“A Mobile Internet Powered by a Planetary Computer"

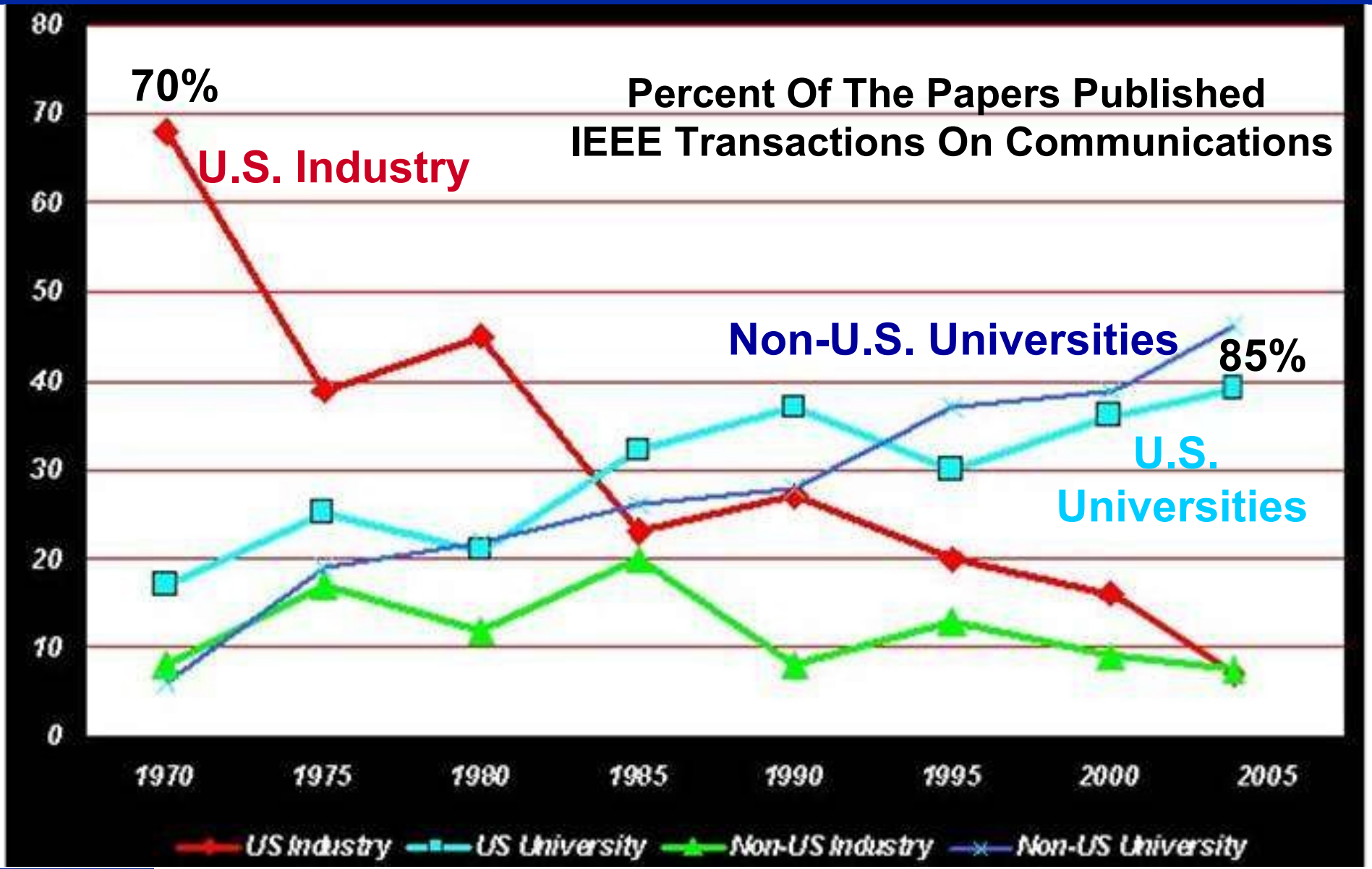
Banquet Talk
Motorola SABA Meeting 2005
San Diego, CA
April 21, 2005

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD

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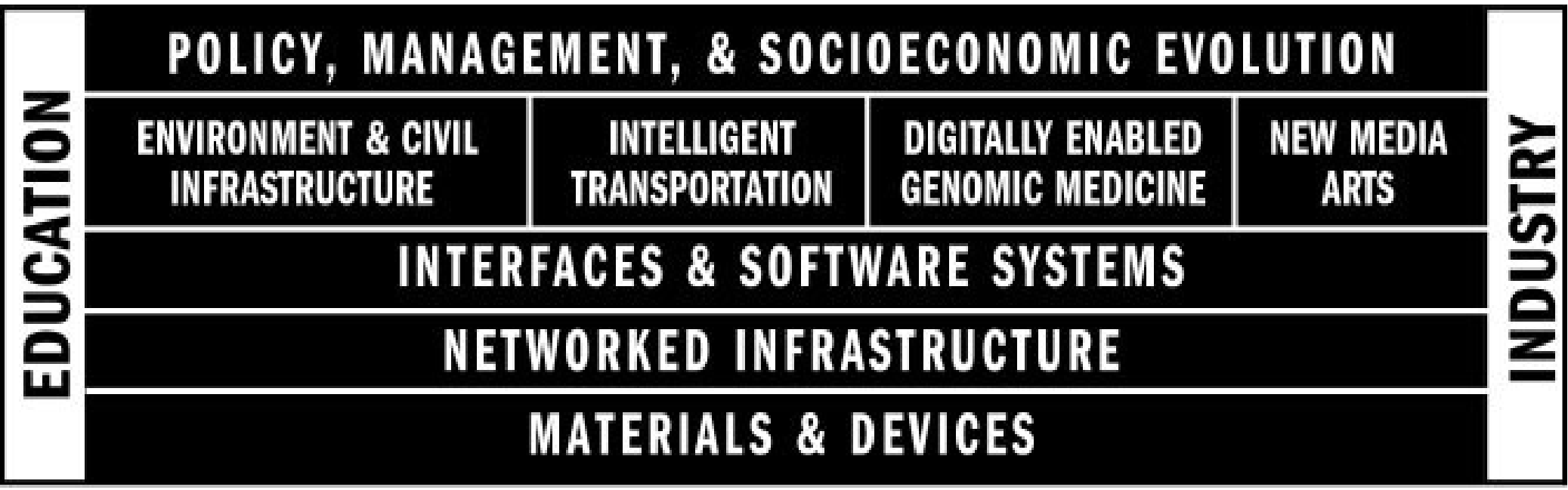
Where is Telecommunications Research Performed? A Historic Shift



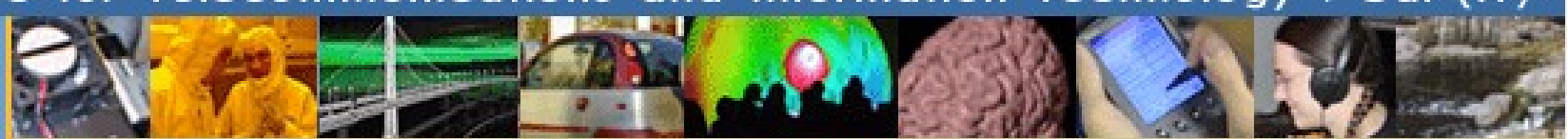
Source: Bob Lucky, Telcordia/SAIC

Calit2 -- Research and Living Laboratories on the Future of the Internet

UC San Diego & UC Irvine Faculty
Working in Multidisciplinary Teams
With Students, Industry, and the Community



www.calit2.net



Two New Calit2 Buildings Will Provide a Persistent Collaboration "Living Laboratory"



- Will Create New Laboratory Facilities
  - Nano, MEMS, RF, Optical, Visualization
- International Conferences and Testbeds
- Over 1000 Researchers in Two Buildings
- 150 Optical Fibers into UCSD Building



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California Provided $100M for Buildings
Industry Partners $85M, Federal Grants $250M

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The Internet Is Extending Throughout the Physical World
A Mobile Internet Powered by a Planetary Computer

- **Emergence of a Distributed Planetary Computer**
  - Parallel Lambda Optical Backbone
  - Storage of Data Everywhere
  - Scalable Distributed Computing Power
- **Wireless Access--Anywhere, Anytime**
  - Broadband Speeds
  - "Always Best Connected"
- **Billions of New Wireless Internet End Points**
  - Information Appliances
  - Sensors and Actuators
  - Embedded Processors
- **Transformational From Medicine to Transportation**

"The all optical fibersphere in the center finds its complement in the wireless ethersphere on the edge of the network."
--George Gilder

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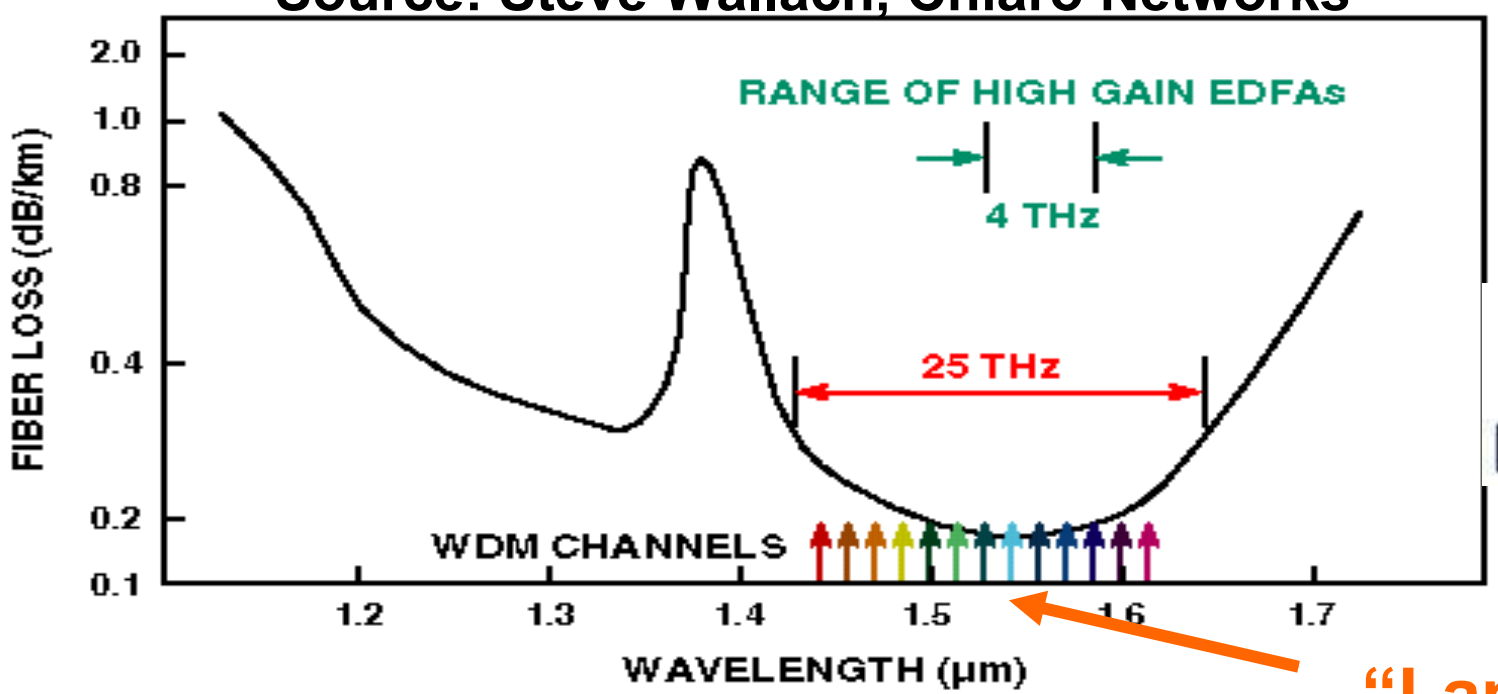
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Dedicated Optical Channels Makes High Performance Cyberinfrastructure Possible

