“Preparing Your Campus for Data Intensive Researchers”

Featured Speaker

EDUCAUSE 2008

Orlando, FL

October 29, 2008

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

The NSF-funded OptIPuter project has been exploring how user-controlled high-bandwidth dedicated lightwaves (lambdas) can provide direct access to global data repositories, scientific instruments, and computational resources from the researchers' Linux clusters in their campus laboratories. These clusters are reconfigured as "OptIPortals," providing the end users with local scalable visualization, computing, and storage. This session will report on several campuses that have deployed this high-performance cyberinfrastructure and describe how this user-configurable OptIPuter global platform opens new frontiers in research.

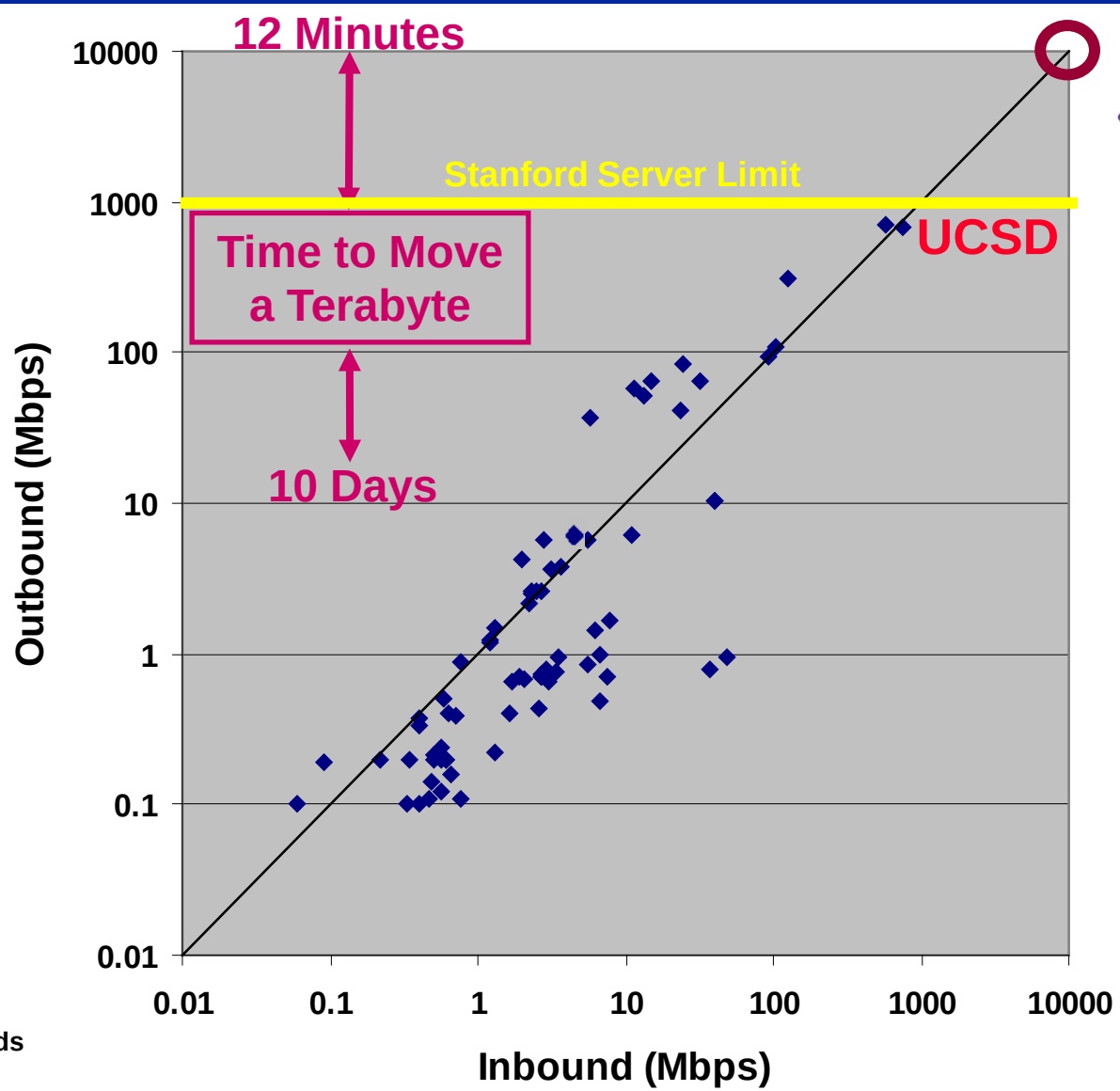
OptIPuter

it²

Shared Internet Bandwidth: Unpredictable, Widely Varying, Jitter, Asymmetric

Computers In:

Australia
Canada
Czech Rep.
India
Japan
Korea
Mexico
Moorea
Netherlands
Poland
Taiwan
United States



OptIPuter

100-1000x Normal Internet!

Data Intensive Sciences Require Fast Predictable Bandwidth

Source: Larry Smarr and Friends

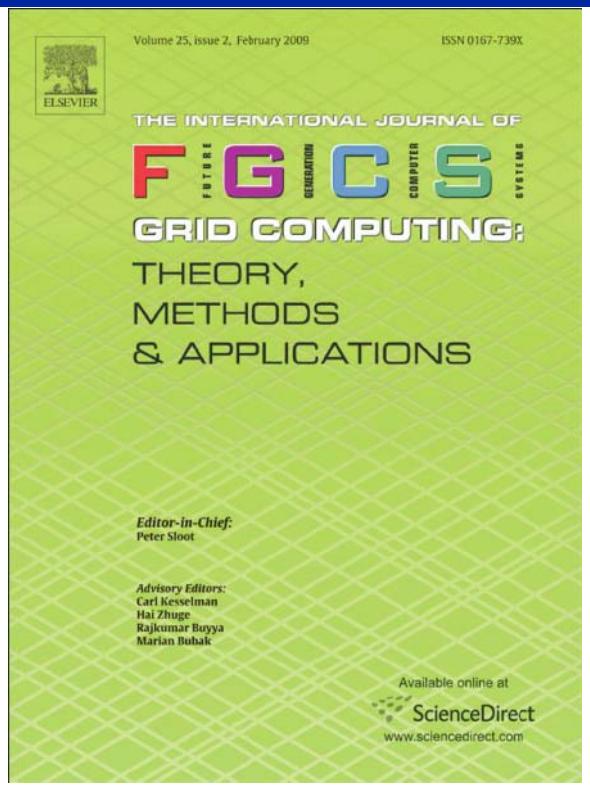
Measured Bandwidth from User Computer to Stanford Gigabit Server in Megabits/sec
http://netspeed.stanford.edu/

OptIPuter

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The OptIPuter Creates an OptIPlanet Collaboratory: Enabling Data-Intensive e-Research



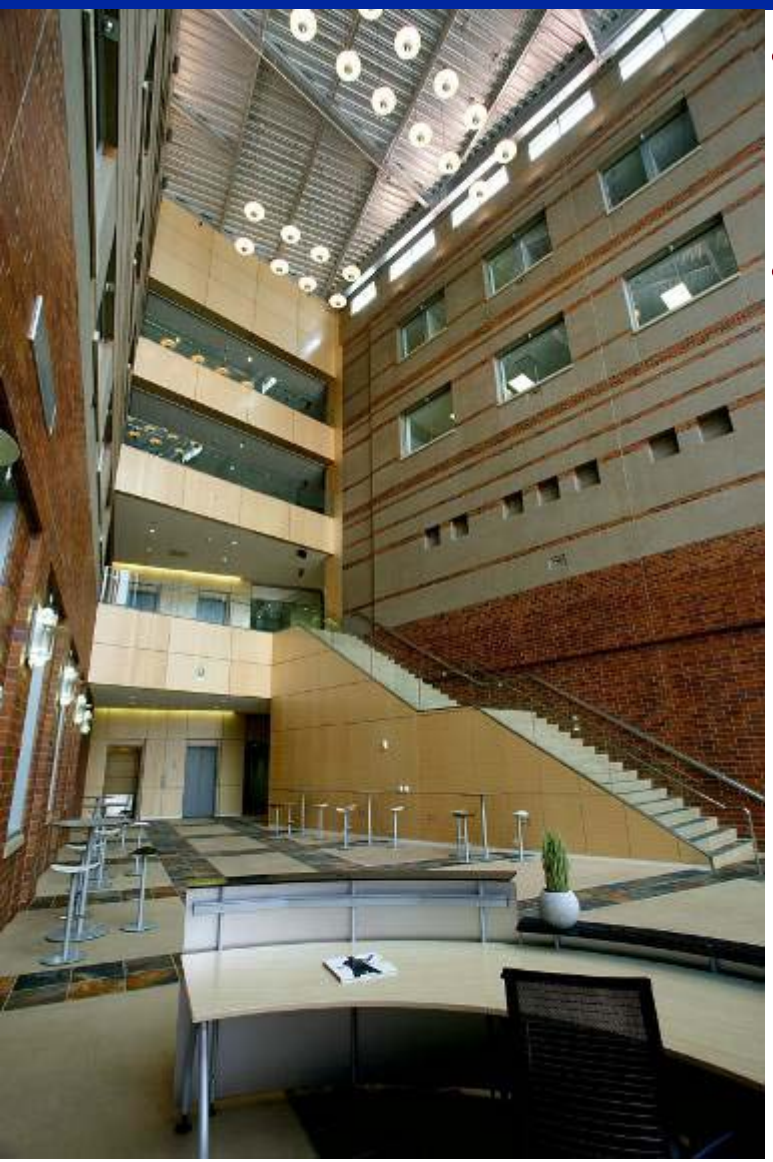


SAGE software, developed by UIC/EVL for OptIPuter, Supports Global Collaboration. Five Sites Streaming *Compressed* HD Video (~600mb Per Stream) Using "SAGE Visualcasting" to Replicate Streams

***"OptIPlanet: The OptIPuter Global Collaboratory"* – Special Section of Future Generations Computer Systems, Volume 25, Issue 2, February 2009**

Calit2 (UCSD, UCI), SDSC, and UIC Leads—Larry Smarr PI
Univ. Partners: NCSA, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

Two New Calit2 Buildings Provide New Laboratories for "Living in the Future"



- "Convergence" Laboratory Facilities
  - Nanotech, BioMEMS, Chips, Radio, Photonics
  - Virtual Reality, Digital Cinema, HDTV, Gaming
- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks



www.calit2.net

Preparing for a World in Which Distance is Eliminated…

OptIPuter

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Discovering New Applications and Services Enabled by 1-10 Gbps Lambdas

Maxine Brown, Tom DeFanti, Co-Chairs

iGrid 2005

www.igrid2005.org

THE GLOBAL LAMBDA INTEGRATED FACILITY

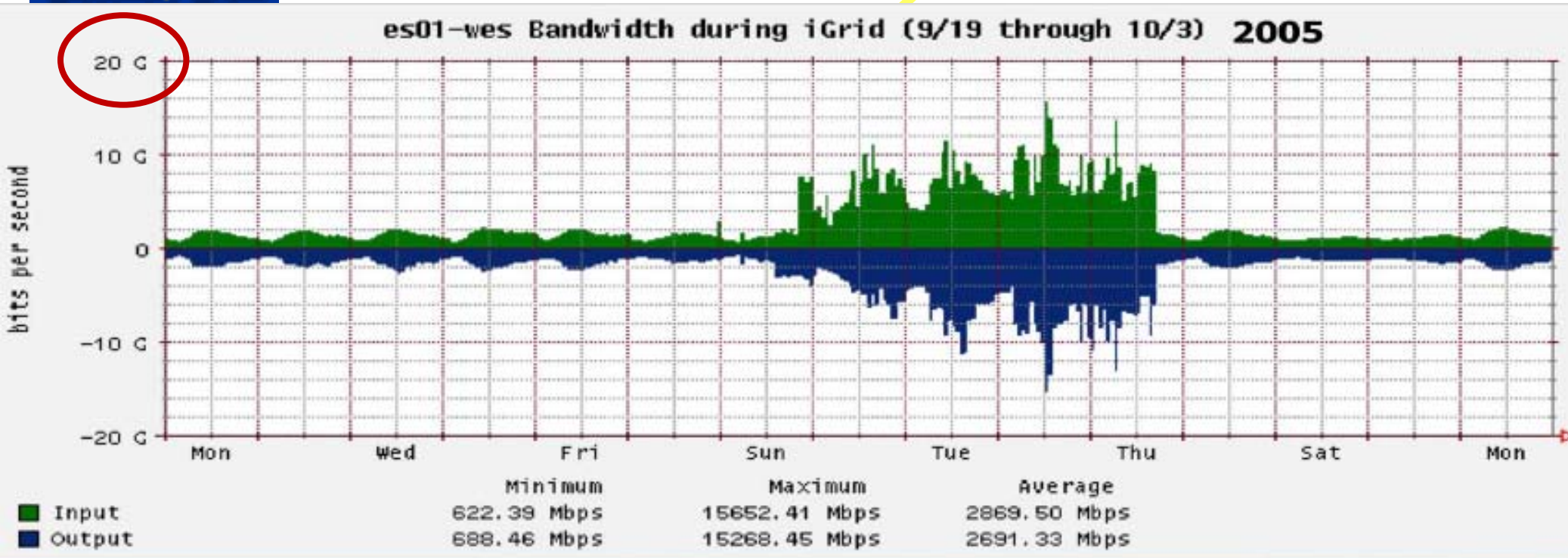


September 26-30, 2005

Calit2 @ University of California, San Diego

California Institute for Telecommunications and Information Technology

the UC Discovery Grant



The Large Hadron Collider Uses a Global Fiber Infrastructure To Connect Its Users

CERN Unveils Global Grid For Particle Physics Research

The network can pull in the IT power of more than 140 computer centers in 33 countries to crunch an expected 15 million GB of data every year.

