# “Blowing up the Box--the Emergence of the Planetary Computer"

**Invited Talk**
**Oak Ridge National Laboratory**
**Oak Ridge, TN**
**October 13, 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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# Long-Term Goal: Dedicated Fiber Optic Infrastructure Collaborative Interactive Visualization of Remote Data

**"What we really have to do is eliminate distance between individuals who want to interact with other people and with other computers."**
**— Larry Smarr, Director, NCSA**

**SIGGRAPH 1989**









**"We're using satellite technology…to demo what It might be like to have high-speed fiber-optic links between advanced computers in two different geographic locations."**

**— Al Gore, Senator**
**Chair, US Senate Subcommittee on Science, Technology and Space**

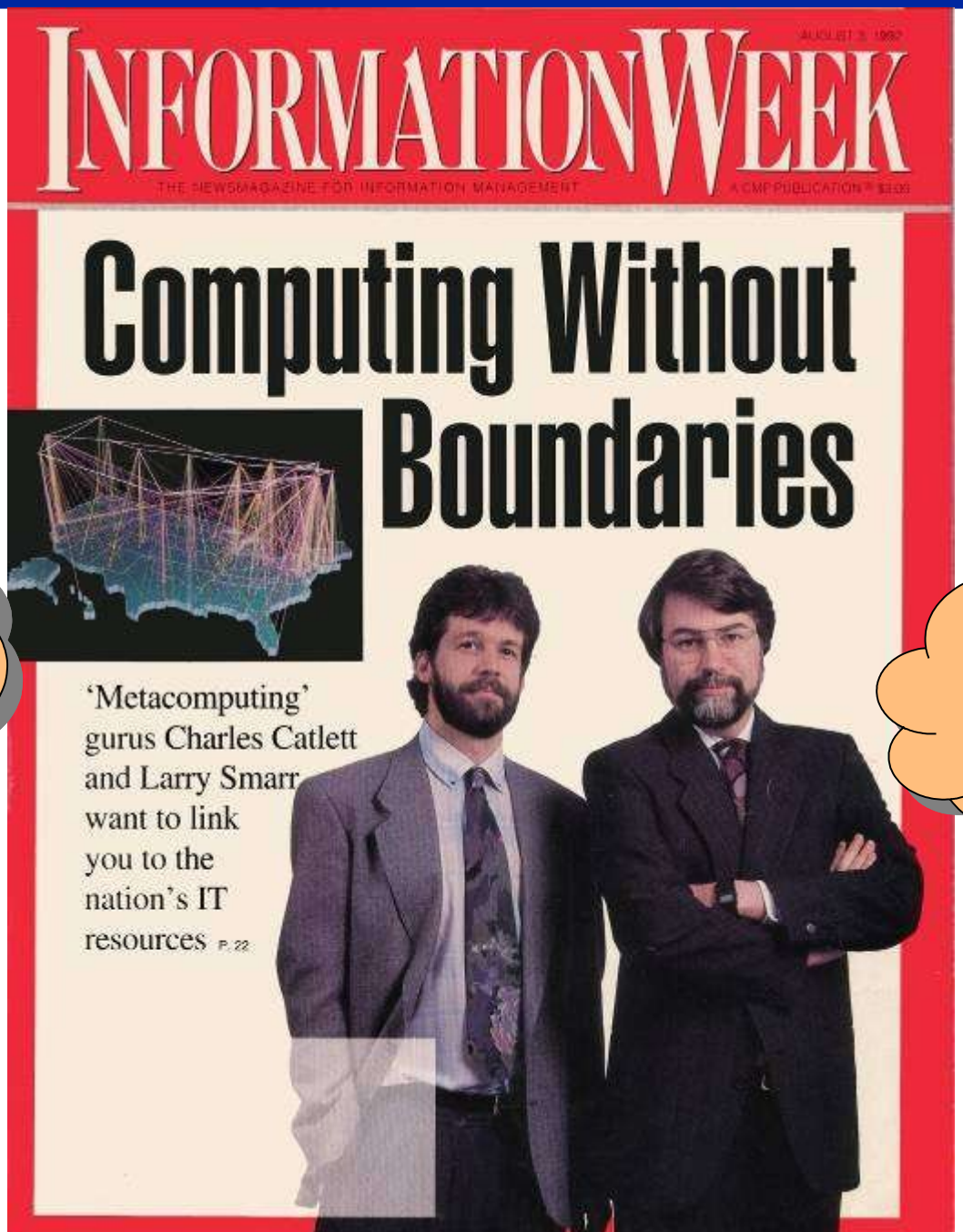
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NCSA™

it²

# From Metacomputer to TeraGrid and OptIPuter: 15 Years of Development

TeraGrid PI



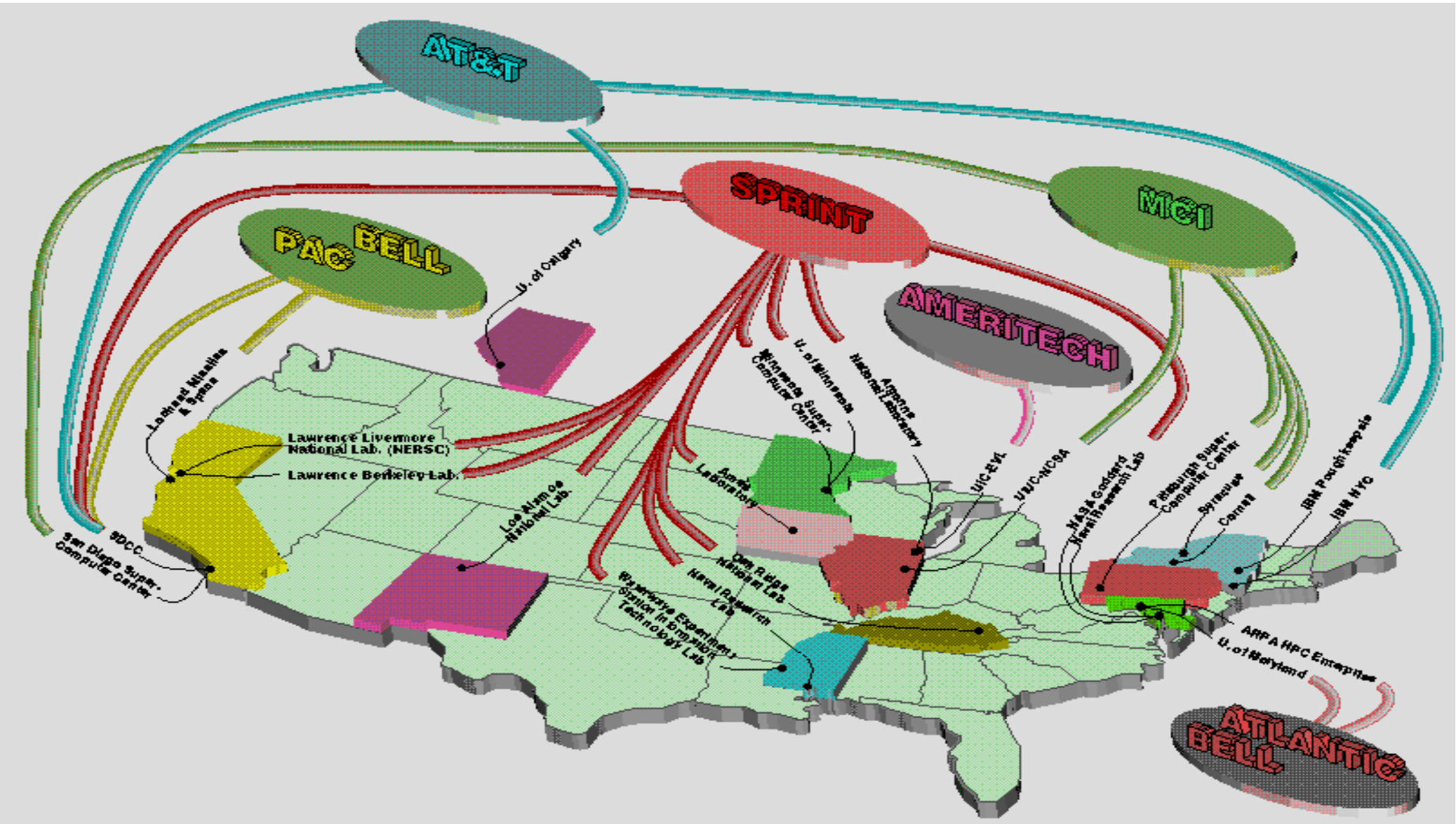

OptIPuter PI

OptIPuter

it2

# I-WAY Prototyped the Grid
# Supercomputing '95 I-WAY Project

## From I-Soft to Globus

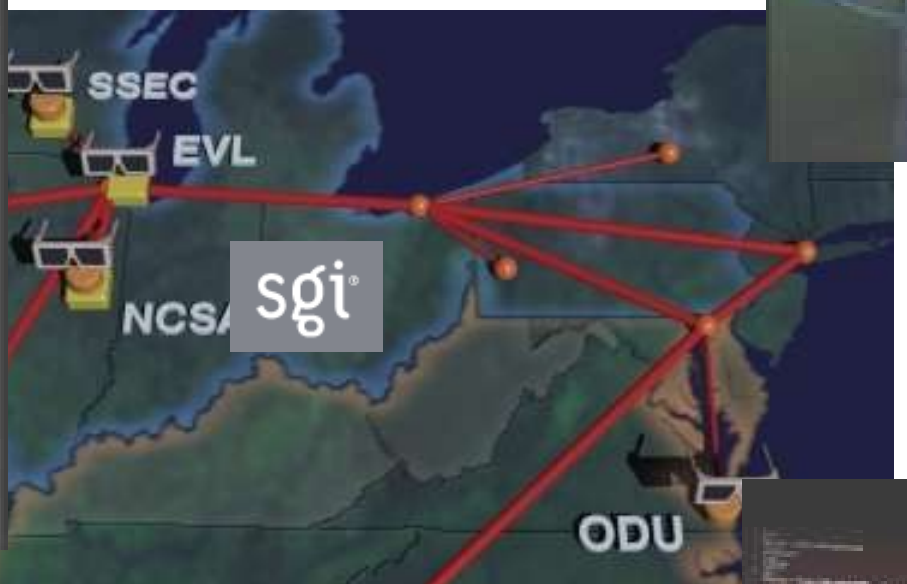


# Alliance 1997: Collaborative Video Production via Tele-Immersion and Virtual Director

## Alliance Project Linking CAVE, Immersadesk, Power Wall, and Workstation












NCSA™ UIC

sgi

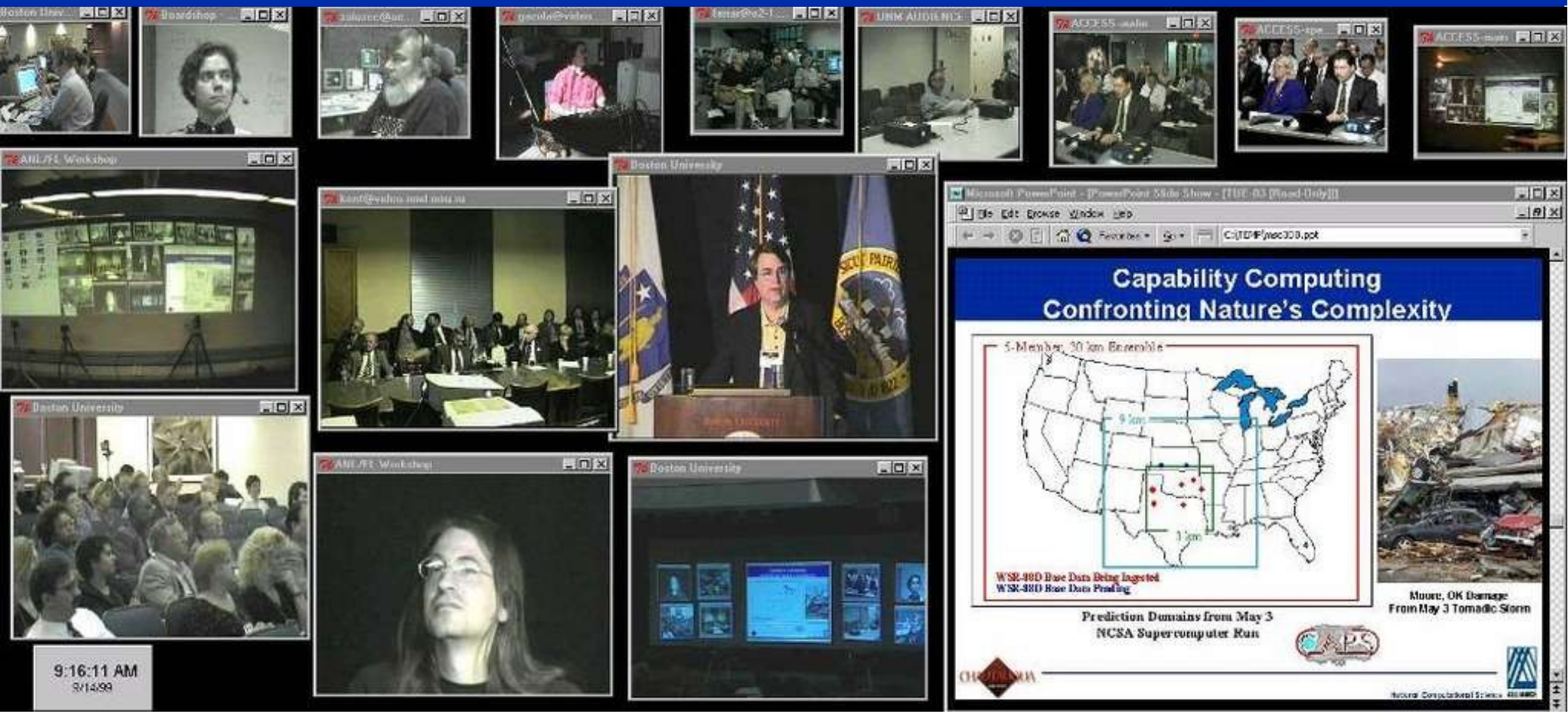
ALLIANCE

Donna Cox, Bob Patterson, Stuart Levy, Glen Wheless
www.ncsa.uiuc.edu/People/cox/

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# In Pursuit of Realistic TelePresence
# Access Grid International Video Meetings




## Can We Modify This Technology To Create Global Performance Spaces?

OptIPuter

Access Grid Lead-Argonne
NSF STARTAP Lead-UIC's Elec. Vis. Lab

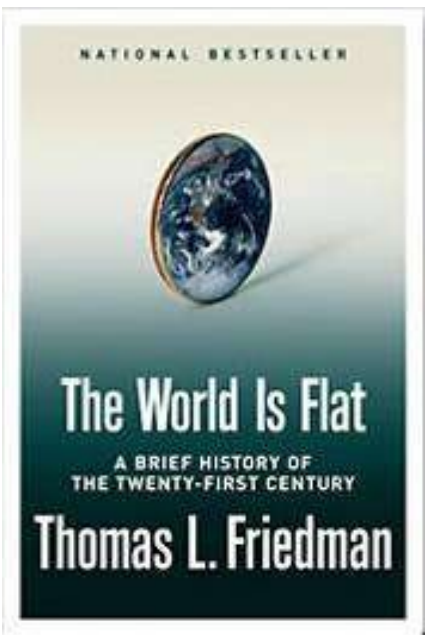
it2

# We Are Living Through A Fundamental Global Change—How Can We Glimpse the Future?

**[The Internet] has created a [global] platform where intellectual work, intellectual capital, could be delivered from anywhere. It could be disaggregated, delivered, distributed, produced, and put back together again…**

**The playing field is being leveled."**

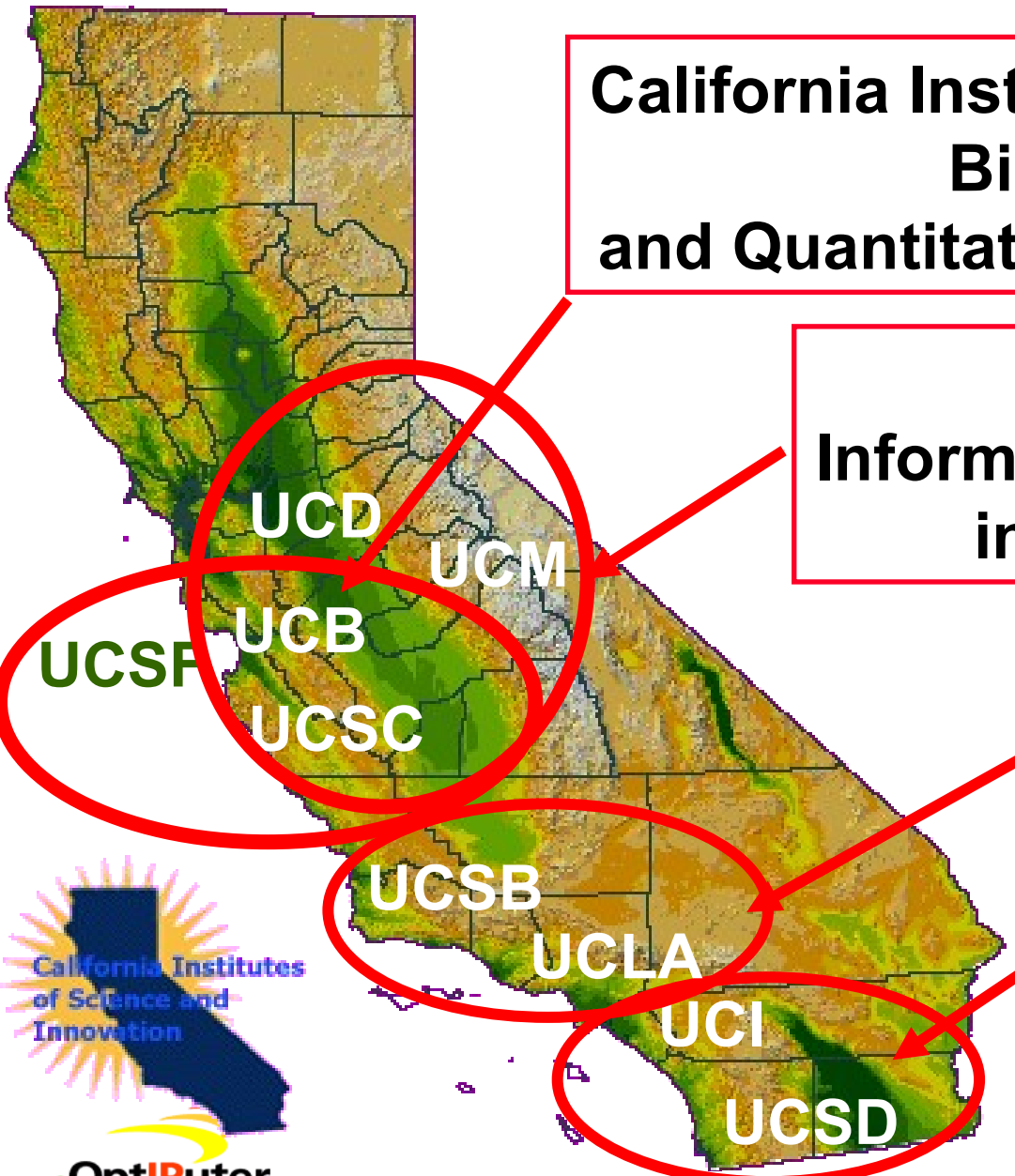
**Nandan Nilekani, CEO Infosys (Bangalore, India)**




