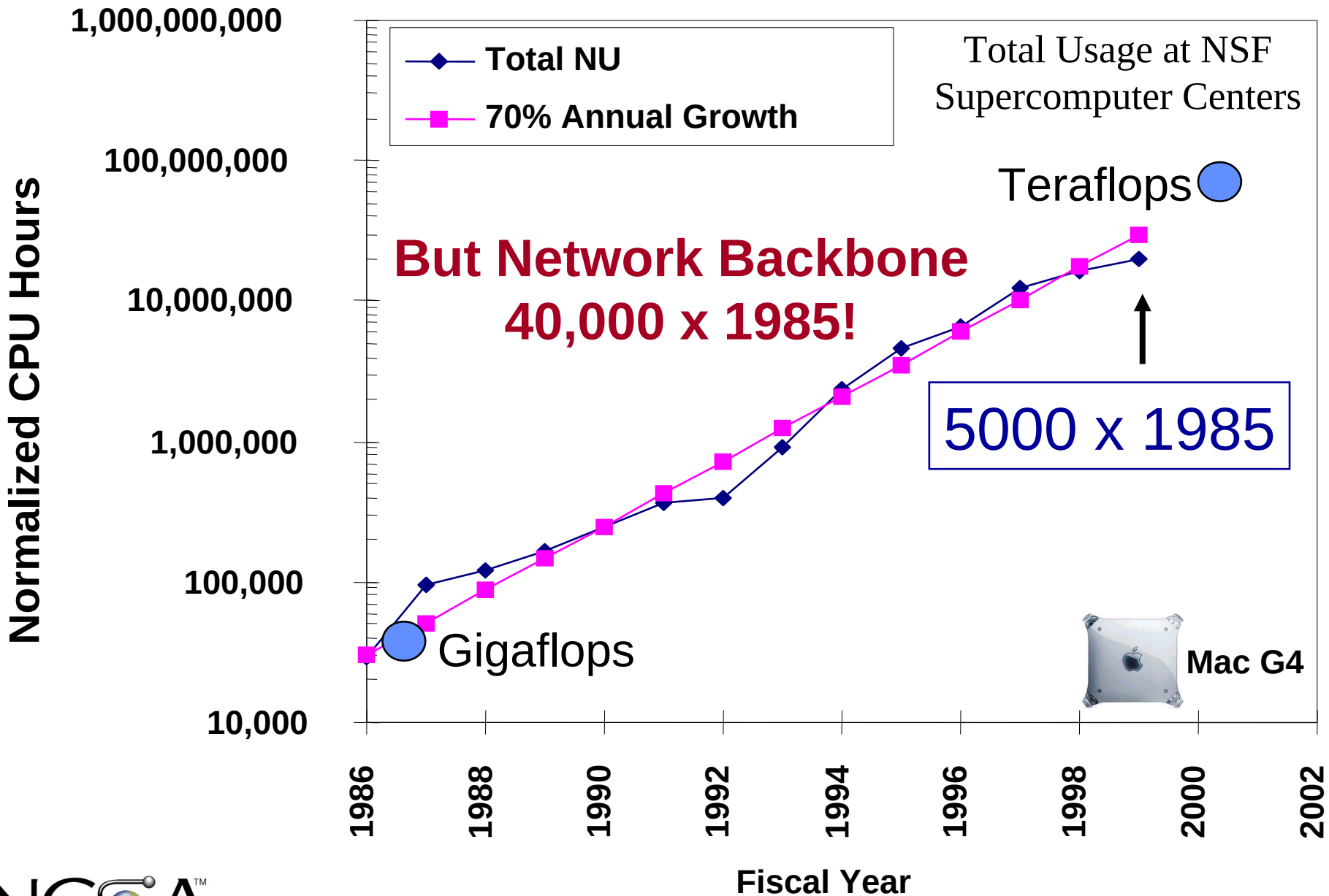


- **Akamai Had its IPO November, 1999**
  - Current Market Capitalization $20 Billion
- **Akamai Bought InterVU in February, 2000**
  - With Stock for $2.8 Billion