By Antone Gonsalves
InformationWeek
October 3, 2008 04:57 PM

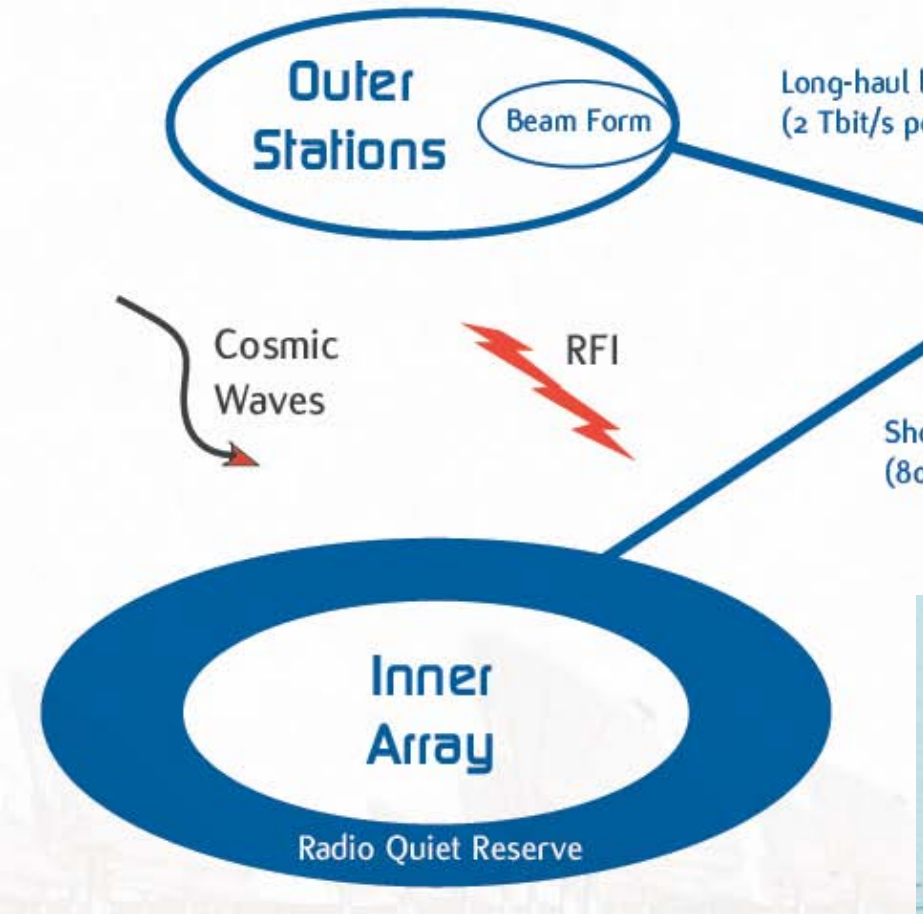
- **The grid relies on optical fiber networks to distribute data from CERN to 11 major computer centers in Europe, North America, and Asia**
- **The grid is capable of routinely processing 250,000 jobs a day**
- **The data flow will be ~6 Gigabits/sec or 15 million gigabytes a year for 10 to 15 years**

OptIPuter

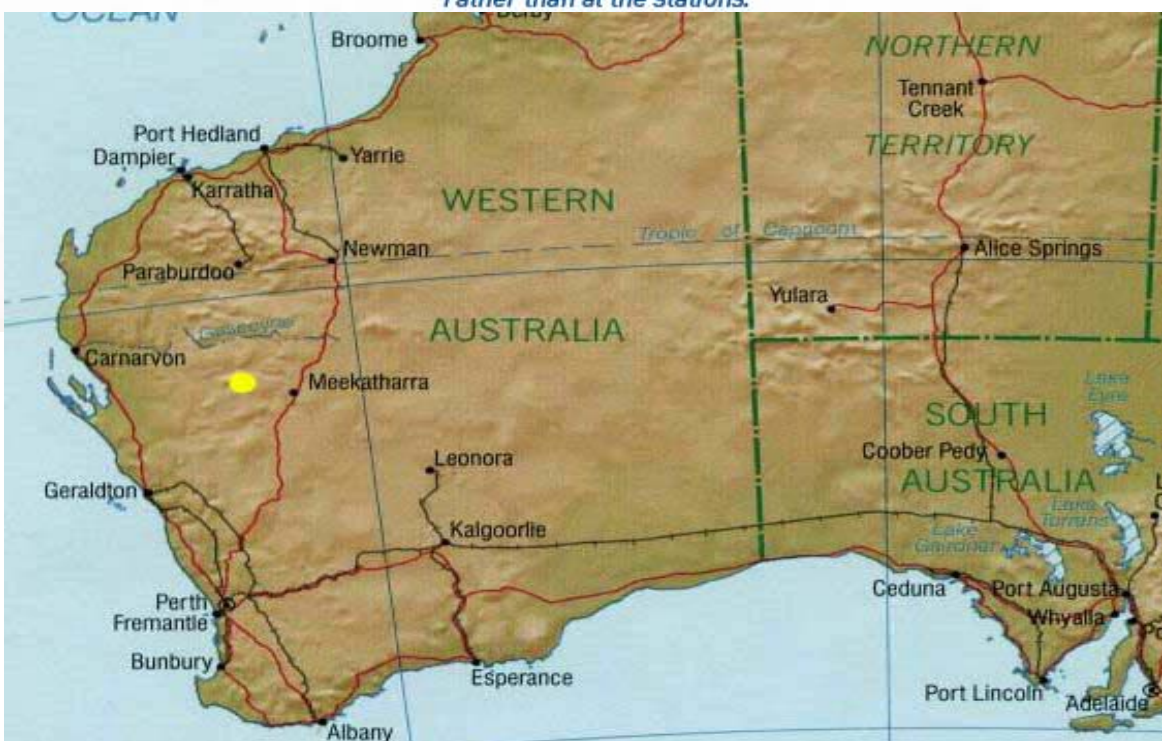
it²

Next Great Planetary Instrument: The Square Kilometer Array Requires Dedicated Fiber

www.skatelescope.org



Schematic of SKA signal flow. Advances in signal transport technology may later allow more signals to be processed at the core, rather than at the stations.



Transfers Of 1 TByte Images World-wide Will Be Needed Every Minute!

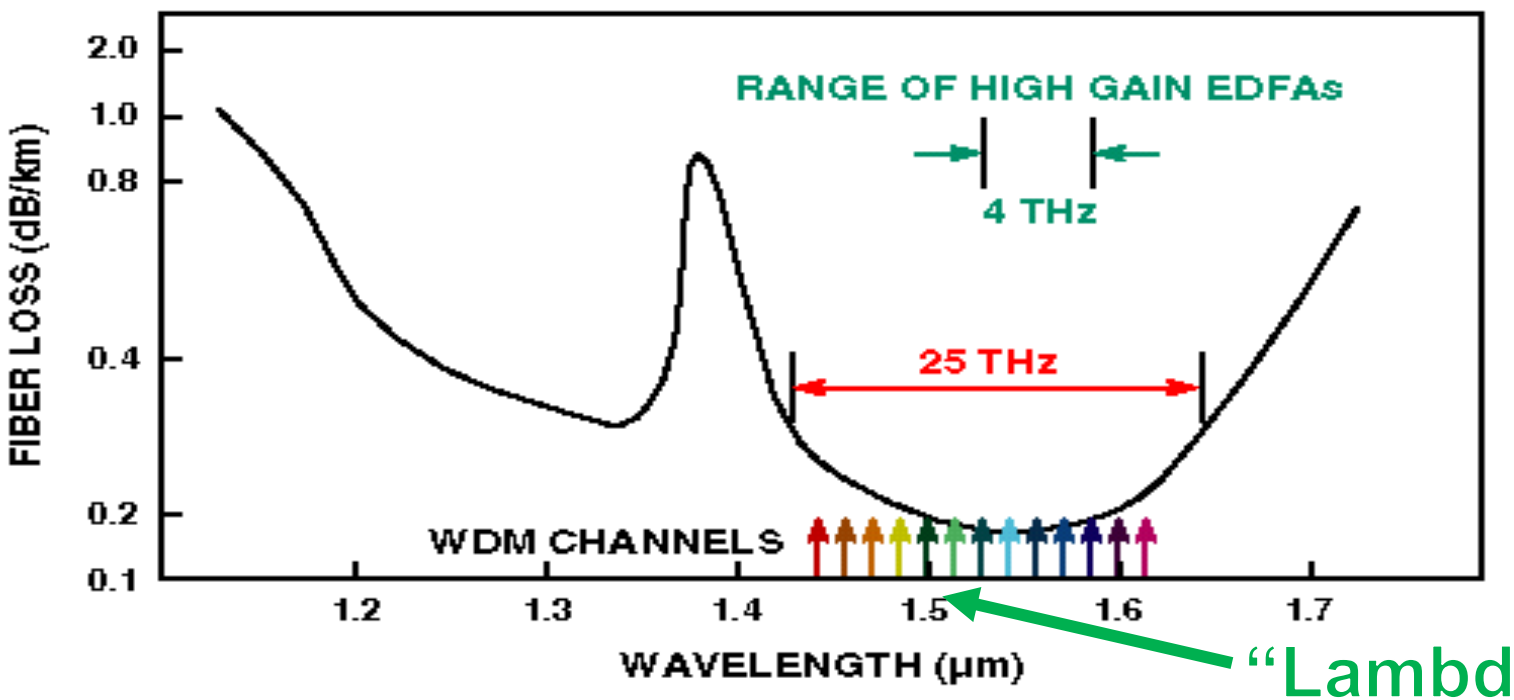
OptIPuter

OptIPuter Step I:
From Shared Internet to Dedicated Lightpaths

Dedicated Optical Fiber Channels Makes High Performance Cyberinfrastructure Possible

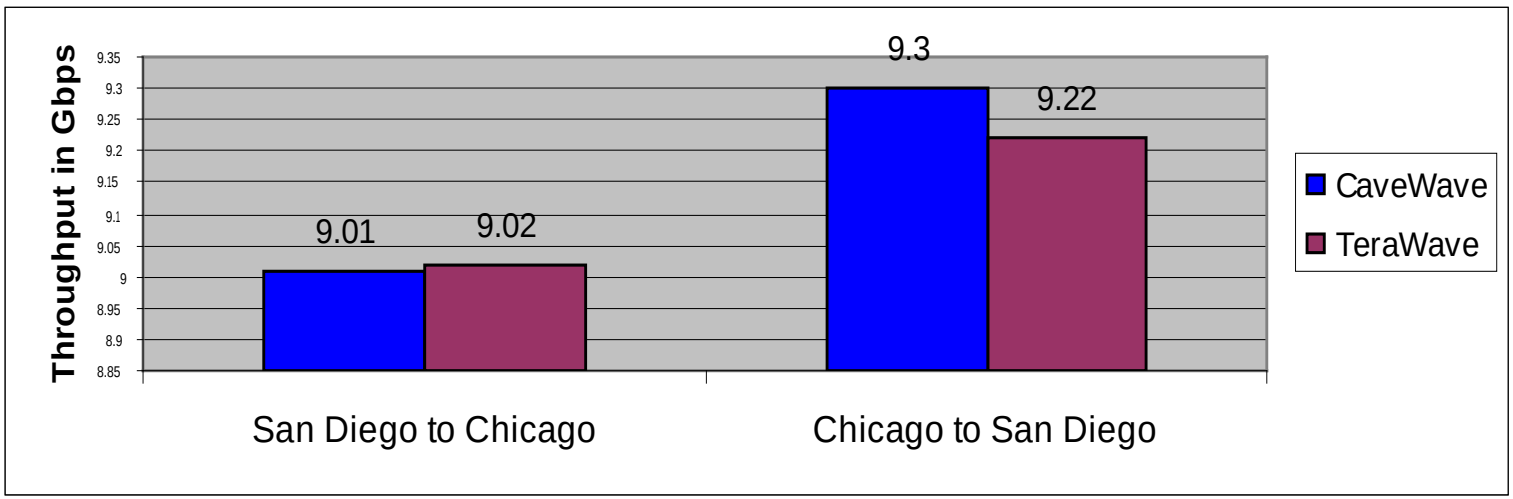
WAVELENGTH DIVISION MULTIPLEXING (WDM)

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



WDM Enables 10Gbps Shared Internet on One Lambda and a Personal 10Gbps Lambda on the Same Fiber!

9Gbps Out of 10 Gbps Disk-to-Disk Performance Using LambdaStream between EVL and Calit2



CAVEWave:
20 senders to 20 receivers (point to point)

Effective Throughput = **9.01** Gbps
(San Diego to Chicago)
450.5 Mbps disk to disk transfer per stream

Effective Throughput = **9.30** Gbps
(Chicago to San Diego)
465 Mbps disk to disk transfer per stream

TeraGrid:
20 senders to 20 receivers (point to point)

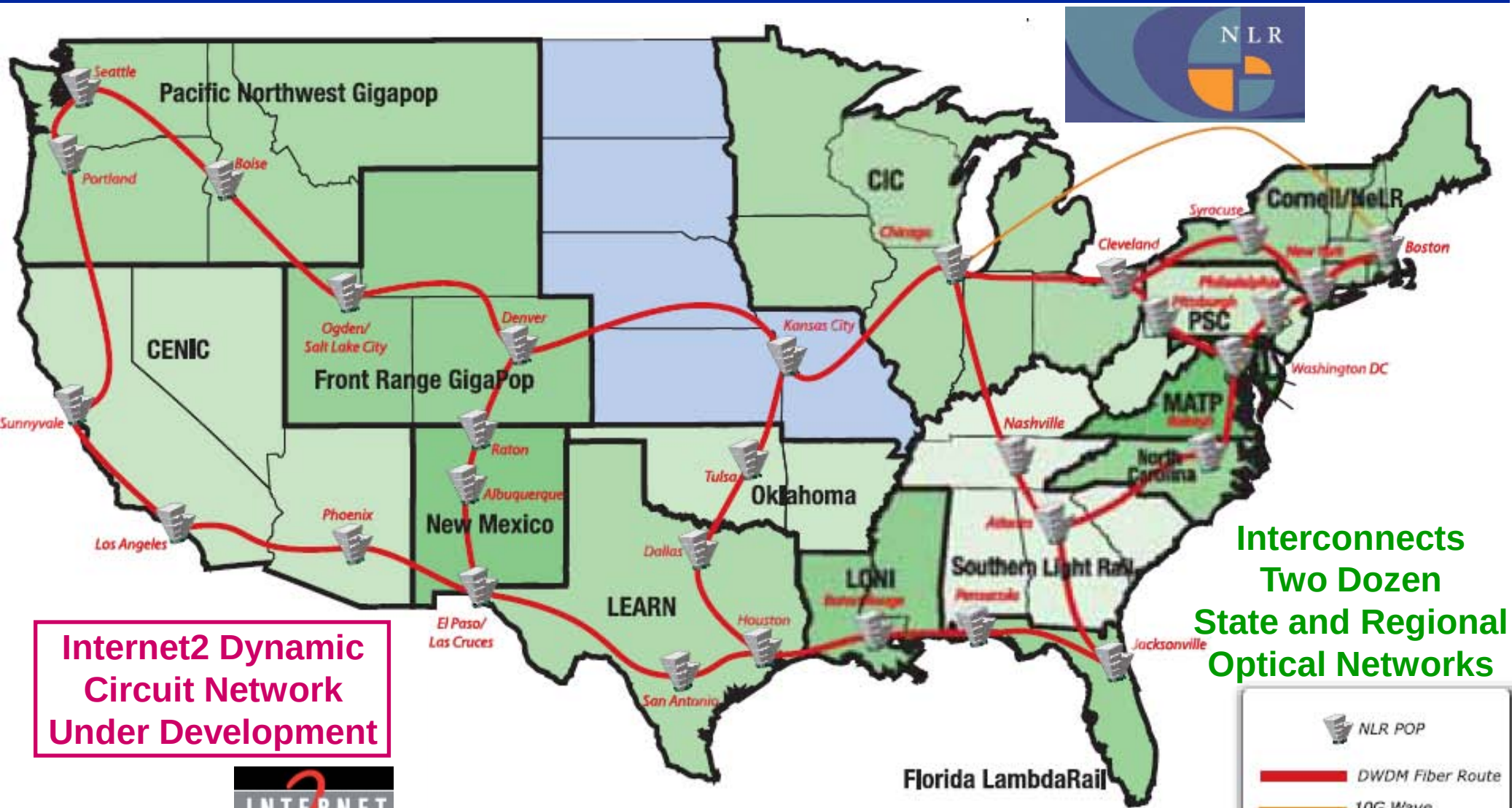
Effective Throughput = **9.02** Gbps
(San Diego to Chicago)
451 Mbps disk to disk transfer per stream