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# California's Institutes for Science and Innovation
# A Bold Experiment in Collaborative Research




**California Institute for Bioengineering, Biotechnology, and Quantitative Biomedical Research**

**Center for Information Technology Research in the Interest of Society**

**California NanoSystems Institute**

**California Institute for Telecommunications and Information Technology**

California Institutes of Science and Innovation

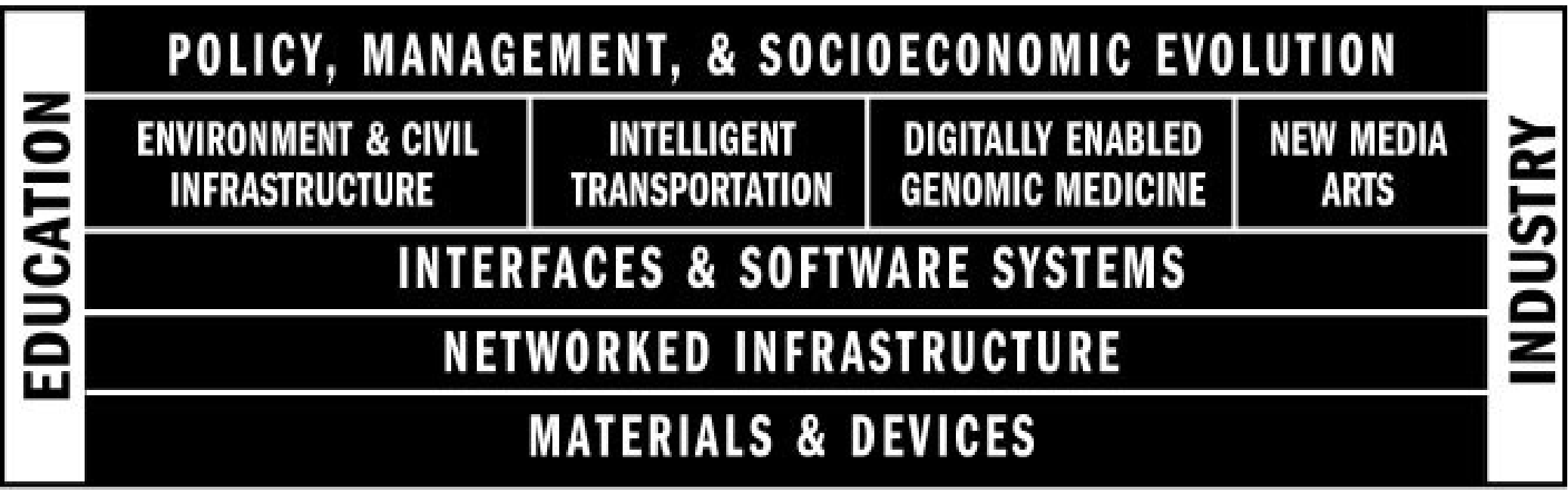
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www.ucop.edu/california-institutes

it²

# 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**

California Institute for Telecommunications and Information Technology . Cal-(IT)$^2$



Extending the Internet Throughout the Physical World

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




- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks
  - International Conferences and Testbeds
- New Laboratory Facilities
  - Virtual Reality, Digital Cinema, HDTV, Synthesis
  - Nanotech, BioMEMS, Chips, Radio, Photonics, Grid, Data, Applications



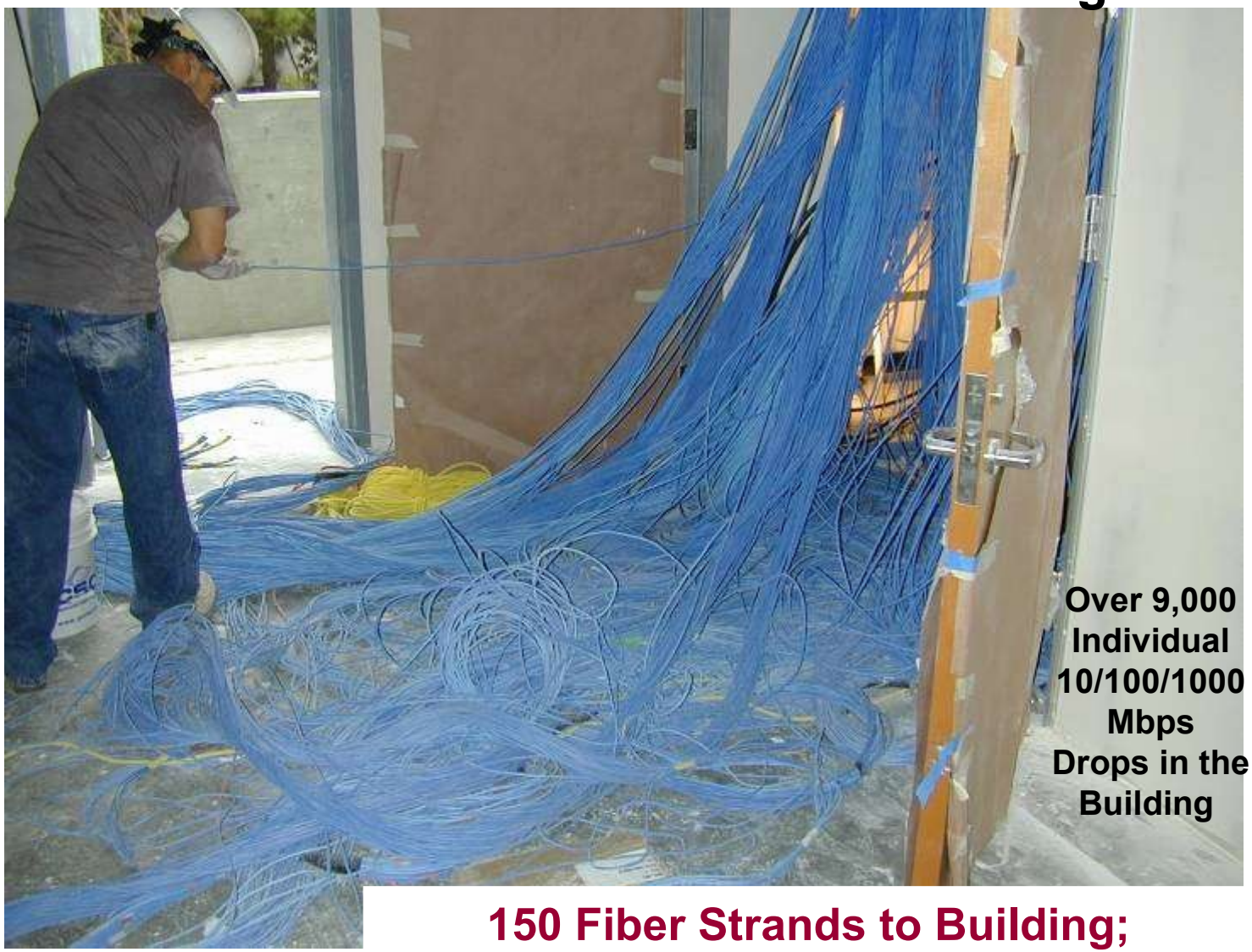

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**Preparing for an World in Which Distance Has Been Eliminated…**

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# The Calit2@UCSD Building is Designed for Extremely High Bandwidth

## 1.8 Million Feet of Cat6 Ethernet Cabling



Over 9,000 Individual 10/100/1000 Mbps Drops in the Building

Photo: Tim Beach, Calit2

**150 Fiber Strands to Building;**
**Experimental Roof Radio Antenna Farm**
**Ubiquitous WiFi**

# "This is What Happened with the Internet Stock Boom"

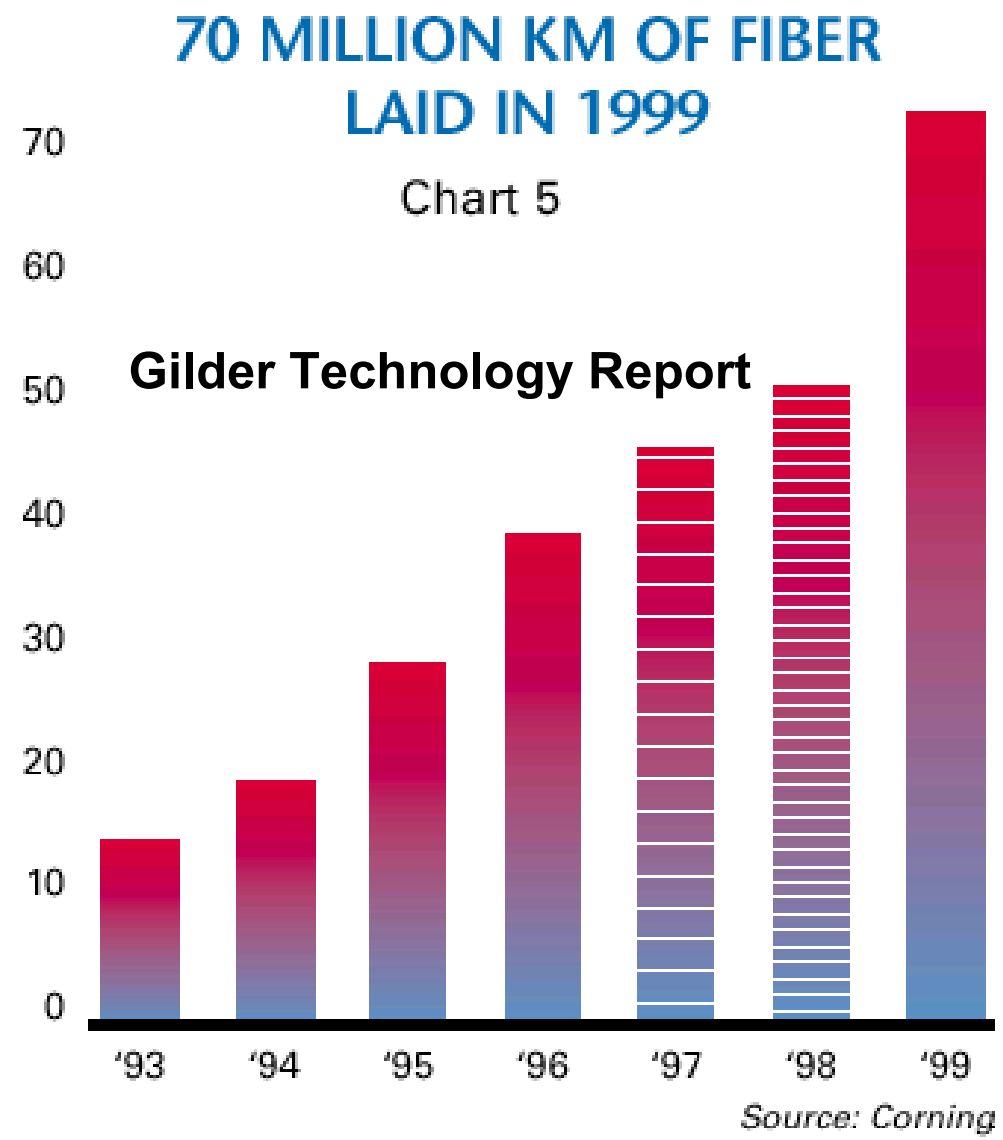
**"It sparked a huge overinvestment in fiber-optic cable companies, which then laid massive amount of fiber-optic cable on land and under the oceans, which dramatically drove down the cost of making a phone call or transmitting data anywhere in the world."**

**--Thomas Friedman, The World is Flat (2005)**

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# Worldwide Deployment of Fiber Up 42% in 1999



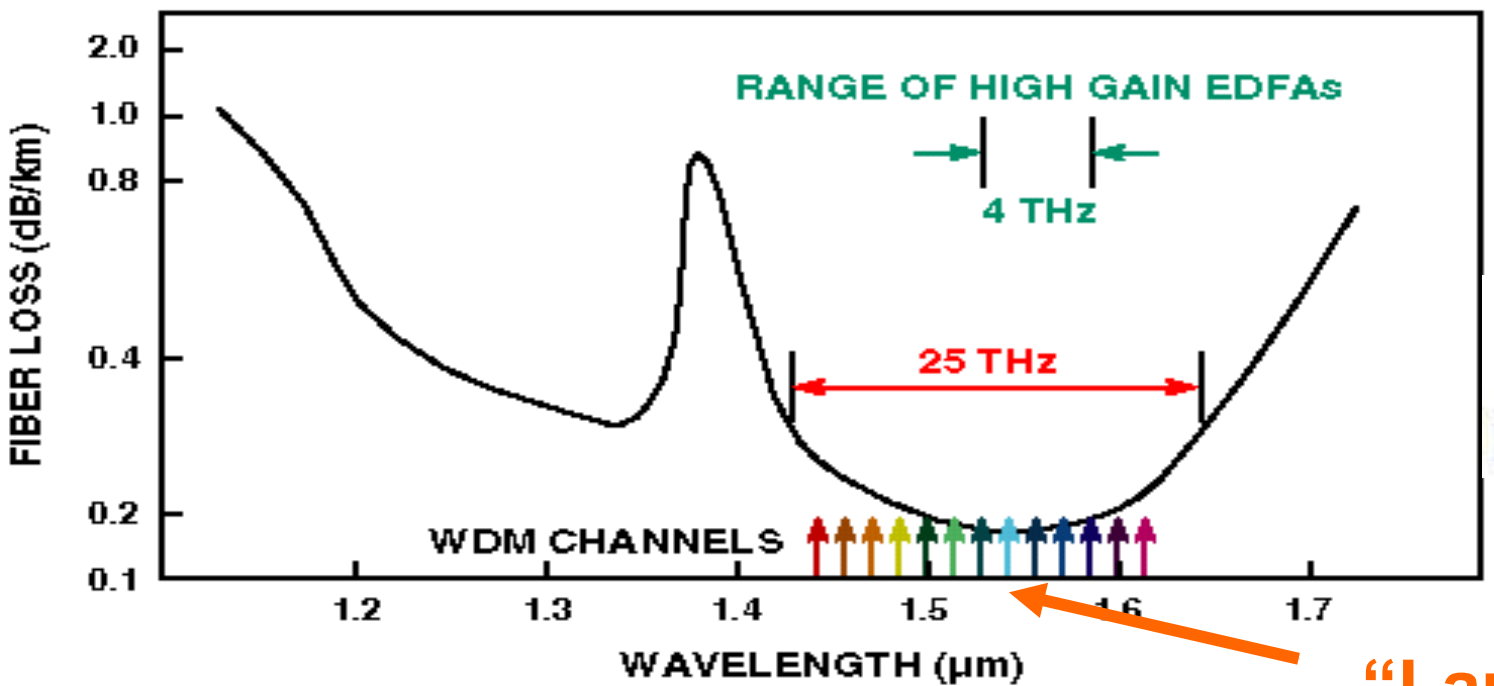

**That's Laying Fiber at the Rate of Nearly 10,000 km/hour!!**

From Smarr Talk (2000)

# Each Optical Fiber Can Now Carry Many Parallel Line Paths or "Lambdas"

## WAVELENGTH DIVISION MULTIPLEXING (WDM)

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




"Lambdas"