WAVELENGTH DIVISION MULTIPLEXING (WDM)

- EXPLOITS
  - ENORMOUS BANDWIDTH OF SILICA FIBER
  - HIGH-GAIN WIDEBAND OPTICAL AMPLIFIERS

Source: Steve Wallach, Chiaro Networks



CHIARO

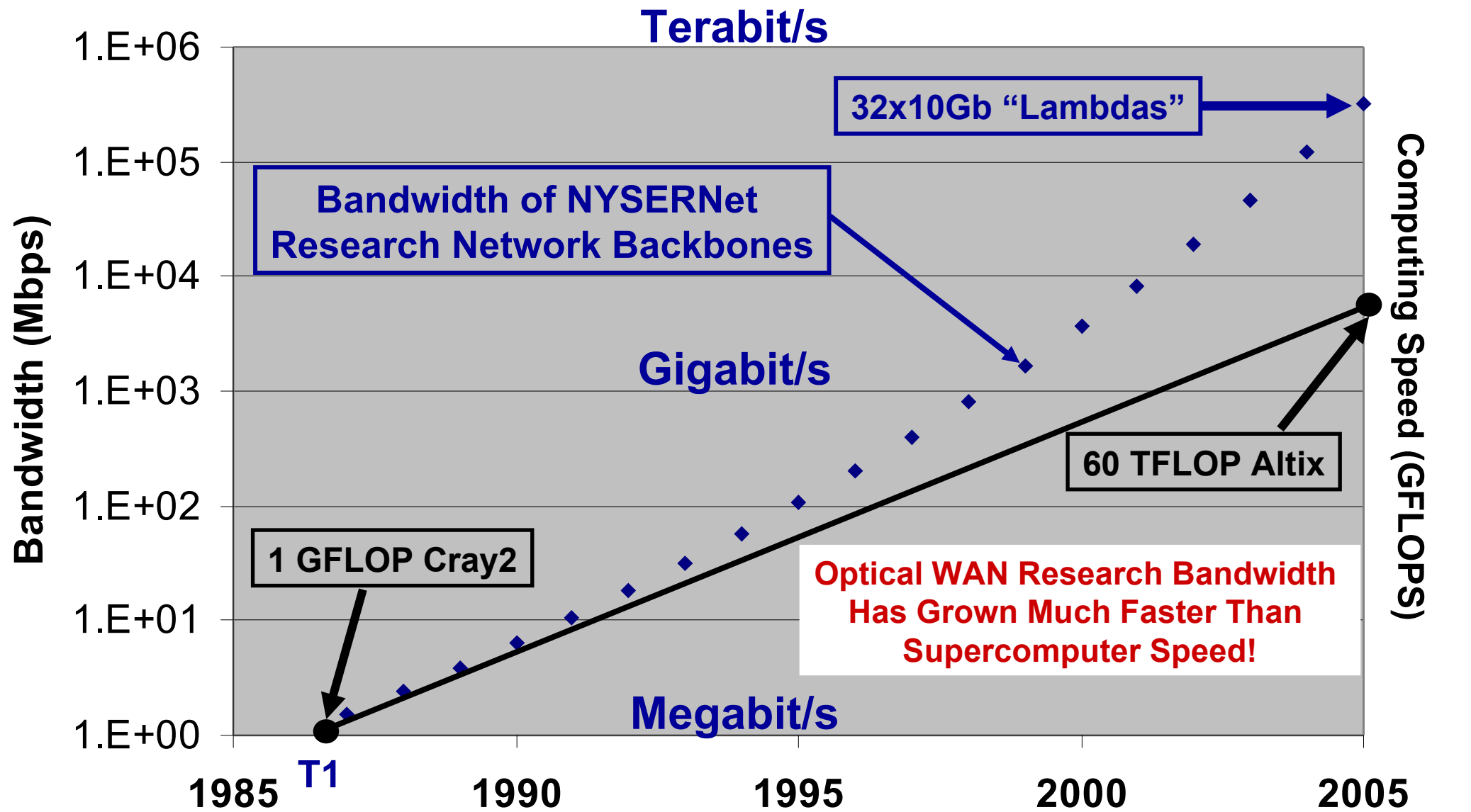
"Lambdas"

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Parallel Lambdas are Driving Optical Networking
The Way Parallel Processors Drove 1990s Computing

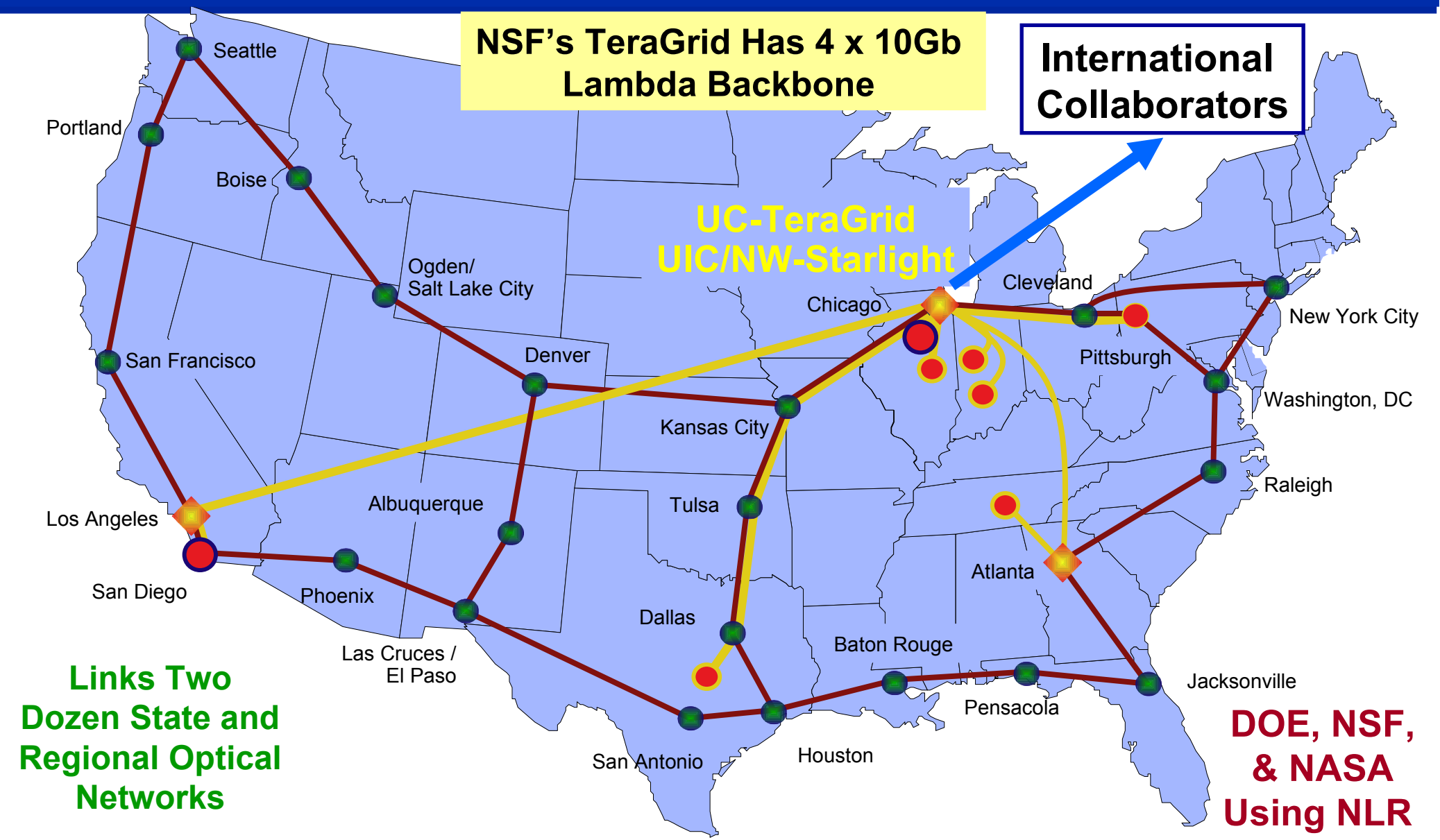
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From "Supercomputer–Centric" to "Supernetwork-Centric" Cyberinfrastructure



Network Data Source: Timothy Lance, President, NYSERNet

NLR and TeraGrid Provides the Cyberinfrastructure Backbone for U.S. University Researchers



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The DoD Global Information Grid
Optical IP Terrestrial Backbone

Source: Bob Young, SAIC

Optical IP terrestrial backbone with a ubiquitous presence. Mitigates constraints in terrestrial bandwidth.

- Diverse physical access to the network, the near term effort secure, robust
- CONUS & OCONUS
- Key to integrated net-centric transformation

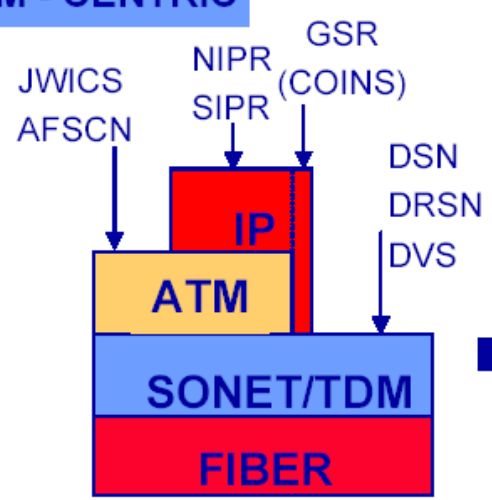
Investment $800+M

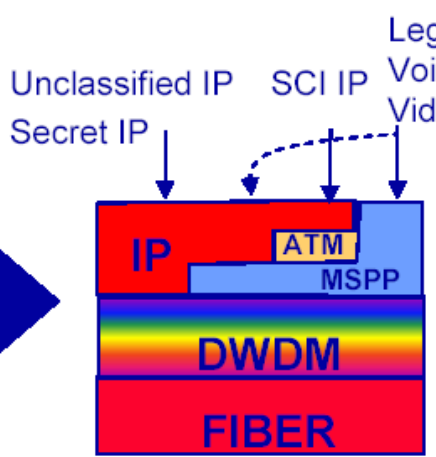
FY03: $500+M
- Requests for Proposals
- Contract awards
- Site surveys
- Installations begin

FY04: $300M
- Complete al installations
- Provide minimum 100 Mbps per site per service

Today:

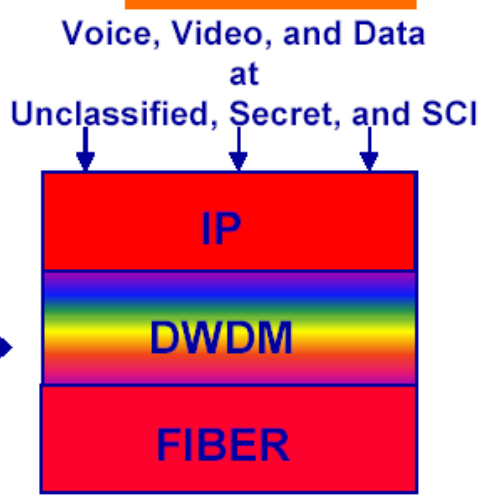
TDM - CENTRIC





Tomorrow:

IP - CENTRIC

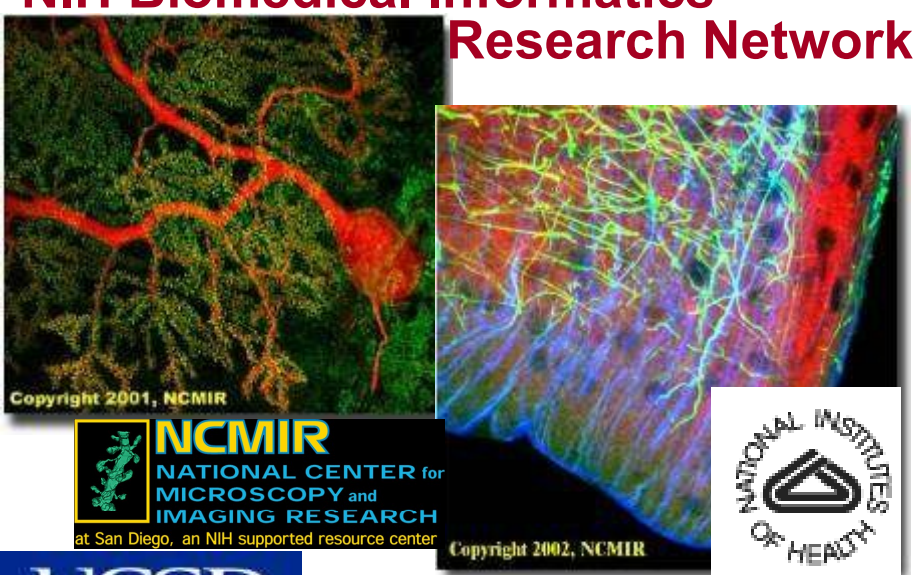


The OptIPuter Project –
Removing Bandwidth as an Obstacle In Data Intensive Sciences

- **NSF Large Information Technology Research Proposal**
  - Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
  - Partnering Campuses: USC, SDSU, NW, TA&M, UvA, SARA, NASA
- **Industrial Partners**
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- **$13.5 Million Over Five Years**
- **Extending the Grid Middleware to Control Optical Circuits**

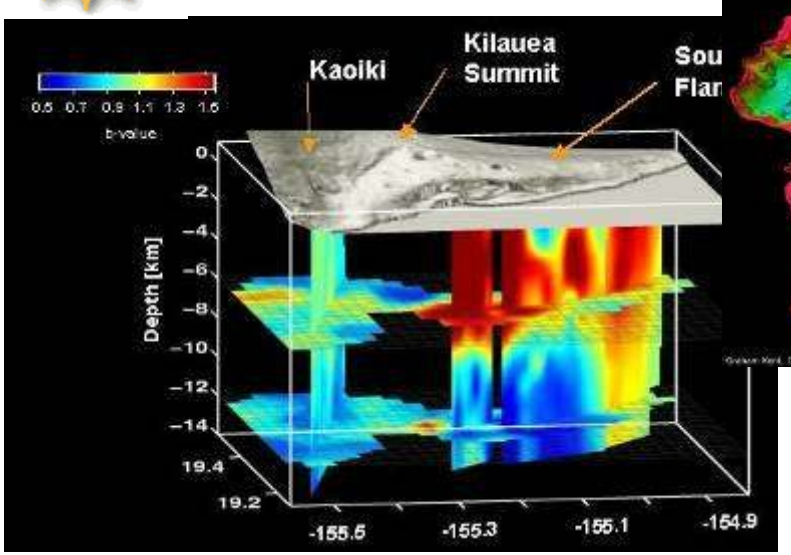
OptIPuter

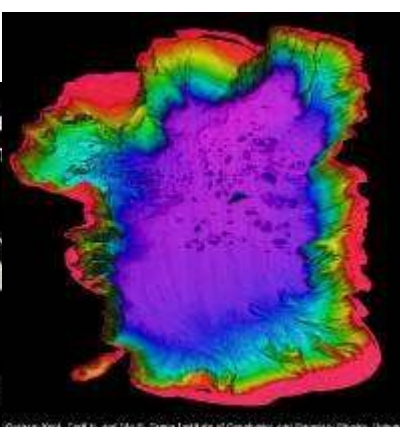
NIH Biomedical Informatics Research Network



http://ncmir.ucsd.edu/gallery.html

NSF EarthScope and ORION



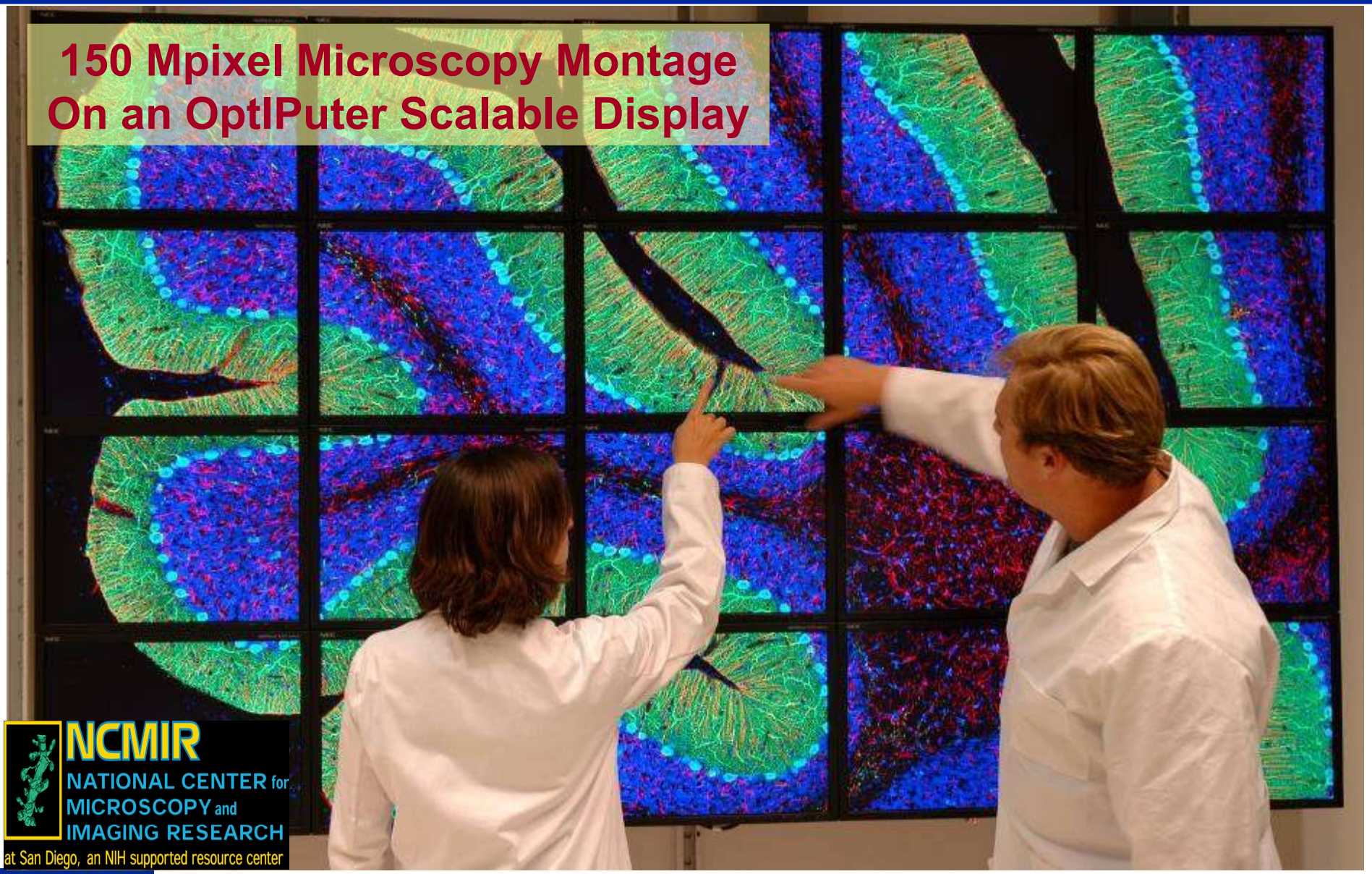


siovizcenter.ucsd.edu/library/gallery/shoot1/index.shtml

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Realizing the Dream: High Resolution Portals to Global Science Data



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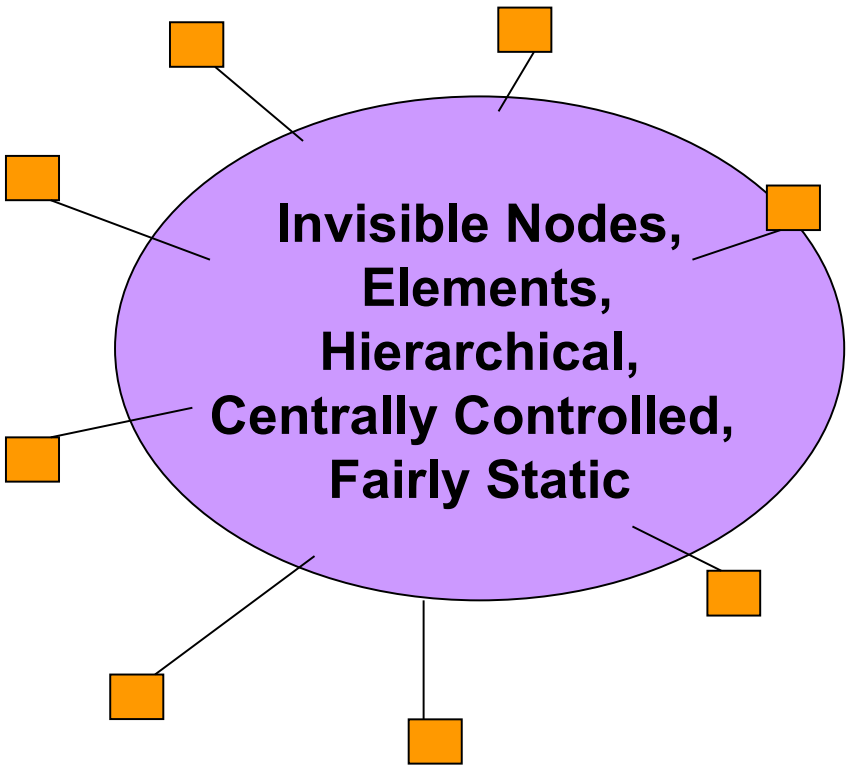
30 MPixel SunScreen Display Driven by a 20-node Sun Opteron Visualization Cluster

Source: Mark Ellisman, David Lee, Jason Leigh

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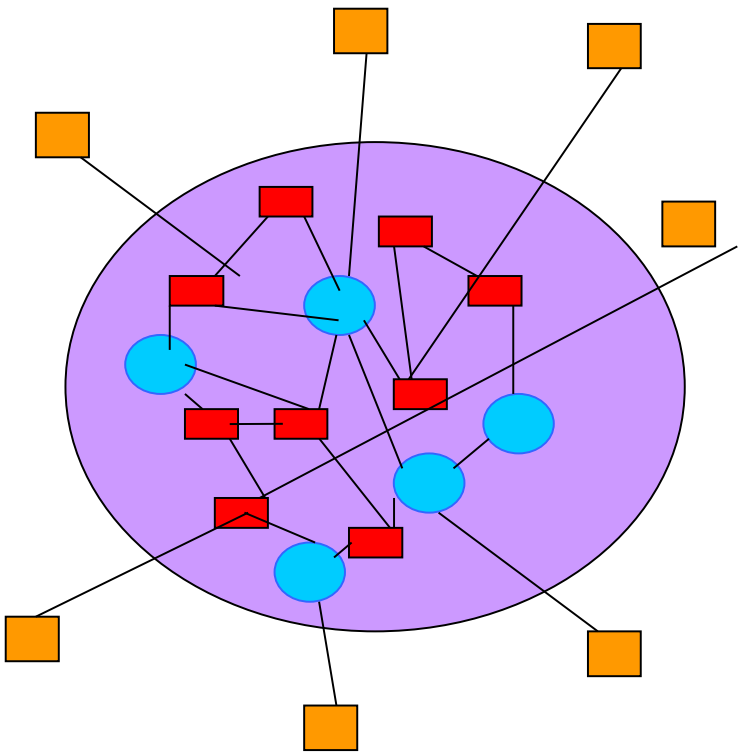
The LambdaGrid Control Plane Paradigm Shift from Commercial Practice

Traditional Provider Services:
Invisible, Static Resources, Centralized Management