Building Portals to Unify Commercial and Research Computing

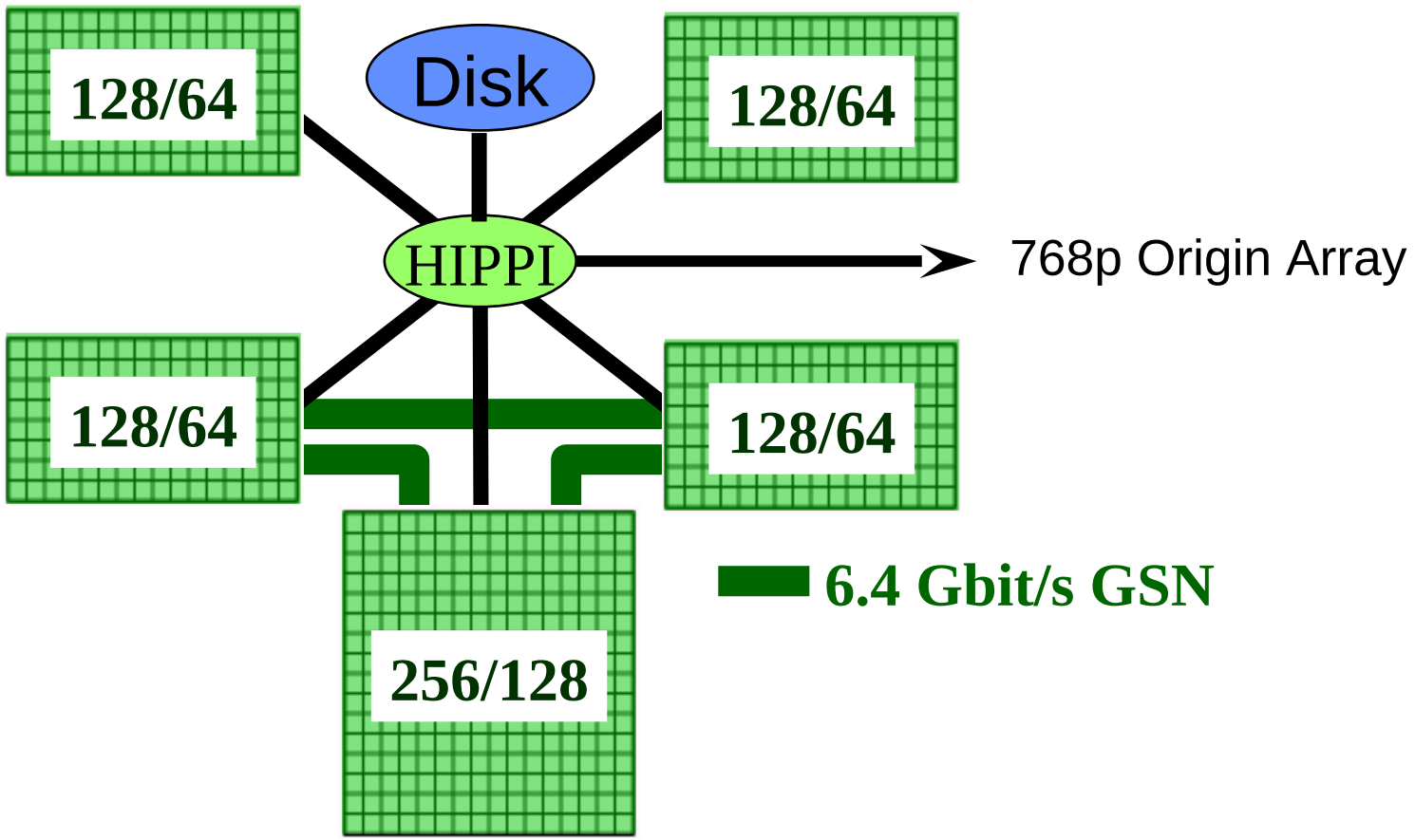


The Exponential Demand Function of Computational Science and Engineering



Source: Quantum Research; Lex Lane, NCSA

NCSA's Tightly Coupled Origin Cluster



- Supports 128-, 256-, 512-, or 768-way Parallelism
- Dedicated Access for Very Large Projects
- "Unobtrusive" Grand Challenges