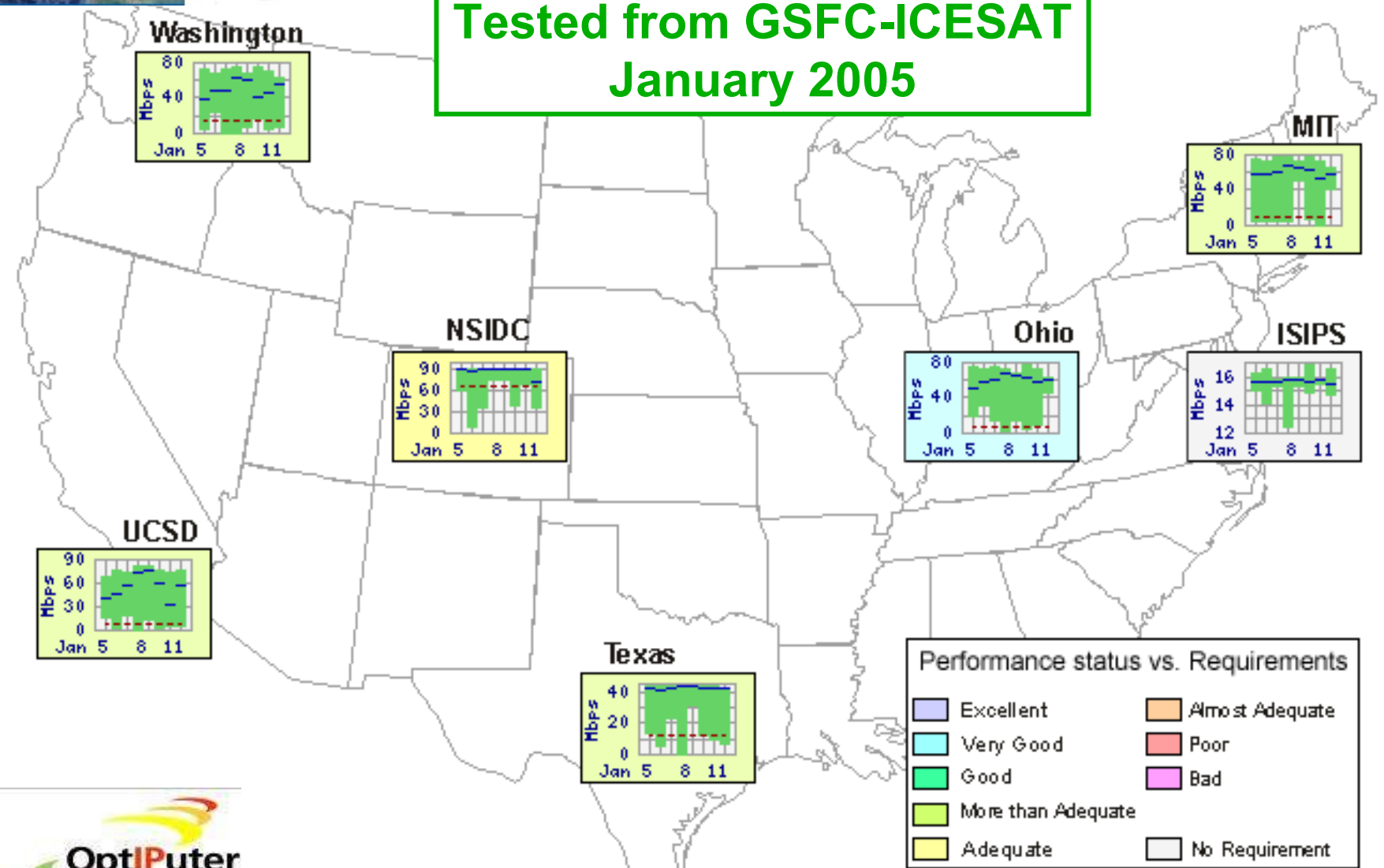
Source: Steve Wallach, Chiaro Networks

# Challenge: Average Throughput of NASA Data Products to End User is Only < 50 Megabits/s



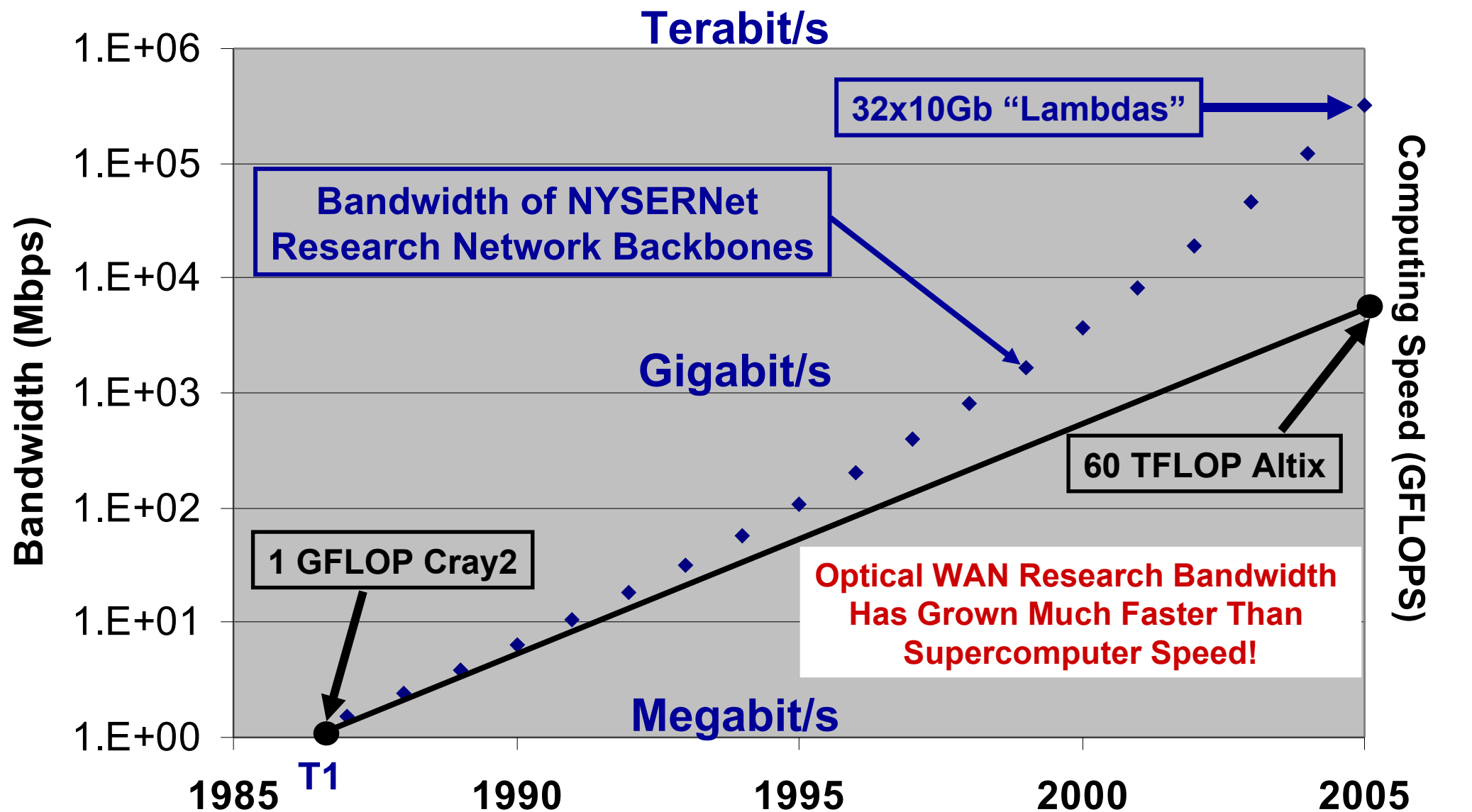
## ENSIGHT Active Testing ICESat Destinations

**Tested from GSFC-ICESAT January 2005**




http://ensight.eos.nasa.gov/Missions/icesat/index.shtml

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




Network Data Source: Timothy Lance, President, NYSERNet

# 15 Years Later
# 10Gb Parallel Lambda Cyber Backplane

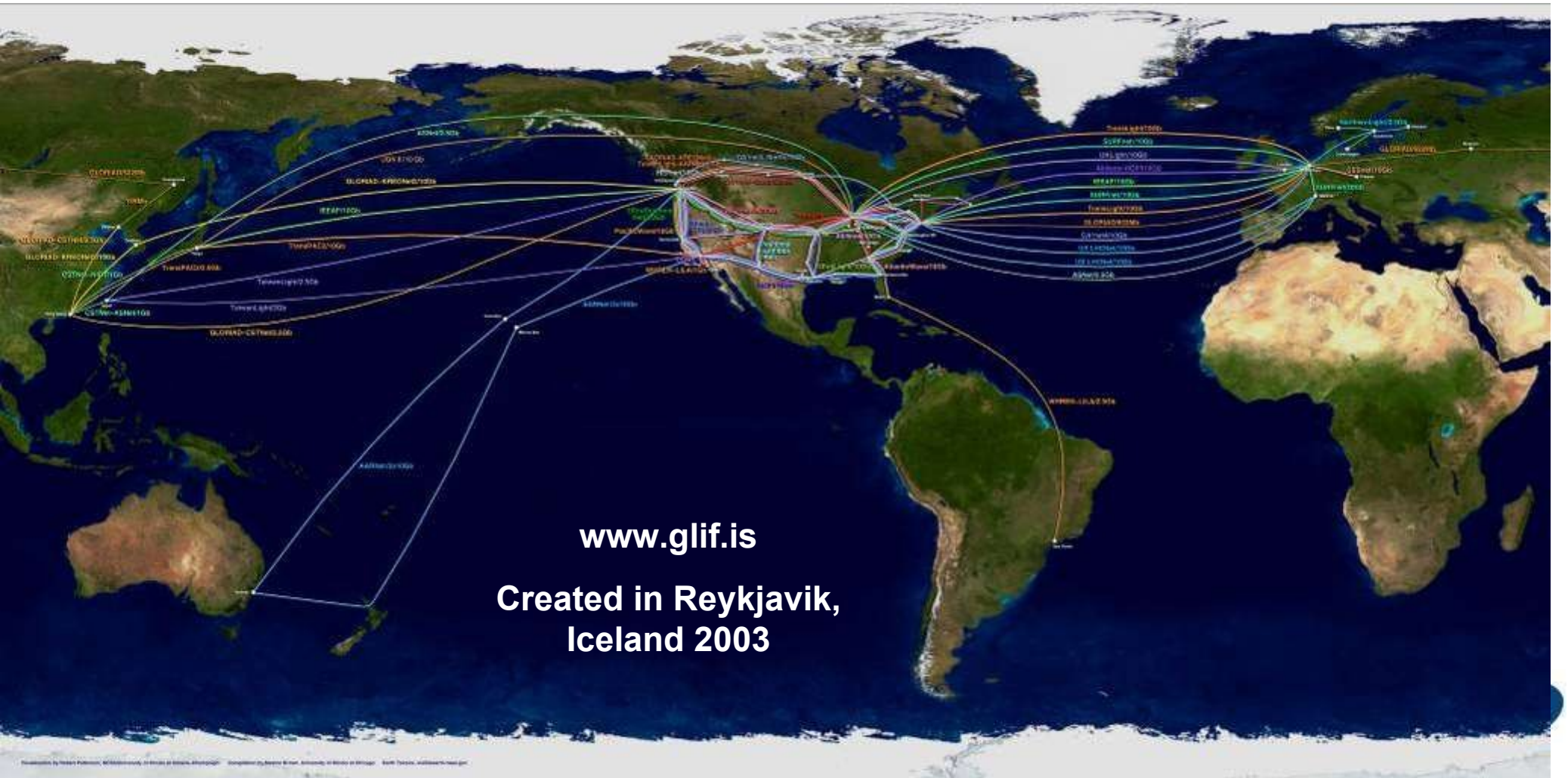



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# The Global Lambda Integrated Facility (GLIF) Creates MetaComputers on the Scale of Planet Earth

## Many Countries are Interconnecting Optical Research Networks

## to form a Global SuperNetwork



# The Networking Double Header of the Century Will Be Driven by LambdaGrid Applications

the UC Discovery Grant

Maxine Brown, Tom DeFanti, Co-Organizers

## iGrid 2005

THE GLOBAL LAMBDA INTEGRATED FACILITY



www.startap.net/igrid2005/

**September 26-30, 2005**

**Calit2 @ University of California, San Diego**

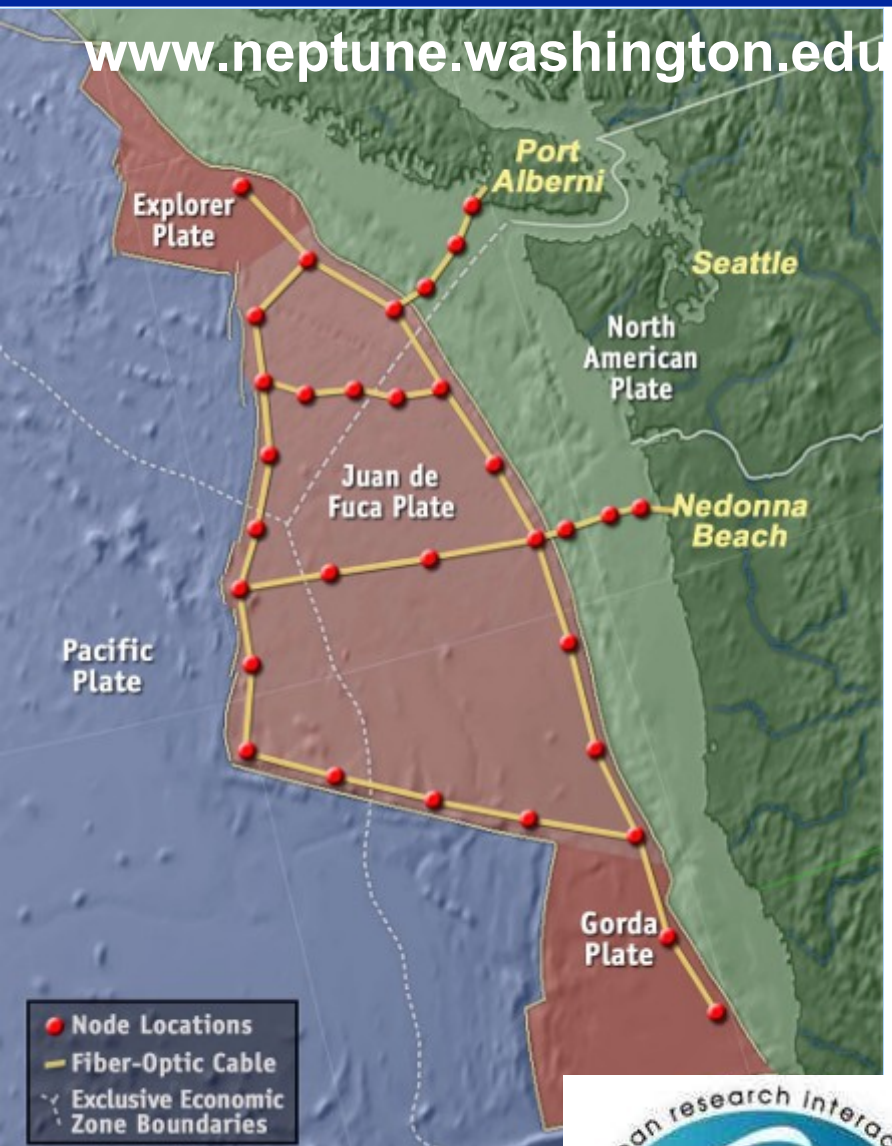
**California Institute for Telecommunications and Information Technology**

## SC|05 Gateway to Discovery

Washington State Convention and Trade Center Seattle, WA
November 12-18 2005

http://sc05.supercomp.org

# Adding Web and Grid Services to Lambdas to Provide Real Time Control of Ocean Observatories




**LOOKING:**
**(Laboratory for the Ocean Observatory Knowledge Integration Grid)**

**http://lookingtosea.ucsd.edu/**

- **Goal:**
  - Prototype Cyberinfrastructure for NSF's Ocean Research Interactive Observatory Networks (ORION) Building on OptIPuter
- **LOOKING NSF ITR with PIs:**
  - John Orcutt & Larry Smarr - UCSD
  - John Delaney & Ed Lazowska –UW
  - Mark Abbott – OSU
- **Collaborators at:**
  - MBARI, WHOI, NCSA, UIC, CalPoly, UVic, CANARIE, Microsoft, NEPTUNE-Canarie

OptIPuter NSF ocean research interactive ORION observatory networks it2

# First Remote Interactive High Definition Video Exploration of Deep Sea Vents




Source John Delaney & Deborah Kelley, UWash

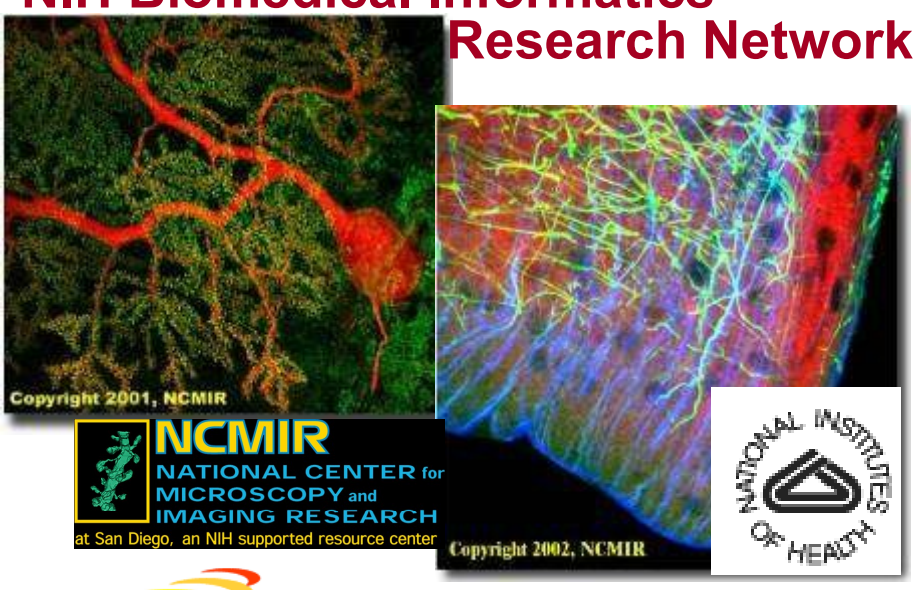
# The OptIPuter Project –

## Creating a LambdaGrid "Web" for Gigabyte Data Objects

- **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**
- **Linking Global Scale Science Projects to User's Linux Clusters**

