“Riding the Light: How Dedicated Optical Circuits are Enabling New Science"

Future of Imaging Plenary Session
SPIE Optics and Photonics Convention
San Diego, CA
August 15, 2006

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

OptIPuter

it²

Abstract

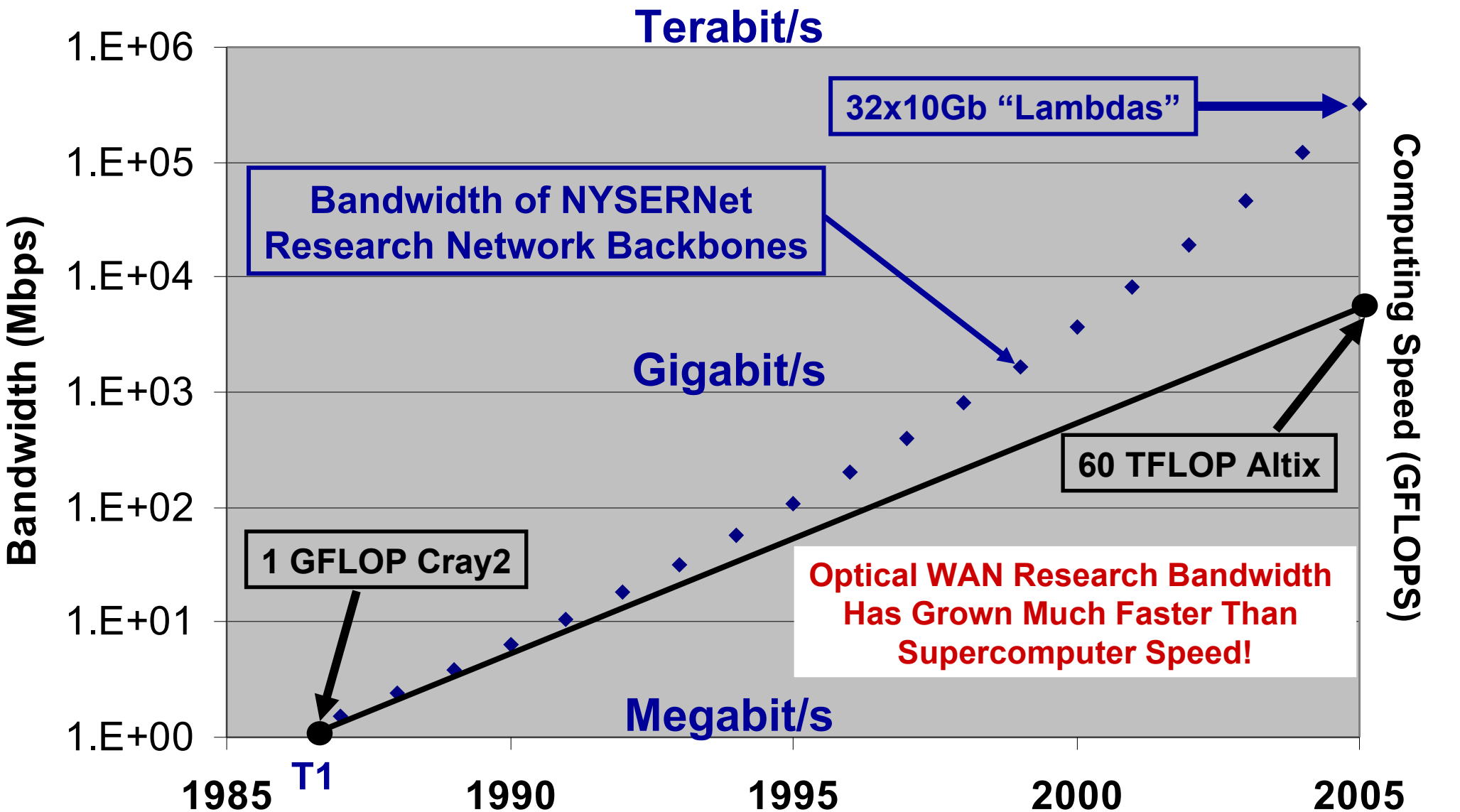
During the last few years, a radical restructuring of optical networks supporting e-Science projects is beginning to occur around the world. U.S. universities are now able to acquire access to private, high bandwidth light pipes (termed "lambdas") through the National LambdaRail, providing direct access to scalable Linux clusters in individual user laboratories. These dedicated connections have a number of significant advantages over shared internet connections, including high bandwidth (10Gbps+), controlled performance (no jitter), lower cost per unit bandwidth, and security. These lambdas enable the Grid program to be completed, in that they add the network elements to the compute and storage elements which can be discovered, reserved, and integrated by the Grid middleware to form global LambdaGrids.

I will describe our experience in setting up and using LambdaGrids as part of the NSF-funded OptIPuter (www.optiputer.net) and LOOKING (http://lookingtosea.ucsd.edu/), and Moore Foundation funded CAMERA research projects. These three projects explore how the lambdas enable new capabilities in medical imaging, earth sciences, interactive ocean observatories, and marine microbial metagenomics. A glimpse into future of global e-science was provided by the iGrid2005 workshop held at Calit2 in September 2005. I will review some of the most exciting new uses for lambdas demonstrated there by the two dozen countries participating.

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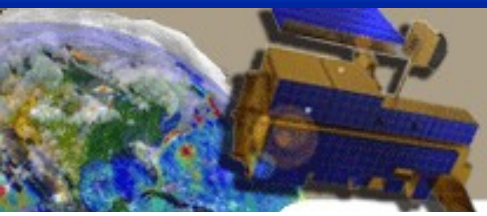
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From "Supercomputer–Centric" to "Supernetwork-Centric" Cyberinfrastructure



Network Data Source: Timothy Lance, President, NYSERNet

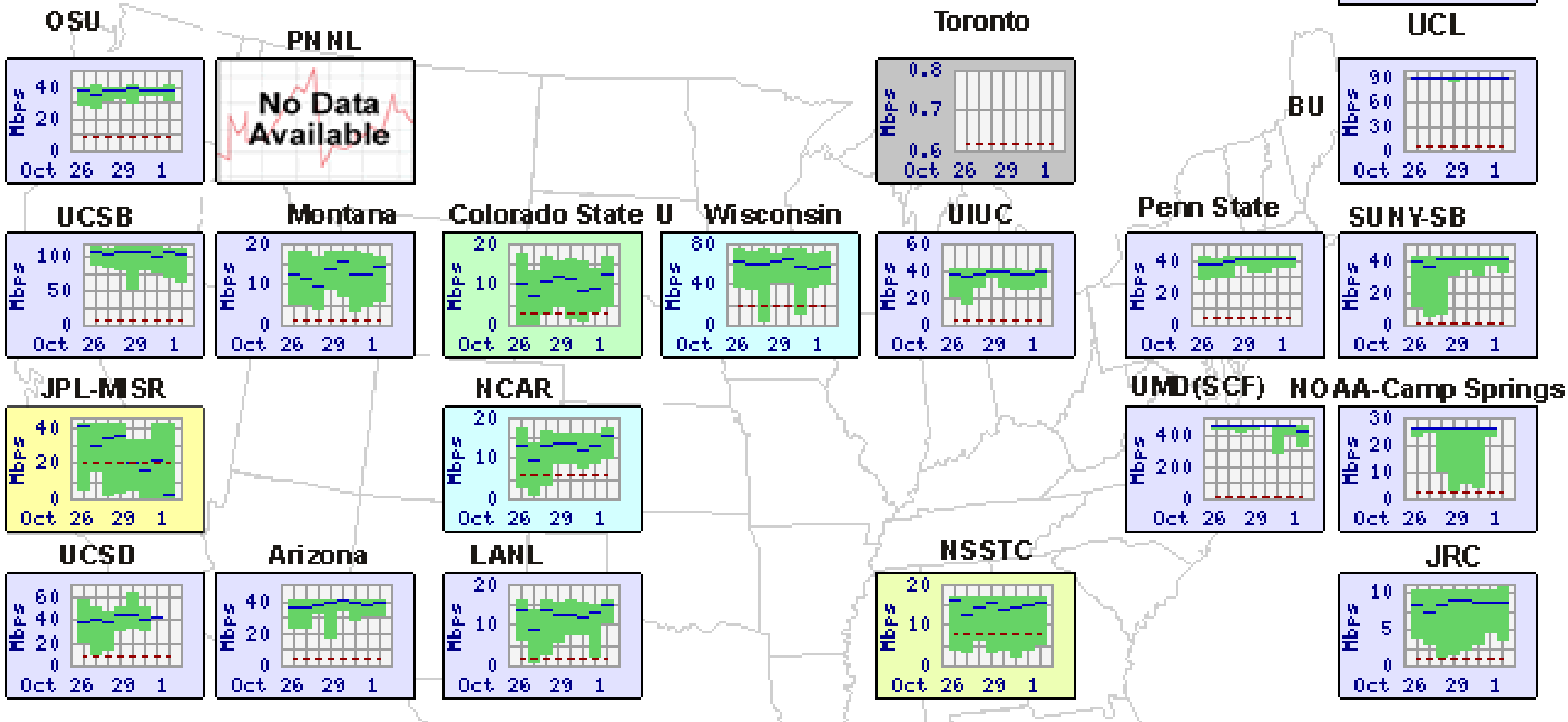
Challenge: Average Throughput of NASA Data Products to End User is < 50 Mbps