Limited Functionality, Flexibility

OptIPuter:
Distributed Device, Dynamic Services, Visible & Accessible Resources, Integrated As Required By Apps



Unlimited Functionality, Flexibility

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Source: Joe Mambretti, Oliver Yu, George Clapp

End-to-End Optical Circuits: a Campus-Scale OptIPuter



0.320 Tbps Backplane Bandwidth

Juniper T320

20X

6.4 Tbps Backplane Bandwidth



Chiaro Estara

To CENIC

SDSC

SDSC Annex

Engineering

High School

Medicine

Collocation

Earth Sciences

½ Mile

Campus Provided Dedicated Fibers Between Sites Linking Linux Clusters

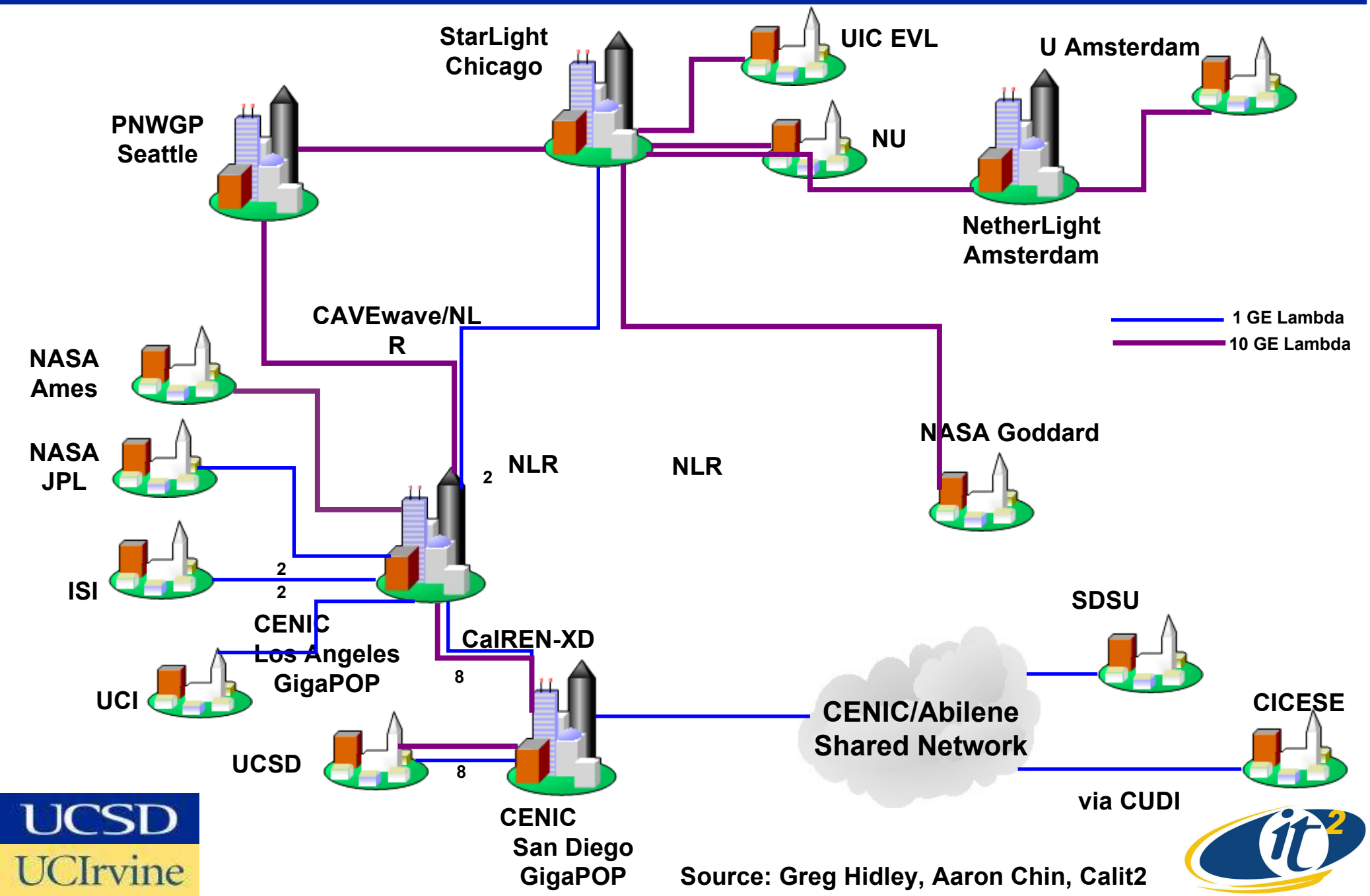
UCSD Has ~ 50 Labs With Clusters

Source: Phil Papadopoulos, SDSC; Greg Hidley, Calit2

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The OptIPuter LambdaGrid is Rapidly Expanding



Source: Greg Hidley, Aaron Chin, Calit2

Lambdas Provide Global Access to Large Data Objects and Remote Instruments

Global Lambda Integrated Facility (GLIF)
Integrated Research Lambda Network



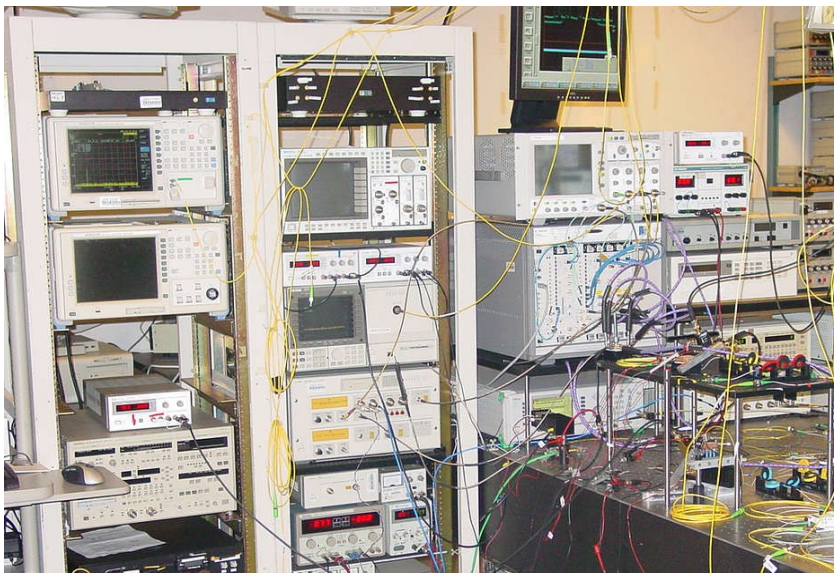
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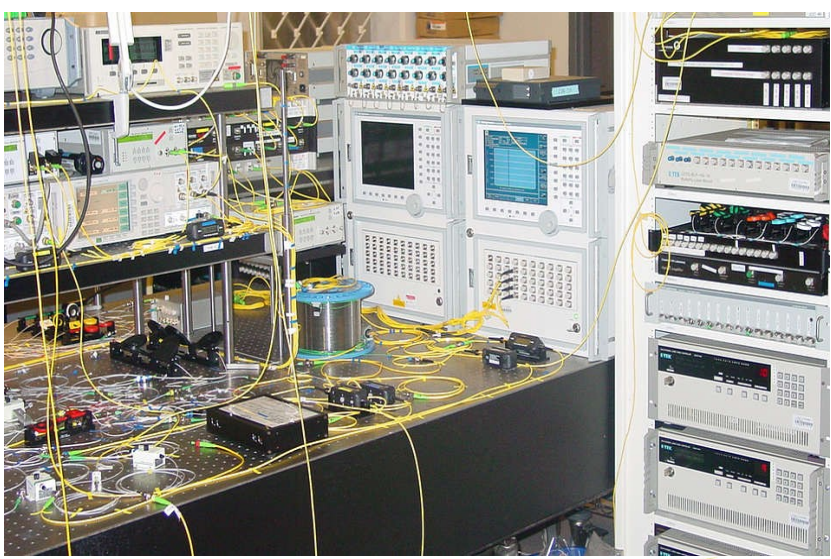
Visualization courtesy of
Bob Patterson, NCSA

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Calit2@UCSD Building will House a Photonics Networking Laboratory

- **Networking "Living Lab" Testbed Core**
  - Unconventional Coding
  - High Capacity Networking
  - Bidirectional Architectures
  - Hybrid Signal Processing
- **Interconnected to OptIPuter**
  - Access to Real World Network Flows
  - Allows System Tests of New Concepts







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Peering Into The Future
1000x Goals for 2015

- **Home Bandwidth**
  - Today: Mbit/s Cable/ DSL
  - 2015: Gbit/s to the Home
- **Information Appliances**
  - Today: GHz PCs
  - 2015: Terahertz Ubiquitous Embedded Computing
- **Personal Storage**
  - Today: 100 GBytes PC or Tivo
  - 2015: 100 TBytes Personal Storage Available Everywhere
- **Visual Interface**
  - Today: 1M Pixels PC Screen or HD TV
  - 2015: GigaPixel Wallpaper

15 Years ~ 1000x with Moore's Law

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Multiple HD Streams Over Lambdas Will Radically Transform Campus Collaboration





Telepresence Using Uncompressed 1.5 Gbps HDTV Streaming Over IP on Fiber Optics--
1000 x Home Cable "HDTV" Bandwidth!



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Source: U Washington Research Channel

Multi-Gigapixel Images are Available from Film Scanners Today



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The Gigapxl Project
http://gigapxl.org

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Large Image with Enormous Detail Require Interactive LambdaVision Systems



The OptIPuter Project is Pursuing Obtaining some of these Images for LambdaVision 100M Pixel Walls

One Square Inch Shot From 100 Yards

Toward an Interactive Gigapixel Display

- Scalable Adaptive Graphics Environment (SAGE) Controls:
- 100 Megapixels Display
  - 55-Panel
- 1/4 TeraFLOP
  - Driven by 30-Node Cluster of 64-bit Dual Opterons
- 1/3 Terabit/sec I/O
  - 30 x 10GE interfaces
  - Linked to OptIPuter
- 1/8 TB RAM
- 60 TB Disk