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**NIH Biomedical Informatics Research Network**

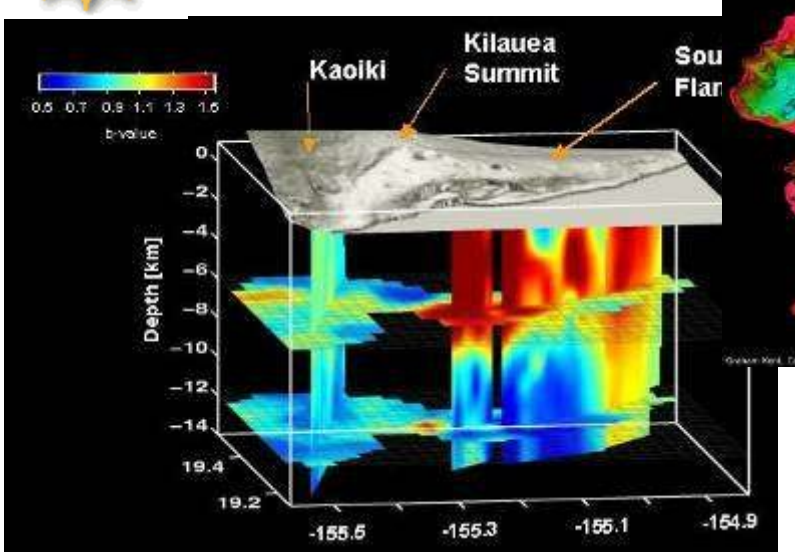


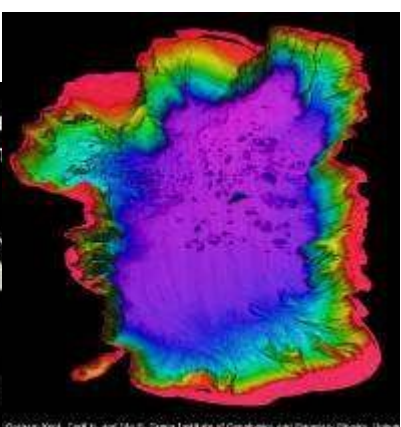

NCMIR
NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH
at San Diego, an NIH supported resource center

NATIONAL INSTITUTES OF HEALTH

NSF

**NSF EarthScope and ORION**



OptIPuter

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

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# OptIPuter End Nodes Are Smart Bit Buckets
## i.e. Scalable Standards-Based Linux Clusters with Rocks & Globus

**Building RockStar at SC2003**








**Complete SW Install and HW Build in Under 2 Hours**

**Rocks Team is Working with Sun to Understand How to Apply These Techniques to Solaris X – Based Clusters.**
**Make it Possible to Match the Installation Speed of the Linux Version**

**Rocks is the 2004 Most Important Software Innovation**
**HPCwire Reader's Choice and Editor's Choice Awards**

**Source: Phil Papadopoulos, SDSC**

Sun microsystems
SDSC
ROCKS
GAMESS
BIRN
OMEDICAL INFORMATICS RESEARCH NETWORK
NPACI

# 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

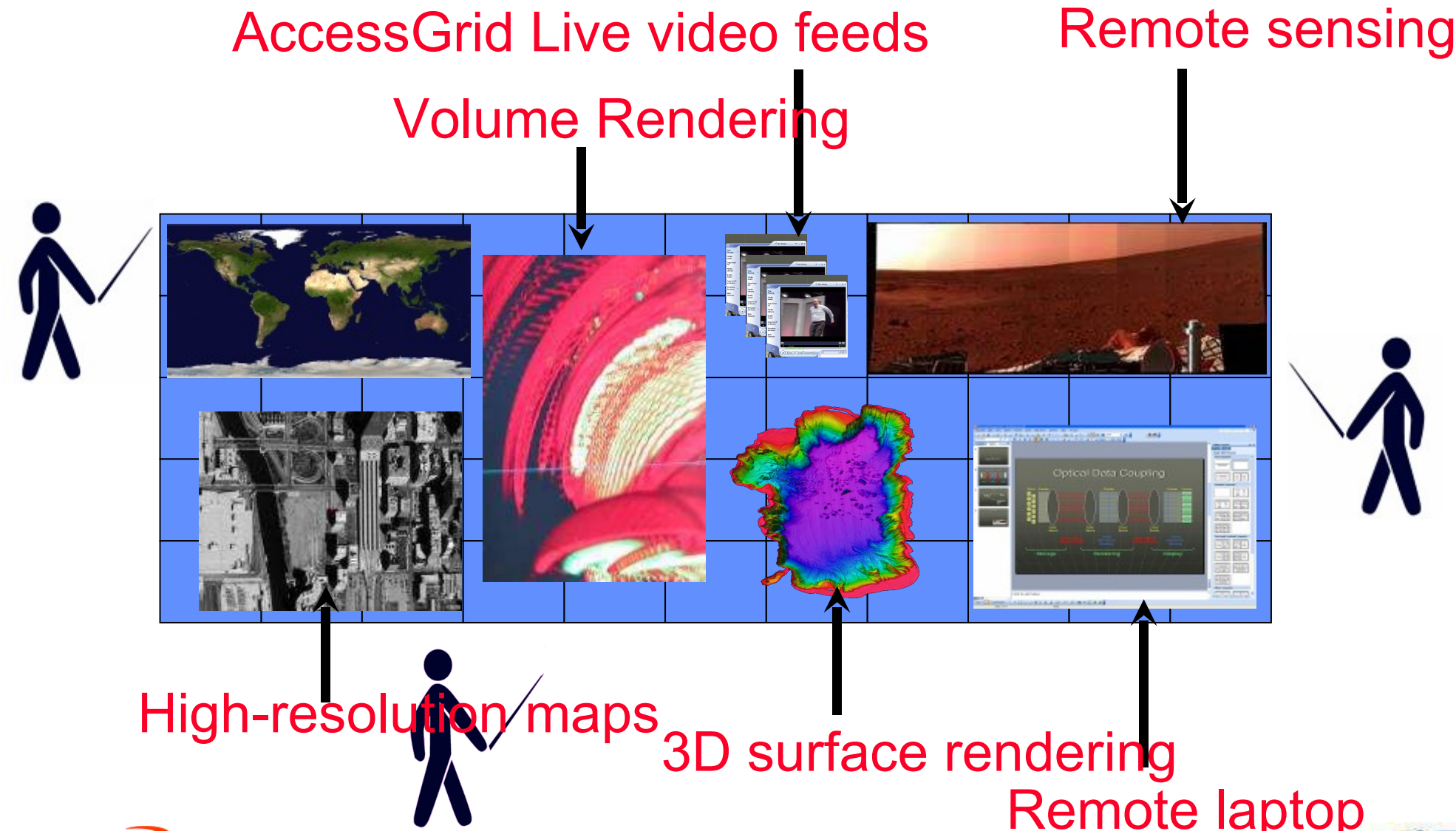
**Calit2 is Building a LambdaVision Wall in Each of the UCI & UCSD Buildings**



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

# Scalable Adaptive Graphics Environment (SAGE) Required for Working in Display-Rich Environments

## Information Must Be Able To Flexibly Move Around The Wall




Source: Jason Leigh, UIC

# UCSD is Prototyping a Campus-Scale OptIPuter



0.320 Tbps Backplane Bandwidth

Juniper T320

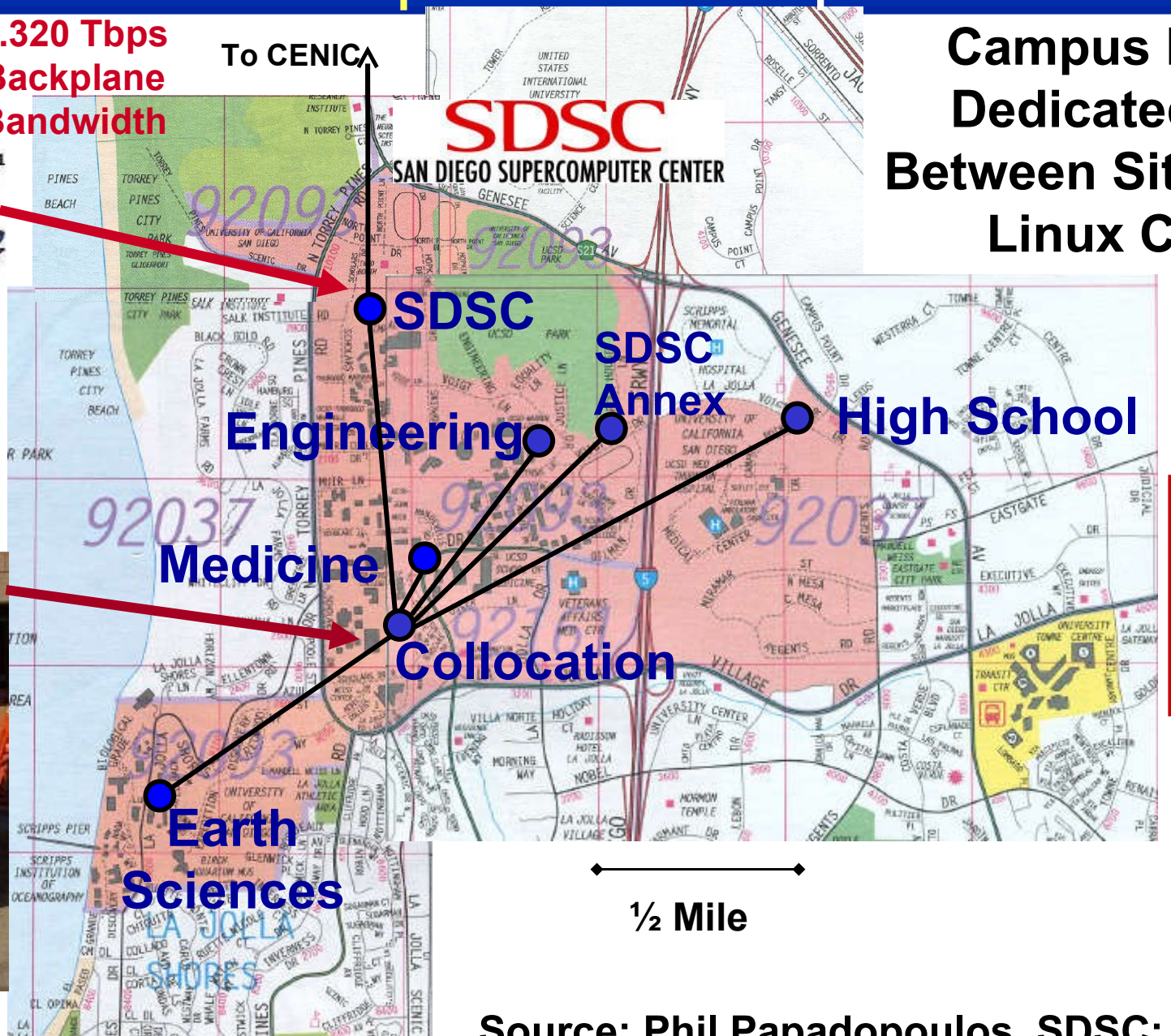
20X

6.4 Tbps Backplane Bandwidth



Chiaro Estara

To CENIC




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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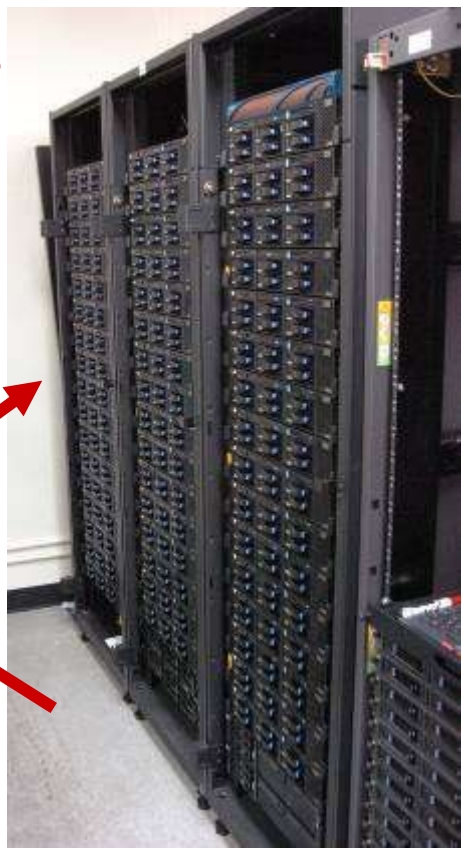
# Campuses Must Provide Fiber Infrastructure to End-User Laboratories & Large Rotating Data Stores

SIO Ocean Supercomputer



UCSD Campus LambdaStore Architecture

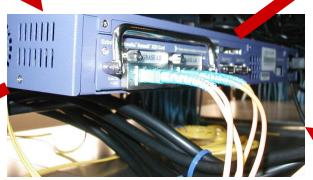
IBM Storage Cluster



Streaming Microscope

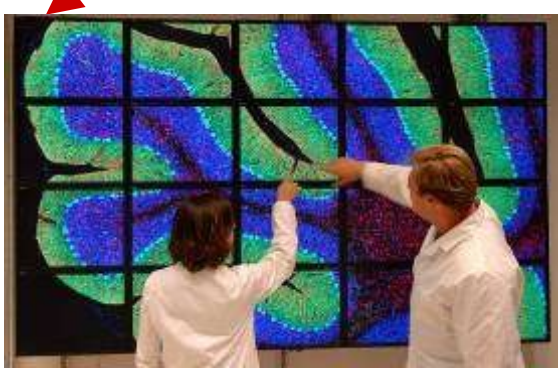






2 Ten Gbps Campus Lambda Raceway







Global LambdaGrid

Source: Phil Papadopoulos, SDSC, Calit2

OptIPuter

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# The Optical Core of the UCSD Campus-Scale Testbed -- Evaluating Packet Routing versus Lambda Switching

**Goals by 2007:**

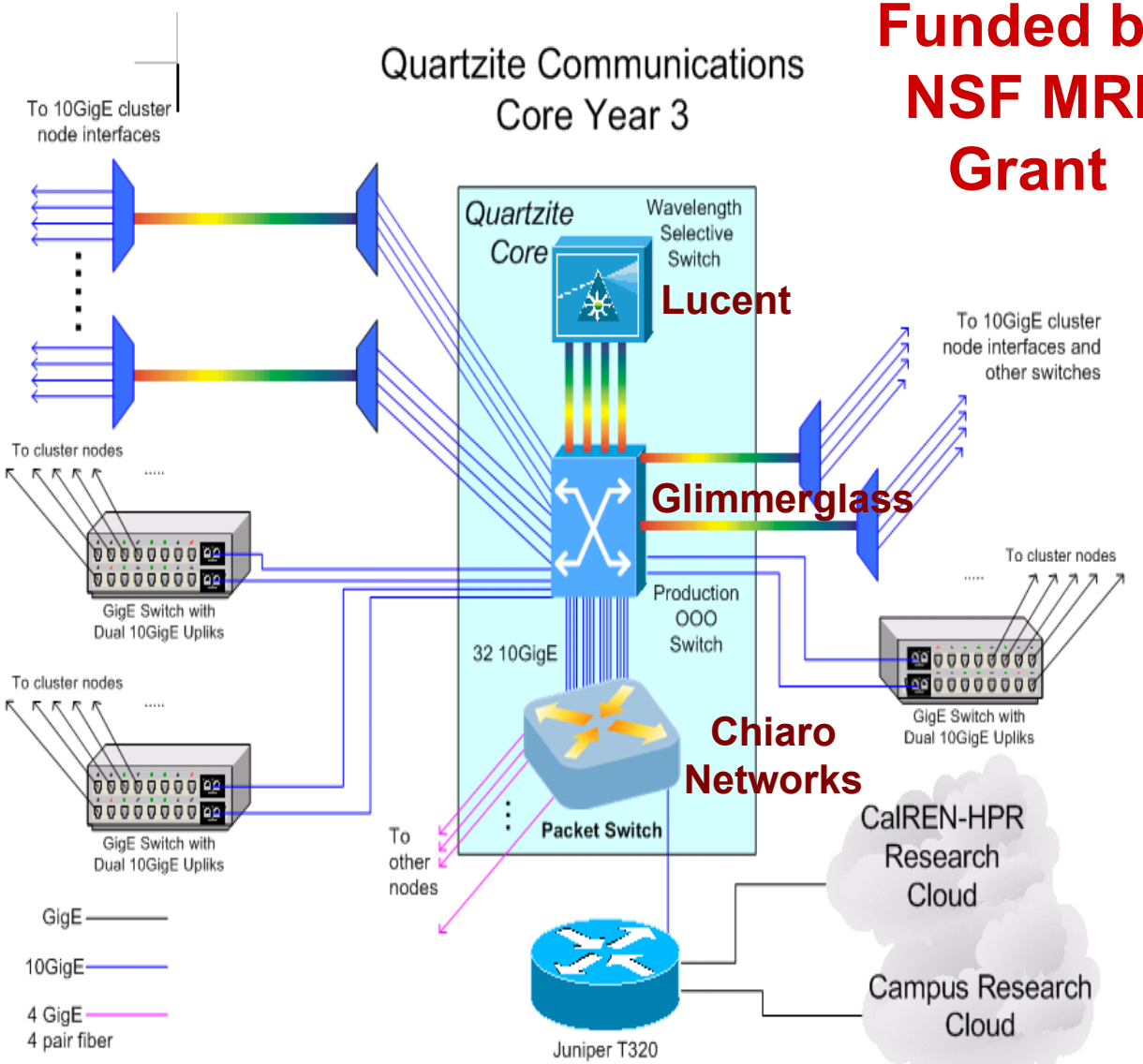
**>= 50 endpoints at 10 GigE**

**>= 32 Packet switched**

**>= 32 Switched wavelengths**

**>= 300 Connected endpoints**

**Approximately 0.5 TBit/s Arrive at the "Optical" Center of Campus**
**Switching will be a Hybrid Combination of:**
**Packet, Lambda, Circuit -- OOO and Packet Switches Already in Place**