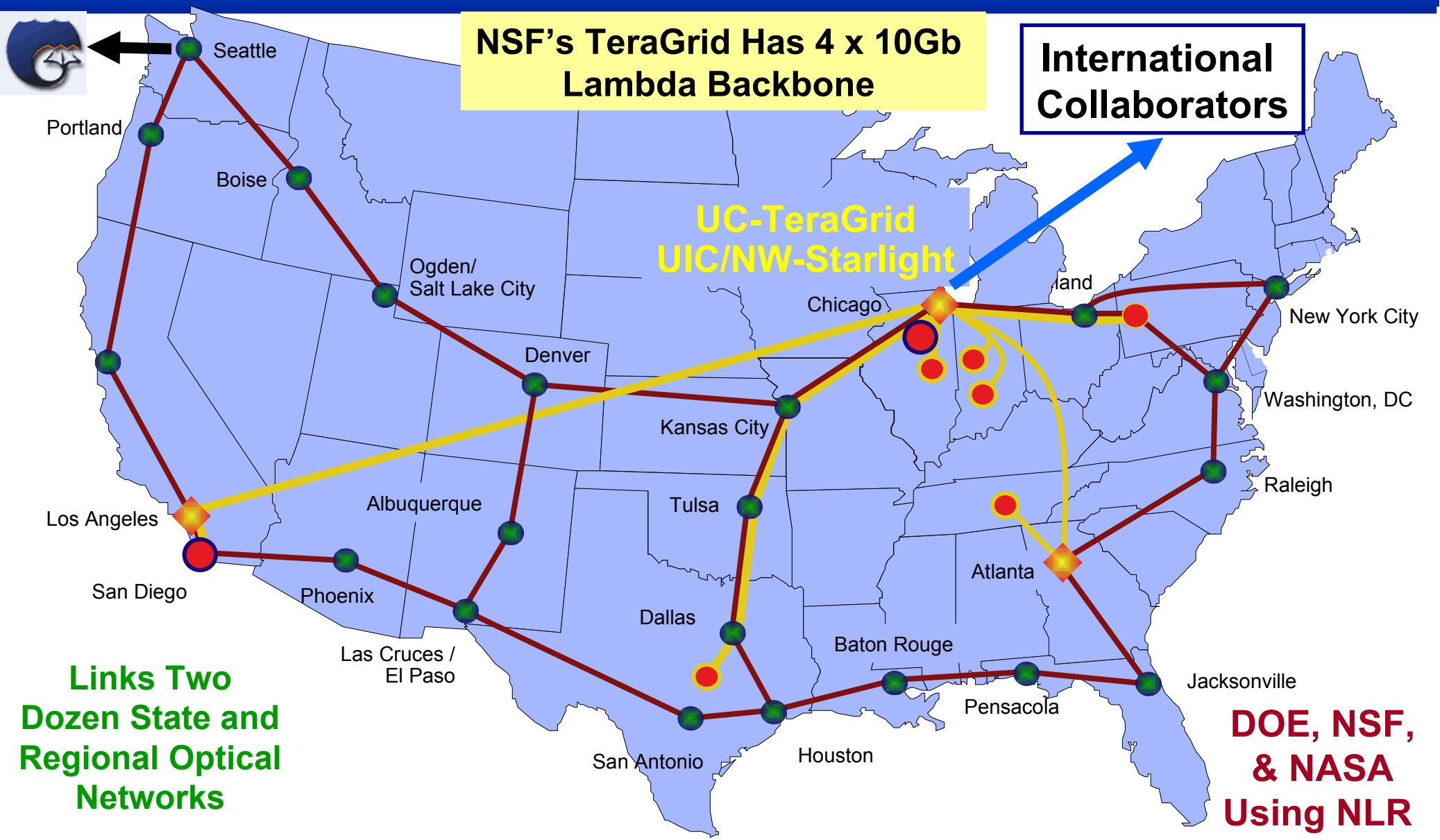
ENSIGHT Active Testing TERRA Destinations

Tested October 2005

Internet2 Backbone is 10,000 Mbps!
Throughput is < 0.5% to End User



National Lambda Rail (NLR) and TeraGrid Provides Cyberinfrastructure Backbone for U.S. Researchers



High Energy and Nuclear Physics
A Terabit/s WAN by 2010!

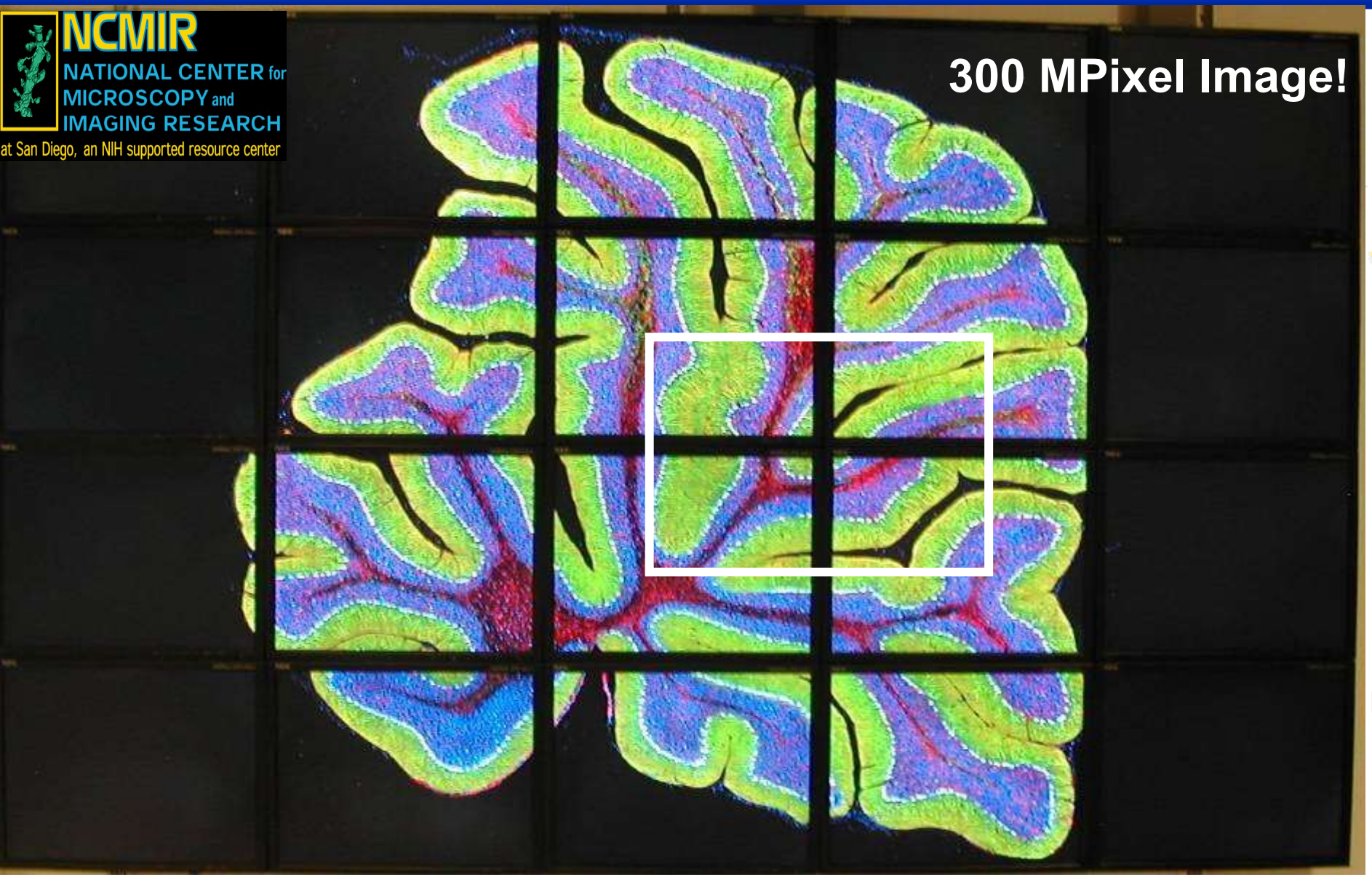
Year	Production	Experimental	Remarks
2001	0.155	0.622-2.5	SONET/SDH
2002	0.622	2.5	SONET/SDH DWDM; GigE Integ.
2003	2.5	10	DWDM; 1 + 10 GigE Integration
2005	10	2-4 X 10	λ Switch; λ Provisioning
2007	2-4 X 10	~10 X 10; 40 Gbps	1st Gen. λ Grids
2009	~10 X 10 or 1-2 X 40	~5 X 40 or ~20-50 X 10	40 Gbps λ Switching
2011	~5 X 40 or ~20 X 10	~25 X 40 or ~100 X 10	2nd Gen λ Grids Terabit Networks
2013	~Terabit	~MultiTbps	~Fill One Fiber

Source: Harvey Newman, Caltech

Continuing the Trend: ~1000 Times Bandwidth Growth Per Decade; We are Rapidly Learning to Use Multi-Gbps Networks Dynamically

The OptIPuter--High Resolution Interaction Visualization Over Dedicated Optical Channels to Global Science Data