Effective Throughput = **9.22** Gbps
(Chicago to San Diego)
461 Mbps disk to disk transfer per stream

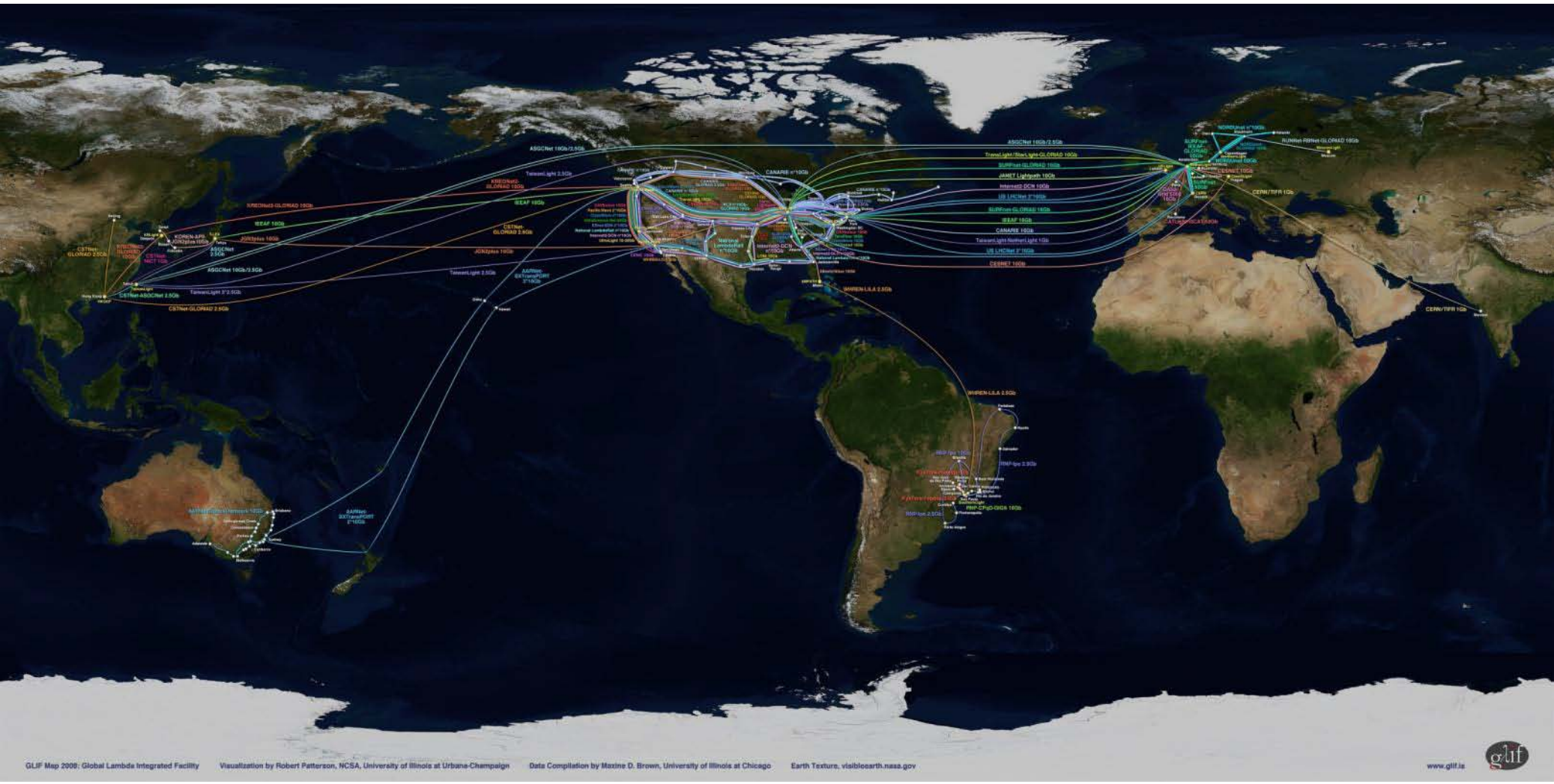
Dataset: 220GB Satellite Imagery of Chicago courtesy USGS.
Each file is 5000 x 5000 RGB image with a size of 75MB i.e ~ 3000 files

Source: Venkatram Vishwanath, UIC EVL

Dedicated 10Gbps Lightpaths Tie Together State and Regional Fiber Infrastructure



Global Lambda Integrated Facility
1 to 10G Dedicated Lambda Infrastructure



Interconnects Global
Public Research Innovation Centers

Source: Maxine Brown, UIC and Robert Patterson, NCSA

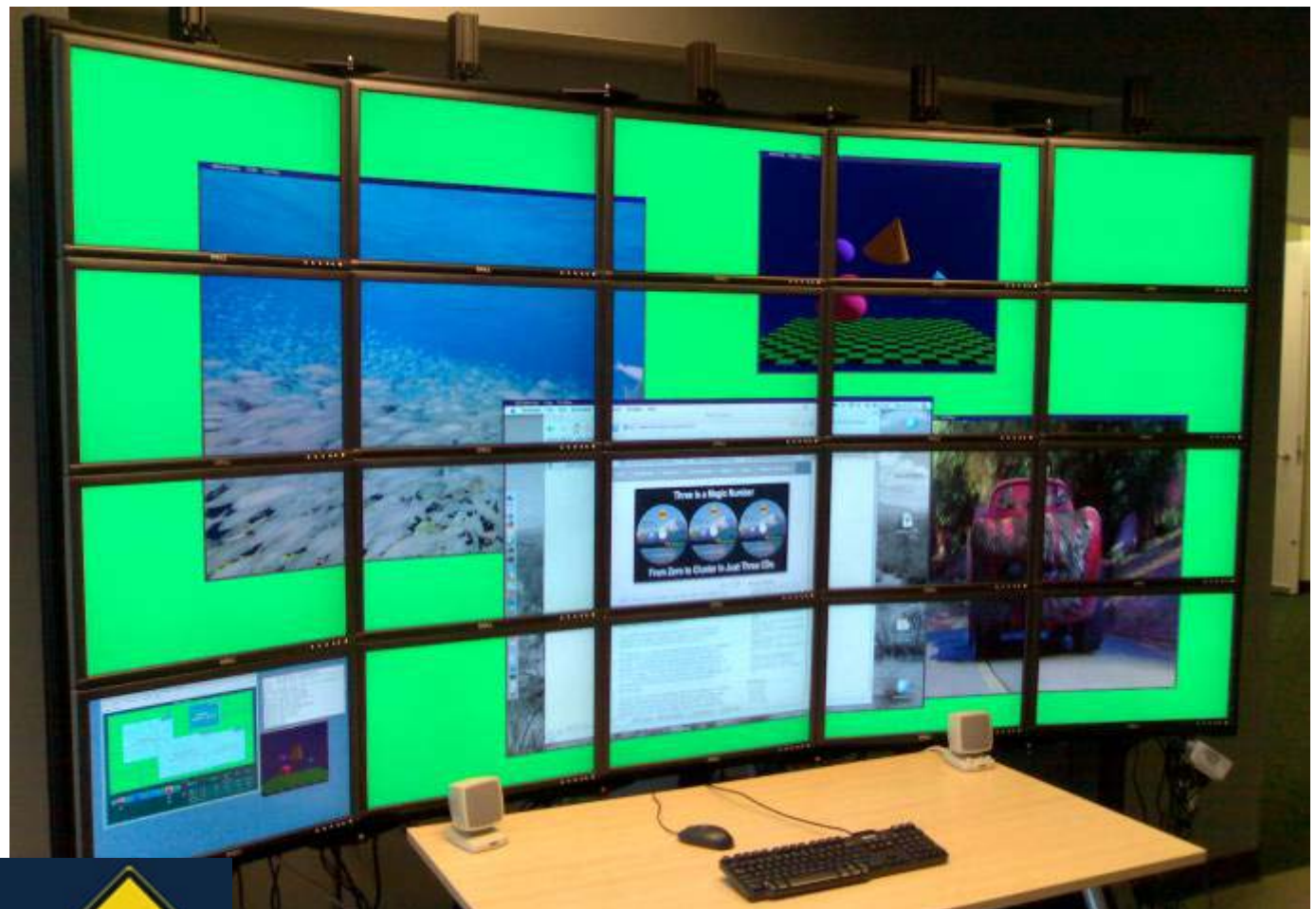
OptIPuter Step II:
From User Analysis on PCs to OptIPortals

My OptIPortal™ – Affordable Termination Device for the OptIPuter Global Backplane

- 20 Dual CPU Nodes, 20 24” Monitors, ~$50,000
- 1/4 Teraflop, 5 Terabyte Storage, 45 Mega Pixels--Nice PC!
- Scalable Adaptive Graphics Environment (SAGE) Jason Leigh, EVL-UIC

evl electronic visualization laboratory





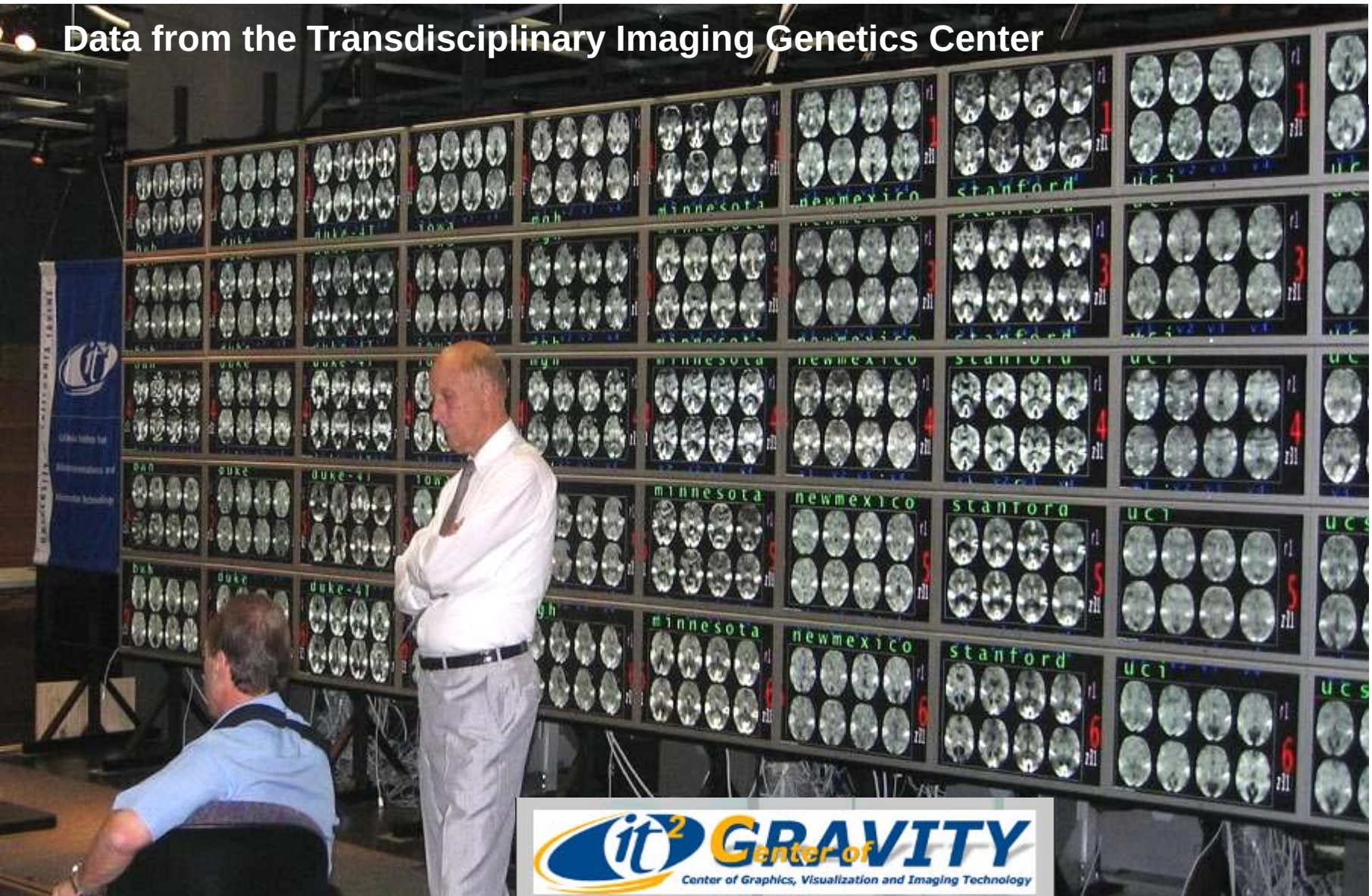
OptIPuter

Powered by Rocks ROCKS

Source: Phil Papadopoulos SDSC, Calit2

it²

Prototyping the PC of 2015:
Two Hundred Million Pixels Connected at 10Gbps



OptIPuter

50 Apple 30” Cinema Displays Driven by 25 Dual-Processor G5s

OptIPuter

Source: Falko Kuester, Calit2@UCI
NSF Infrastructure Grant

it²

Visualizing Human Brain Pathways Along White Matter Bundles that Connect Distant Neurons