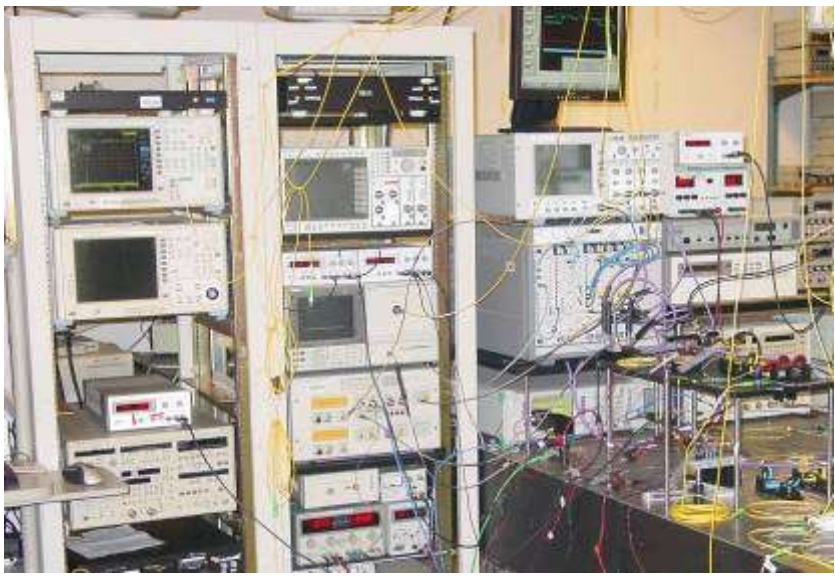


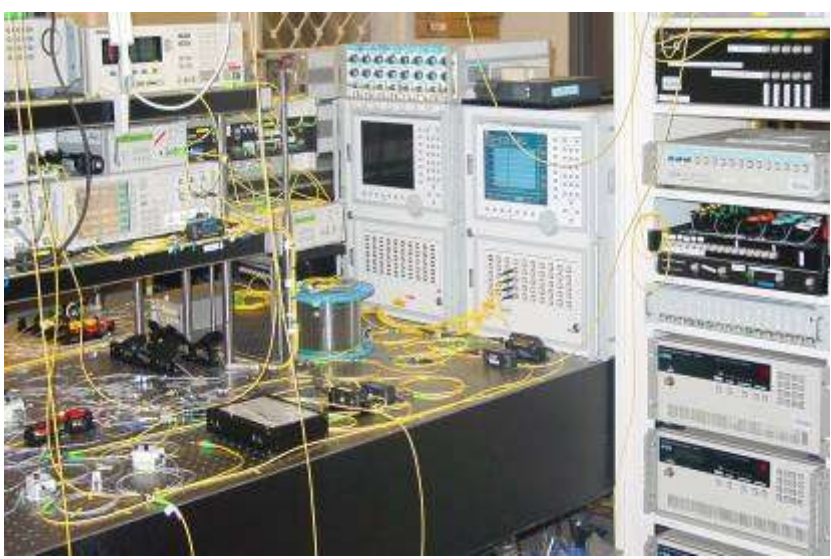

**Funded by NSF MRI Grant**

**Source: Phil Papadopoulos, SDSC, Calit2**

# 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





UCSD Parametric Processing Laboratory



OptIPuter

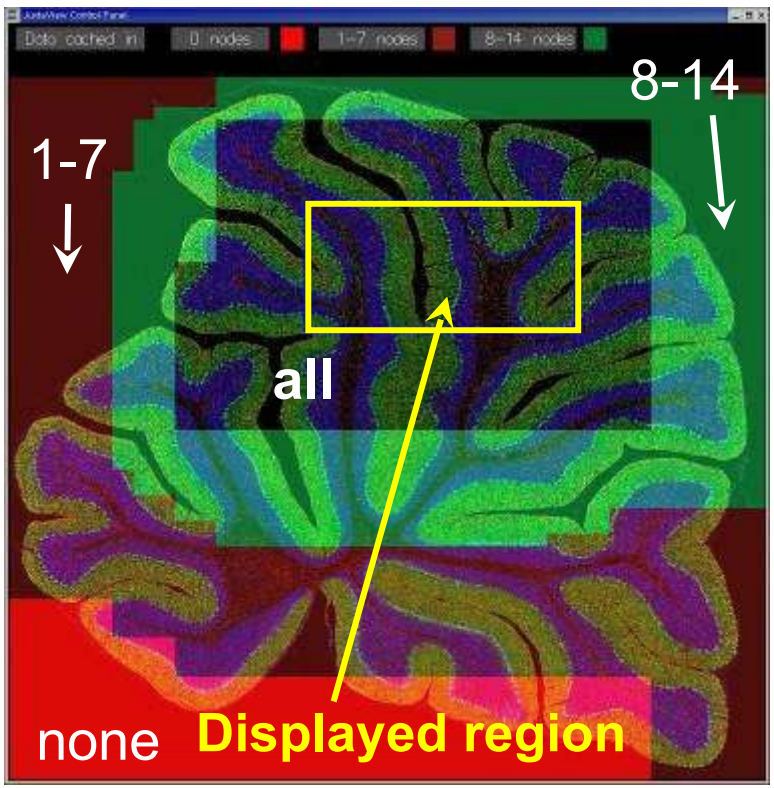
UCSD Photonics

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# LambdaRAM: Clustered Memory To Provide Low Latency Access To Large Remote Data Sets

- **Giant Pool of Cluster Memory Provides Low-Latency Access to Large Remote Data Sets**
  - **Data Is Prefetched Dynamically**
  - **LambdaStream Protocol Integrated into JuxtaView Montage Viewer**
- **3 Gbps Experiments from Chicago to Amsterdam to UIC**
  - **LambdaRAM Accessed Data From Amsterdam Faster Than From Local Disk**