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



NSF

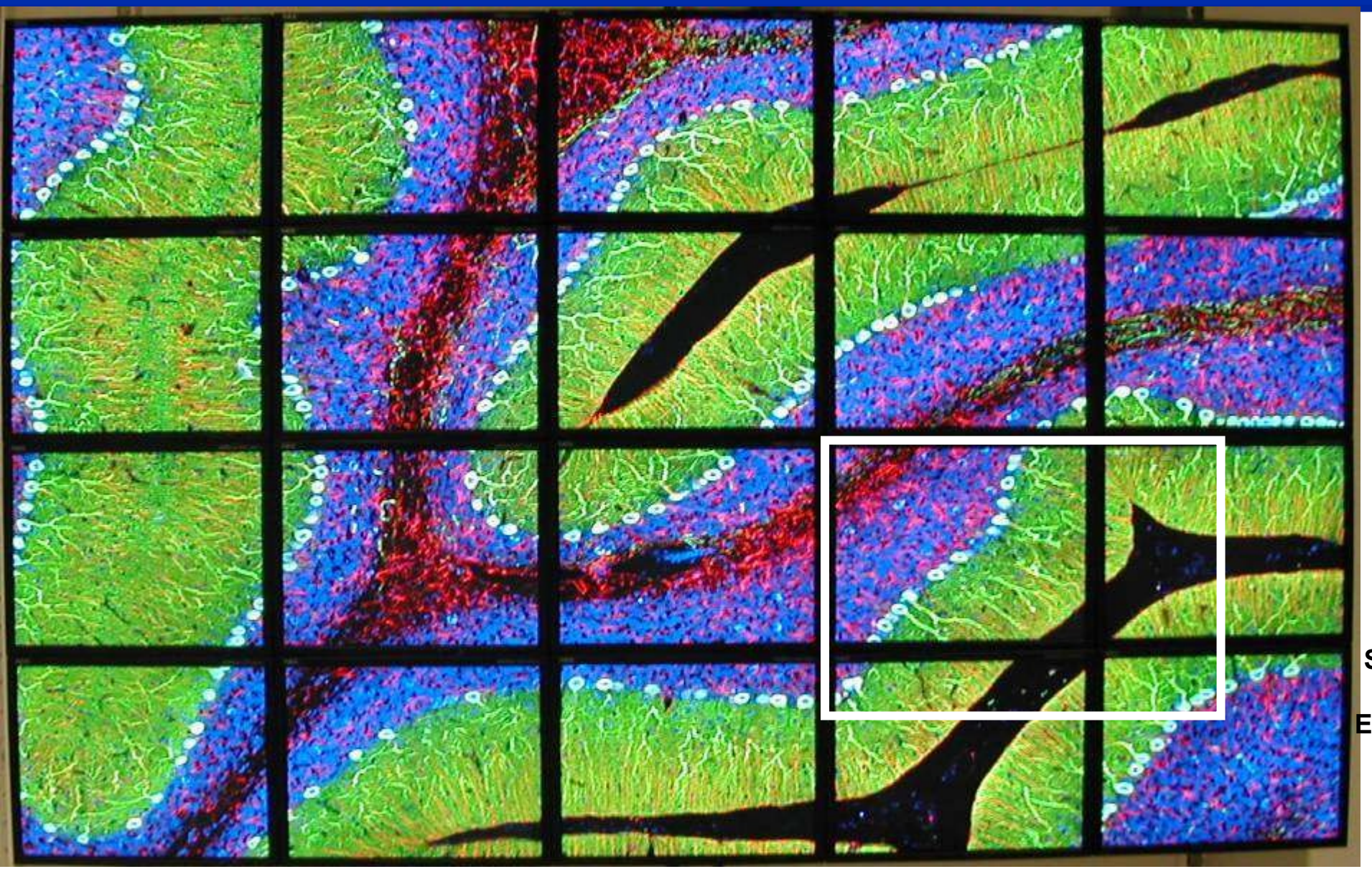
Source: Mark Ellisman, David Lee, Jason Leigh

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Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
Partners: SDSC, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST

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Scalable Displays Allow Both Global Content and Fine Detail



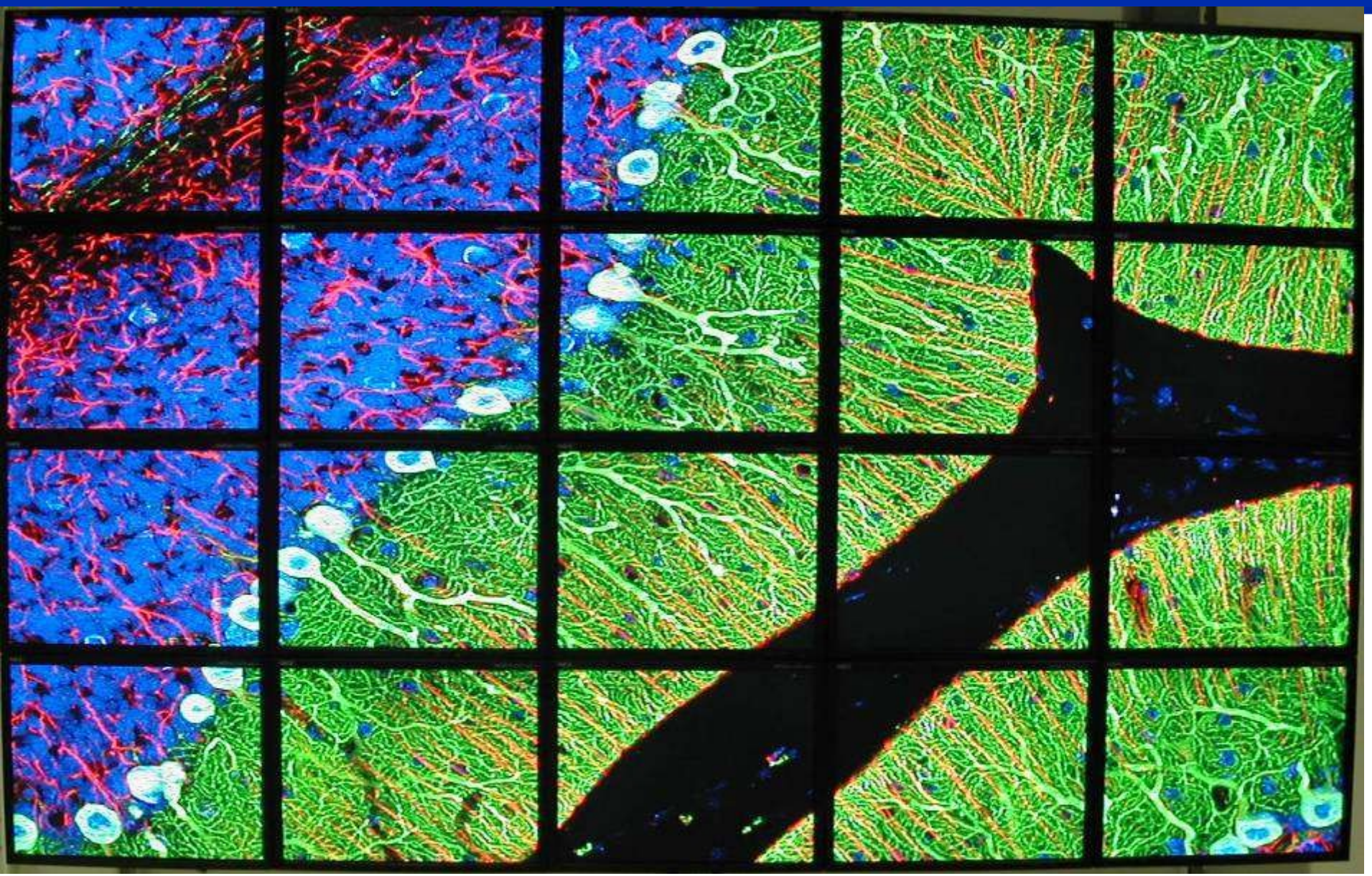
Source: Mark Ellisman, David Lee, Jason Leigh

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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



OptIPuter

Source: Mark Ellisman, David Lee, Jason Leigh

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Calit2 @ UCI Has the Largest Tiled Display Wall--HIPerWall



Calit2@UCI Apple Tiled Display Wall
Driven by 25 Dual-Processor G5s
50 Apple 30” Cinema Displays
200 Million Pixels of Viewing Real Estate!

Zeiss Scanning Electron Microscope in Calit2@ UCI



However, SAGE Must be Modified to Run on Mac Walls

What is the OptIPuter?

- Applications Drivers → Interactive Analysis of Large Data Sets
- OptIPuter Nodes → Scalable PC Clusters with Graphics Cards
- IP over Lambda Connectivity →Predictable Backplane
- Open Source LambdaGrid Middleware→ Network is Reservable
- Data Retrieval and Mining → Lambda Attached Data Servers
- High Defn. Vis., Collab. SW → High Performance Collaboratory