First Teraflops Computer Accepted in PACI for Academic Access

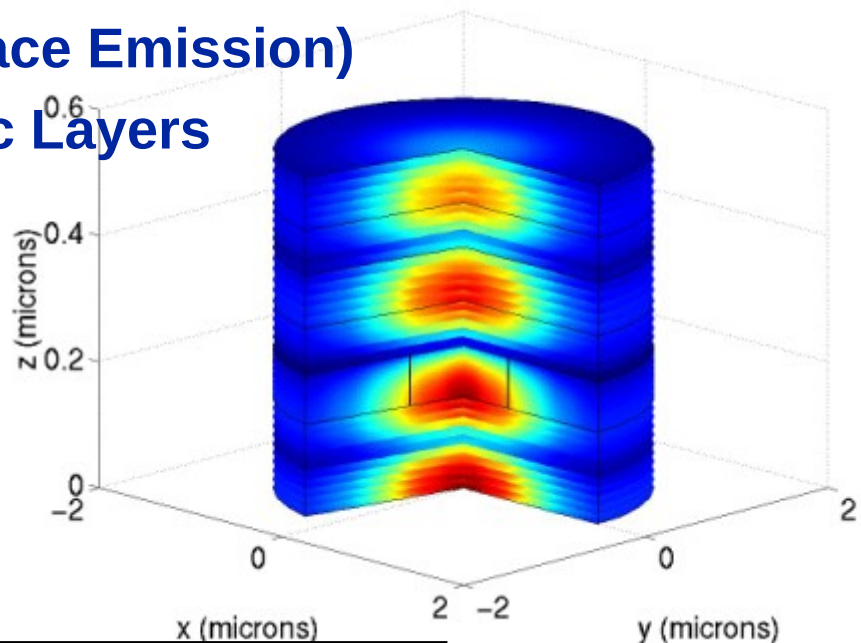


SDSC IBM SP with 1152 Processors

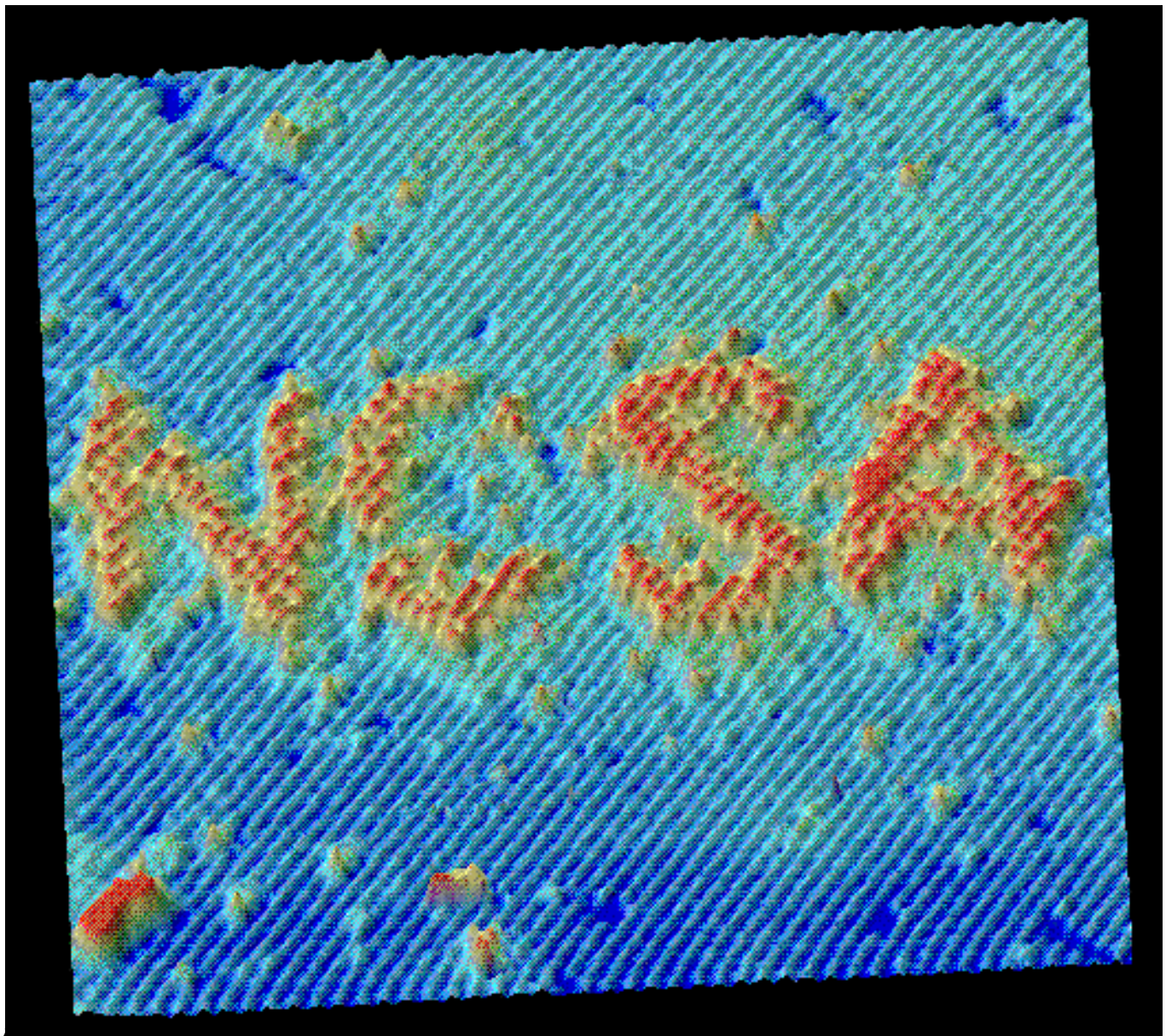
http://www.sdsc.edu/Live/teraflops.html

Supercomputer Engineering Design of Optoelectronic Semiconductor Laser Diodes

- **Three Interacting Problems**
  - Carrier Transport (Shockley Eqns.)
  - Electromagnetic Modes (Maxwell Eqns.)
  - Quantum Mechanical Energy States (Schroedinger Eqns.)
- **Vertical-Cavity Surface-Emitting Lasers**
  - Optical Cavity Formed in Vertical Direction
  - Light Taken From Top of Device (Surface Emission)
  - Mirrors Formed by Stacks of Dielectric Layers