**Visualization of the Pre-Fetch Algorithm**



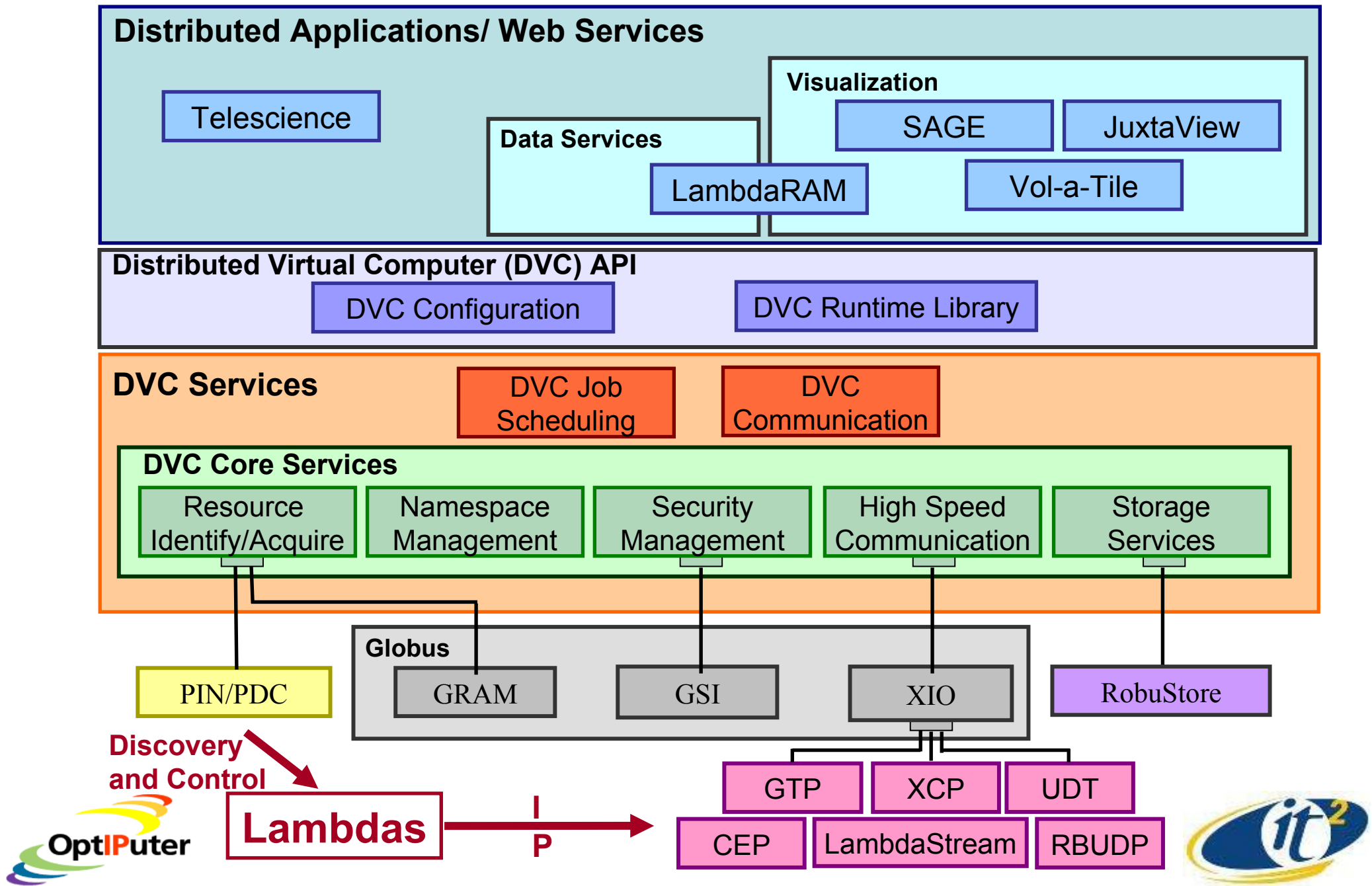




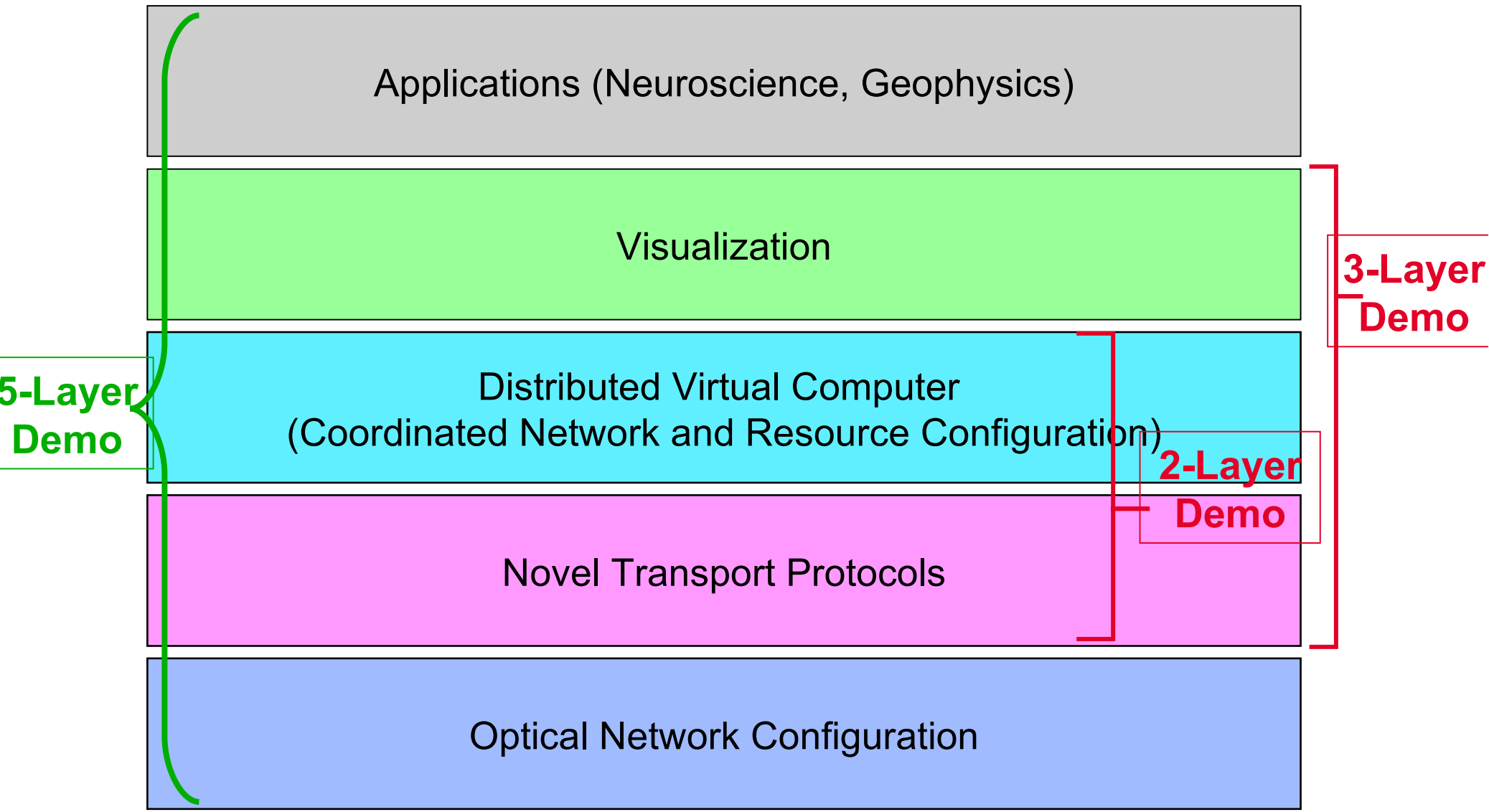
**Data on Disk in Amsterdam**

**Source: David Lee, Jason Leigh**

# OptIPuter Software Architecture--a Service-Oriented Architecture Integrating Lambdas Into the Grid

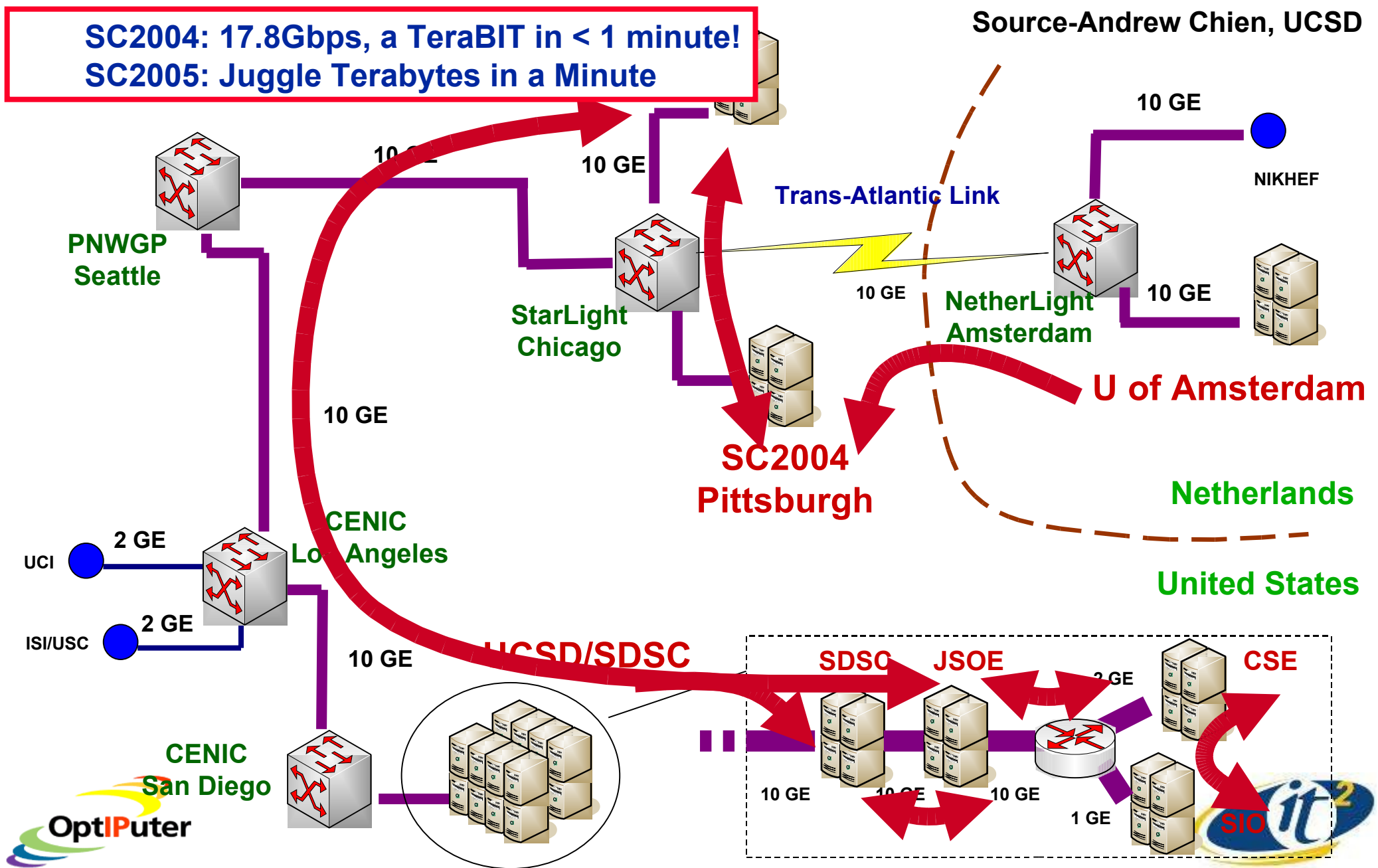


# Exercising the OptIPuter Middleware Software "Stack"

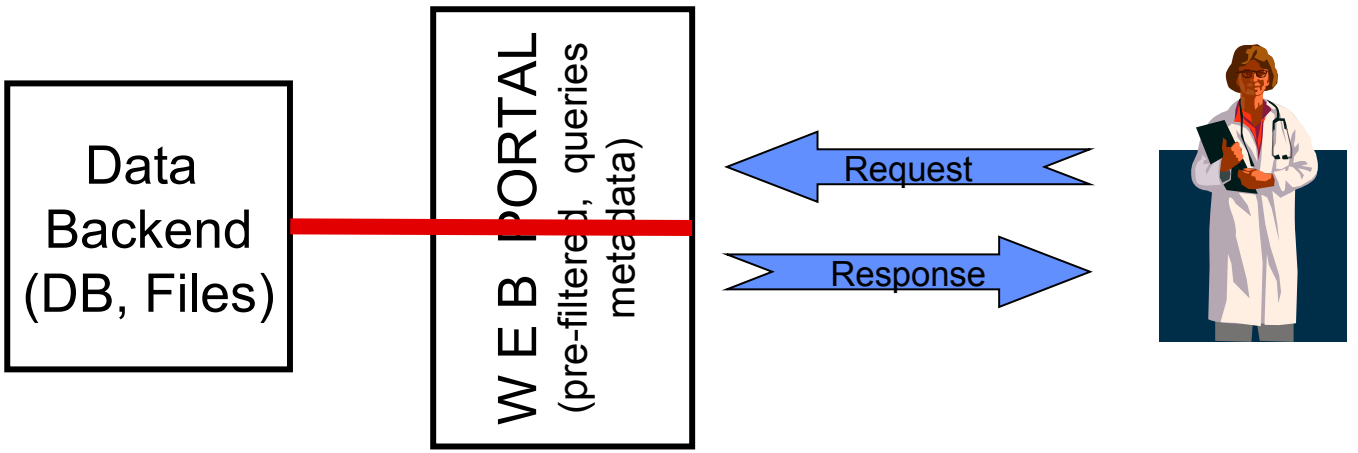


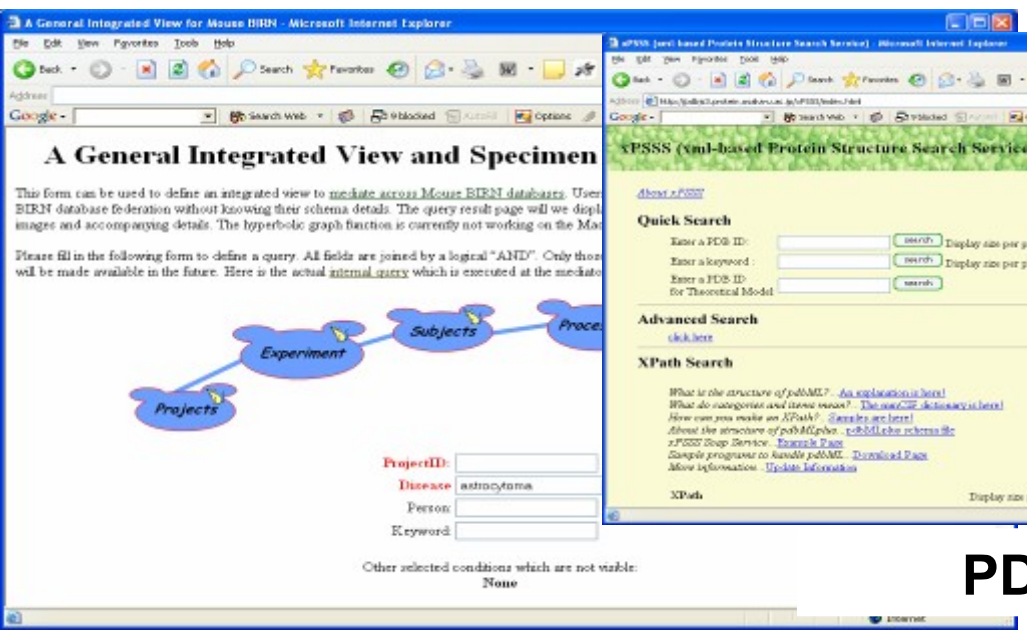

Source-Andrew Chien, UCSD- OptIPuter Software System Architect

# First Two-Layer OptIPuter Terabit Juggling on 10G WANs



# Calit2 Intends to Jump Beyond Traditional Web-Accessible Databases

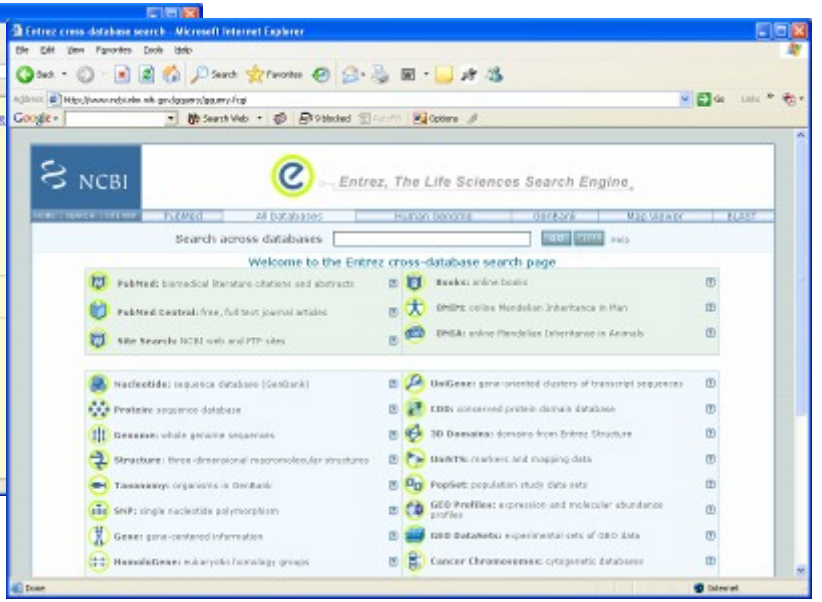



BIRN




PDB

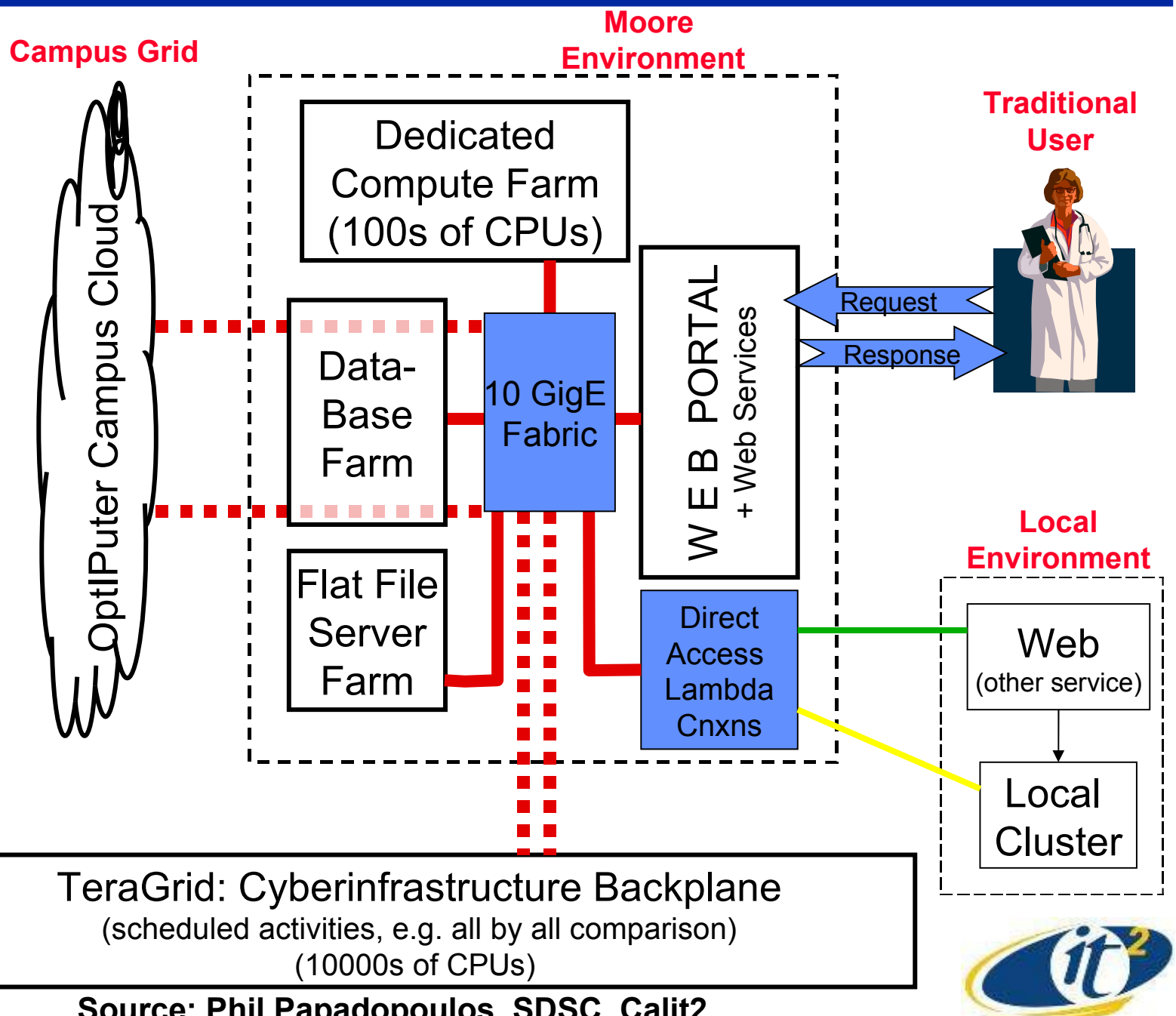



NCBI Genbank

**+ many others**

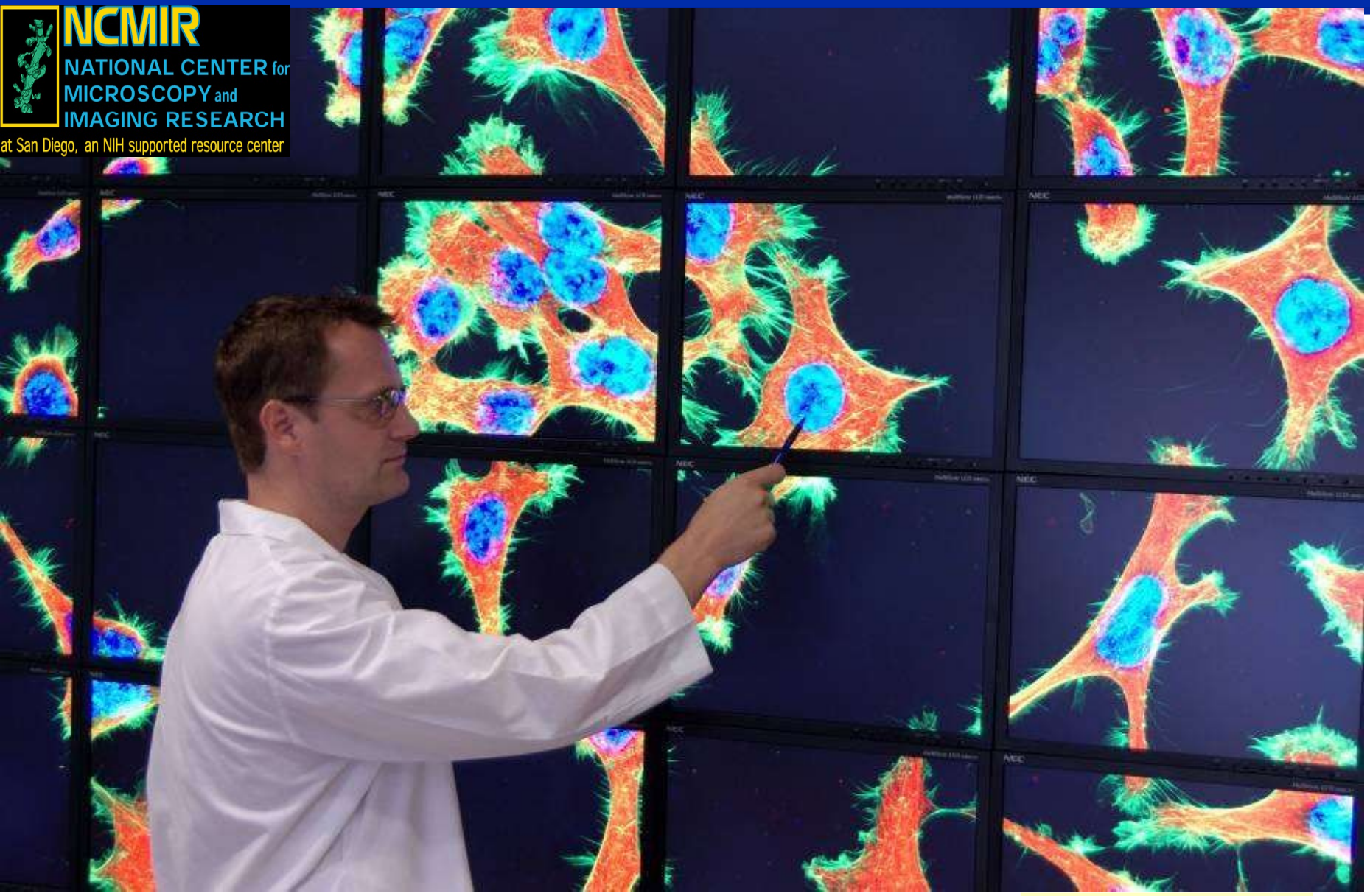
Source: Phil Papadopoulos, SDSC, Calit2

# Calit2's Direct Access Core Architecture




**Source: Phil Papadopoulos, SDSC, Calit2**

# Realizing the Dream:
# High Resolution Portals to Global Science Data




Source: Mark Ellisman, David Lee, Jason Leigh, Tom Deerinck

OptIPuter

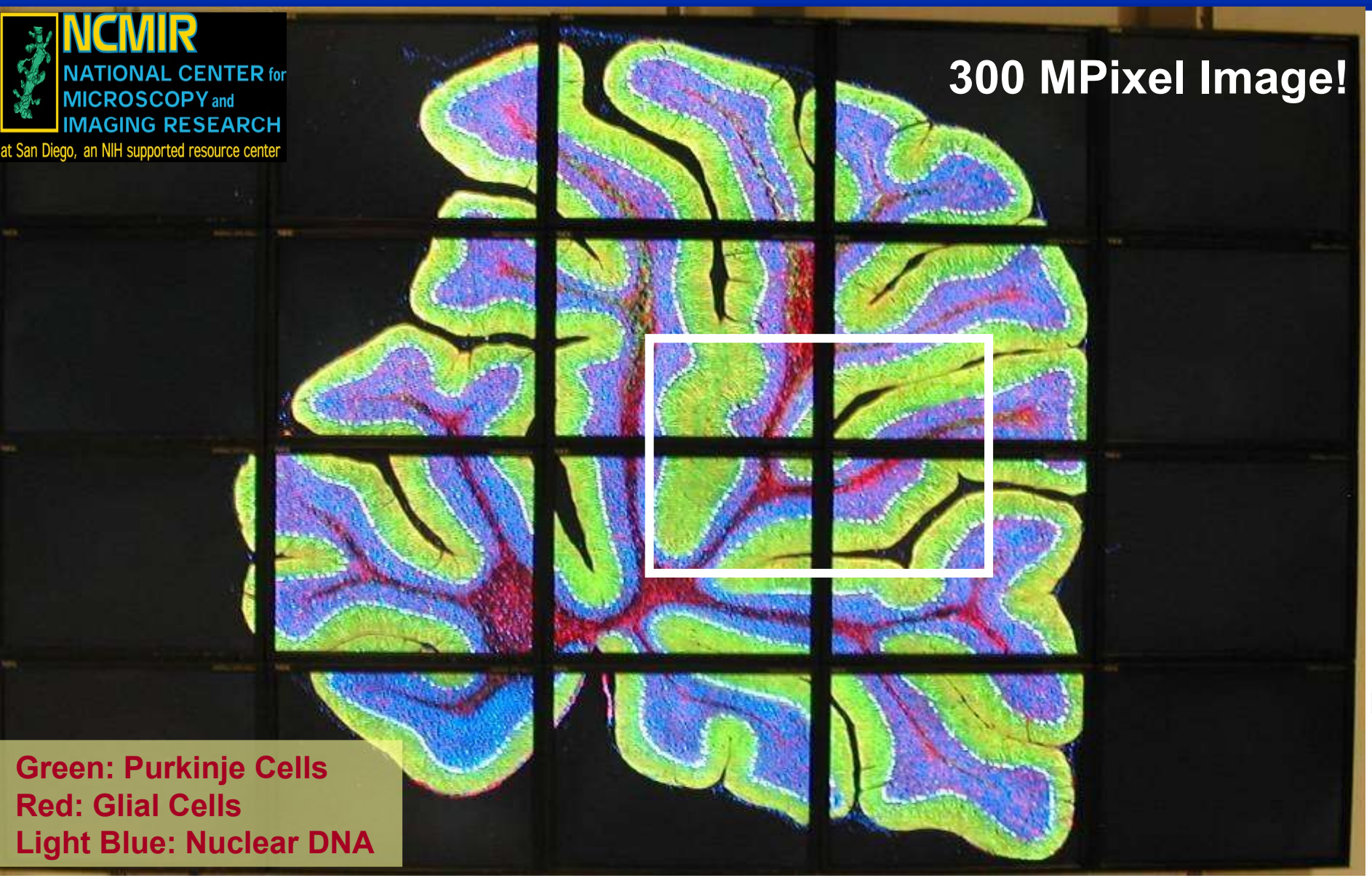
650 Mpixel 2-Photon Microscopy
Montage of HeLa Cultured Cancer Cells