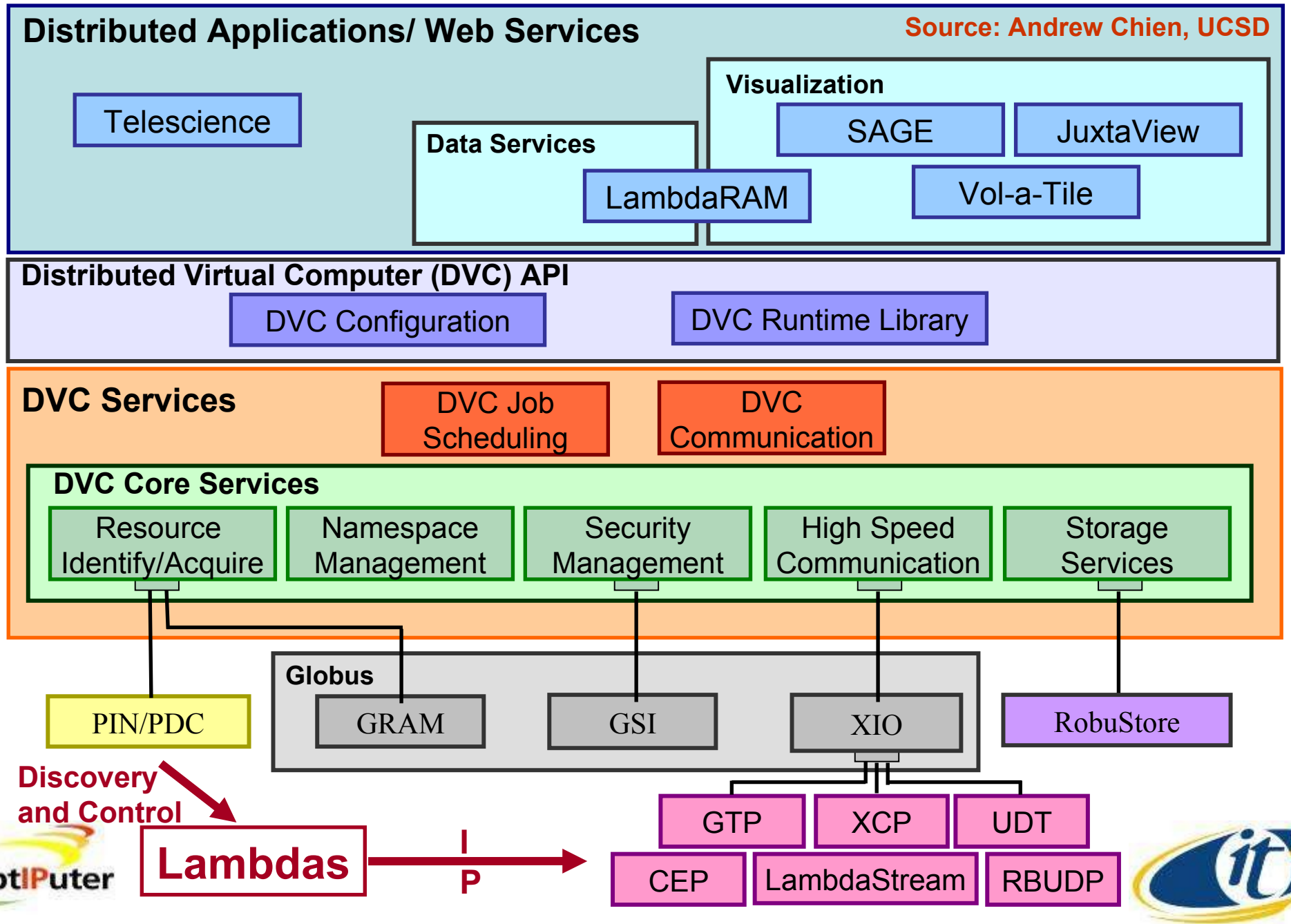
www.optiputer.net

OptIPuter

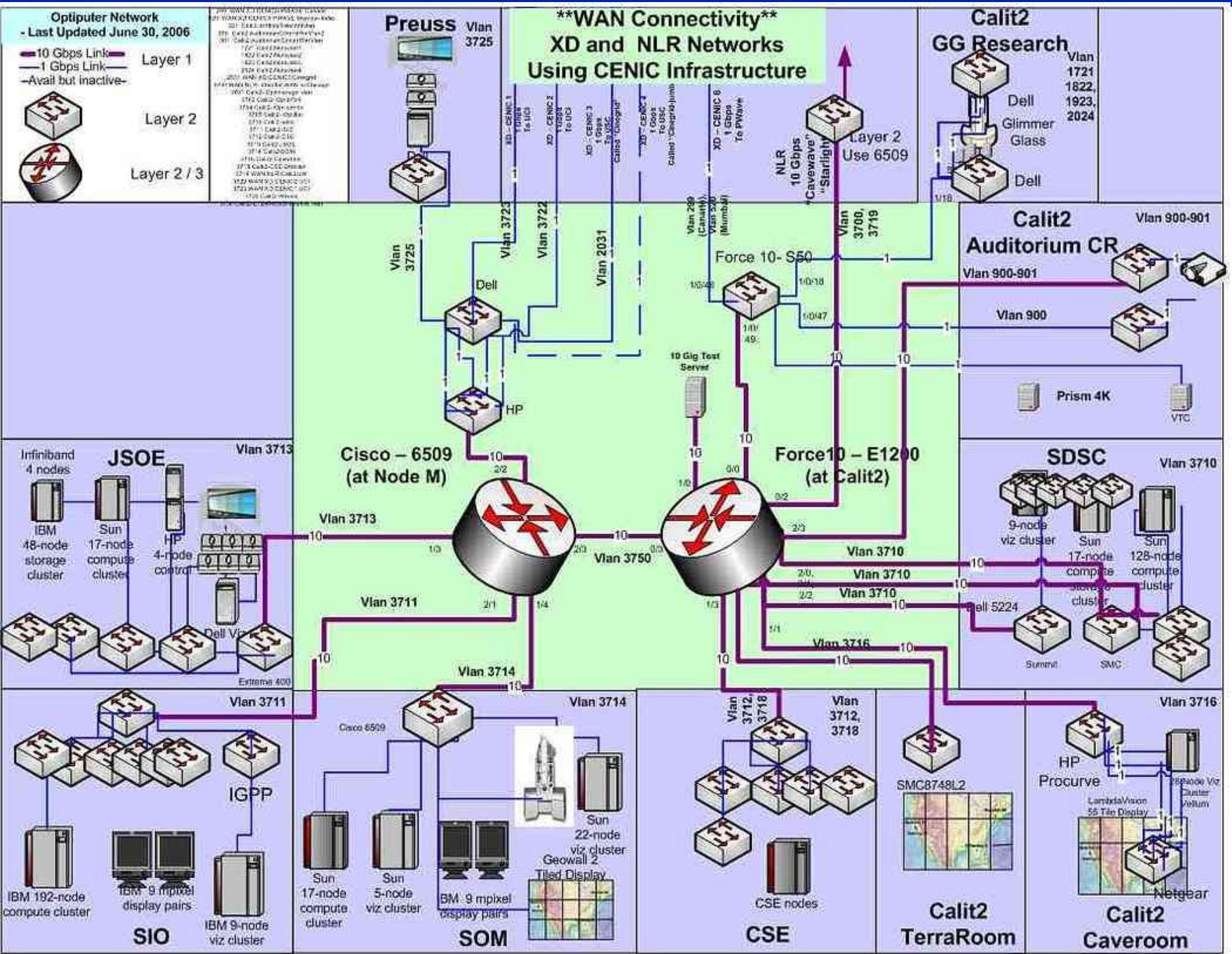
See Nov 2003 Communications of the ACM for Articles on OptIPuter Technologies

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



UCSD Campus-Scale Routed OptIPuter with Nodes for Storage, Computation and Visualization



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

Goals by 2007:

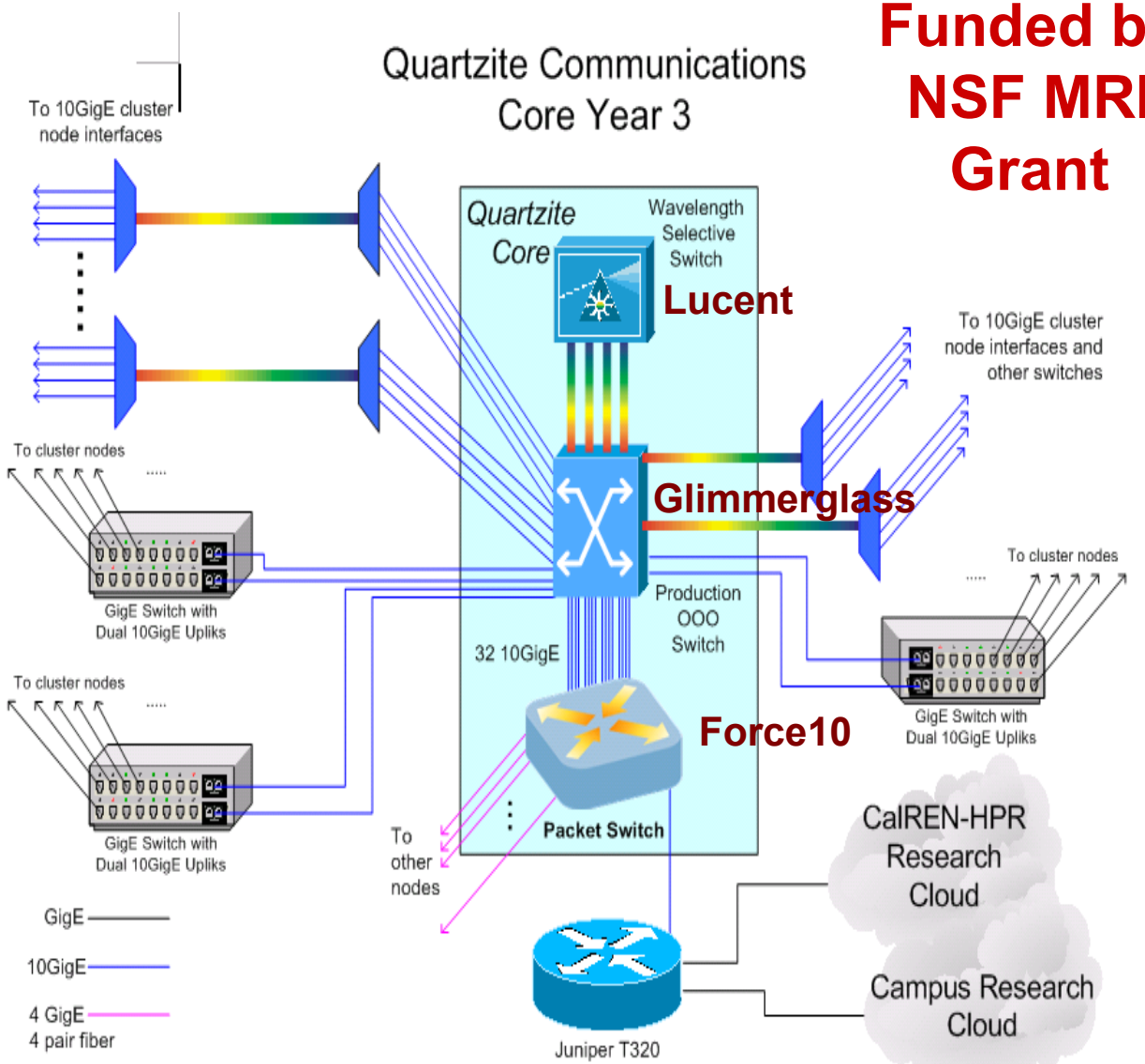
>= 50 endpoints at 10 GigE

>= 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

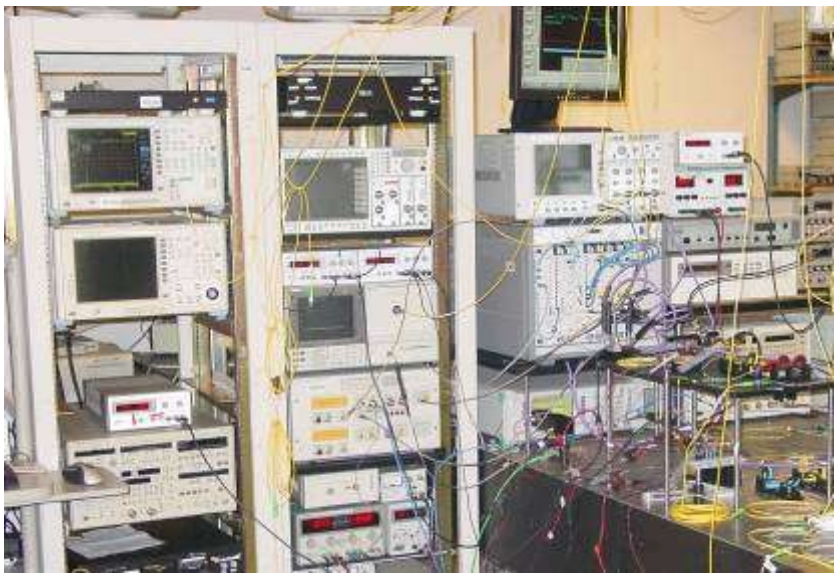
NSF

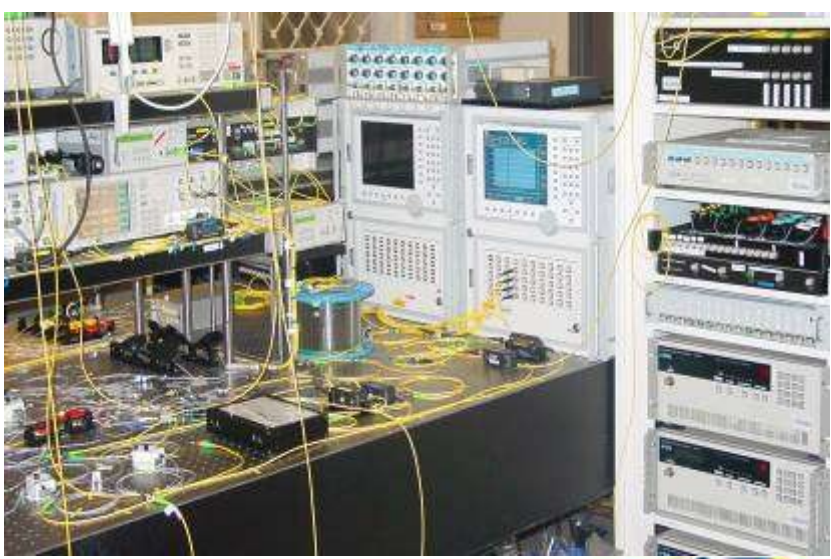
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Calit2@UCSD Photonics Networking Laboratory: Driving the Future Exponential Growthof Bandwidth