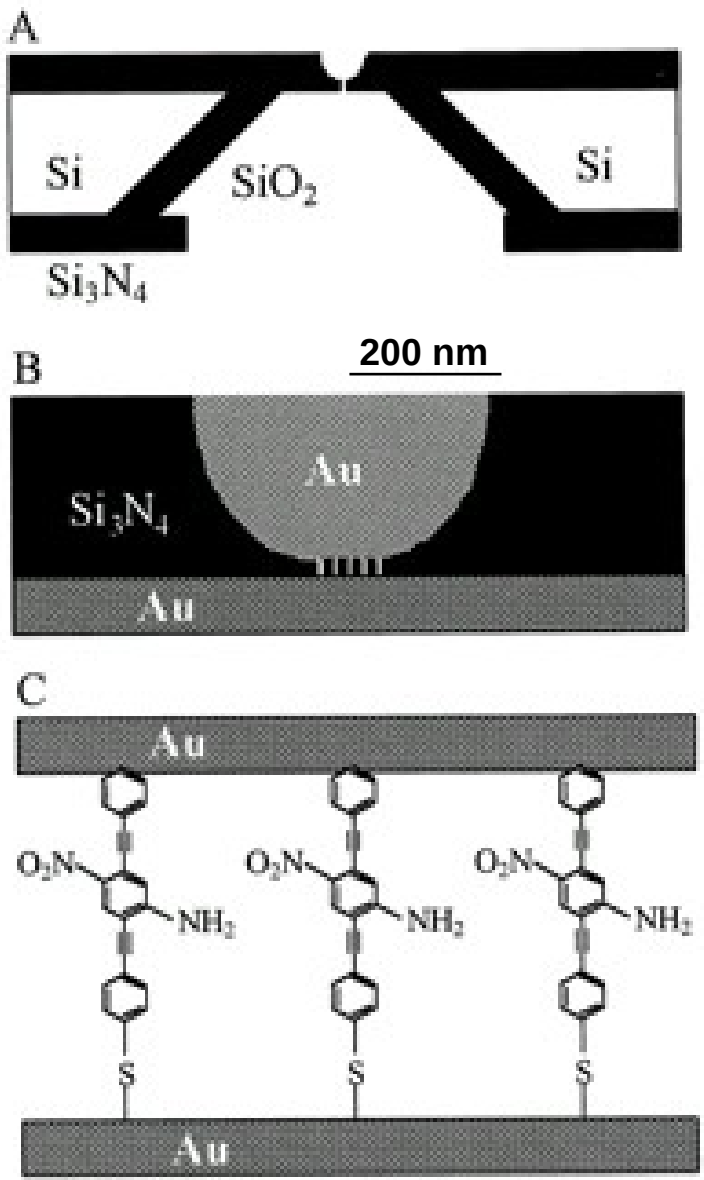


The Era of Nanolithography
BI / NCSA Remote Scanning Tunneling Microscope

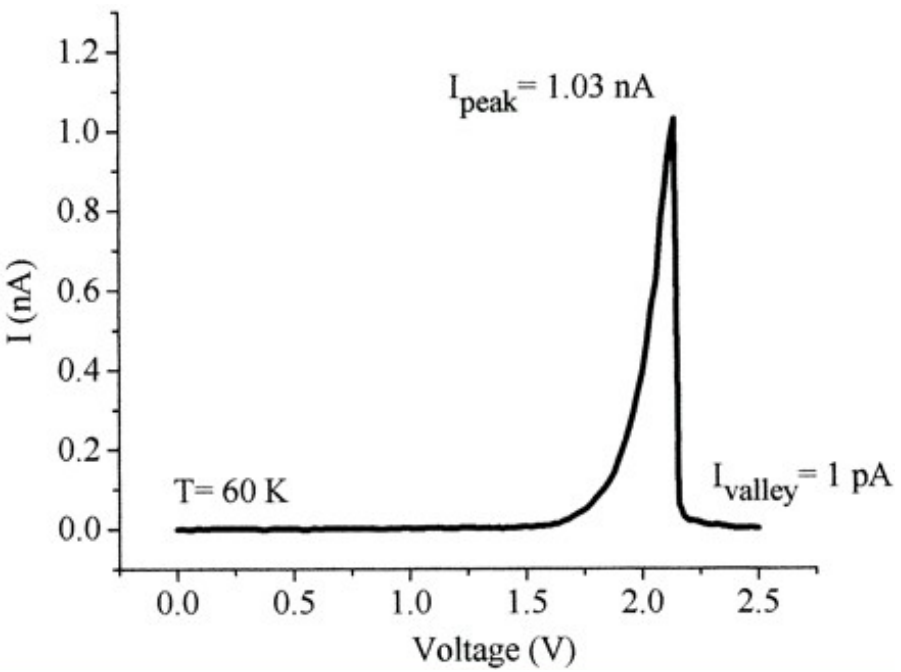


Source: Lyding, Brady (UIUC Beckman Institute)

Molecular Nanostructure Logic Gates Self-Assembled Monolayer Junction



- One Million Times Smaller Area than Silicon Device
- Second US Group (UCLA, HP was First)
- Schematics of Device Fabrication.
  - (A) Cross Section of a Silicon Wafer With a Nanopore Etched Through a Suspended Silicon Nitride Membrane.
  - (B) Au-SAM-Au Junction in the Pore Area.
  - (C) Blowup of (B) With Nitroamine Redox Center Sandwiched in the Junction