Very Large Images Can be Viewed Using CGLX's TiffViewer



Spitzer Space Telescope (Infrared)



Hubble Space Telescope (Optical)

Source: Falko Kuester, Calit2@UCSD

On-Line Resources
Help You Build Your Own OptIPortal

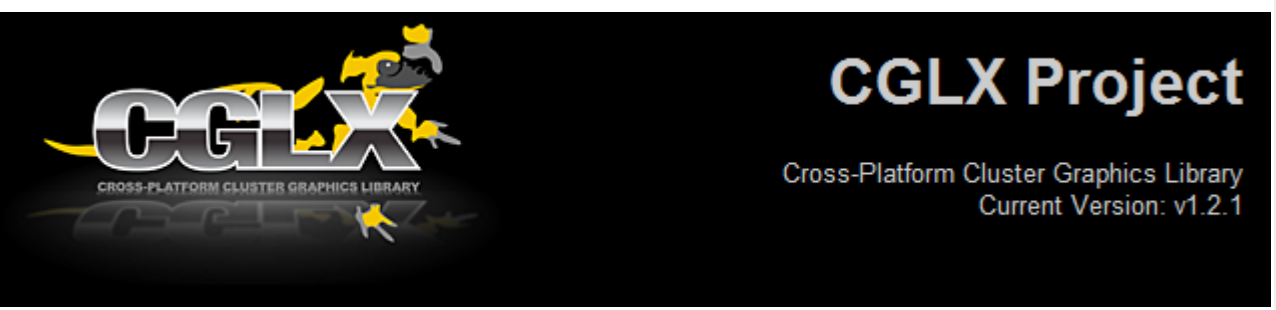
www.optiputer.net

http://wiki.optiputer.net/optiportal



www.evl.uic.edu/cavern/sage





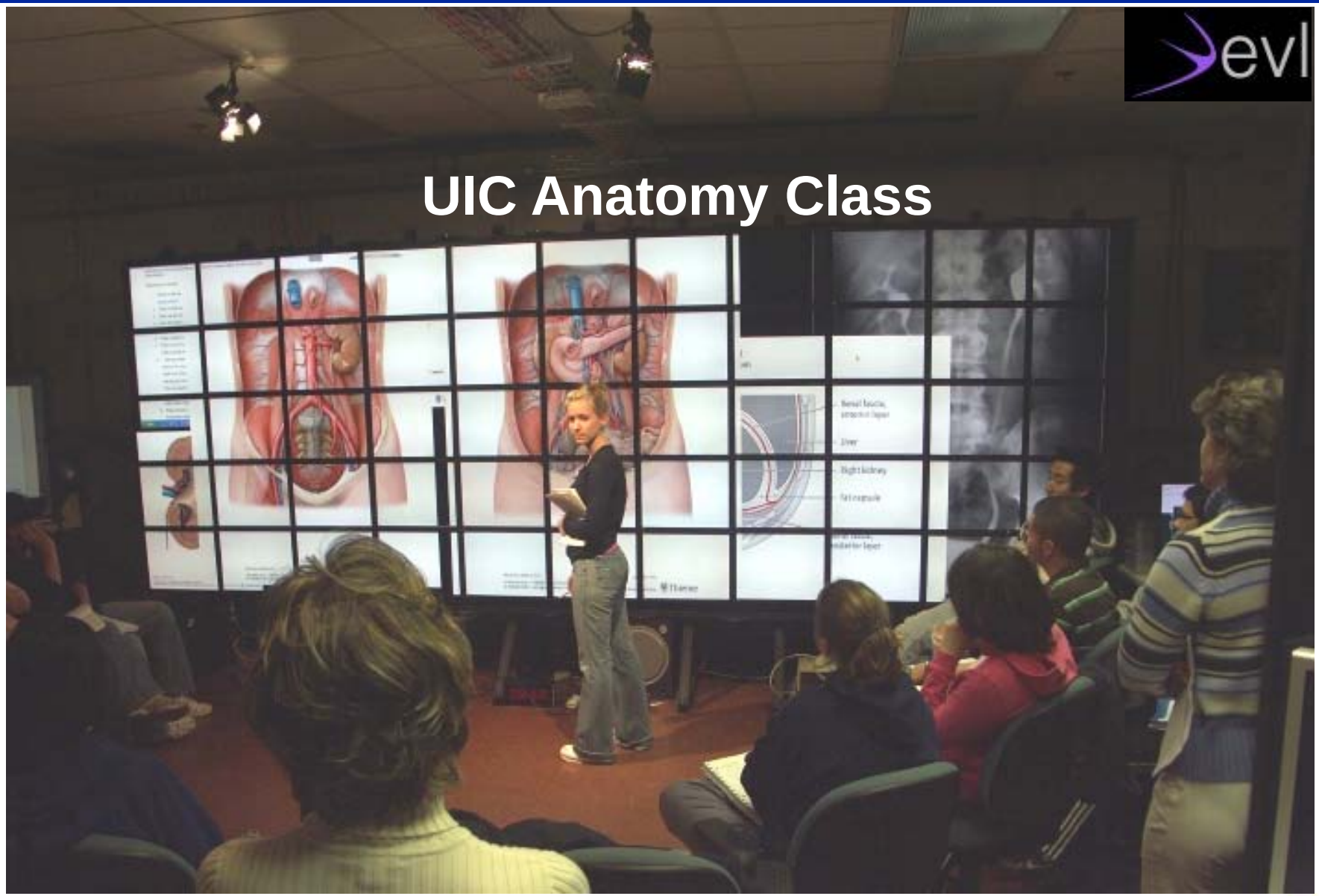
http://vis.ucsd.edu/~cglx/



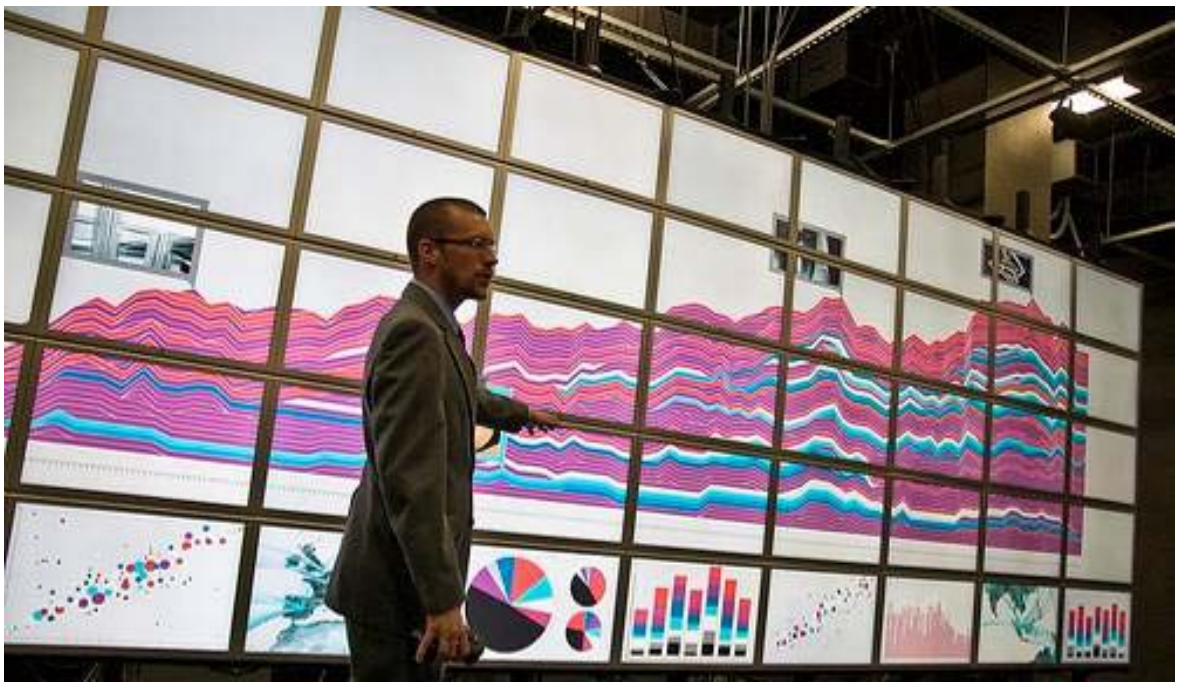
OptIPuter

it²

Students Learn Case Studies in the Context of Diverse Medical Evidence



Using HIPerWall OptIPortals for Humanities and Social Sciences



Calit2@UCI
200 Mpixel
HIPerWall



Software Studies Initiative, Calti2@UCSD

Interface Designs for Cultural Analytics Research Environment

Jeremy Douglass (top) & Lev Manovich (bottom)

Second Annual Meeting of the Humanities, Arts, Science, and Technology Advanced Collaboratory (HASTAC II)
UC Irvine May 23, 2008

OptIPuter

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OptIPuter Step III:
From YouTube to Digital Cinema Streaming Video

HD Talk to Australia's Monash University from Calit2: Reducing International Travel



Qvidium Compressed HD ~140 mbps

Source: David Abramson, Monash Univ

e-Science Collaboratory Without Walls
Enabled by iHDTV Uncompressed HD Telepresence

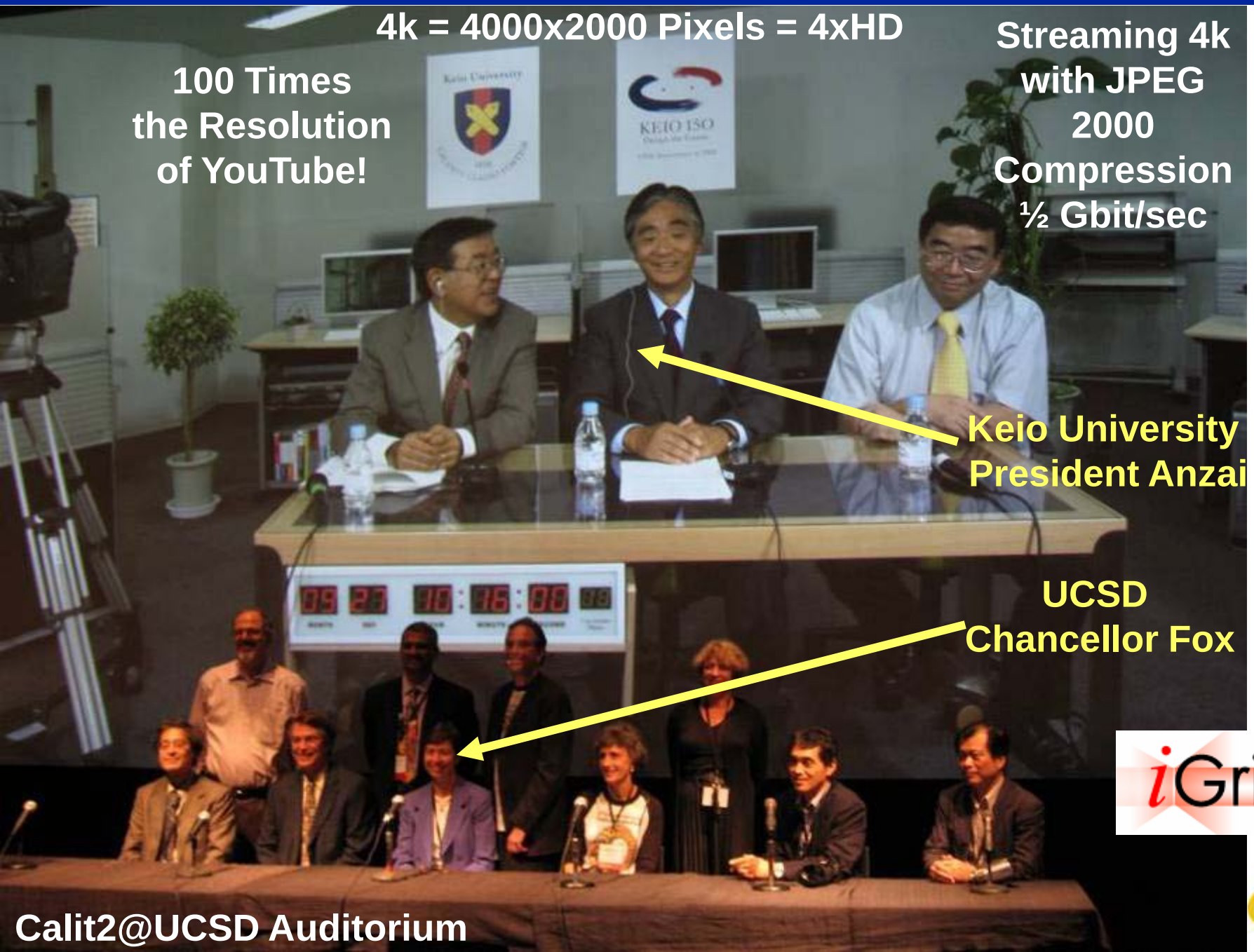
1500 Mbits/sec Calit2 to UW Research Channel Over NLR