- **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





ECE Testbed Faculty



Stojan Radic
Optical communication networks; all-optical processing; parametric processes in high-confinement fiber and semiconductor devices.



George Papen
Advanced photonic systems including optical communication systems, optical networking, and environmental and atmospheric remote sensing.



Joseph Ford
Optoelectronic subsystems integration (MEMS, diffractive optics, VLSI); Fiber optic and free-space communications.



Shaya Fainman
Nanoscale science and technology; ultrafast photonics and signal processing



Shayan Mookherjea
Optical devices and optical communication networks, including photonics, lightwave systems and nano-scale optics.



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UCSD Photonics

UCSD Parametric Processing Laboratory

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Global Connections
Between University Research Centers at 10Gbps

Maxine Brown, Tom DeFanti, Co-Chairs

iGrid 2005

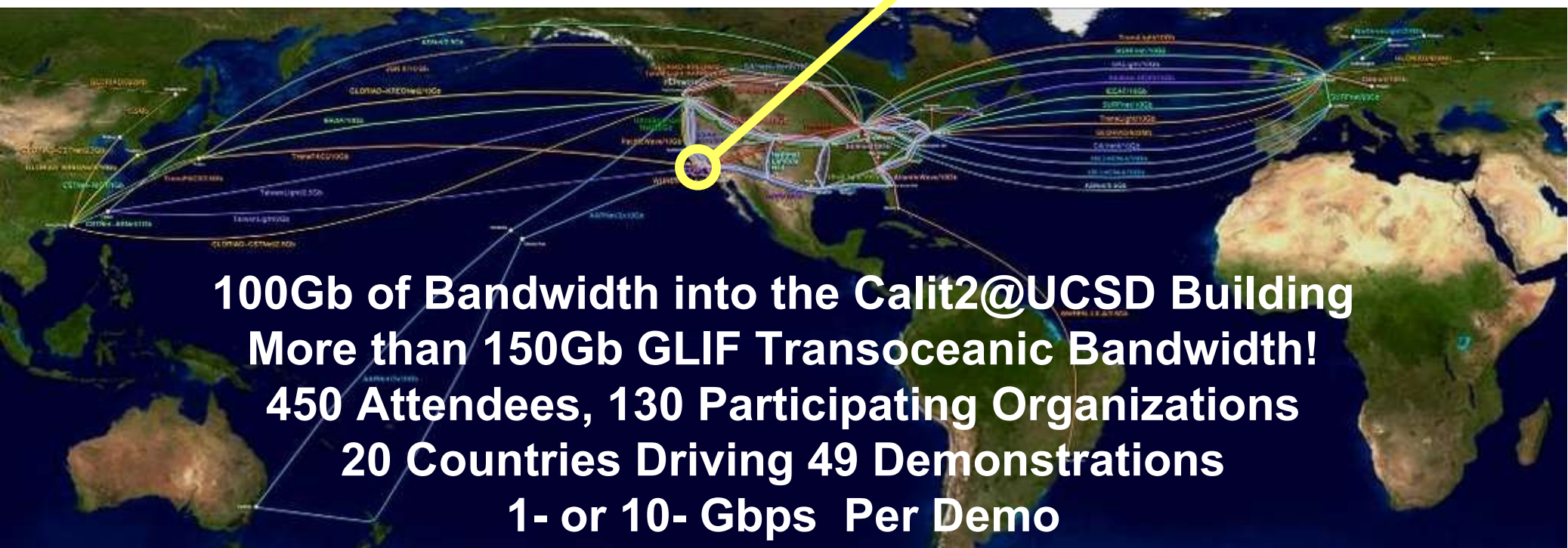
THE GLOBAL LAMBDA INTEGRATED FACILITY

www.igrid2005.org



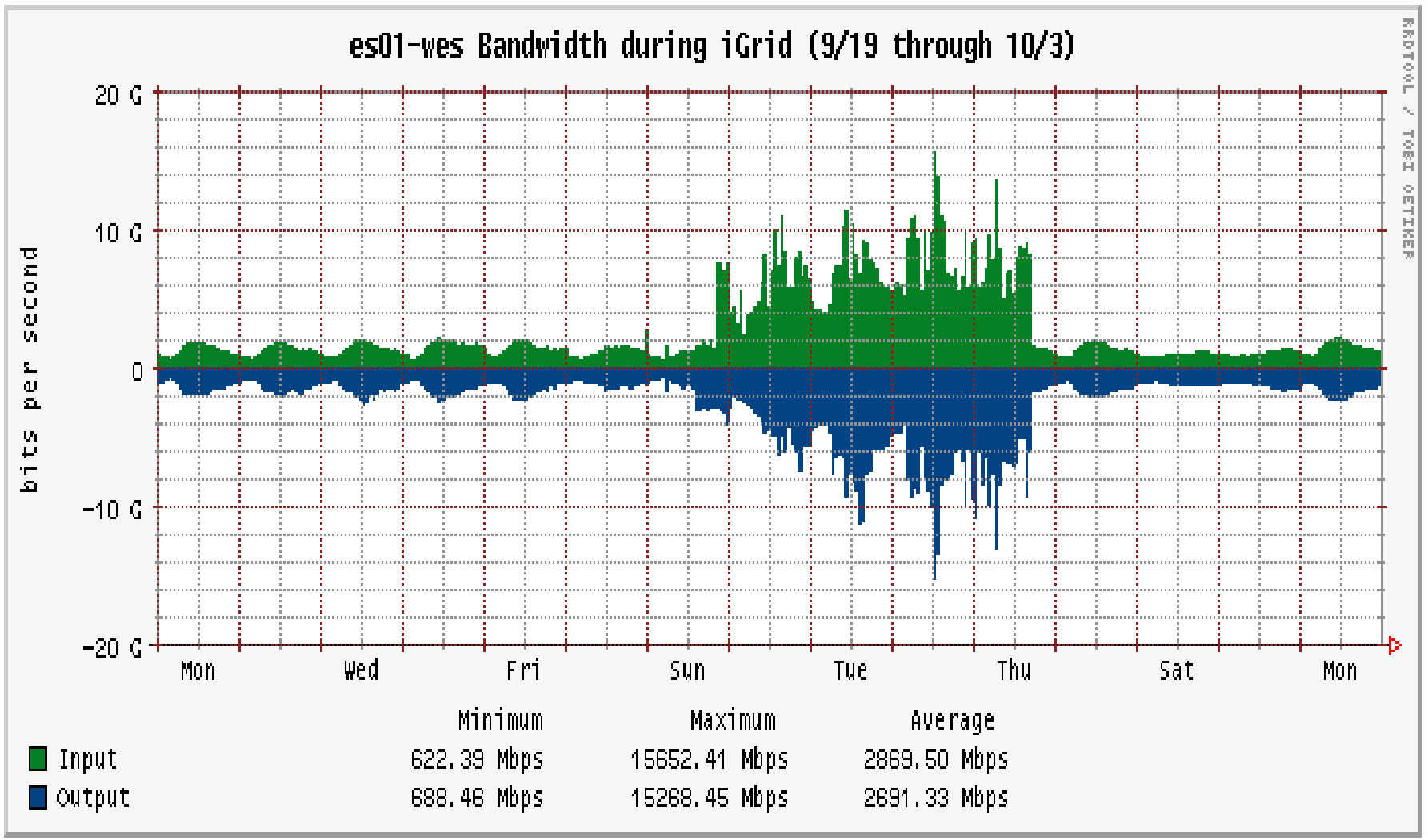
the UC Discovery Grant

September 26-30, 2005
Calit2 @ University of California, San Diego
California Institute for Telecommunications and Information Technology



100Gb of Bandwidth into the Calit2@UCSD Building
More than 150Gb GLIF Transoceanic Bandwidth!
450 Attendees, 130 Participating Organizations
20 Countries Driving 49 Demonstrations
1- or 10- Gbps Per Demo

iGrid2005 Data Flows Multiplied Normal Flows by Five Fold!