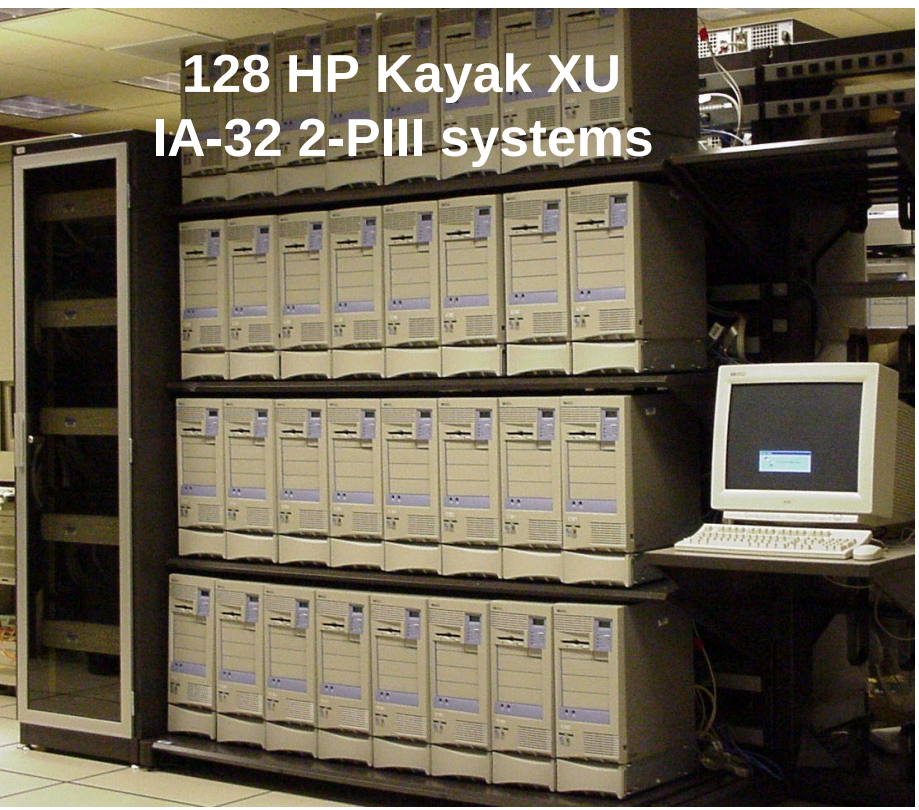


Nanoelectronics Holds the Promise of Extending Moore's Law

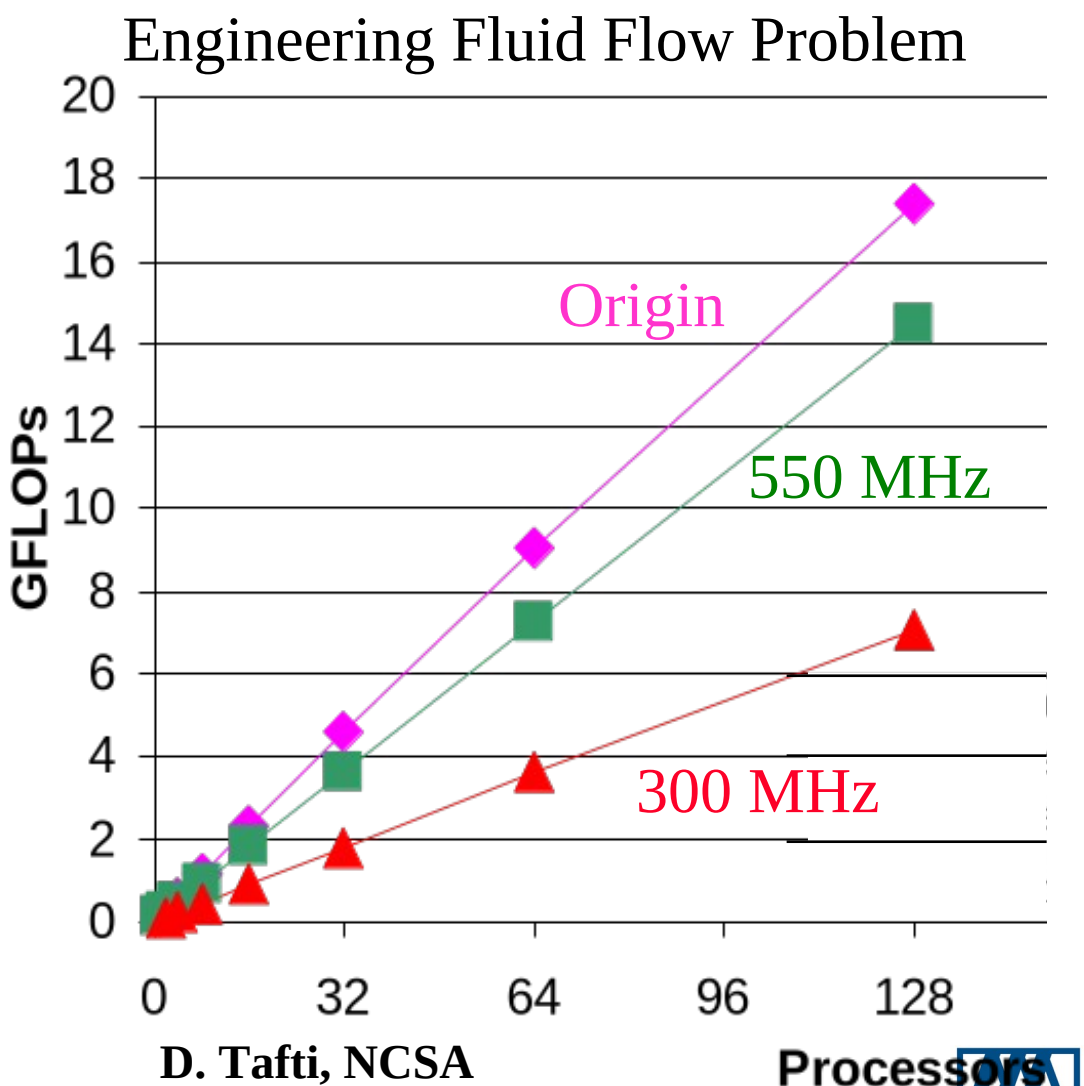
"Because of the recent rapid and radical progress in molecular electronics – where individual atoms and molecules replace lithographically drawn transistors – and related nanoscale technologies, we should be able to meet or exceed the Moore's Law rate of progress for another 30 years."

--Bill Joy, in "Why the Future Doesn't Need Us", Wired April 2000

The Movement Toward Commodity Supercomputing



Using NT, Myrinet Interconnect, and HPVM



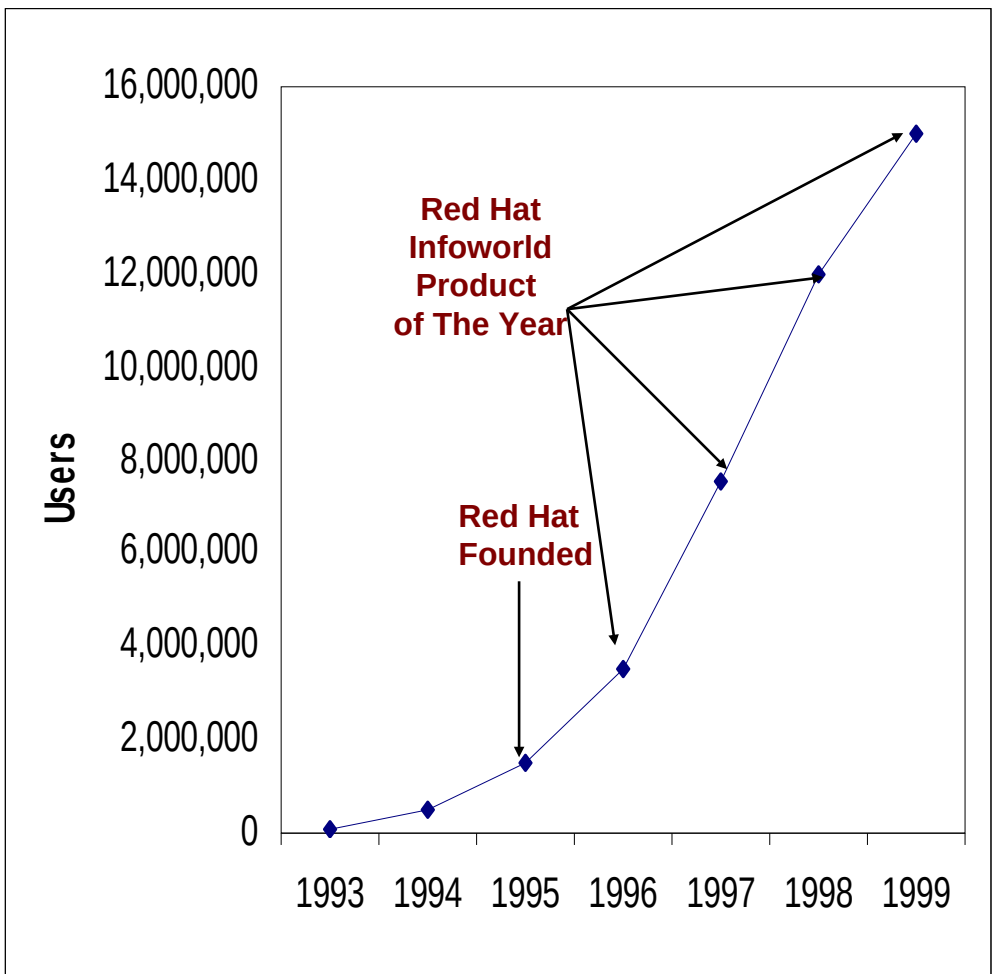
PC Superclusters Can Run Either Microsoft NT or Linux