John Delaney, PI LOOKING, Neptune

Photo: Harry Ammons, SDSC

Telepresence Meeting
Using Digital Cinema 4k Streams



CineGrid

Lays Technical Basis for Global Digital Cinema

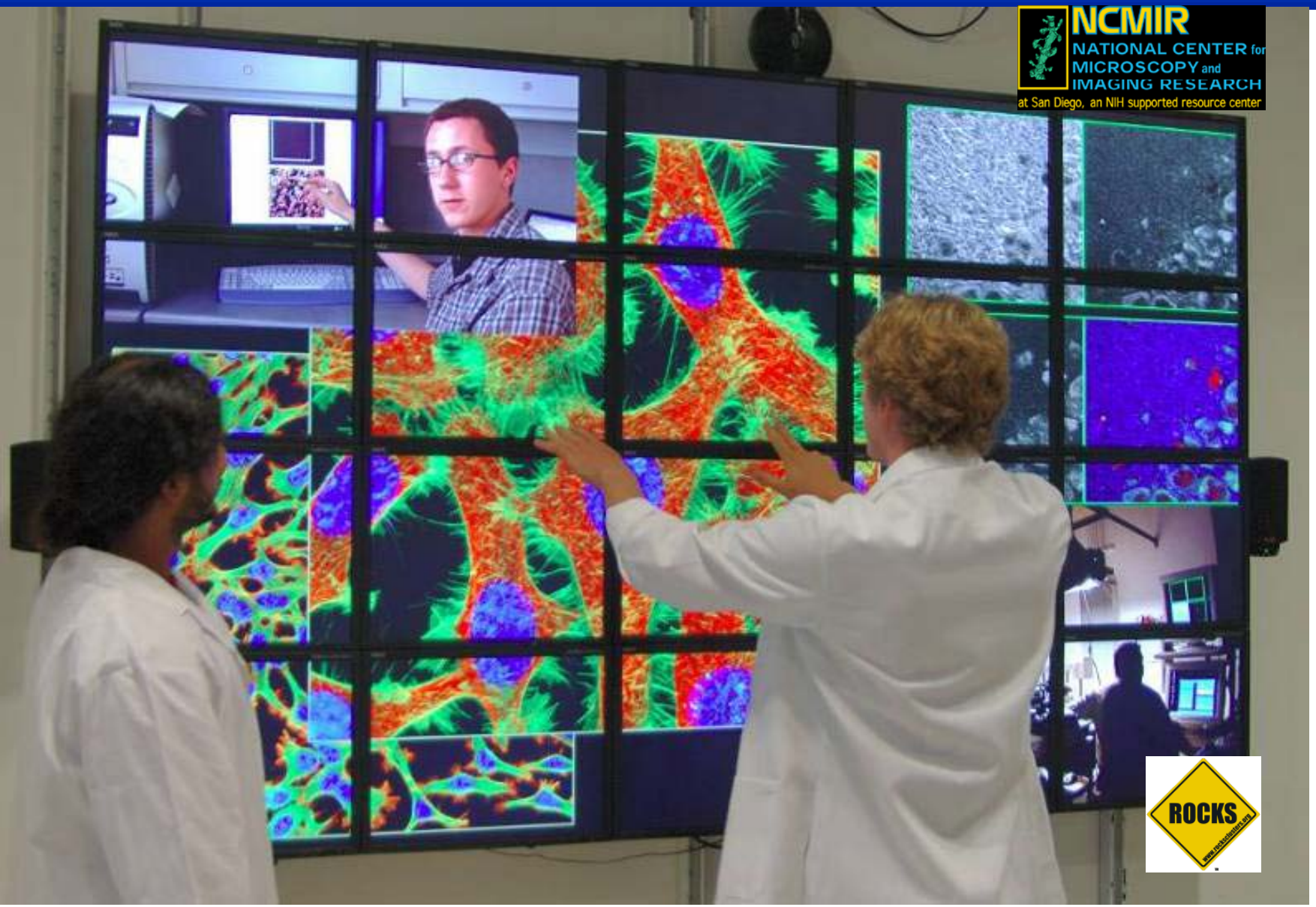
Sony
NTT
SGI

iGrid 2005

it²

OptIPuter Step IV:
Integration of Lightpaths, OptIPortals, and Streaming Media

OptIPuter Enables Real Time Remote Microscopy



TS telescience project

Picture Source: Mark Ellisman, David Lee, Jason Leigh

OptIPuter

evl electronic visualization laboratory

Scalable Adaptive Graphics Environment (SAGE)

it2

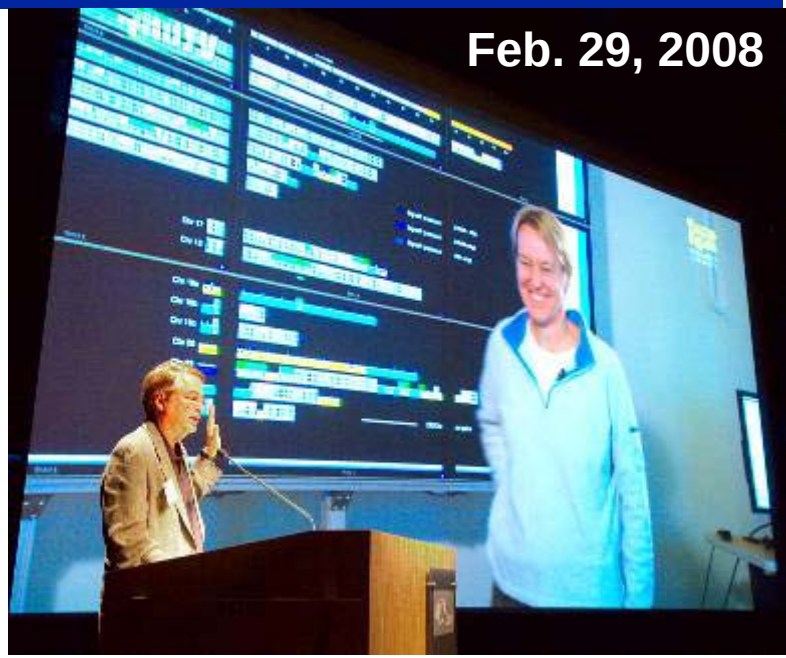
OptIPuter Persistent Infrastructure Enables Calit2 and U Washington Collaboratory



OptIPuter

Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly

ROCKS







UW's Research Channel
Michael Wellings

it²

The Calit2 OptIPortals at UCSD and UCI Are Now a Gbit/s HD Collaboratory



OptIPuter

UCSD cluster: 15 x Quad core Dell XPS with Dual nVIDIA 5600s
UCI cluster: 25 x Dual Core Apple G5

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Command and Control:
Live Session with JPL and Mars Rover from Calit2



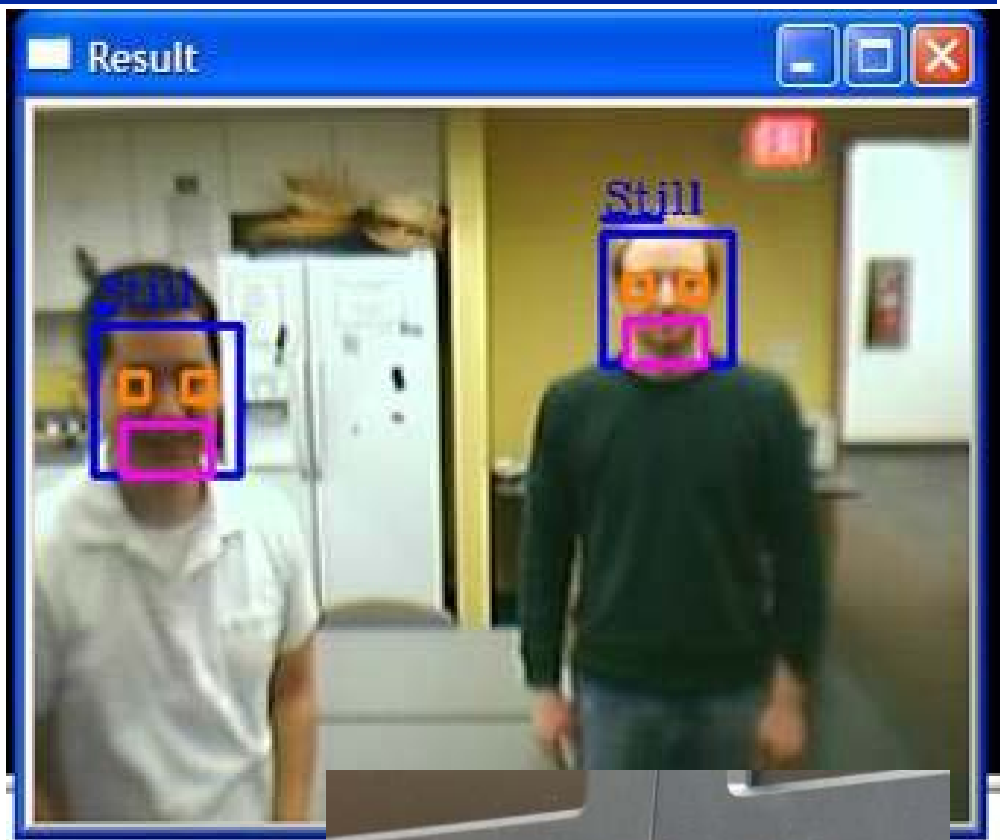
OptIPuter

Source: Falko Kuester, Calit2; Michael Sims, NASA

it²

U Michigan Virtual Space Interaction Testbed (VISIT) Instrumenting OptIPortals for Social Science Research

- **Using Cameras Embedded in the Seams of Tiled Displays and Computer Vision Techniques, we can Understand how People Interact with OptIPortals**
  - **Classify Attention, Expression, Gaze**
  - **Initial Implementation Based on Attention Interaction Design Toolkit (J. Lee, MIT)**
- **Close to Producing Usable Eye/Nose Tracking Data using OpenCV**





Leading U.S. Researchers on the Social Aspects of Collaboration

OptIPuter

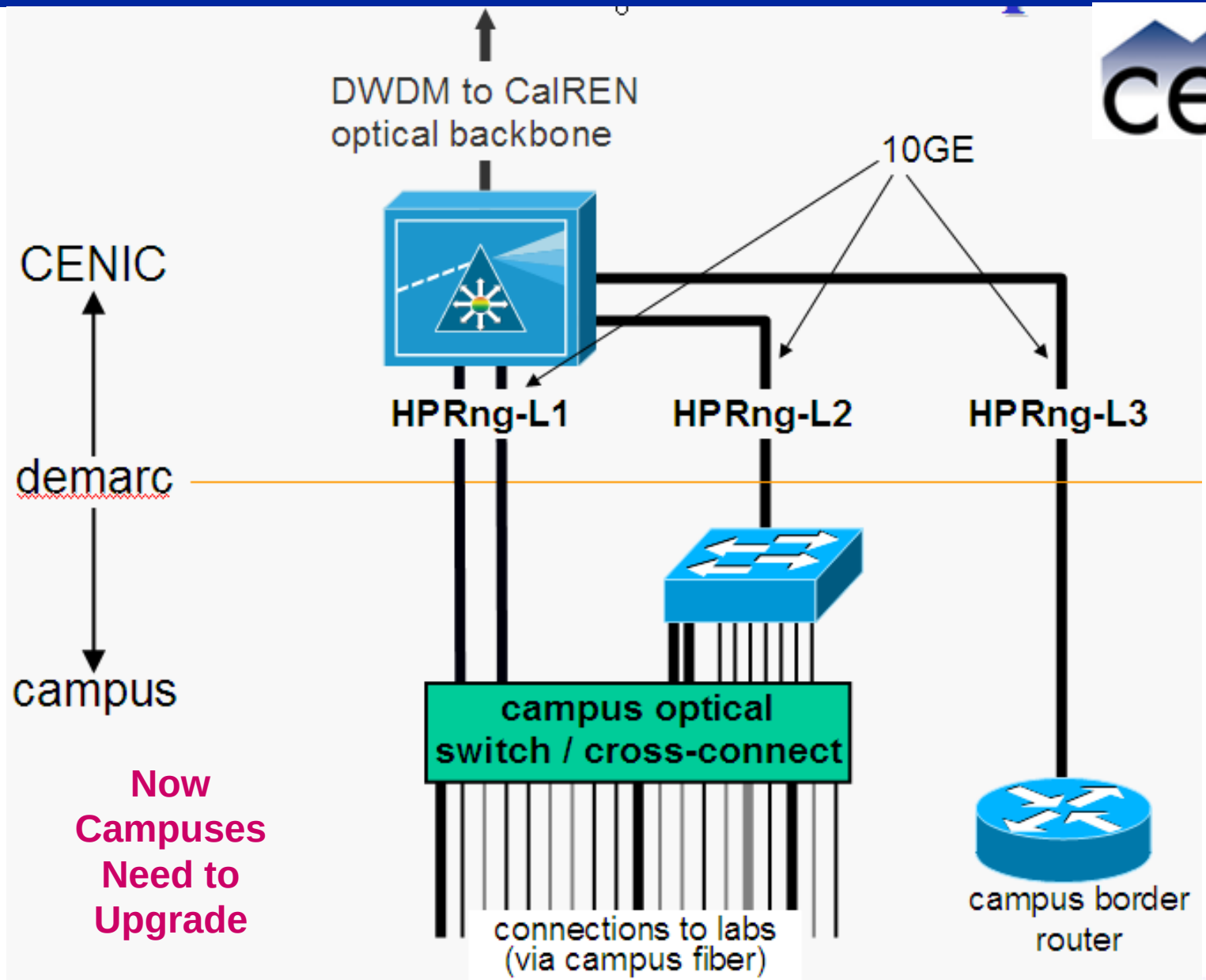
Source: Erik Hofer, UMich, School of Information

it²

OptIPuter Step VI:
The Campus Last Mile

CENIC's New "Hybrid Network" - Traditional Routed IP and the New Switched Ethernet and Optical Services

~ $14M Invested in Upgrade



Now Campuses Need to Upgrade

Source: Jim Dolgonas, CENIC

The "Golden Spike" UCSD Experimental Optical Core: Ready to Couple Users to CENIC L1, L2, L3 Services



Goals by 2008:

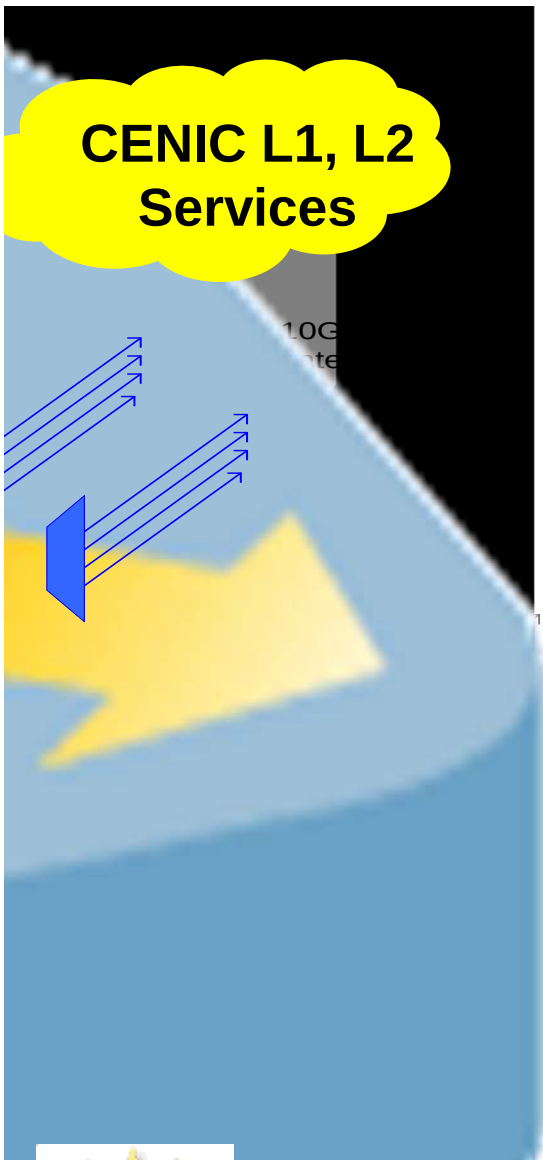
>= 60 endpoints at 10 GigE

>= 30 Packet switched

>= 30 Switched wavelengths

>= 400 Connected endpoints

Approximately 0.5 Tbps Arrive at the "Optical" Center of Hybrid Campus Switch



Funded by NSF MRI Grant

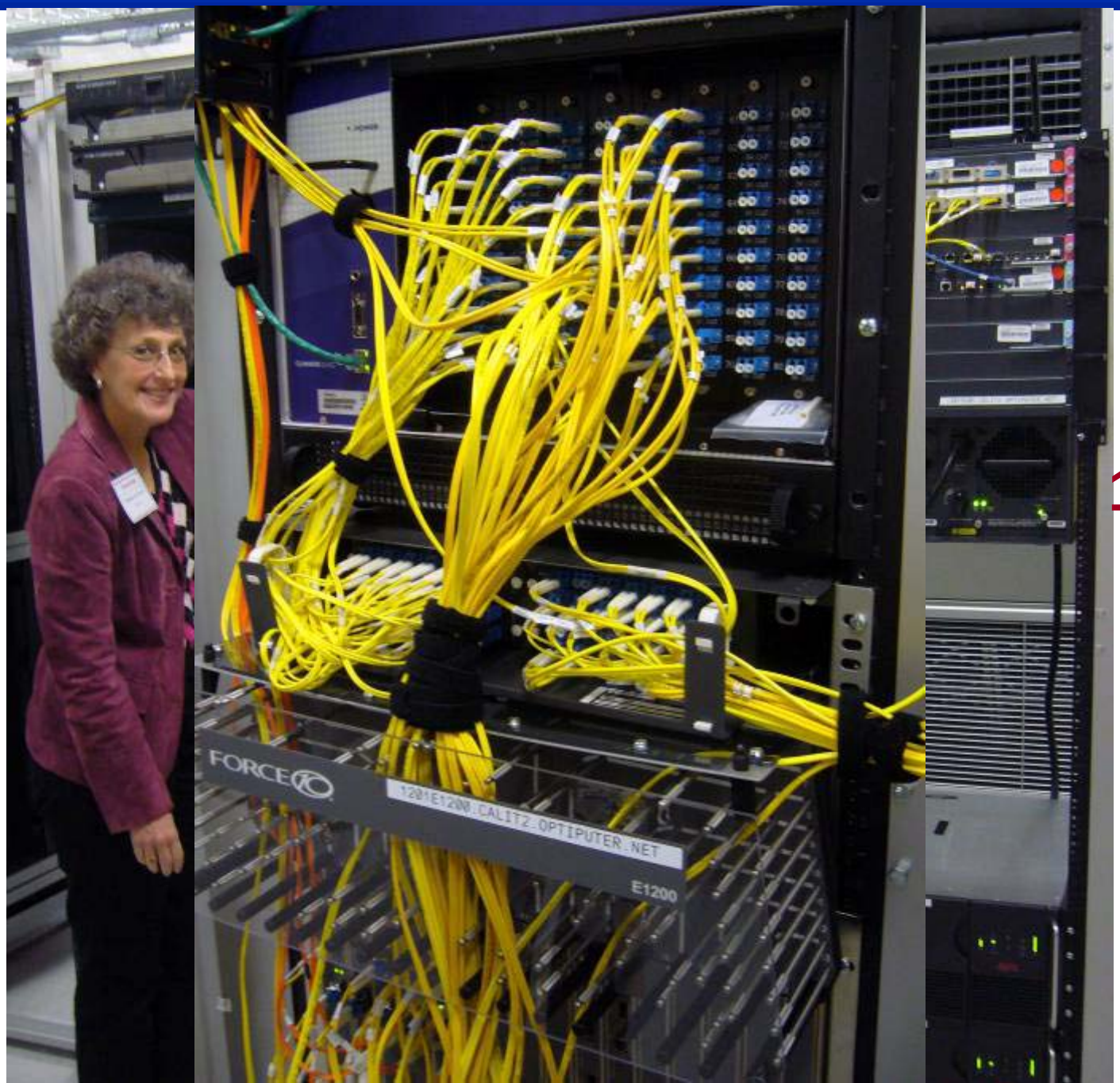
OptIPuter SDSC

Source: Phil Papadopoulos, SDSC/Calit2 (Quartzite PI, OptIPuter co-PI)

NSF

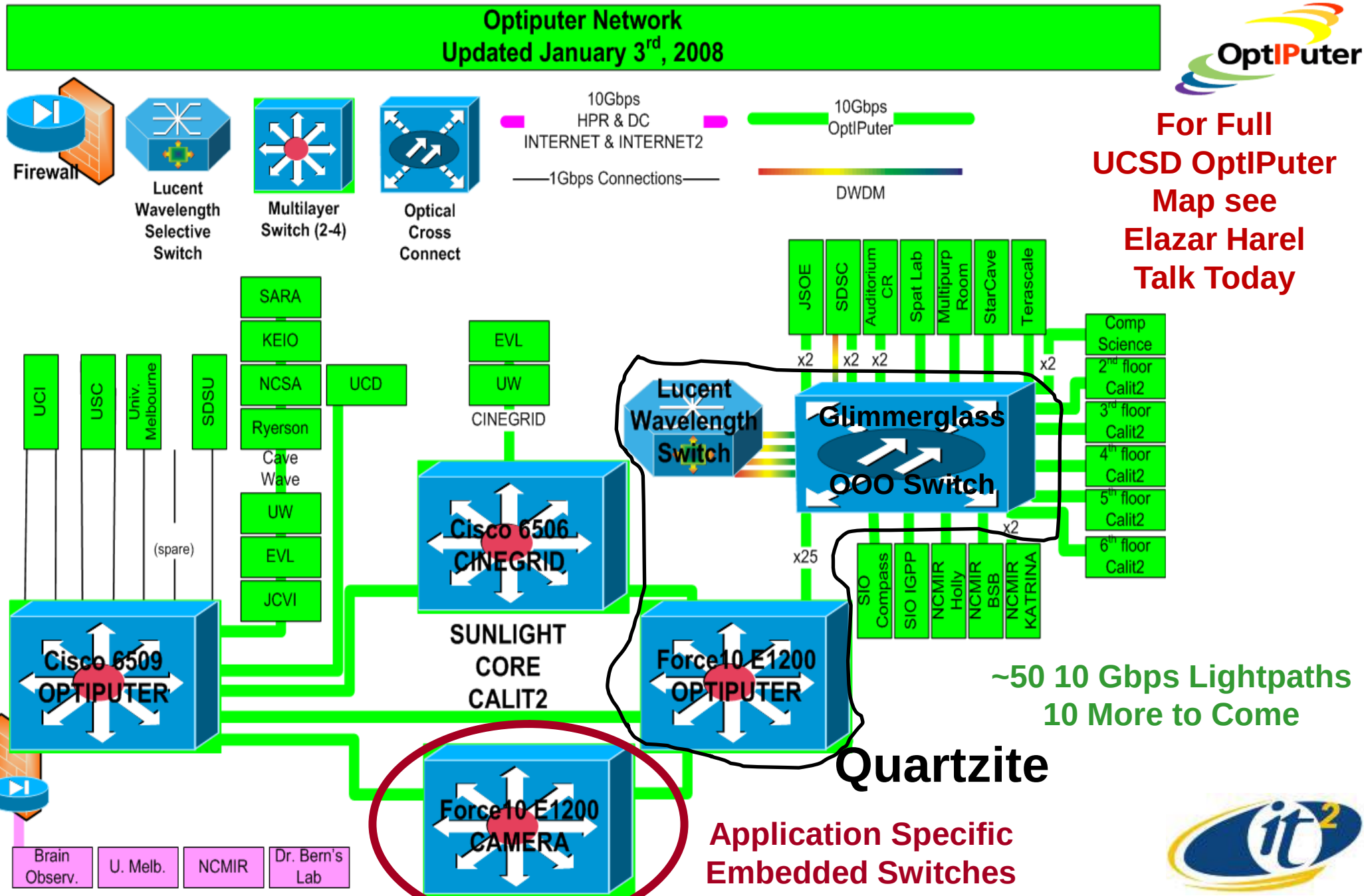
it²

Calit2 Sunlight
Optical Exchange Contains Quartzite



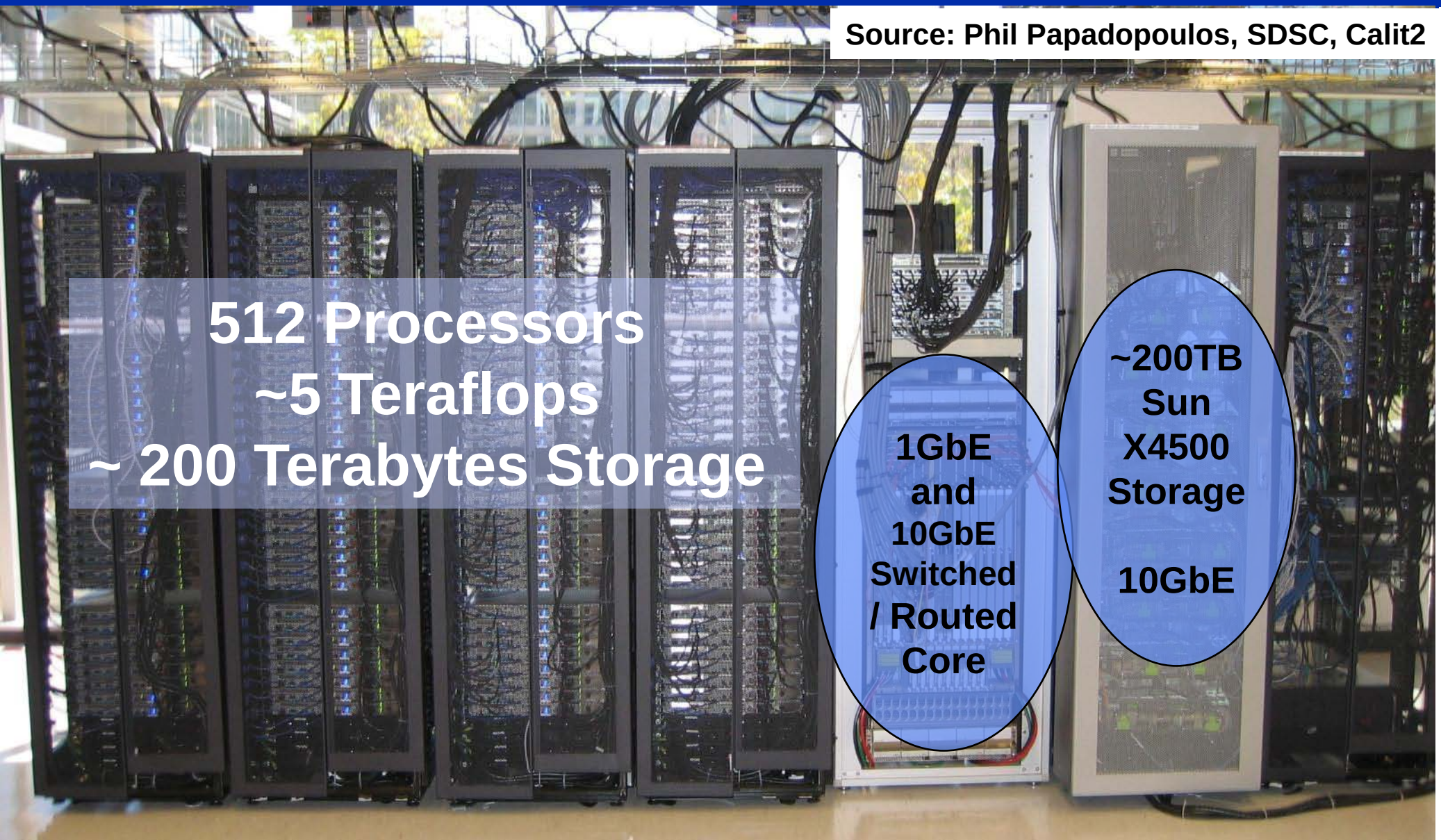
10:45 am Feb. 21, 2008

Block Layout of UCSD Quartzite/OptIPuter Network



Calit2 Microbial Metagenomics Cluster- Next Generation Optically Linked Science Data Server

Source: Phil Papadopoulos, SDSC, Calit2



OptIPuter SDSC ROCKS camera Marine Microbial Ecology J. Craig Venter INSTITUTE it2