Green: Actin
Red: Microtubles
Light Blue: DNA

it2

# Scalable Displays Being Developed for Multi-Scale Biomedical Imaging

NCMIR
NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH
at San Diego, an NIH supported resource center



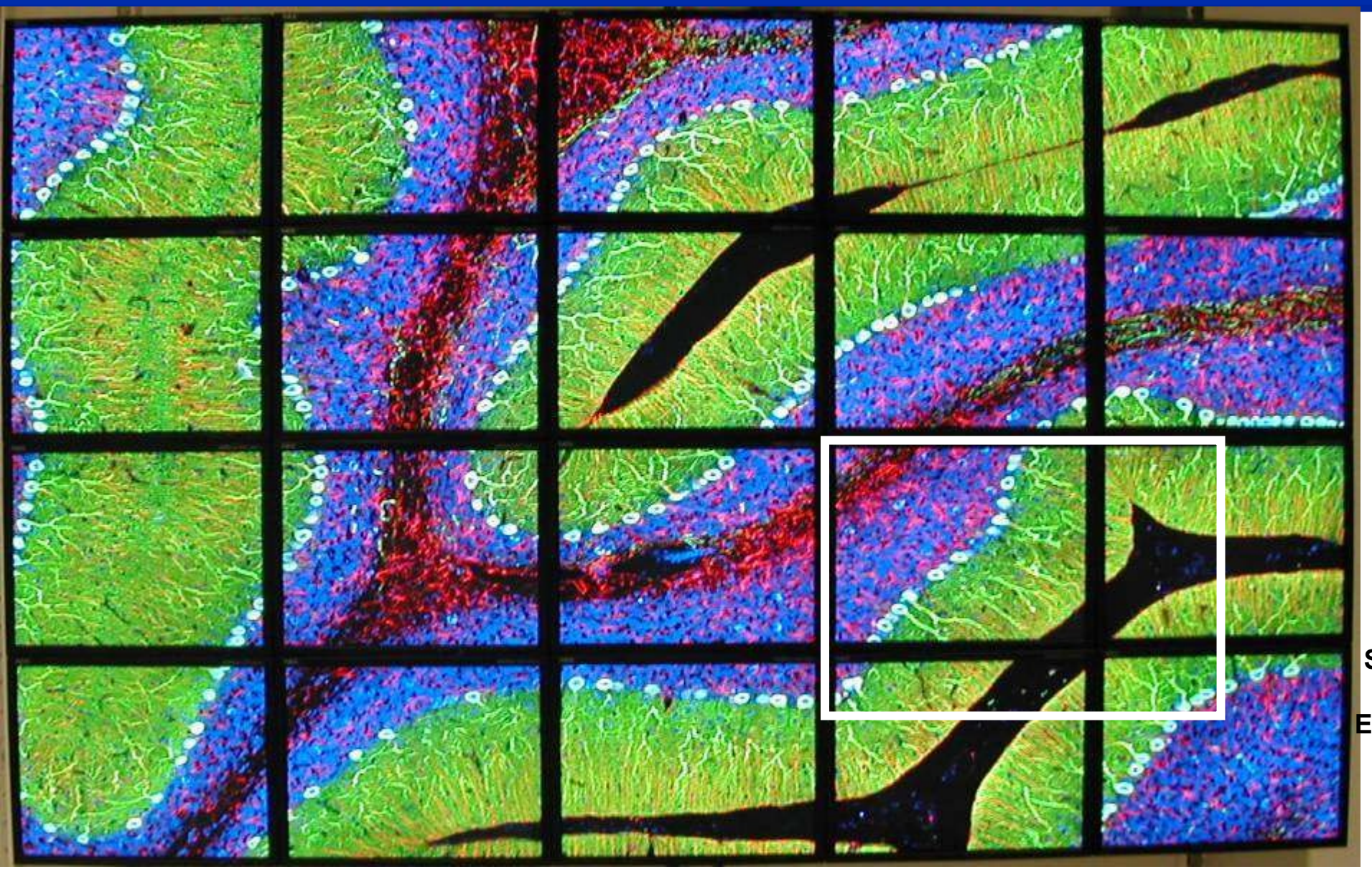

Source: Mark Ellisman, David Lee, Jason Leigh

Two-Photon Laser Confocal Microscope Montage of 40x36=1440 Images in 3 Channels of a Mid-Sagittal Section of Rat Cerebellum Acquired Over an 8-hour Period

OptIPuter

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# Scalable Displays Allow Both Global Content and Fine Detail



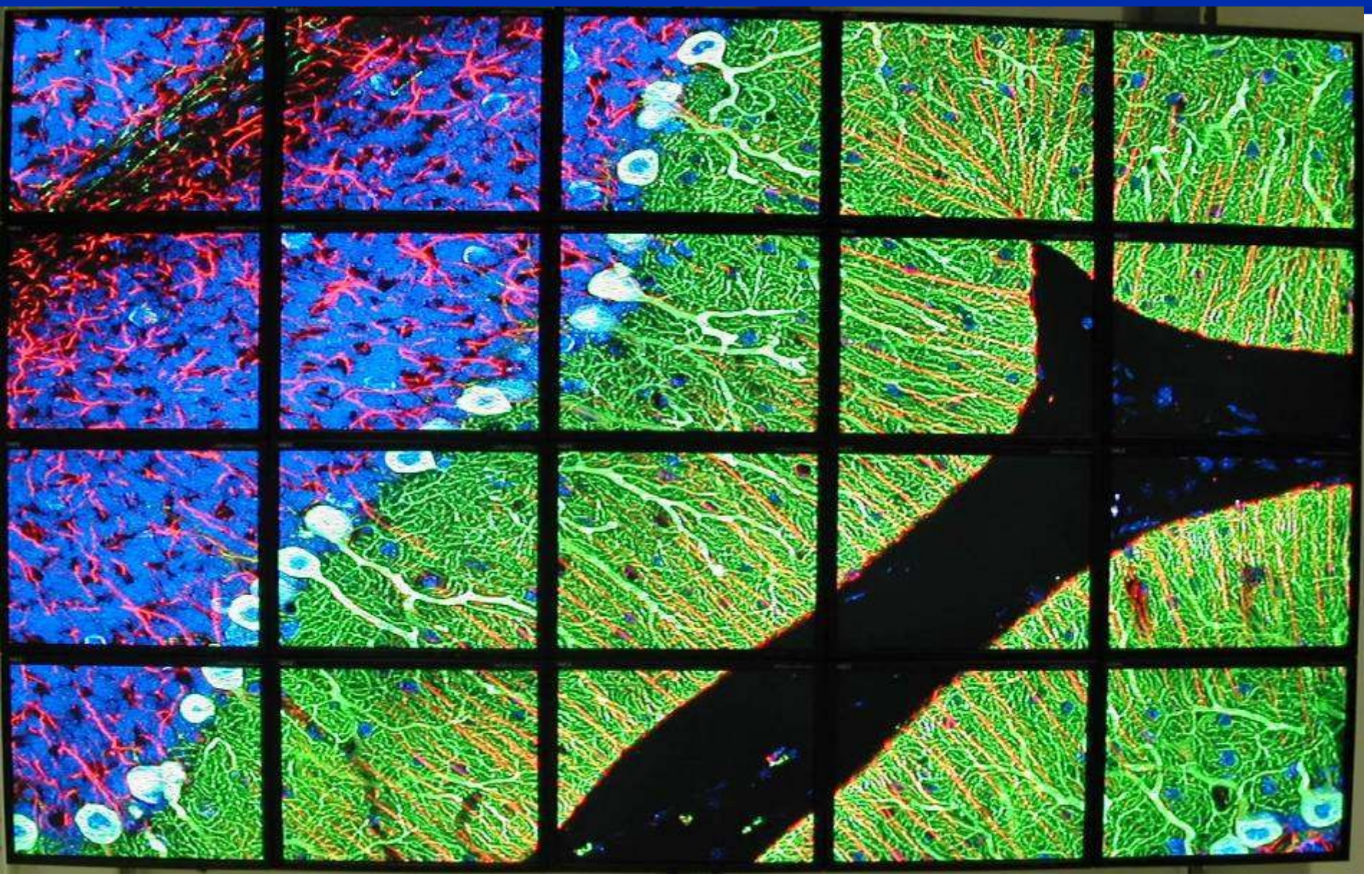
Source: Mark Ellisman, David Lee, Jason Leigh

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

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# Allows for Interactive Zooming from Cerebellum to Individual Neurons



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Source: Mark Ellisman, David Lee, Jason Leigh

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# 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**

# Calit2 Is Applying OptIPuter Technologies to Post-Hurricane Recovery

**Working with NASA, USGS, NOAA, NIEHS, EPA, SDSU, SDSC, Duke, …**



# “Infosys’s Global Conferencing Center Ground Zero for the Indian Outsourcing Industry.”

**So this is our conference room,
probably the largest screen in Asia-
this is forty digital screens [put together].
We could be setting here [in Bangalore] with somebody from New York, London, Boston, San Francisco, all live.
…That’s globalization.”**

**--Nandan Nilekani, CEO Infosys**

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# Academics use the "Access Grid" for Global Conferencing




**Access Grid Talk with 35 Locations on 5 Continents— SC Global Keynote Supercomputing '04**

# Multiple HD Streams Over Lambdas Will Radically Transform Global Collaboration





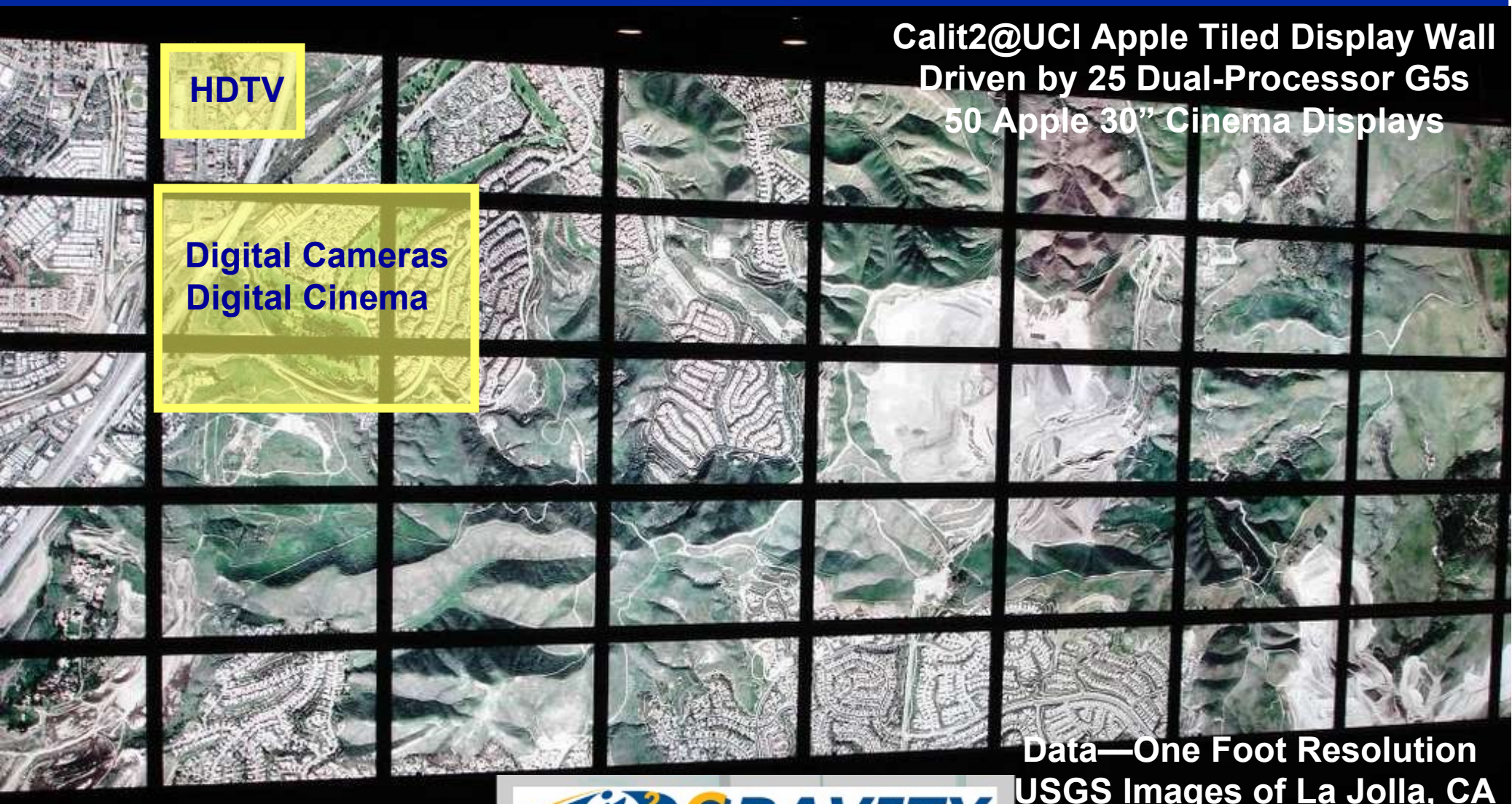


**Telepresence Using Uncompressed 1.5 Gbps HDTV Streaming Over IP on Fiber Optics--**
**75x Home Cable "HDTV" Bandwidth!**



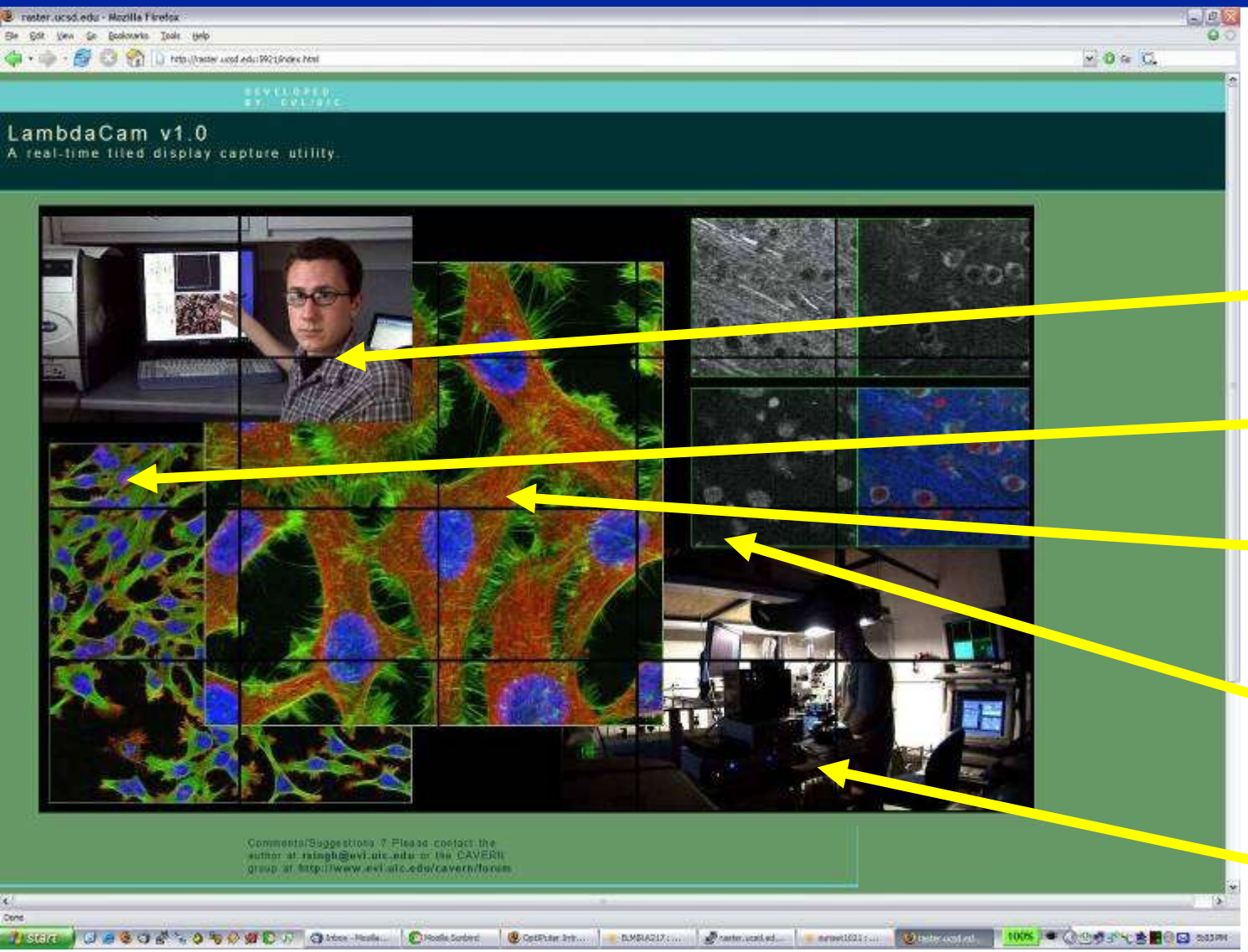

Source: U Washington Research Channel

# 200 Million Pixels of Viewing Real Estate!




Source: Falko Kuester, Calit2@UCI
NSF Infrastructure Grant

# SAGE in Use on the UCSD NCMIR OptIPuter Display Wall




- HD Video from BIRN Trailer
- Macro View of Montage Data
- Micro View of Montage Data
- Live Streaming Video of the RTS-2000 Microscope
- HD Video from the RTS Microscope Room