Alliance Plans to Upgrade to 512 Processors in 2000

Formal Comparison of NCSA NT and UNM Linux SC at SC99 Tutorial

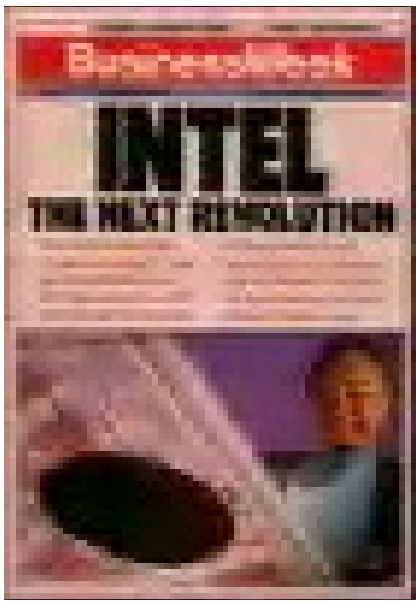


128 PIIs (450Mhz)



ASCI Red May Turn Out to Have Been a Real Glimpse of the Future

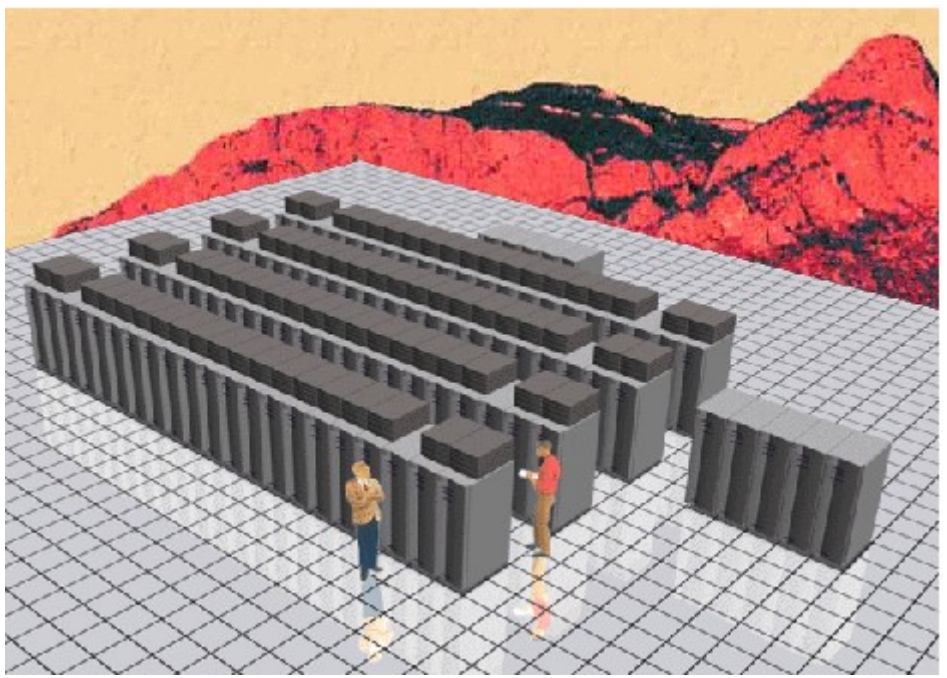
1988-Andy Grove Prediction



"…a chip so powerful it will become the heart of even the biggest computer…"