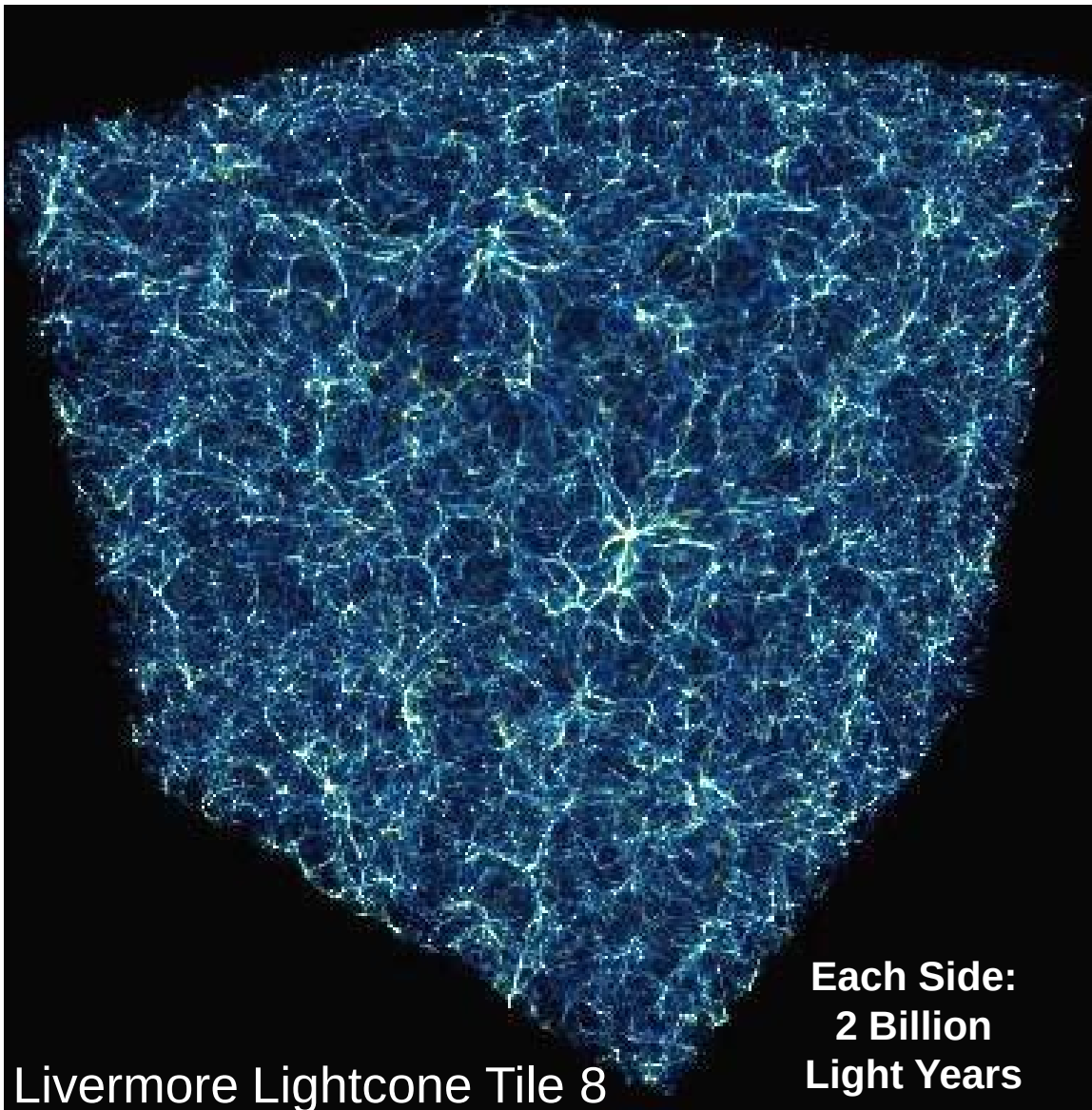
The Livermore Lightcone: 8 Large AMR Simulations Covering 10 Billion Years "Look Back Time"

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

- **1.5 M SU on LLNL Thunder**
- **Generated 200 TB Data**
- **0.4 M SU Allocated on SDSC DataStar for Data Analysis Alone**

512^3 Base Grid, 7 Levels of Adaptive Refinement➔65,000 Spatial Dynamic Range

>300,000 AMR Grid Patches



OptIPuter

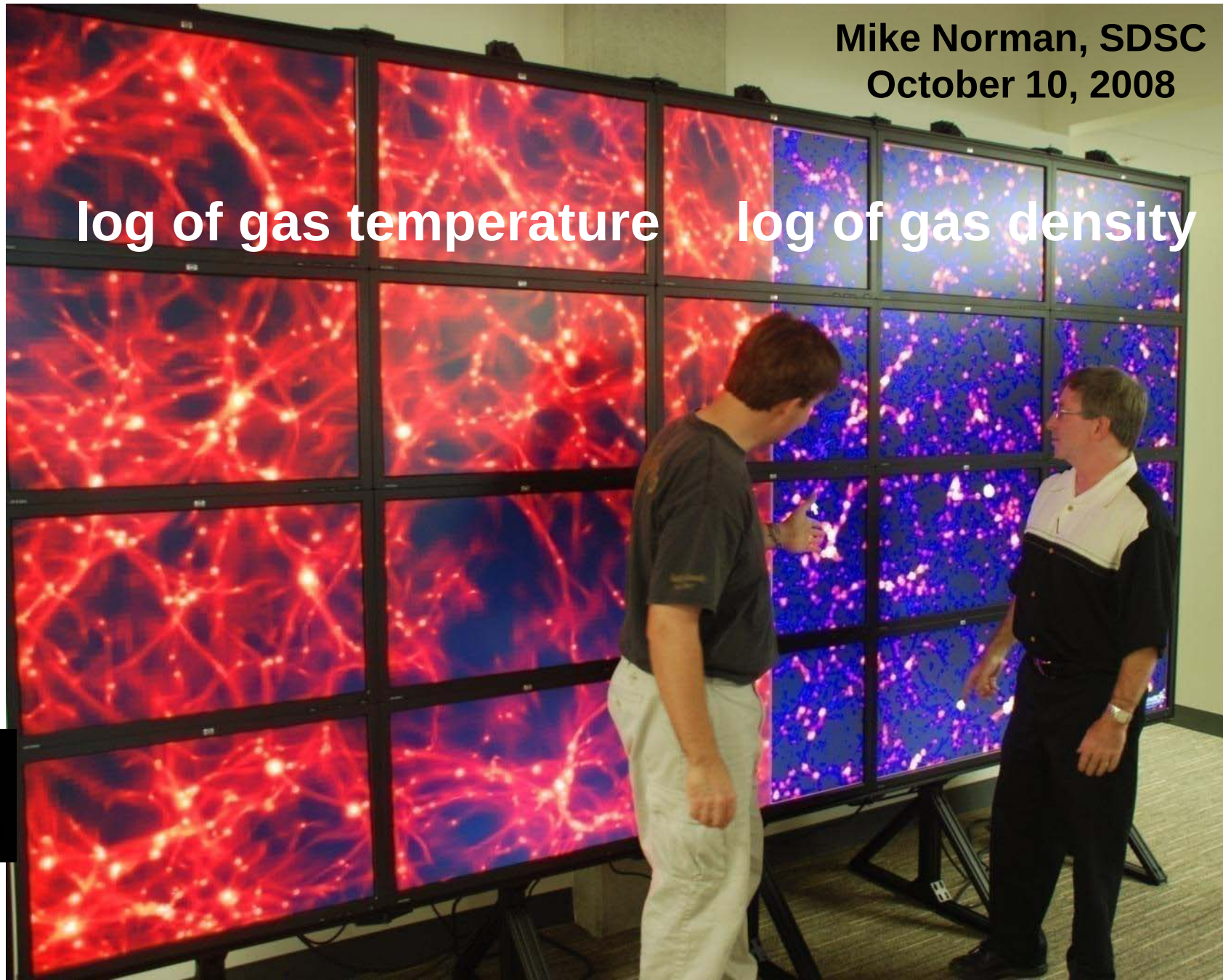
Source: Michael Norman, SDSC, UCSD

it²

Using OptIPortals to Analyze Supercomputer Simulations

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

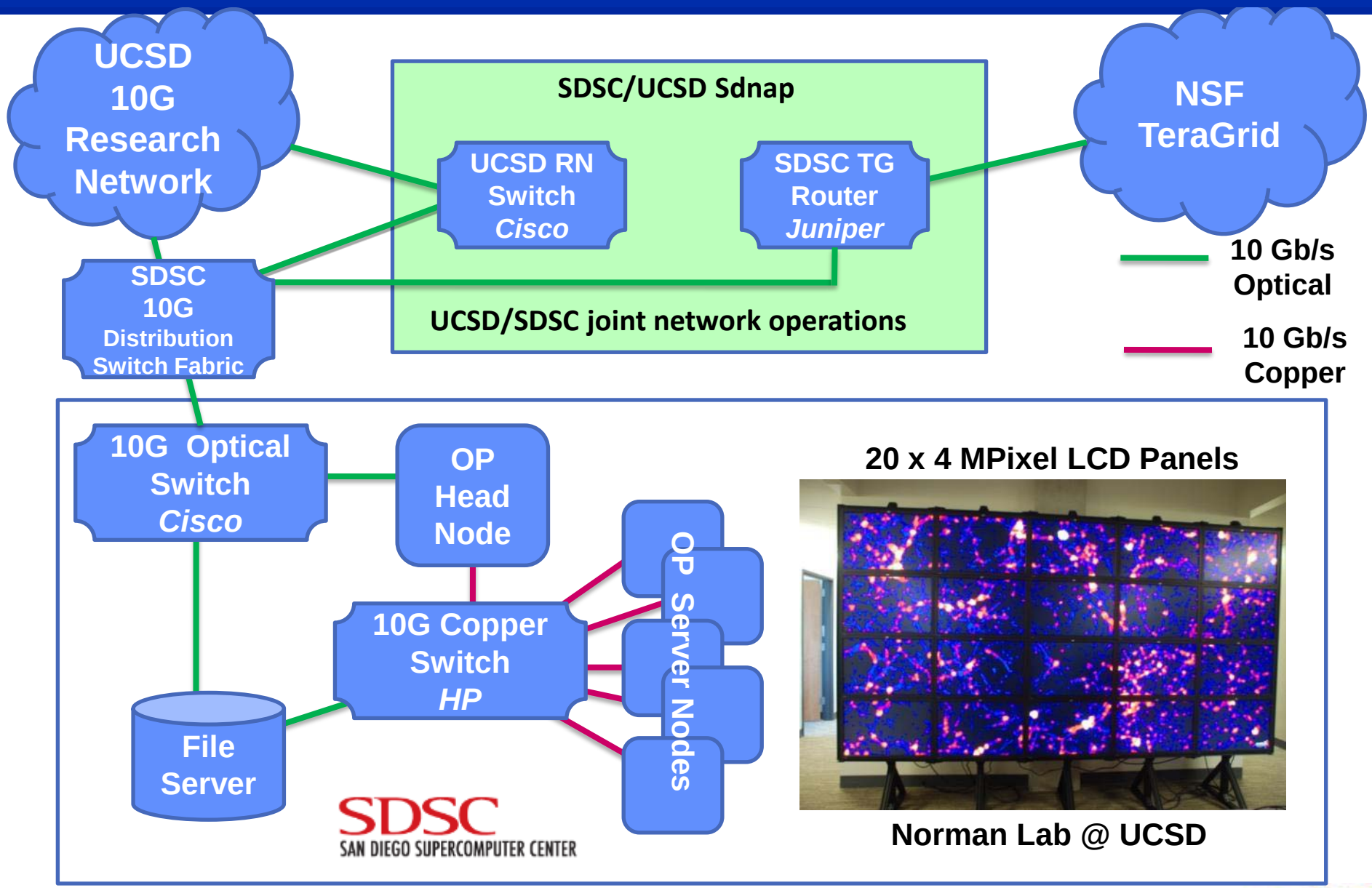
Two 64K Images From a Cosmological Simulation of Galaxy Cluster Formation



CGLX

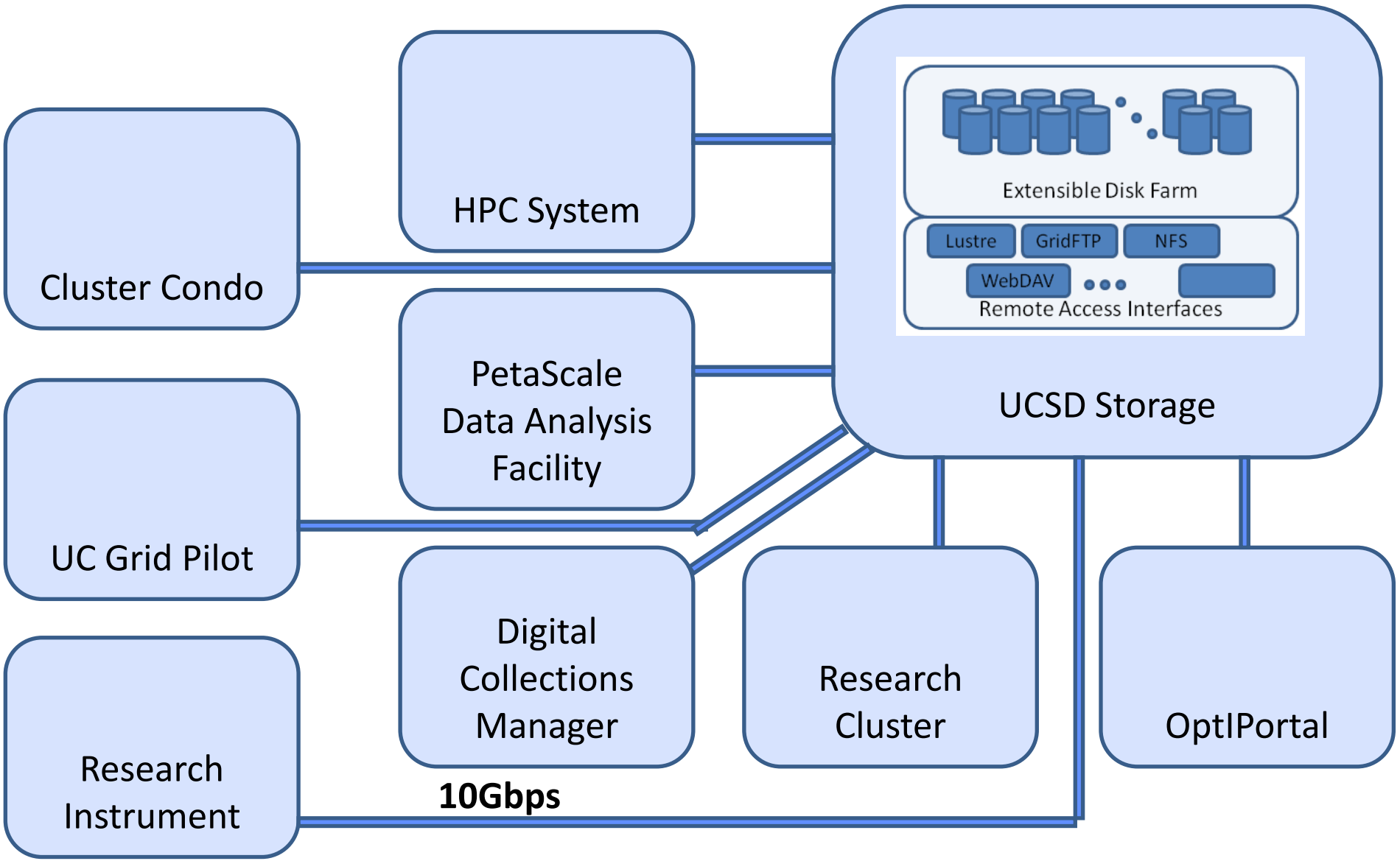
OptIPuter

SDSC OptIPortal Uses UCSD Research Network to Get to TeraGrid with 10Gps Clear Channel