NSF LambdaVision MRI@UIC

Calit2 is Building a LambdaVision Wall in Each of the UCI & UCSD Buildings



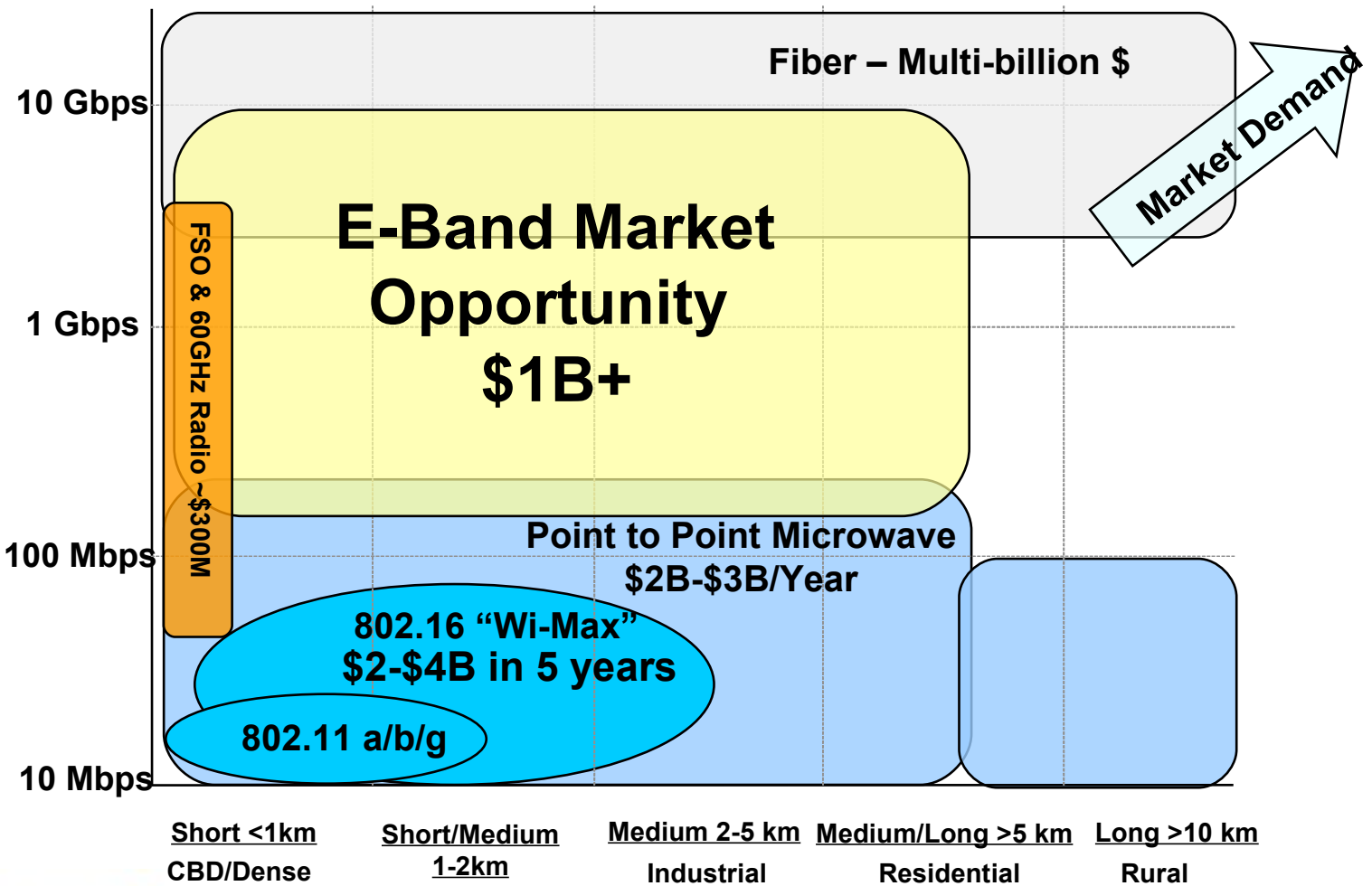
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Source: Jason Leigh, Tom DeFanti, EVL@UIC
OptIPuter Co-PIs

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An Explosion in Wireless Internet Connectivity is Occuring

Broadband Cellular Internet Plus…



The Center for Pervasive Communications and Computing Will Have a Major Presence in the Calit2@UCI Building

Center for Pervasive Communications and Computing

408 Engineering Tower
University of California, Irvine
Irvine, CA 92697-2625
cpcc-info@uci.edu

CPCC Inauguration



Dwight Decker, Chairman and CEO, Conexant Systems; Henry Samueli, CTO and Co-Founder, Broadcom Corp.; Gray Davis, Governor, State of California; Ralph J. Cicerone, Chancellor, UC Irvine; Nicolaos G. Alexopoulos, Dean, The Henry Samueli School of Engineering

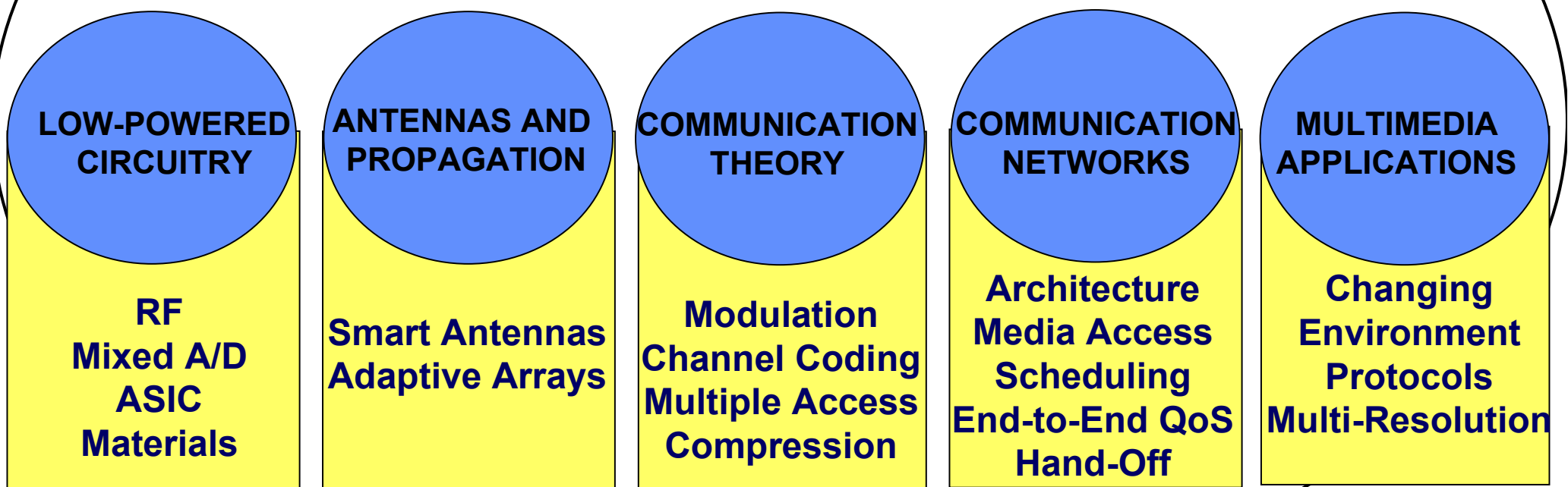


Director Ender Ayanoglu

CWC and Calit2 are Strong Partners

Center for Wireless Communications

Two Dozen ECE and CSE Faculty



Source: UCSD CWC

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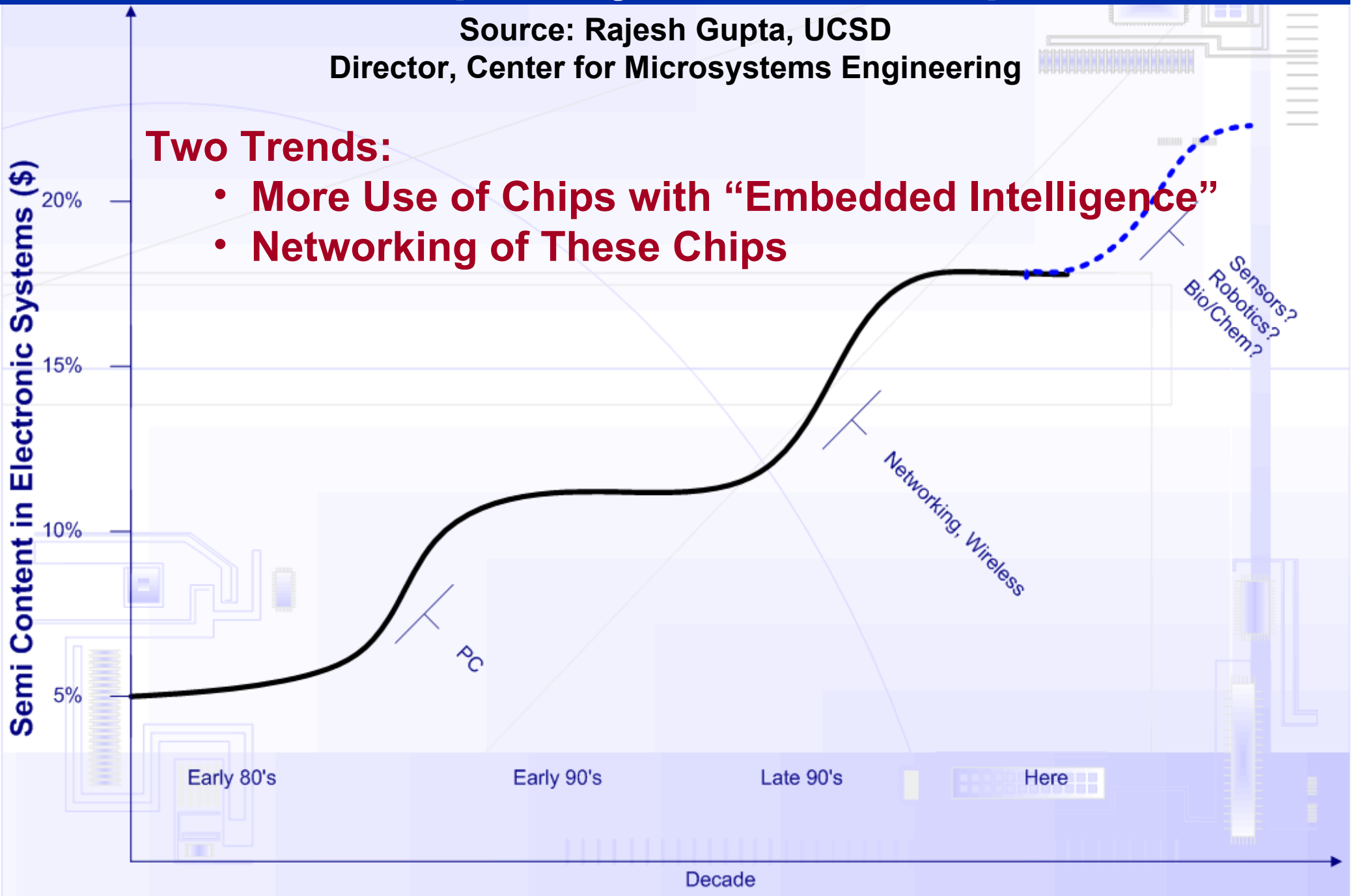
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Network Endpoints Are Becoming Complex Systems-on-Chip

Source: Rajesh Gupta, UCSD
Director, Center for Microsystems Engineering

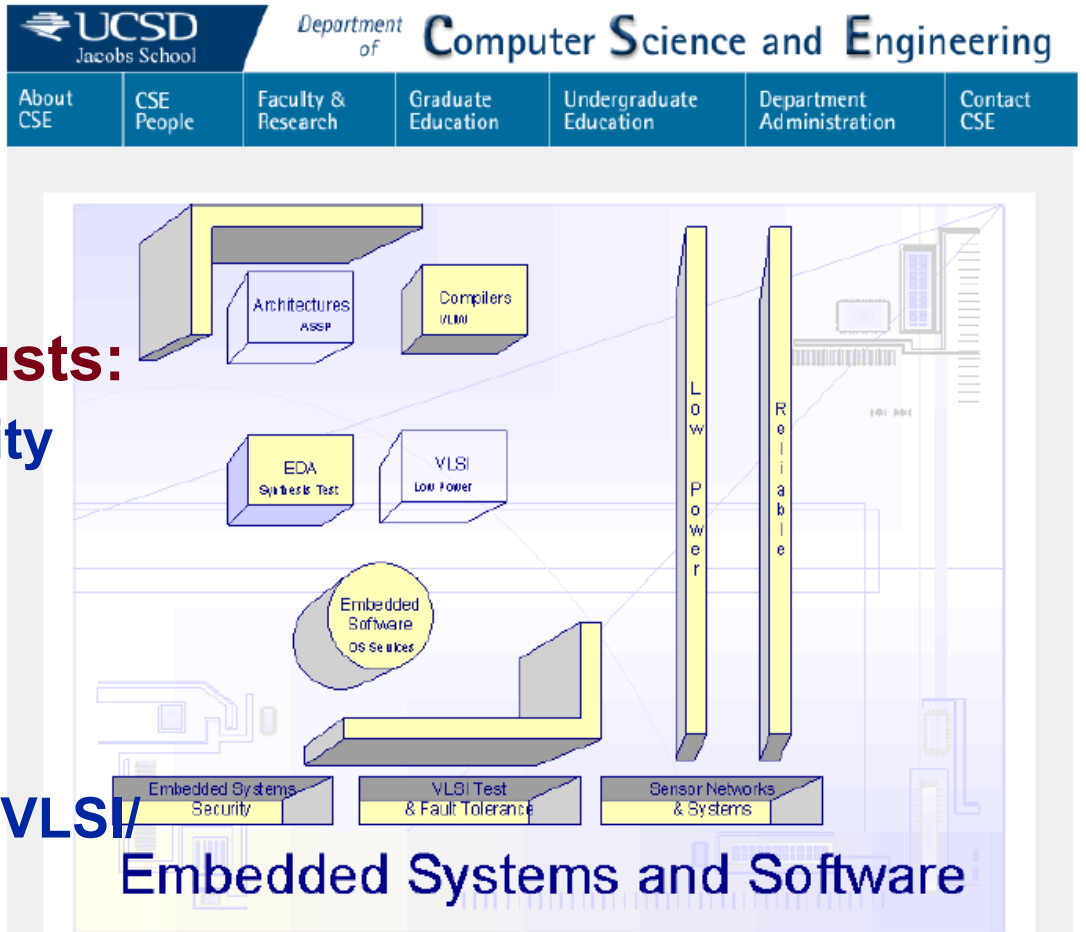
Two Trends:

- More Use of Chips with "Embedded Intelligence"
- Networking of These Chips



The UCSD Program in Embedded Systems & Software

- **Confluence of:**
  - Architecture, Compilers
  - VLSI, CAD, Test
  - Embedded Software
- **Cross-Cutting Research Thrusts:**
  - Low Power, Reliability, Security
  - Sensor Networks
- **Affiliated Laboratories:**
  - High Performance Processor Architecture and Compiler
  - Microelectronic Systems Lab VLSI/ CAD Lab
  - Reliable System Synthesis Lab



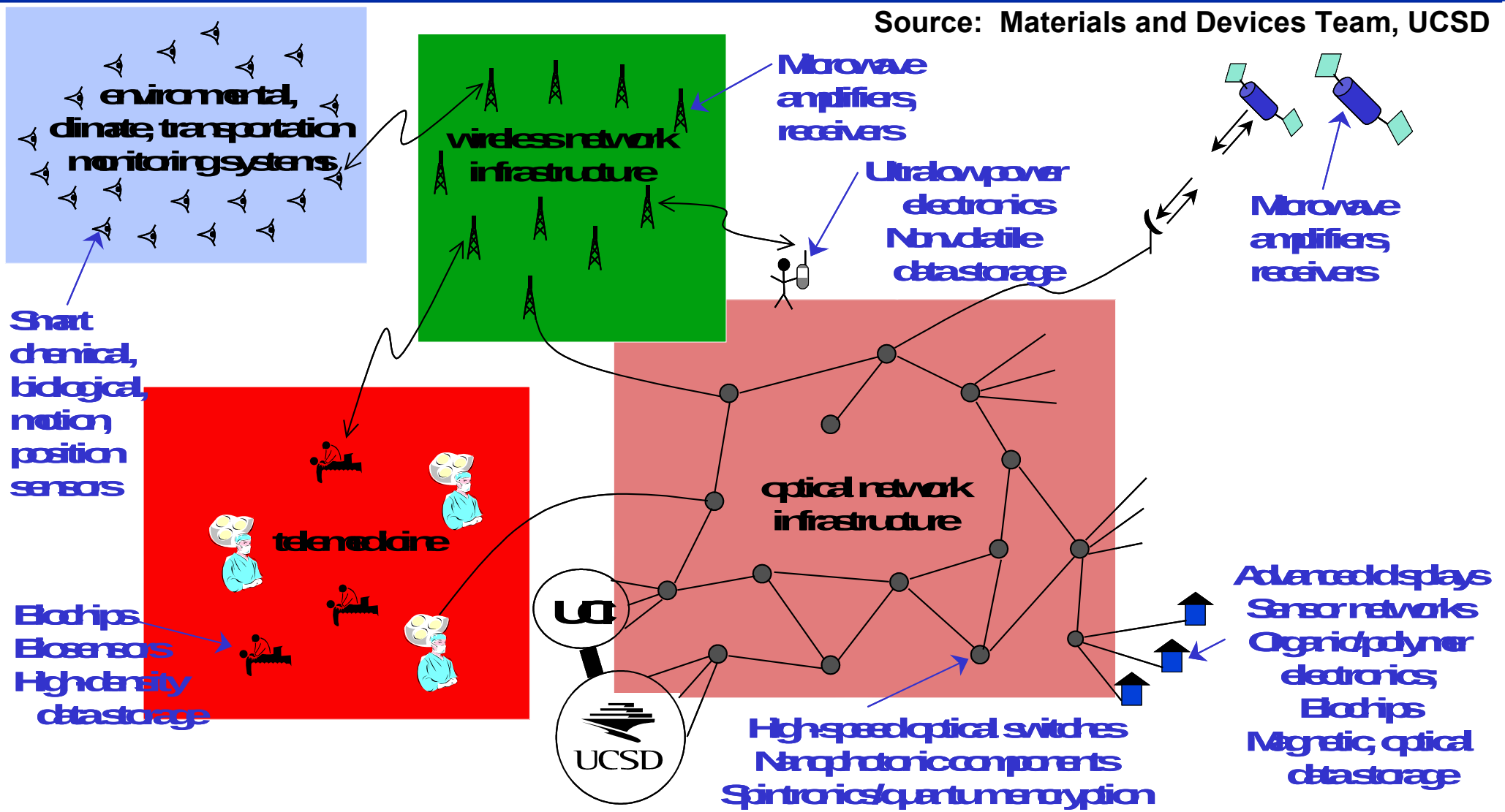
http://mesl.ucsd.edu/gupta/ess/

Calit2 MicroSystems Engineering Initiative

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Novel Materials and Devices are Needed in Every Part of the New Internet

Source: Materials and Devices Team, UCSD

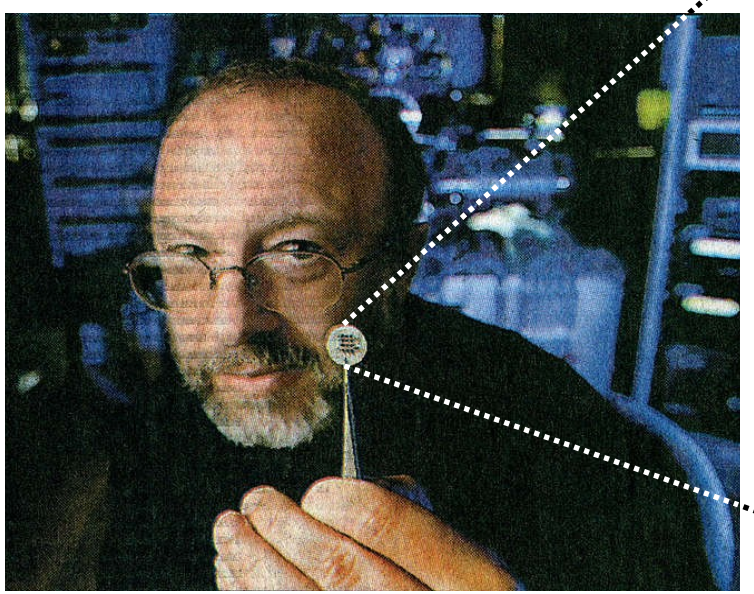


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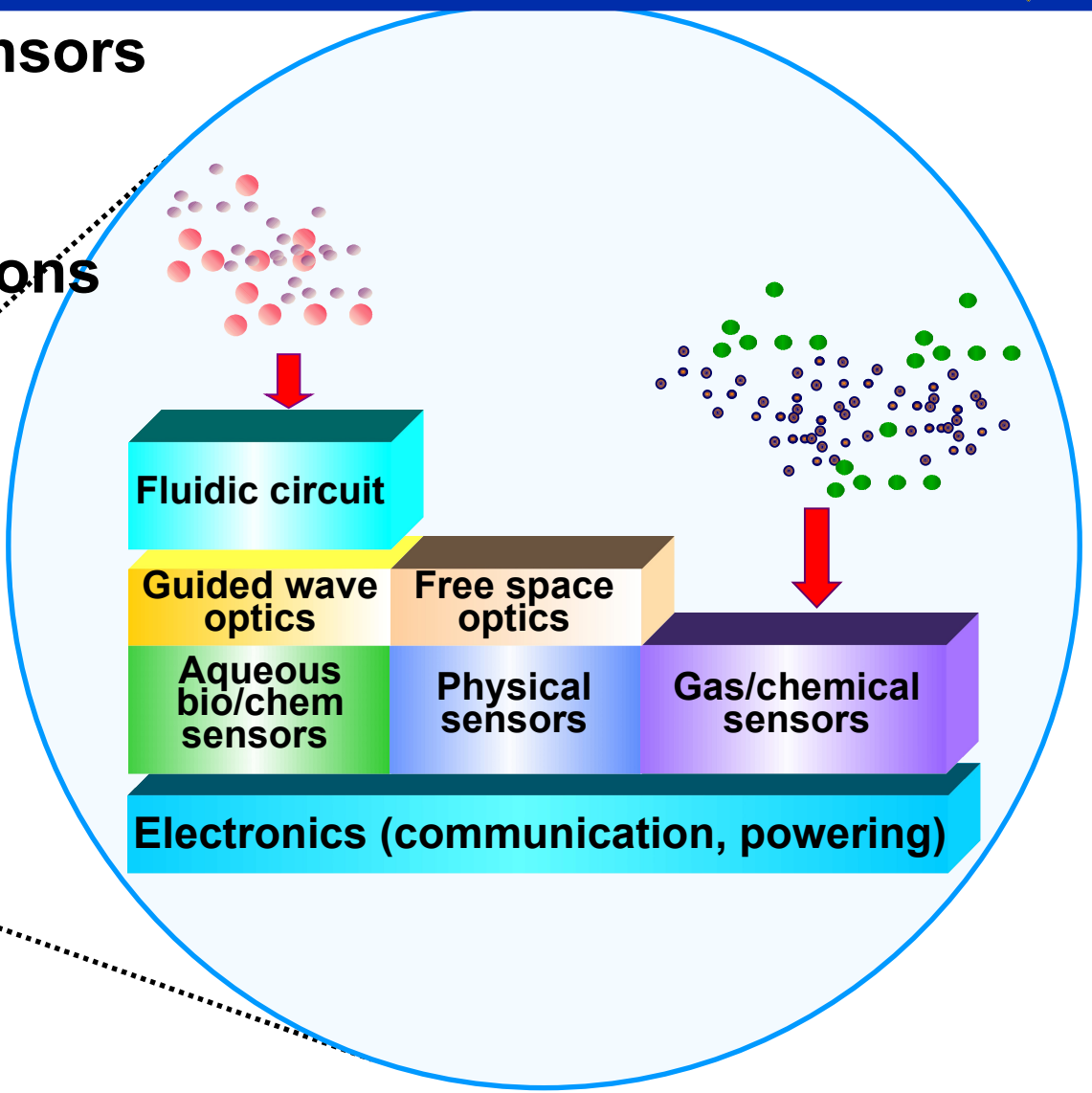
Clean Rooms for NanoScience and BioMEMS in the two Calit2 Buildings

Integrated Nanosensors—
Collaborative Research Between
Physicists, Chemists, Material Scientists and Engineers

Developing Multiple Nanosensors on a Single Chip, with Local Processing and Wireless Communications