**LambdaCam Used to Capture the Tiled Display on a Web Browser**

OptIPuter

evl electronic visualization laboratory

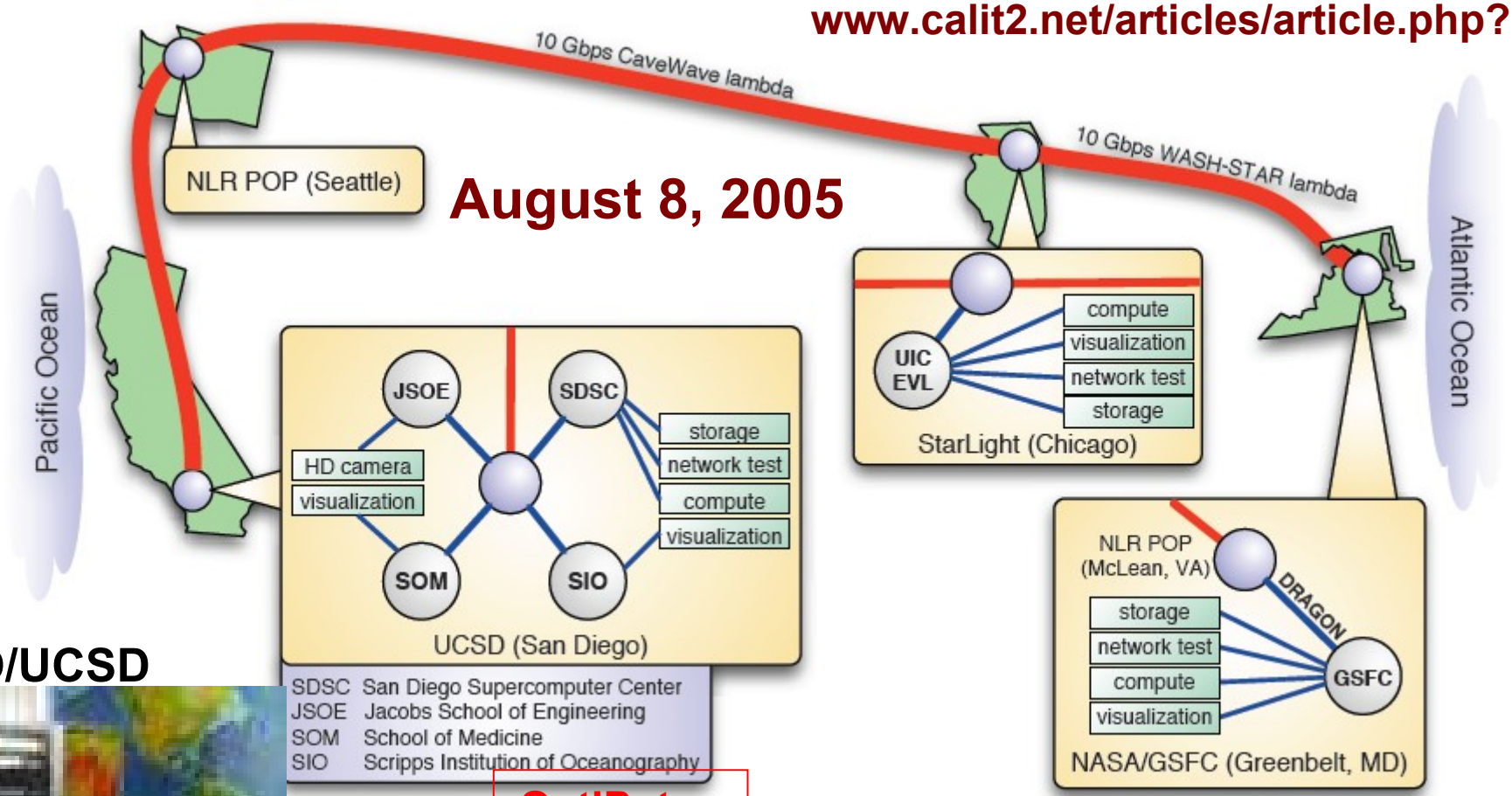
**Source: David Lee, NCMIR, UCSD**

NCMIR NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH at San Diego, an NIH supported resource center

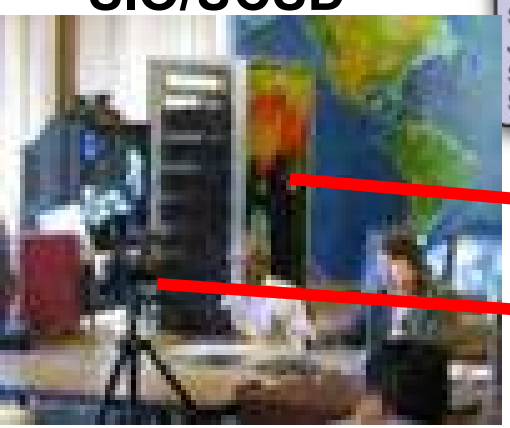
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# Partnering with NASA to Combine Telepresence with Remote Interactive Analysis of Data Over National LambdaRail

www.calit2.net/articles/article.php?id=660




SIO/UCSD



OptIPuter Visualized Data

HDTV Over Lambda

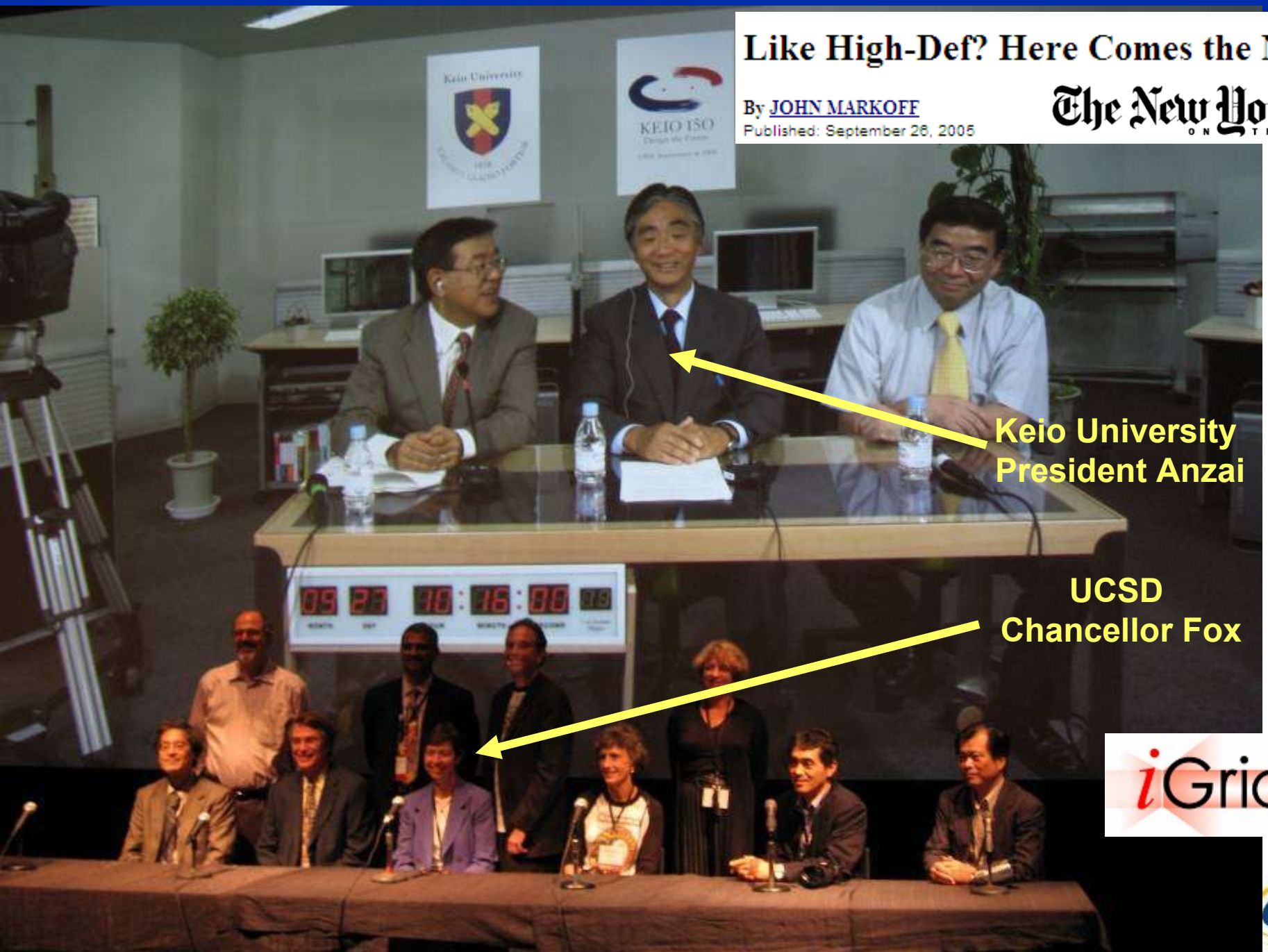



NASA Goddard

OptIPuter

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# First Trans-Pacific Super High Definition Telepresence Meeting in New Calit2 Digital Cinema Auditorium




## Like High-Def? Here Comes the Next Level

By JOHN MARKOFF
Published: September 26, 2005

The New York Times ON THE WEB

Keio University President Anzai

UCSD Chancellor Fox

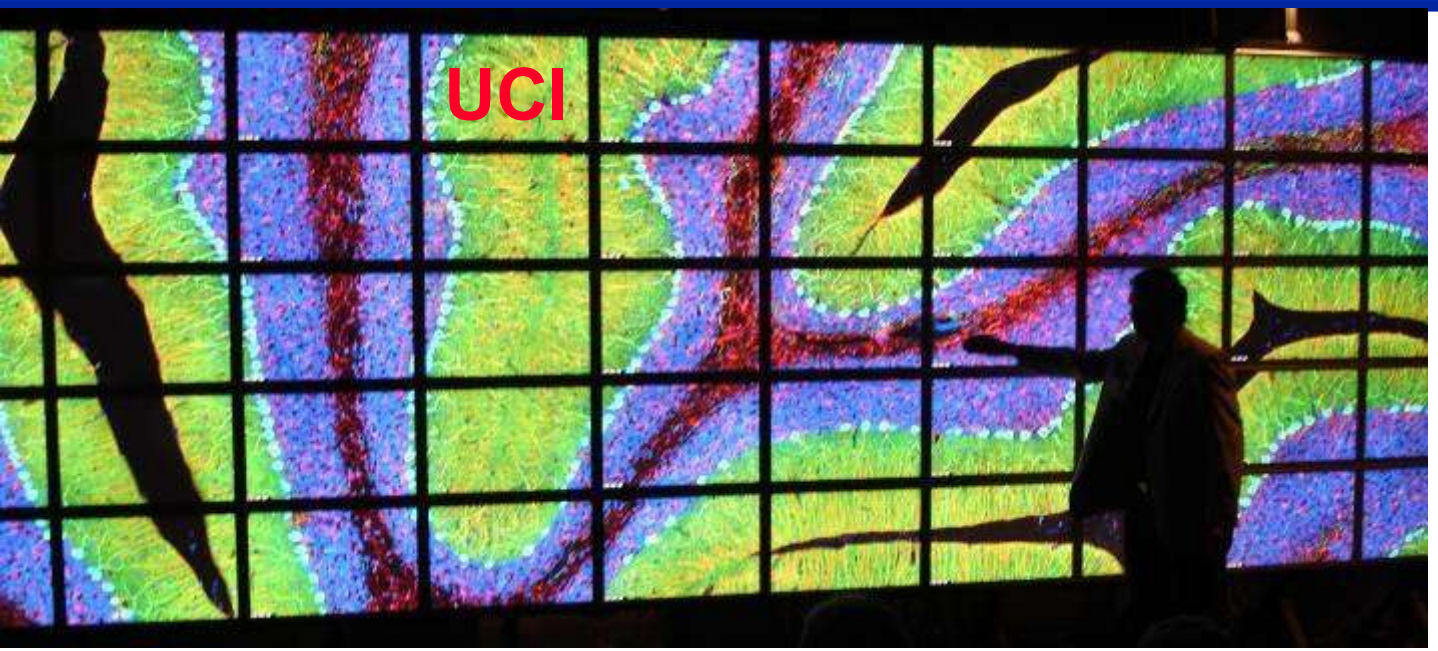
**Lays Technical Basis for Global Digital Cinema**

**Sony**
**NTT**
**SGI**

iGrid 2005

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# The OptIPuter Enabled Collaboratory: Remote Researchers Jointly Exploring Complex Data




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**OptIPuter will Connect**
**The Calit2@UCI**
**200M-Pixel Wall**
**to**
**The Calit2@UCSD**
**100M-Pixel Display**
**With Shared Fast Deep Storage**




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# Creating CyberPorts on the National LambdaRail– Prototypes at ACCESS DC and TRECC Chicago









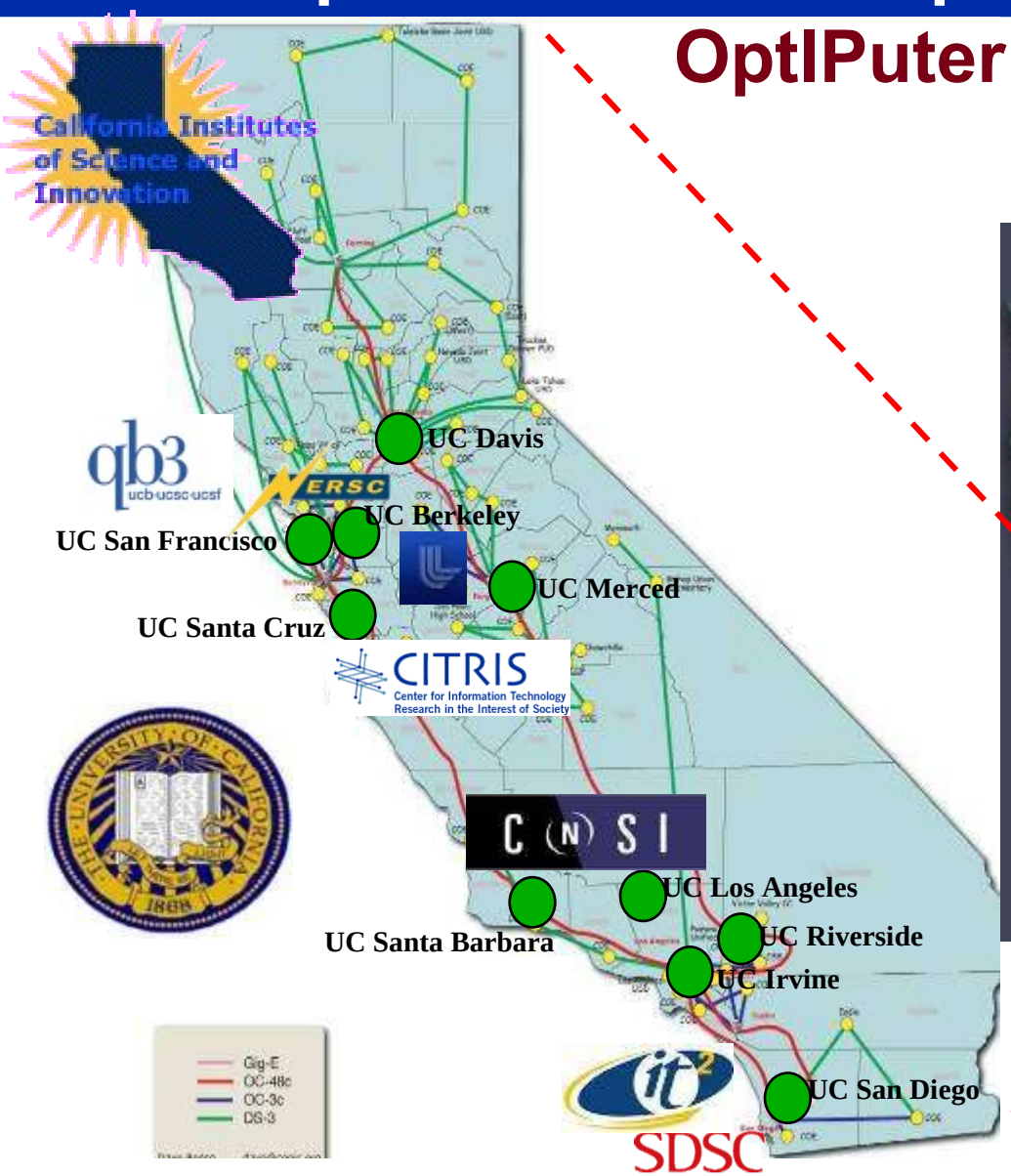




www.trecc.org

# Calit2/SDSC Proposal to Create a UC Cyberinfrastructure of OptIPuter "On-Ramps" to TeraGrid Resources

## OptIPuter + CalREN-XD + TeraGrid = "OptiGrid"







**Creating a Critical Mass of End Users on a Secure LambdaGrid**

Source: Fran Berman, SDSC