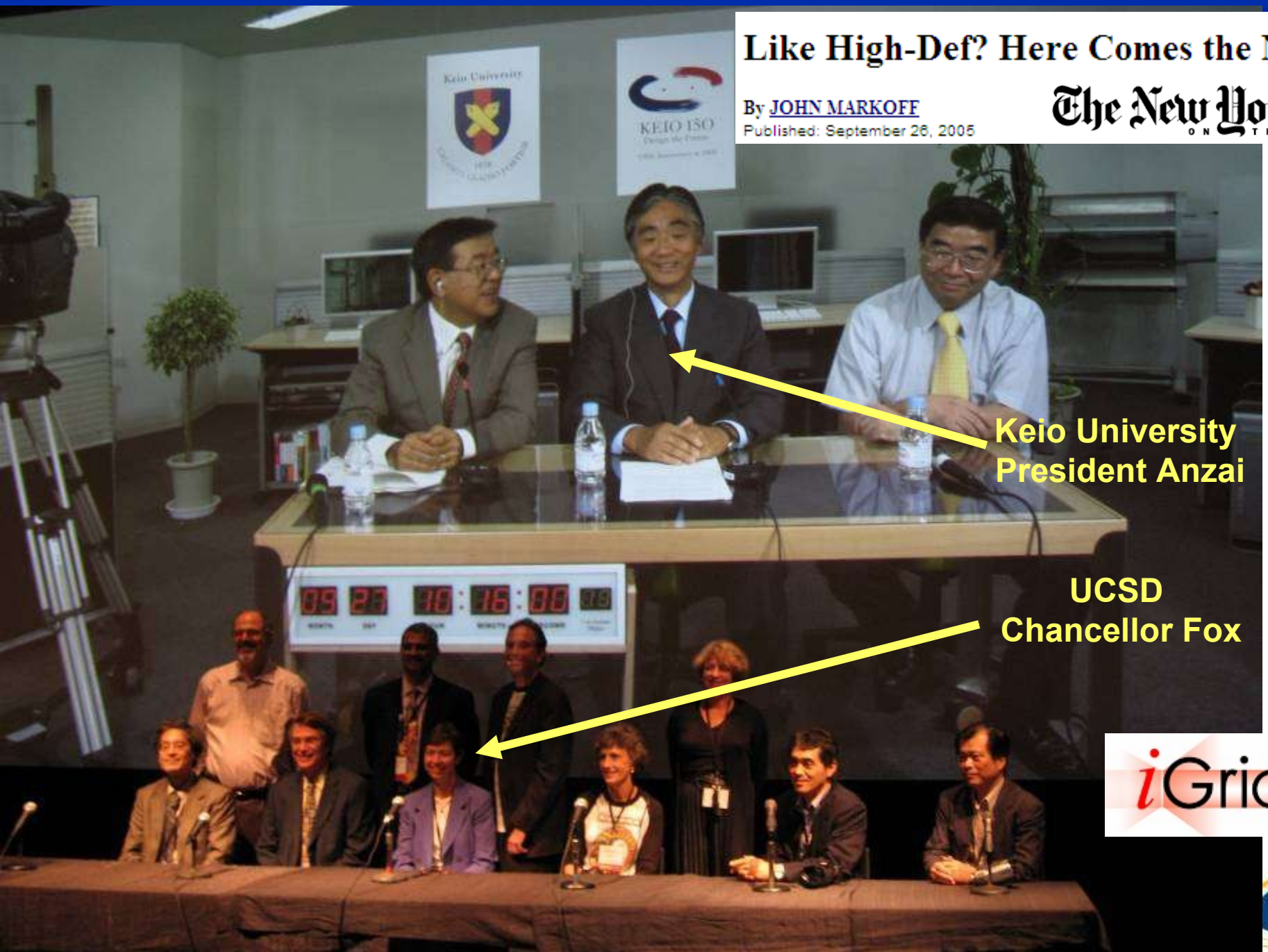


Data Flows Through the Seattle PacificWave International Switch

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iGrid Lambda Digital Cinema Streaming Services: Telepresence Meeting in 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

Lays Technical Basis for Global Digital Cinema

Sony
NTT
SGI

iGrid 2005

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iGrid 2005
Kyoto Nijo Castle









Source: Toppan Printing

Interactive VR Streamed Live from Tokyo to Calit2 Over Dedicated GigE and Projected at 4k Resolution

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iGrid Lambda Control Services: Transform Batch to Real-Time Global e-Very Long Baseline Interferometry



- Goal: Real-Time VLBI Radio Telescope Data Correlation
- Achieved 512Mb Transfers from USA and Sweden to MIT
- Results Streamed to iGrid2005 in San Diego

Optical Connections Dynamically Managed Using the DRAGON Control Plane and Internet2 HOPI Network

Source: Jerry Sobieski, DRAGON

CAMERA: Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis

National LambdaRail
Direct Connect
Computation and Storage Complex

PI Larry Smarr

Funded by: Gordon and Betty Moore Foundation

Joint Partnership of:

camera
Marine Microbial Ecology

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Announced January 17, 2006
$24.5M Over Seven Years

Marine Genome Sequencing Project
Measuring the Genetic Diversity of Ocean Microbes



Sorcerer II Data Will Double Number of Proteins in GenBank!

MARINE MICROBIOLOGY INITIATIVE

Gordon and Betty MOORE FOUNDATION

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J. Craig Venter INSTITUTE

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Calit2's Direct Access Core Architecture Will Create Next Generation Metagenomics Server

Sargasso Sea Data

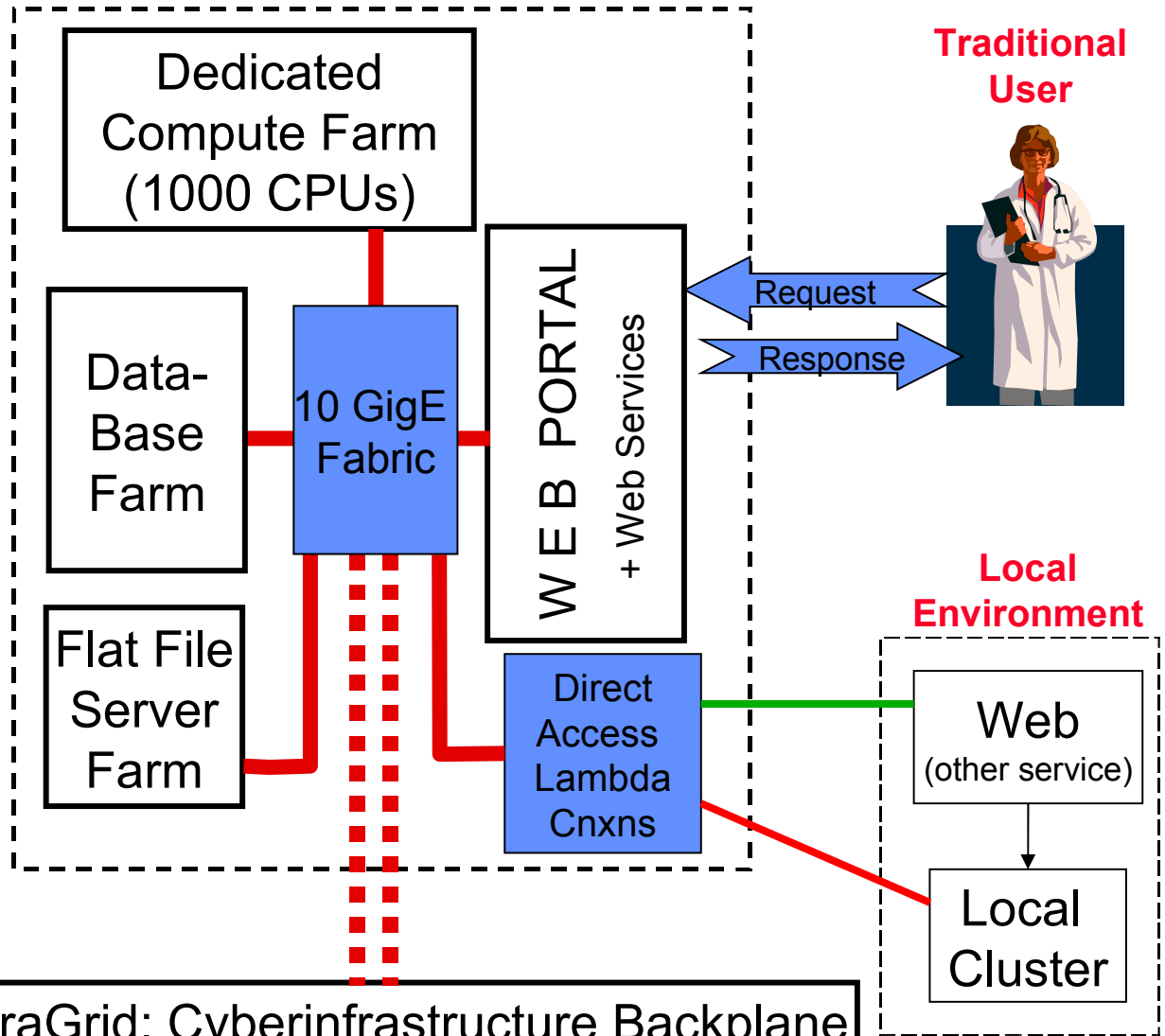
Sorcerer II Expedition (GOS)