I. K. Schuller holding the first prototype



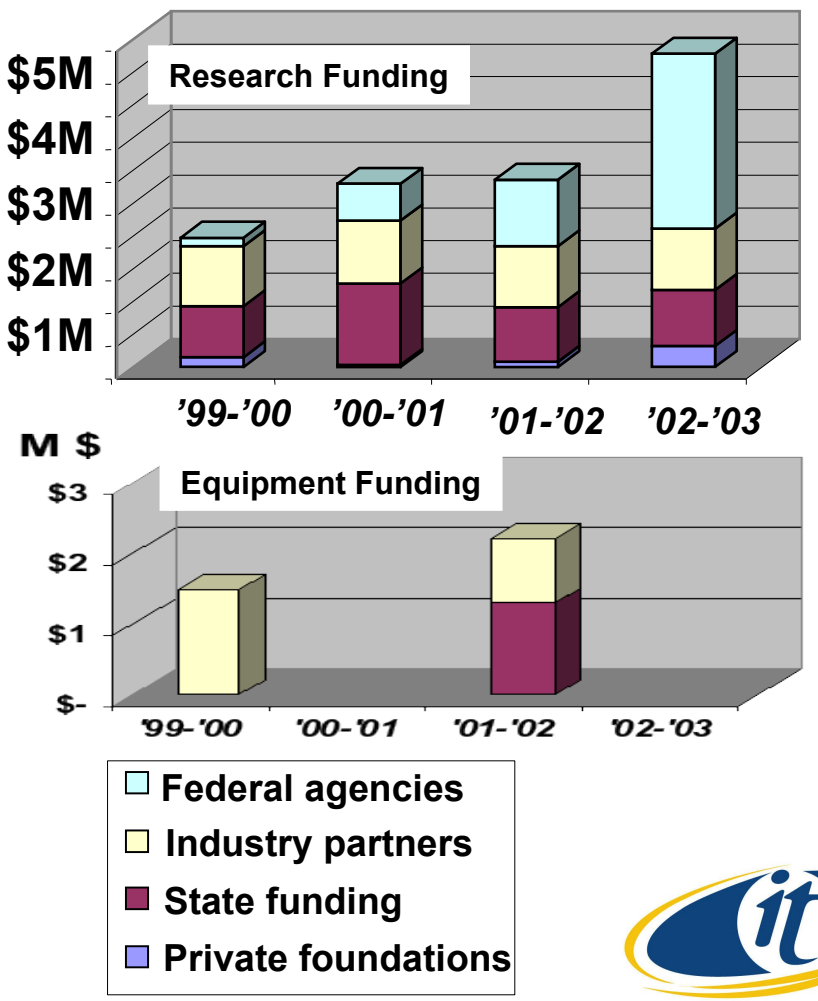
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I. K. Schuller, A. Kummel, M. Sailor, W. Trogler, Y-H Lo

UC Irvine Integrated Nanoscale Research Facility – Nano, MEMS, and BioMEMS Collaboration with Industry

- **Collaborations with Industry**
  - **Joint Research With Faculty**
  - **Shared Facility Available For Industry Use**
- Working with UCI OTA to Facilitate Tech Transfer
- Industry and VC Interest in Technologies Developed at INRF

Agilent Technologies
TAMARACK scientific co., inc.
Raytheon
Auxora
VERSA TECHNOLOGY, INC.
RFIC
Tanner RESEARCH
Conventor
IRVINE SENSORS
hp invent
GCS
BROADCOM.
SKYWORKS
DRS
POC Physical Optics Corporation
TEXAS INSTRUMENTS
nexgen
BMR
MICROTEK
SWT ASSOCIATES
WIN Semiconductors Corp.
ROCKWELL SCIENTIFIC
delivering the winning technical edge
GENERAL MONITORS
ENDEVCO
SEQUENOM
ALPINE SEMICONDUCTOR
SST
MetroLaser, Inc.
MOOG
CONEXANT
IntelliEPI
VSK Photonics
COHERENT
PRINTRONIX
ASI
IJ Research, Inc.
XTAL
TRW
Umachines
Broadley-James
NUMERICAL TECHNOLOGIES, INC. GET THERE
Microsemi
OPLINK
NORTHROP GRUMMAN
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Two-Campus Calit2 Intelligent Transportation Team



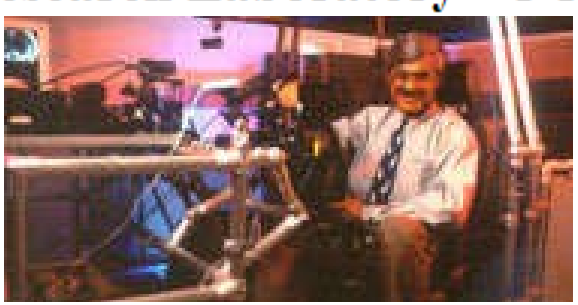
ITS University of California Irvine



zevNet

AUTOMOTIVE SOFTWARE WORKSHOP SAN DIEGO 2004

Computer Vision and Robotics Research Laboratory - UCSD



I-5 Towards Del Mar Heights Road



For Up-To-Date Traffic Reports (866) 500-0977

Over 1,000 Calls Per Day!

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An LA-Specific Perspective on the Cost of Traffic Congestion

Total annual delay	667,352,000 person hours
Percent congestion due to recurring delay	57%
Percent congestion due to incident delay	43%
Annual delay per capita	52 person hours
Percent of daily travel in congestion	88%
Congested freeway and street lane miles	72%
Number of Congested Hours per Day	8
Wasted fuel	78 gallons per person
Annual congestion cost total	$12,837,000,000
Cost per capita	$1,005

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Source: Will Recker, UCI ITS

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Calit2 is Building an Intelligent Transportation "Living Laboratory"

- **Toward Reductions in Traffic Congestion**
  - Restructuring Traffic Flows by Sharing Information
  - Creating Intelligent Networks
  - Fostering Intelligent Management
- **Currently Working in Orange County**
  - Goal is to Expand to San Diego and Riverside

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Source: Will Recker, UCI ITS

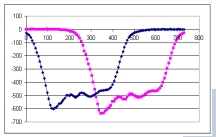
it2

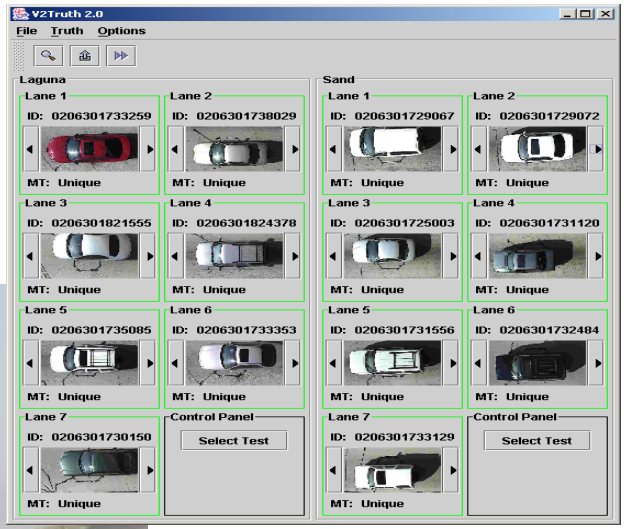
Calit2 Intelligent Transportation Living Laboratory Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars











Source: Will Recker, UCI ITS

Cal(IT)² Testbed Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars
  - In-Vehicle Real-time Tracking of Vehicles and Activities



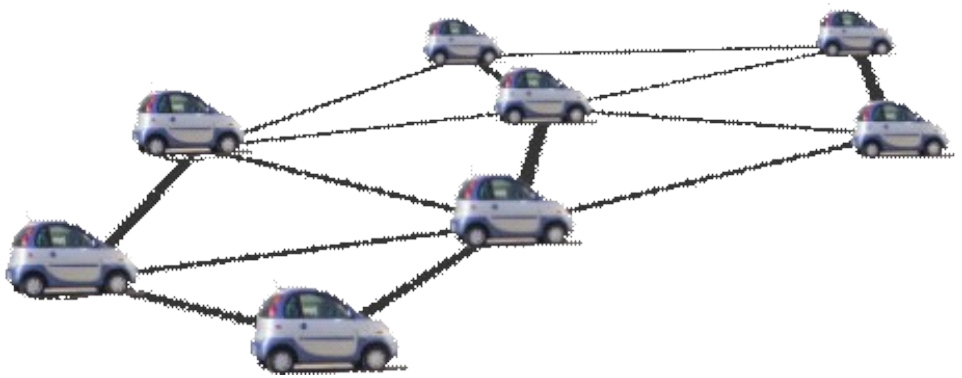
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Source: Will Recker, UCI ITS

it²

Cal(IT)^2 Testbed Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars
  - In-Vehicle Real-Time Tracking of Vehicles And Activities
  - Peer-to-Peer Ad Hoc Communication and Control



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Source: Will Recker, UCI ITS

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Cal(IT)^2 Testbed Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars
  - In-Vehicle Real-Time Tracking of Vehicles and Activities
  - Peer-to-Peer Ad Hoc Communication and Control
  - Extension of the Internet into Automobiles



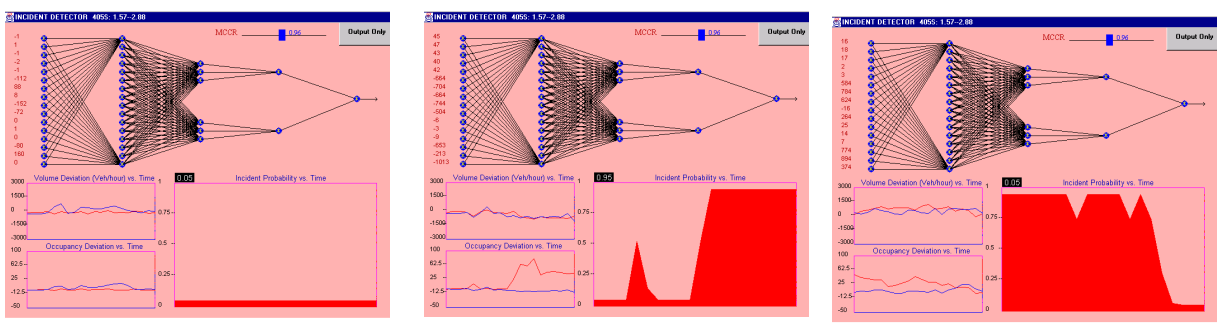
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Source: Will Recker, UCI ITS

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Cal(IT)^2 Testbed Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars
  - In-Vehicle Real-Time Tracking of Vehicles and Activities
  - Peer-to-Peer Ad Hoc Communication and Control
  - Extension of the Internet into Automobiles
- Creating Intelligent Networks
  - Autonomous Agents for Incident Response



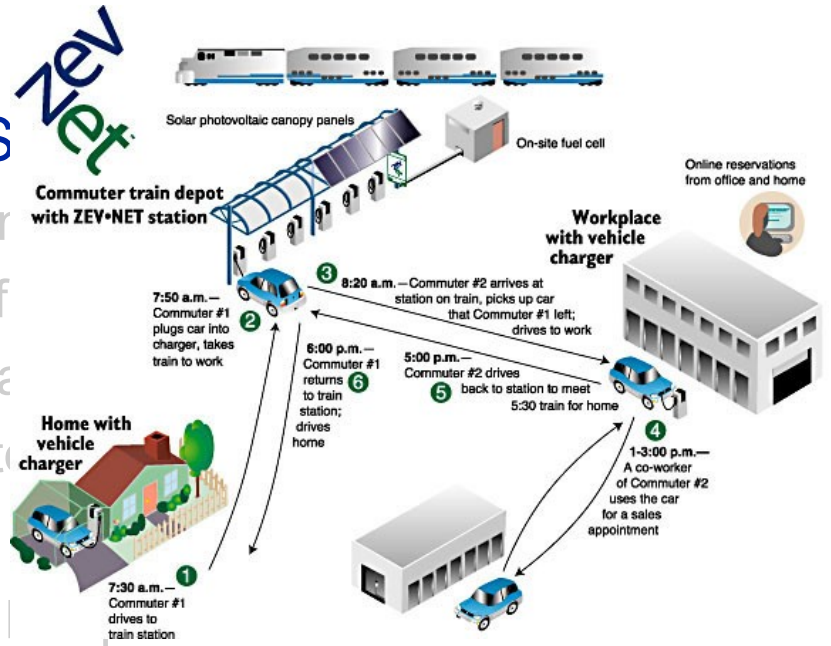
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Source: Will Recker, UCI ITS