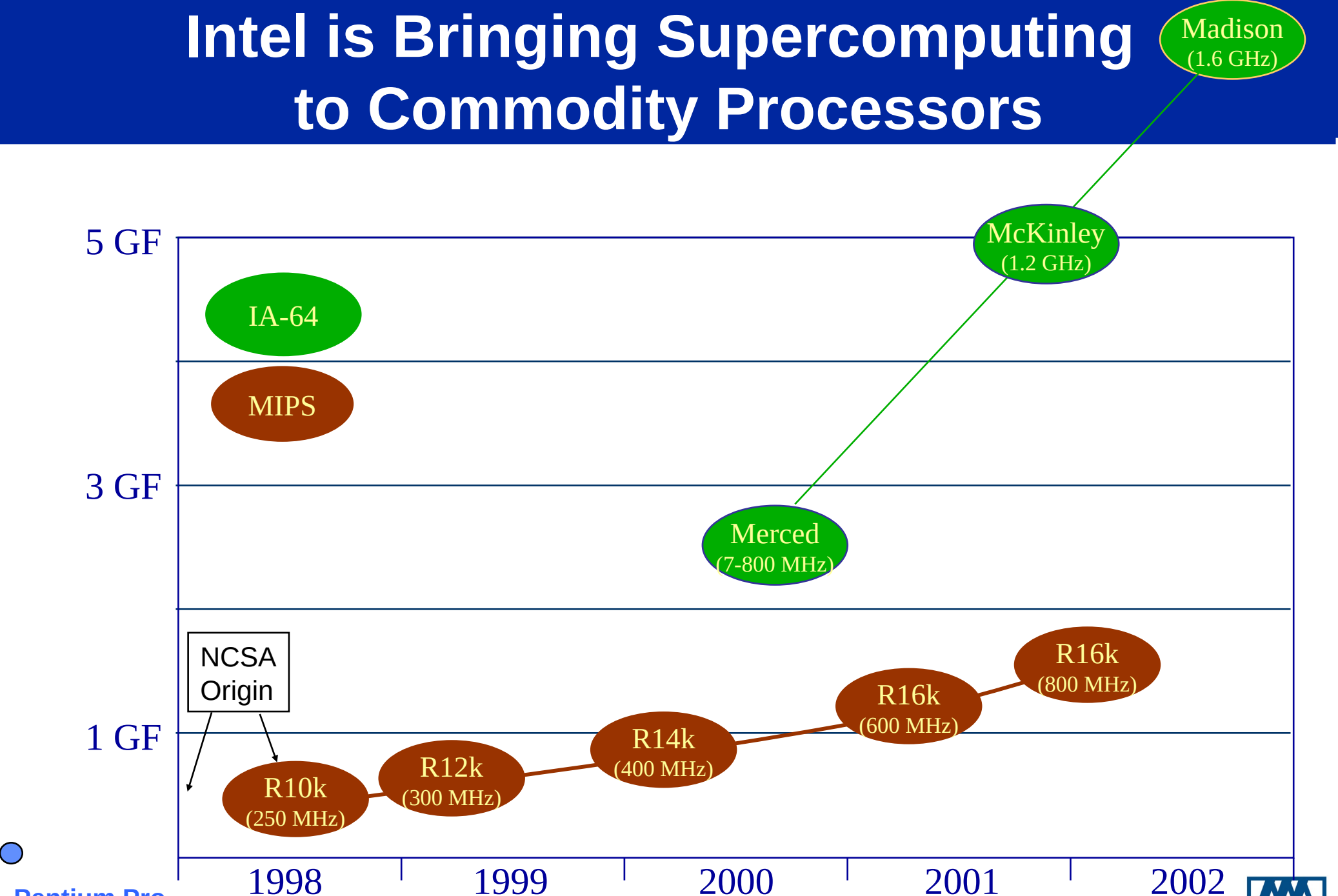
-Business Week, September 25, 1988

1996-Sandia Intel Teraflop

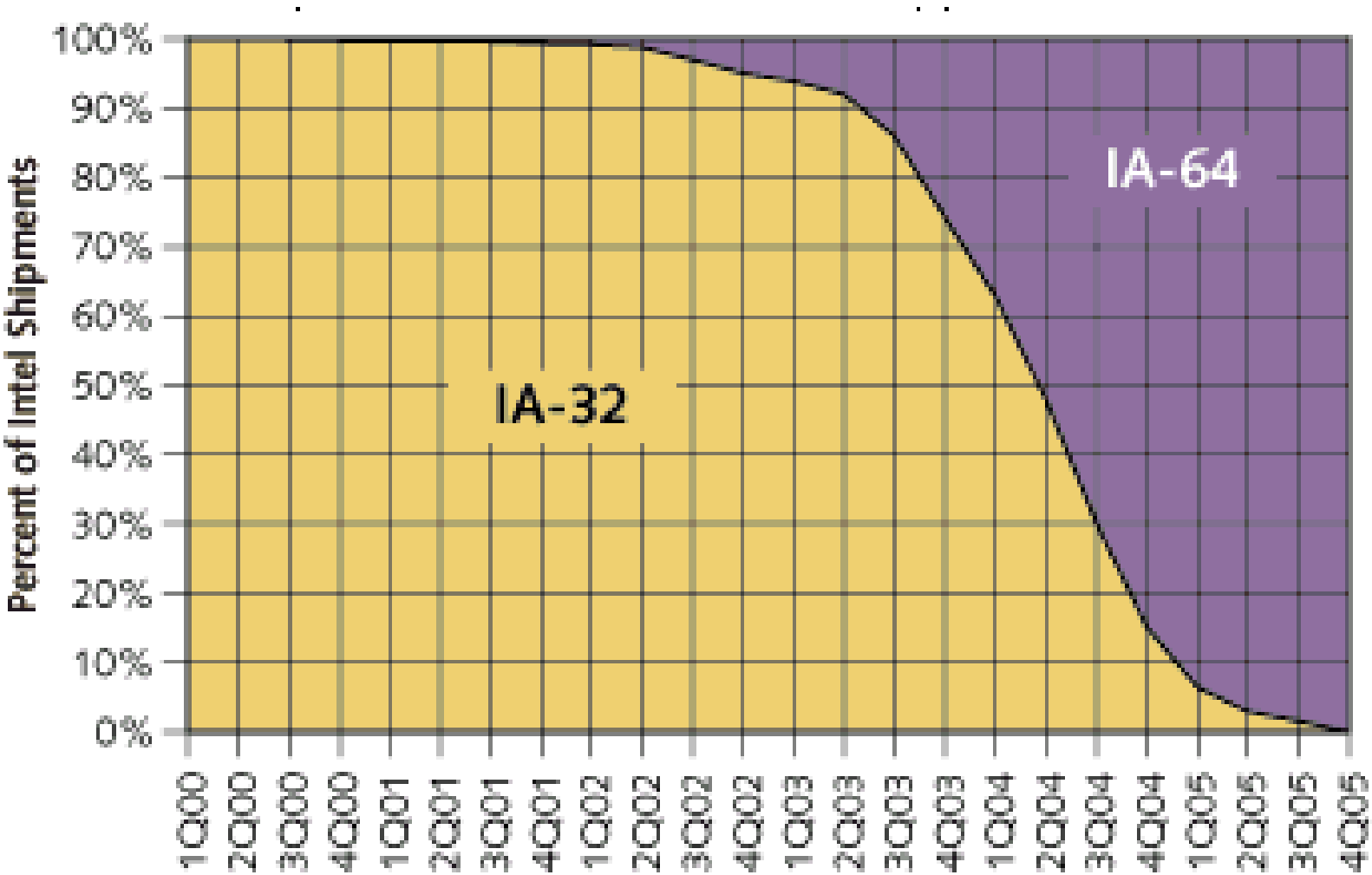


10,000 Intel Pentium Pros!