JGI Community Sequencing Project

Moore Marine Microbial Project

NASA Goddard Satellite Data

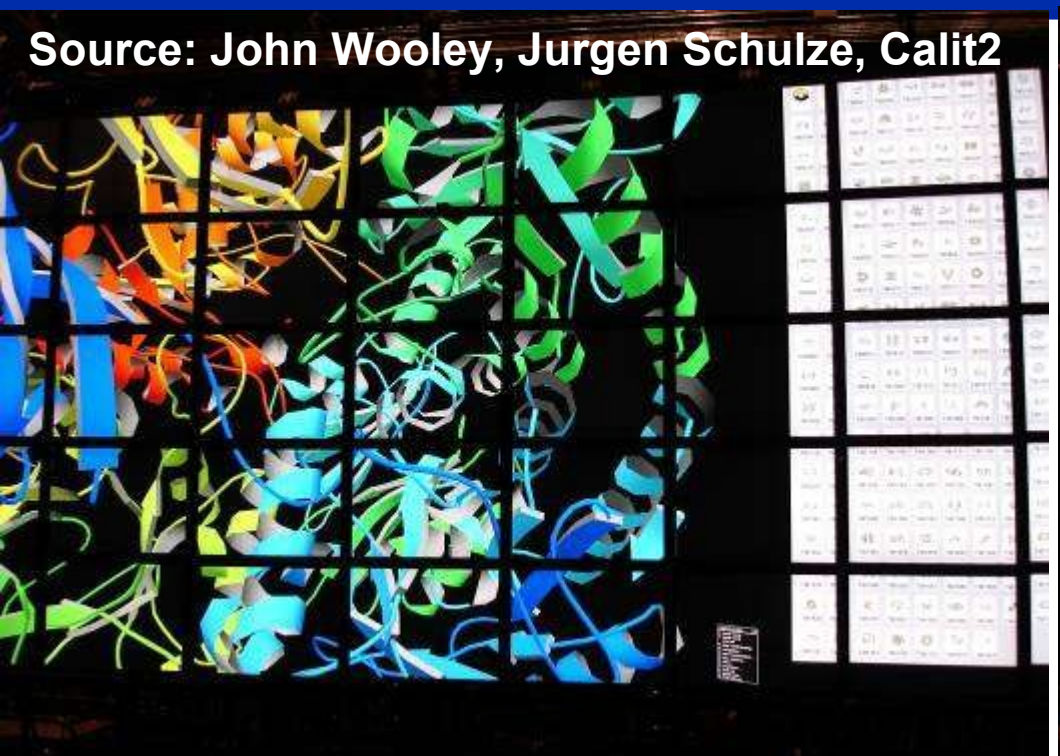
Community Microbial Metagenomics Data



Source: Phil Papadopoulos, SDSC, Calit2

Interactive Visualization of Thermatoga Proteins at Calit2

Source: John Wooley, Jurgen Schulze, Calit2

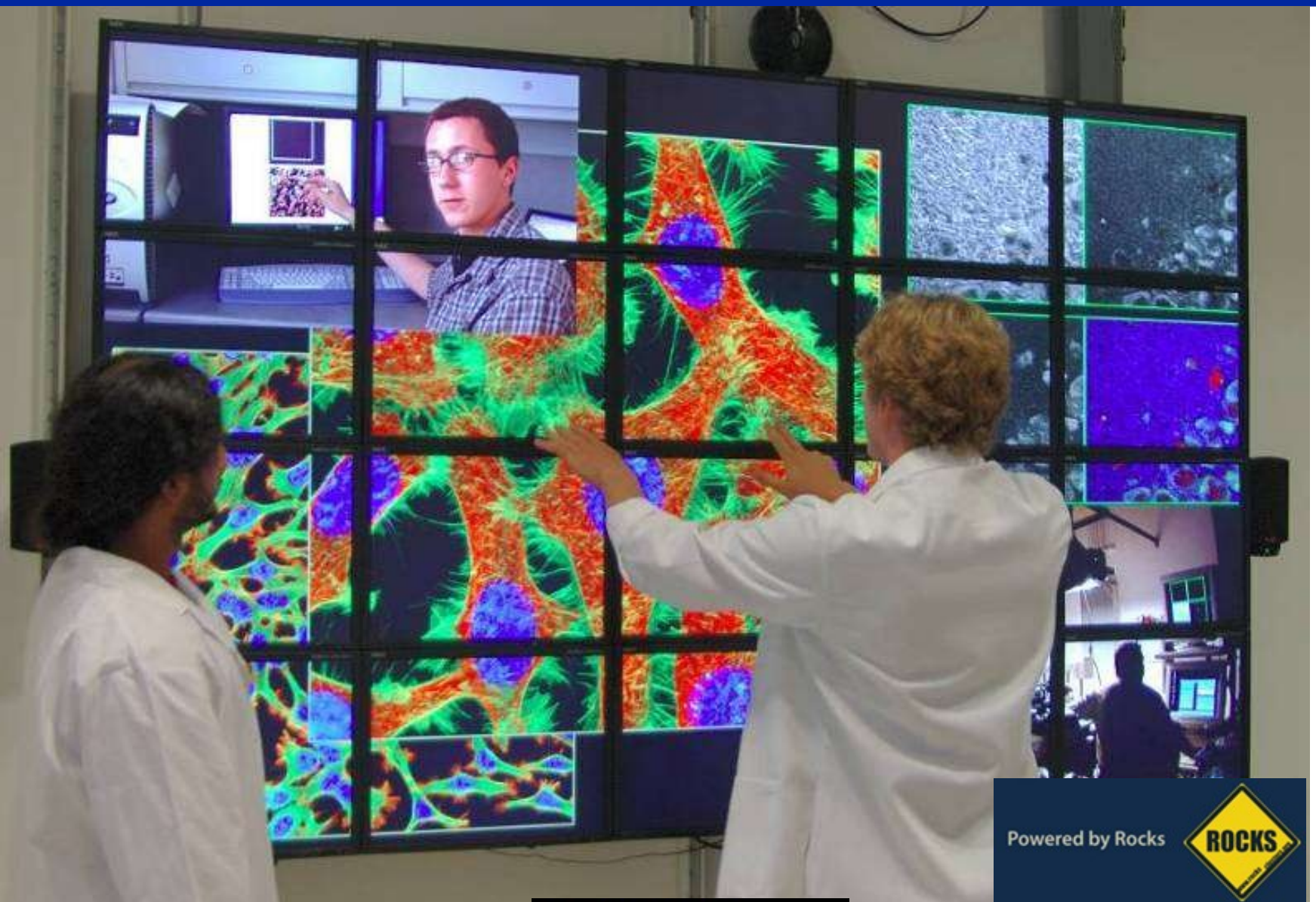








OptIPuter Scalable Adaptive Graphics Environment (SAGE) Allows Integration of HD Streams



OptIPortal– Termination Device for the OptIPuter Global Backplane

Powered by Rocks

ROCKS

evl electronic visualization laboratory

OptIPuter

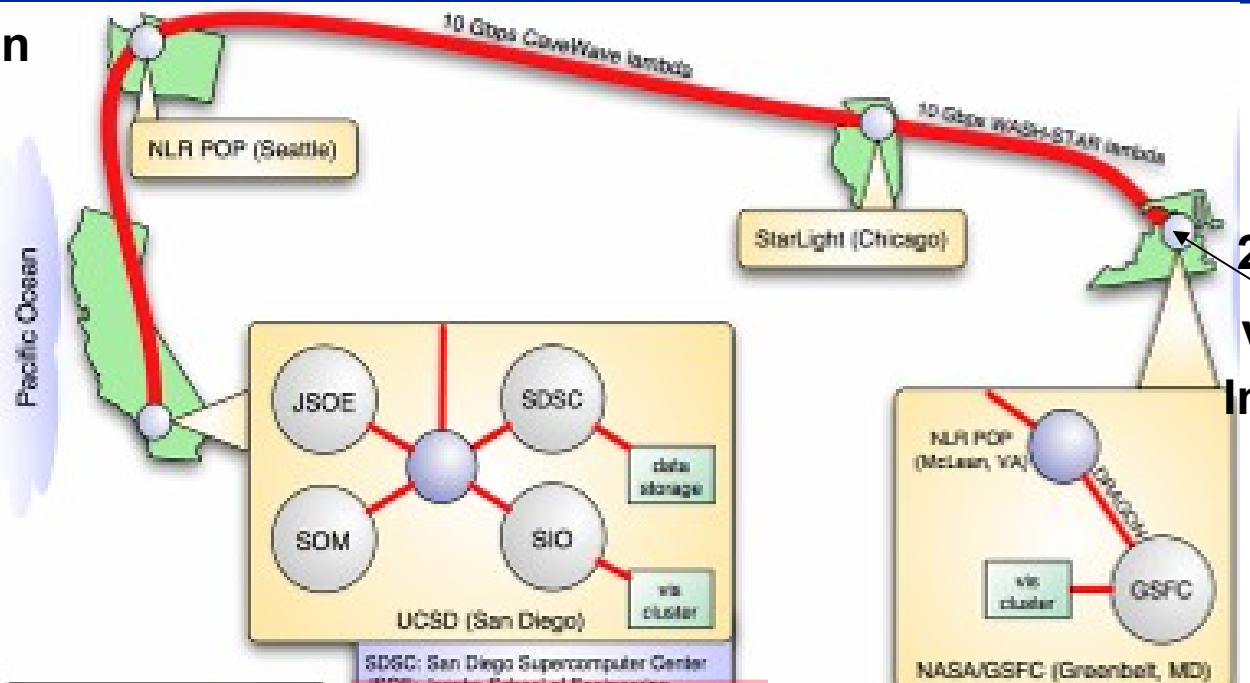
NCMIR NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH at San Diego, an NIH supported resource center

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Calit2 and the Venter Institute Will Combine Telepresence with Remote Interactive Analysis

Live Demonstration

of 21st Century National-Scale Team Science



25 Miles

Venter Institute



OptIPuter Visualized Data

HDTV Over Lambda

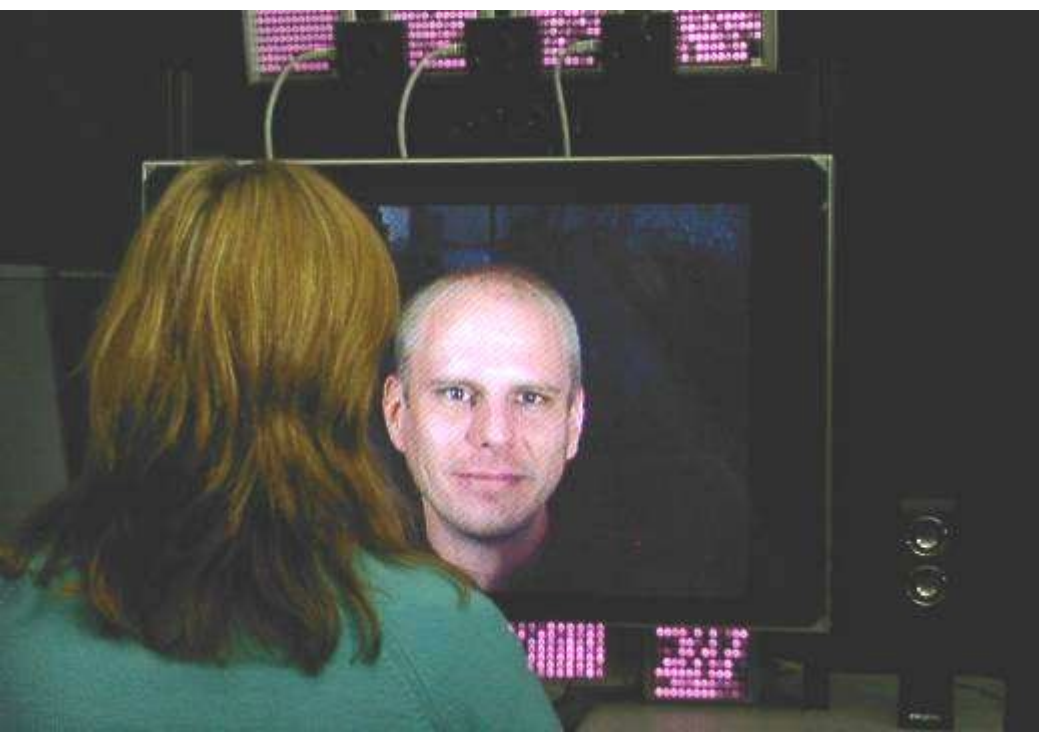


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3D Videophones Are Here!
The Personal Varrier Autostereo Display