it^2

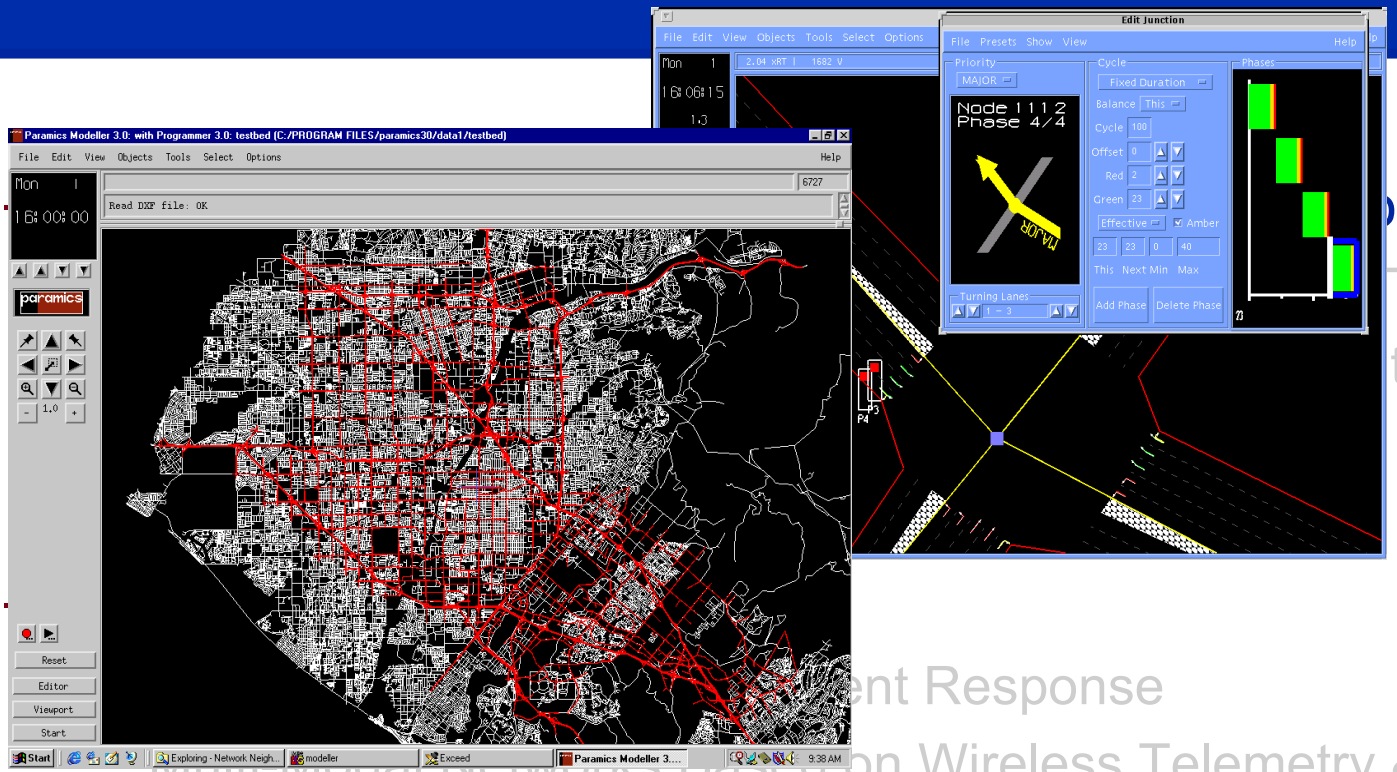
Cal(IT)² Testbed Vision

- Restructuring Traffic Flows by S
  - Sensor-Based Real-Time Anonyr
  - In-Vehicle Real-Time Tracking of
  - Peer-to-Peer Ad Hoc Communica
  - Extension of the Internet into Aut
- Creating Intelligent Networks
  - Autonomous Agents for Incident
  - Multi-Modal Networks Based on Wireless Telemetry & Management



Source: Will Recker, UCI ITS

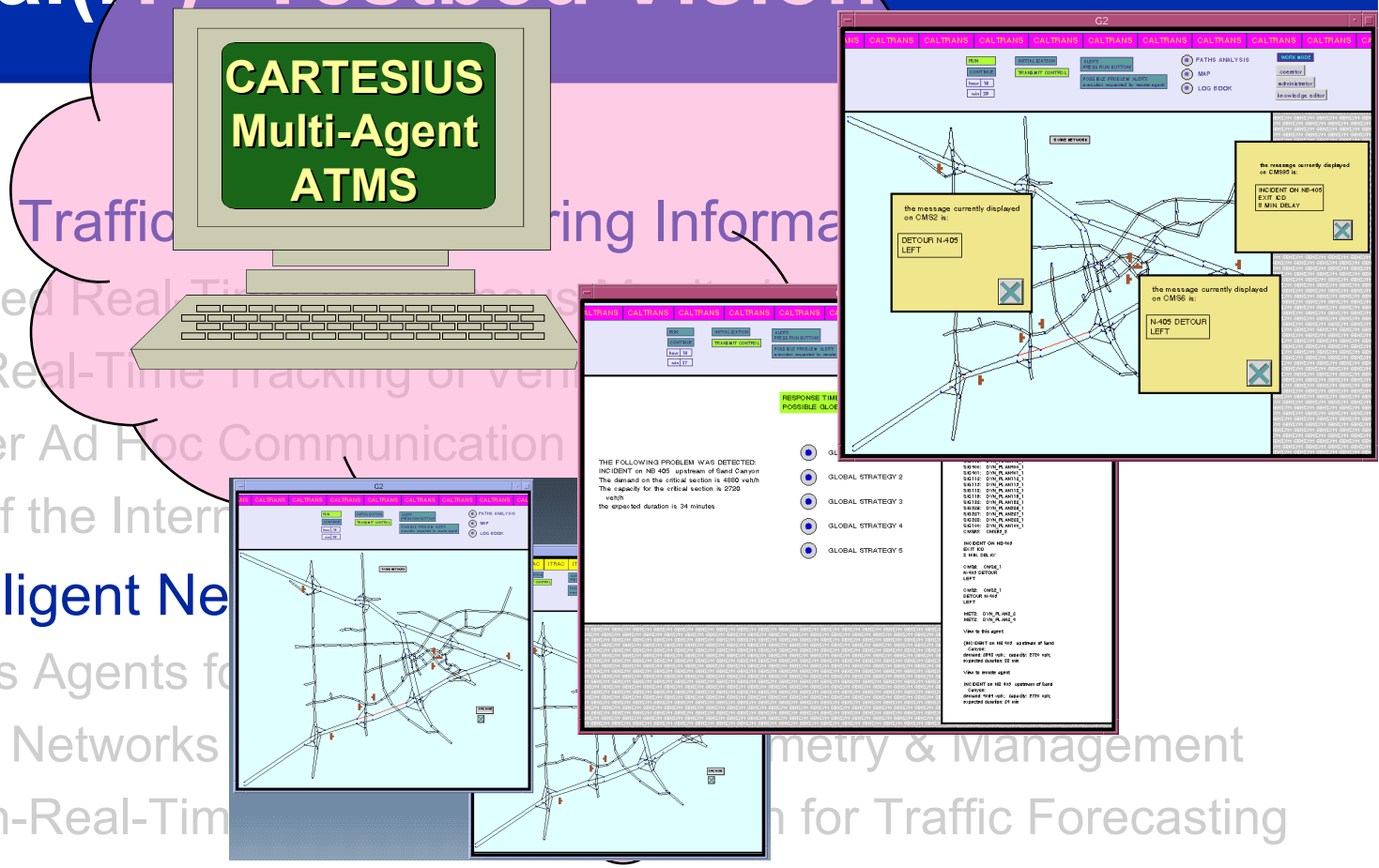
Cal(IT)² Testbed Vision



– Faster-Than-Real-Time Microscopic Simulation for Traffic Forecasting

Source: Will Recker, UCI ITS

Cal(IT)² Testbed Vision



- Restructuring Traffic … ring Informa
  - Sensor-Based Real-Ti… ous …
  - In-Vehicle Real-Time Tracking of Veh…
  - Peer-to-Peer Ad Hoc Communication …
  - Extension of the Interr…
- Creating Intelligent Ne…
  - Autonomous Agents fo…
  - Multi-Modal Networks … metry & Management
  - Faster-Than-Real-Tim… … for Traffic Forecasting
- Fostering Intelligent Management
  - Real-Time Multi-Jurisdictional Corridor Management

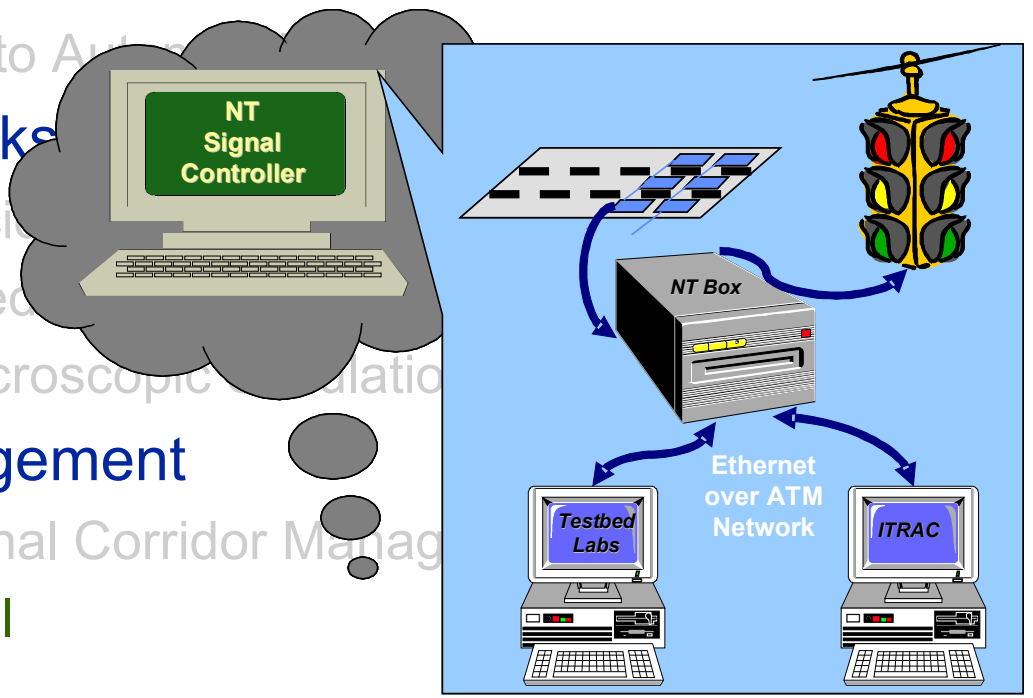
UCSD
UCIrvine

Source: Will Recker, UCI ITS

it²

Cal(IT)^2 Testbed Vision

- Restructuring Traffic Flows by Sharing Information
  - Sensor-Based Real-Time Anonymous Monitoring of Traffic & Cars
  - In-Vehicle Real-Time Tracking of Vehicles and Activities
  - Peer-to-Peer Ad Hoc Communication and Control
  - Extension of the Internet into Au
- Creating Intelligent Networks
  - Autonomous Agents for Inci
  - Multi-Modal Networks Based
  - Faster-Than-Real-Time Microscopic ulatio
- Fostering Intelligent Management
  - Real-Time Multi-Jurisdictional Corridor Manag
  - Real-Time Adaptive Control



UCSD
UCIrvine

Source: Will Recker, UCI ITS

Calit2 Has Established an Interdisciplinary Program on Automotive Software Engineering

- **Cars Have Separate Integrated Networks For:**
  - Power Train
  - Central locking system
  - Crash management
  - Multimedia
  - Body/Comfort Functions etc.

90 % of all Auto Innovations are Now Software-Driven

- **50-100 Electronic Control Units Supporting up to 1,000 Features**
- **Increasing Interaction Between Different Sub-Systems**
- **Increasing Interaction Also Beyond The Car's Boundaries**
- **Movement to Service-Oriented Middleware—i.e. Grids!**
  - Paves The Way For Integration of On-Board And Off-Board Information Systems



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Source: Ingolf Krueger, Calit2

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