Intel is Bringing Supercomputing to Commodity Processors



Intel IA-64 May Lead to Enormous Installed Base



Projected Expansion of Intel IA-64 Installed Base

Source: Linley Gwennap

Editorial Director, *Microprocessor Report*

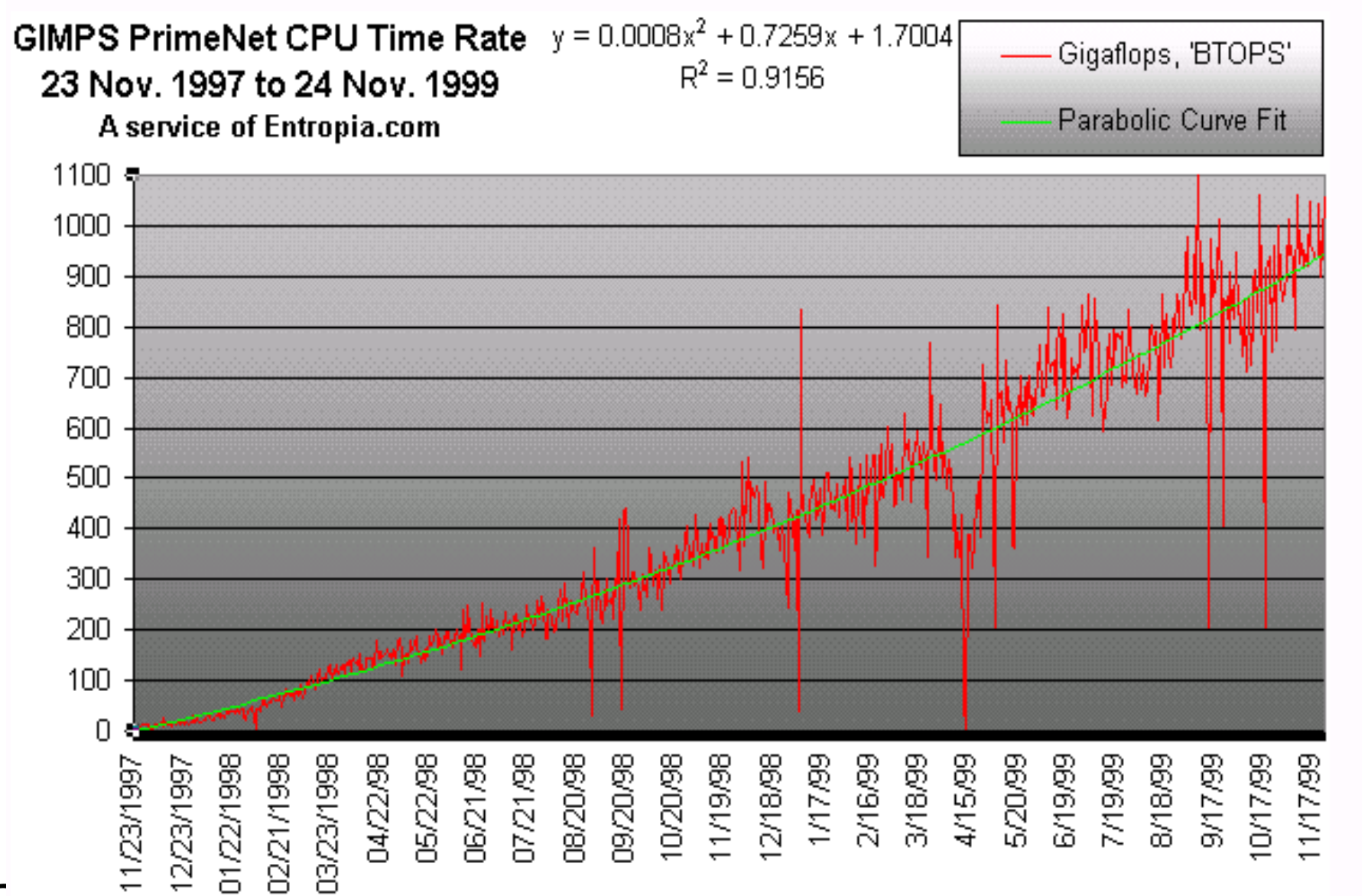
The Emerging HPC Open Source Movement

- **Commodity Physical Components**
  - Microprocessors [eg. Intel IA-64]
  - Interconnect [eg. OC-192 and 10 gigabit Ethernet]
  - Build Computers by the Yard-Up to 100,000 Processors
- **Software Layers Become Open Source**
  - OS [eg. Extreme Linux]
  - Libraries [FFT, Linear Algebra]
  - Middleware [eg. Globus, HPVM, MPICH]
  - Applications [eg. Cactus, QCD, NSF & ASCI users]
  - Visualization [eg. VTK]
- **PITAC Subcommittee**
  - Open Source Software for HPCC
  - Study Issues and Make Recommendations
    - Over Next 6-9 Months

Can We Harness PCs on the Web to Create Virtual Supercomputer?

- **Seti@Home**
  - 35 GB New Data Per Day from Arecibo Telescope
  - 435,000 Active Users (1.6 Million Users Total)
  - So Far Over 160,000 CPU-Years (90% on Windows)
  - Sustains 6TF
- **Distributed.Net**
  - Breaking Cryptographic Keys
  - Over 100,000 Active Computers (Mostly PCs)
  - Peak 7TF
- **Entropia.com**
  - Discovering 10 Million Digit Prime Numbers
  - Primenet Has 30,000 Active Users
  - Sustains over 1TF

Entropia.com's PrimeNet Grew to a Teraflop in Only Two Years



Building a Megacomputer – One Million PC Processors Infrastructure

- **Connectivity**
  - Cable Modems and DSL are Rapidly Growing
  - Each Will Reach ~ 10 Million Sites by 2002
  - Connected PCs are Always On and Available
  - Bandwidth is Much Greater than Modem
- **Processors**
  - Vast Majority will be
    - Intel Processors
    - Microsoft Windows Operating System
  - Largest Country Providing Cycles Will Be U.S.
- **By 2003 a Million Processors will Have a Speed of:**
  - 1000 Teraflop Supercomputers!

Why Will a Million Processor Computer Be Different?

- **Individual Processors Running at Gigaflops**
  - **One Million Means a Collective Petaflops**
  - **One Petaflops is Roughly a Human Brain-Second**
    - **Morovec-Intelligent Robots and Mind Transferral**
    - **Koza-Genetic Programming**
    - **Kurzweil-The Age of Spiritual Machines**
    - **Joy-Humans an Endangered Species?**
- **Will the Grid Become Self-**
  - **Organizing**
  - **Powered**
  - **Aware?**

Things Are About to Get Very Interesting…