- Varrier is a Head-Tracked Autostereo Virtual Reality Display
  - 30” LCD Widescreen Display with 2560x1600 Native Resolution
  - A Photographic Film Barrier Screen Affixed to a Glass Panel
    - The Barrier Screen Reduces the Horizontal Resolution To 640 Lines
- Cameras Track Face with Neural Net to Locate Eyes
- The Display Eliminates the Need to Wear Special Glasses





OptIPuter

Source: Daniel Sandin, Thomas DeFanti, Jinghua Ge, Javier Girado, Robert Kooima, Tom Peterka—EVL, UIC

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New OptIPuter Driver: Gigabit Fibers on the Ocean Floor -- Controlling Sensors and HDTV Cameras Remotely



LOOKING is Driven By NEPTUNE CI Requirements

- **National Science Foundation Is Planning a New Generation of Ocean Observatories**
  - **Ocean Research Interactive Observatory Networks (ORION)**
- **Fibered Observatories Linked to Land Fiber Infrastructure**
- **Laboratory for the Ocean Observatory Knowledge Integration Grid (LOOKING)**
  - **Building a Prototype Based on OptIPuter Technologies Plus Web/ Grid Services**
  - **HDTV Streams Over IP Will be a Major Driver**

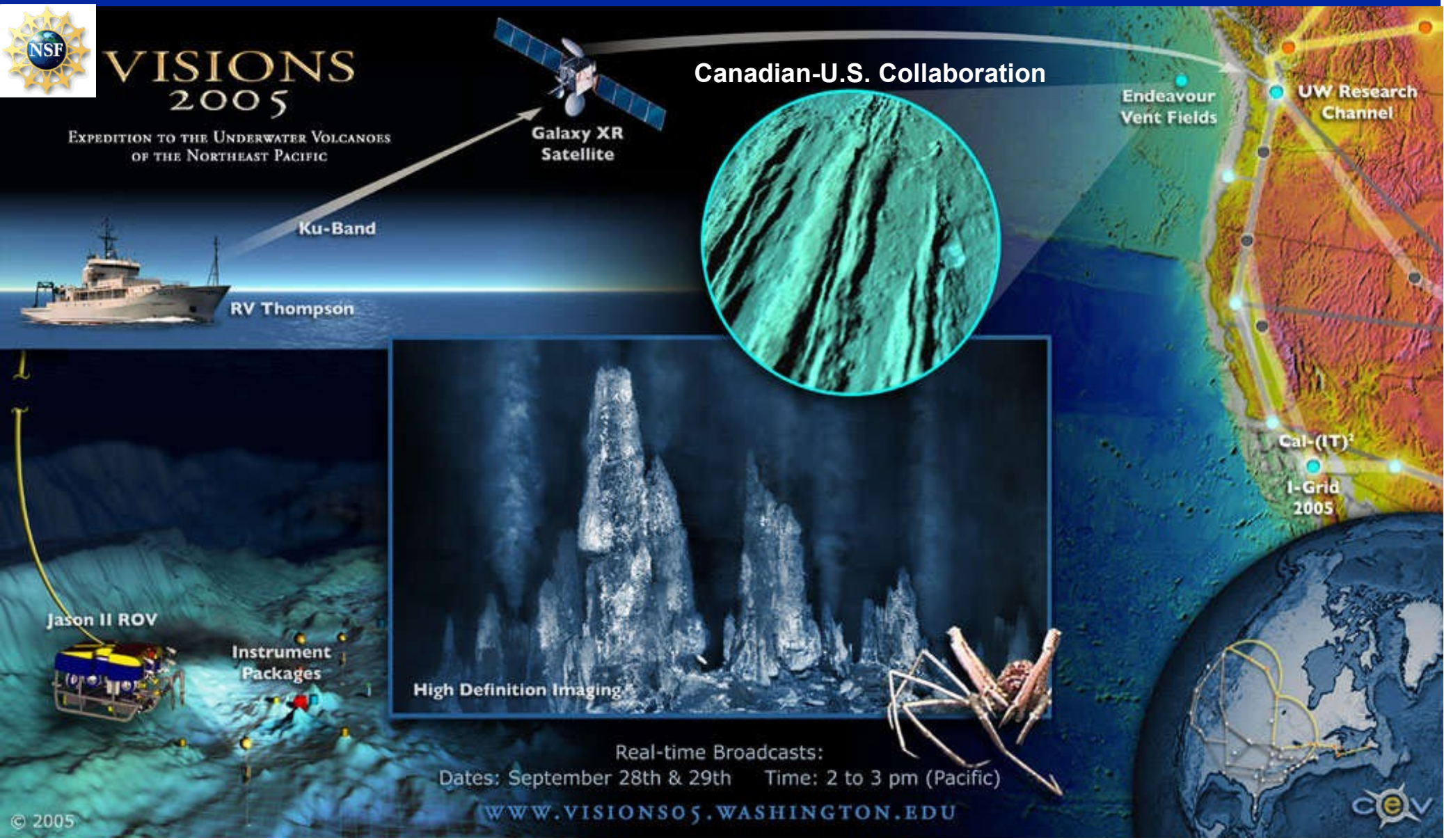
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(Funded by NSF ITR- John Delaney, UWash, PI)

Making Management of Gigabit Flows Routine

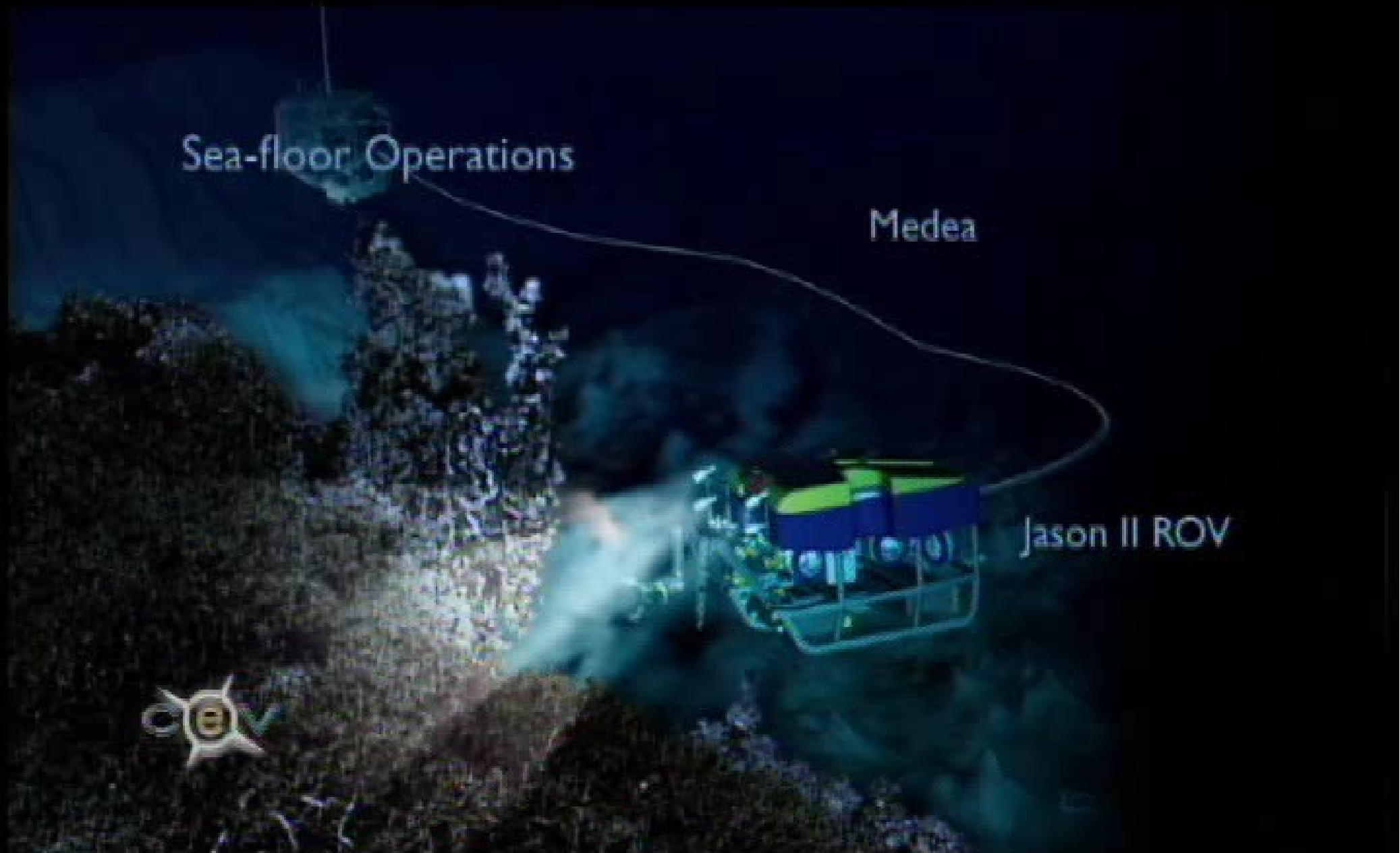
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Dedicated Fiber Optics Enable Remote Interactive HD Imaging of Deep Sea Vent



Source John Delaney & Deborah Kelley, UWash

High Definition Video - 2.5 km Below the Ocean Surface



High Definition Still Frame of Hydrothermal Vent Ecology 2.3 Km Deep



White Filamentous Bacteria on 'Pill Bug' Outer Carapace

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A Near Future Metagenomics Fiber Optic-Enabled Data Generator



Source John Delaney, UWash