Source: Mike Norman, Tom Hutton, Rick Wagner, SDSC

Use Campus Investment in Fiber and Networks to Re-Centralize Campus Resources



Source:Phil Papadopoulos, SDSC/Calit2

OptIPuter Step V:
New Drivers-Green ICT

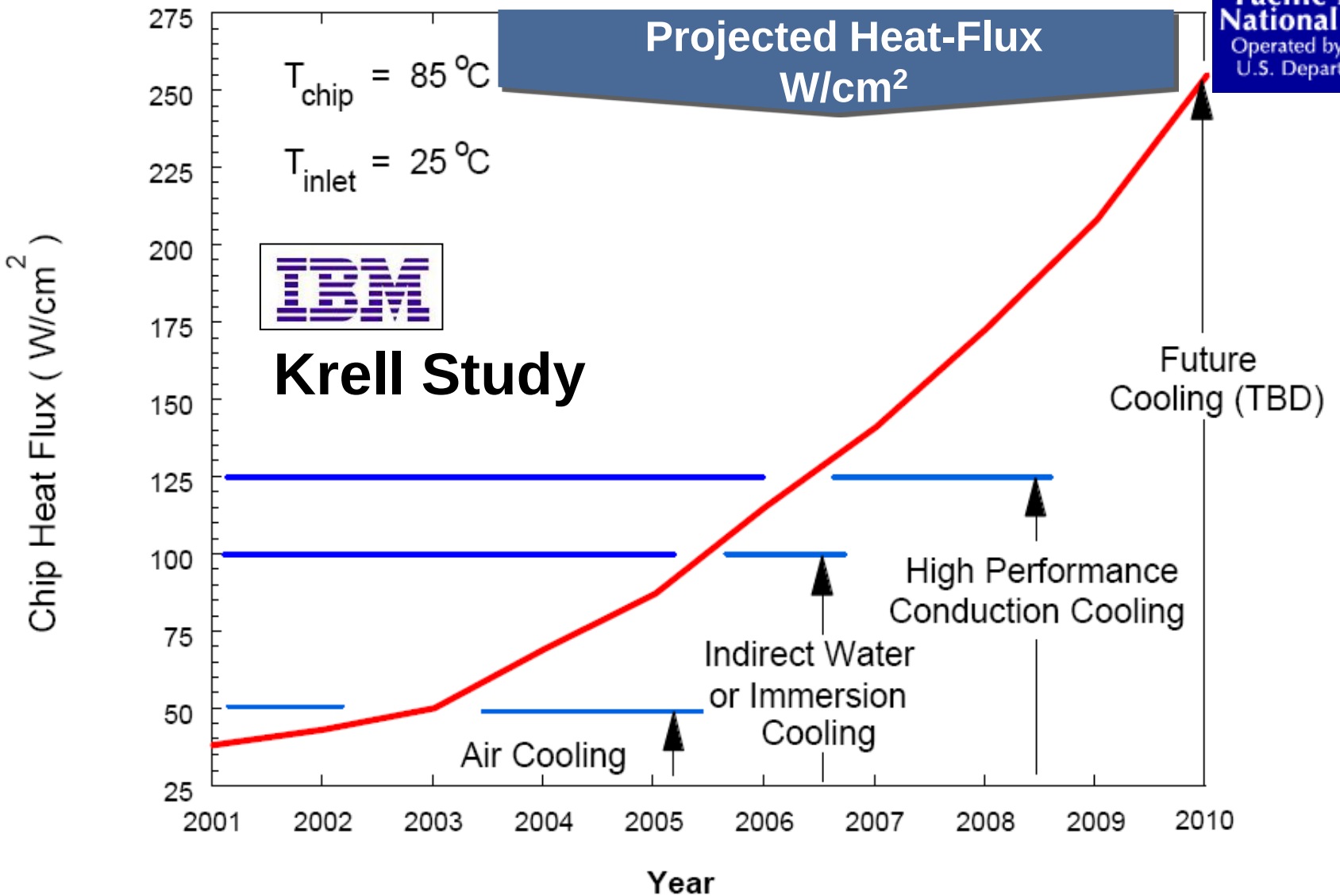
An Inefficient Truth- ICT Is Major Contributor to CO_2 Emissions*

- **The ICT Industry Carbon Footprint is Equivalent to that of the Aviation Industry—But Doubling Every Two Years!**
- **Energy Usage of a Single Compute Rack is Measured in House-Equivalents**
- **ICT Emissions Growth is Fastest of any Sector in Society, Especially at Universities as Data-Intensive Research Spreads Across Disciplines**
- **Data Centers are a Unique Challenge**
  - **2008 50% have Insufficient Power and Cooling**
  - **2009 Energy Costs Second Highest Data Center Cost**

Sources *An Inefficient Truth: http://www.globalactionplan.org.uk/event_detail.aspx?eid=2696e0e0-28fe-4121-bd36-3670c02eda49 and http://www.nanog.org/mtg-0802/levy.html

Data Centers Cooling Requirements Are Rapidly Increasing

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy



Source: PNNL Smart Data Center-Andrés Márquez, Steve Elbert, Tom Seim, Dan Sisk, Darrel Hatley, Landon Sego, Kevin Fox, Moe Khaleel (http://esdc.pnl.gov/)

OptIPuter

it²

ICT Industry is Already Acting to Reduce Carbon Footprint

Sun's 'portable' Blackbox data center

Company unveils new one-box data center

Sun Microsystems' CEO Jonathan Schwartz showed off the company's new "Project Blackbox" in a Menlo Park, Calif., parking lot Tuesday. Sun says the gear is not only preassembled, but it's tough and arrives ready to run.

HP's Green Business Technology Initiative



Innovative Dynamic Smart Cooling

Cut cooling costs in the data center as much as 40%.

» Learn more

Buying Green

updated 10:47 a.m. EST, Wed November 28, 2007

Google pushes 'green' power initiative

Intel Becomes Largest Purchaser of Green Power in the U.S.

Company Tops EPA Green Power Partner List, Vows to Drive for Greater Efficiency While Spurring Growth in Renewable Market

How Microsoft is going green

Biodiesel trucks, solar-powered data centers are just a couple environmentally friendly track

By John Fontana , Network World , 01/09/2008

IBM Project Big Green

Big Green Banner

Project Big Green is a $1 billion investment to dramatically increase the efficiency of IBM products. New IBM products and services,

California's Universities are Engines for Green Innovation—Partnering with Industry

UCSD Structural Engineering Dept. Conducted Tests May 2007

Sun microsystems

UCSD Jacobs School of Engineering



7 Racks plus Network



Takes up 2 Parking Spaces



Data Power Cooling

- **Measure and Control Energy Usage:**
  - **Sun Has Shown up to 40% Reduction in Energy**
  - **Active Management of Disks, CPUs, etc.**
  - **Measures Temperature at 5 Spots in 8 Racks**
  - **Power Utilization in Each of the 8 Racks**
  - **Chilled Water Cooling Systems**



$2M NSF-Funded GreenLight Project

OptIPuter

UCSD (Calit2 & SOM) Bought Two Sun Boxes May 2008

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Calit2 GreenLight Project
Enables Green IT Computer Science Research

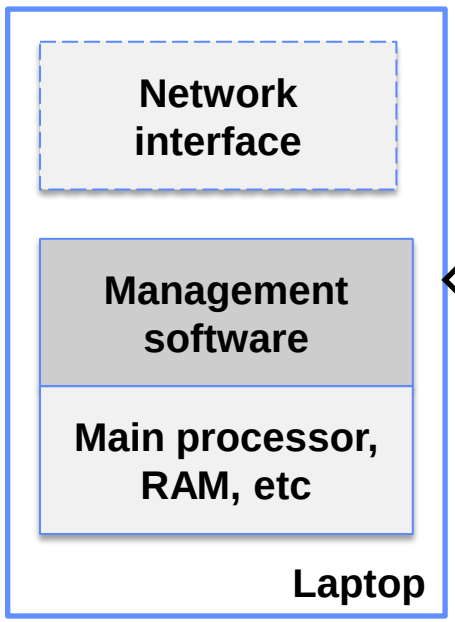


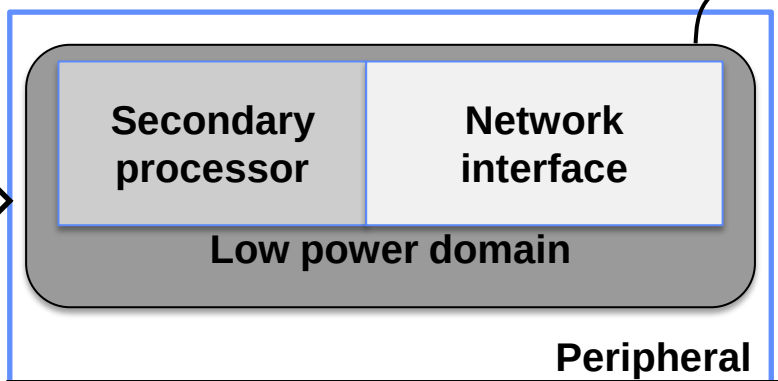
- **Computer Architecture**
  - Rajesh Gupta/CSE
- **Software Architecture**
  - Amin Vahdat & Ingolf Kruger/ CSE
- **CineGrid Exchange**
  - Tom DeFanti/Calit2
- **Visualization**
  - Falko Kuster/Structural Engineering
- **Power and Thermal Management**
  - Tajana Rosing/CSE
- **Analyzing Power Consumption Data**
  - Jim Hollan/Cog Sci

http://greenlight.calit2.net

GreenLight Project: Putting Machines To Sleep Transparently

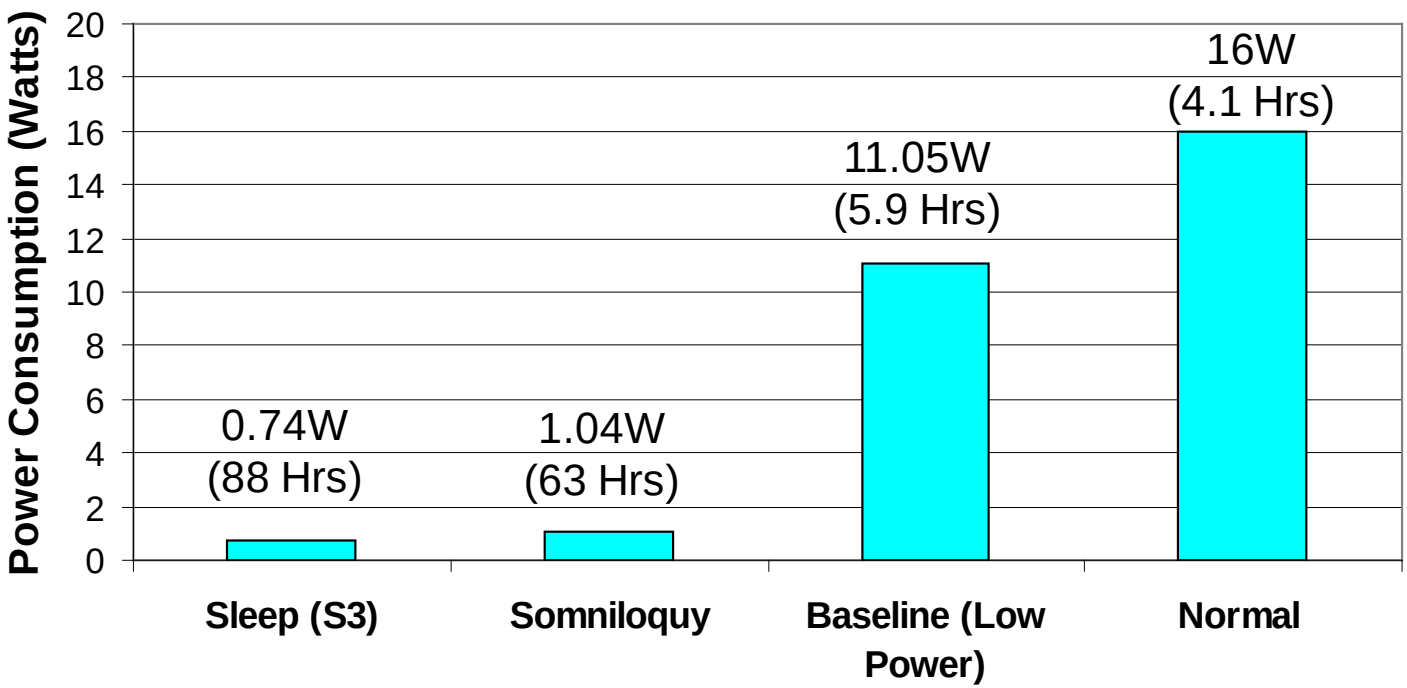
Rajesh Gupta, UCSD CSE; Calit2







Somniloquy Enables Servers to Enter and Exit Sleep While Maintaining Their Network and Application Level Presence



OptIPuter

Improve Mass Spectrometry's Green Efficiency By Matching Algorithms to Specialized Processors

- **Inspect Implements the Very Computationally Intense MS-Alignment Algorithm for Discovery of Unanticipated Rare or Uncharacterized Post-Translational Modifications**
- **Solution: Hardware Acceleration with a FPGA-Based Co-Processor**
  - **Identification and Characterization of Key Kernel for MS-Alignment Algorithm**
  - **Hardware Implementation of Kernel on Novel FPGA-based Co-Processor (Convey Architecture)**
- **Results:**
  - **300x Speedup & Increased Computational Efficiency**

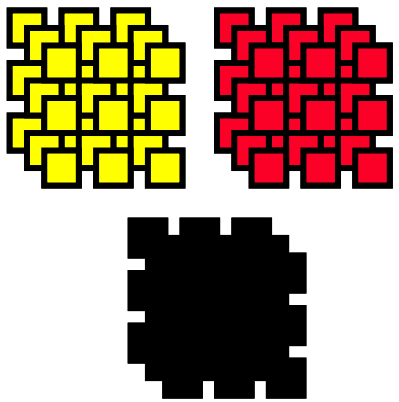
Large Savings in Energy Per Application Task

OptIPuter

it²

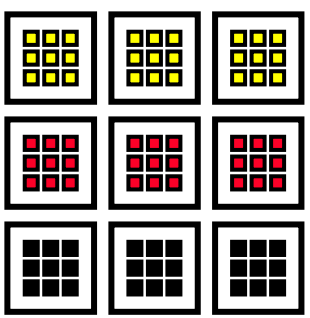
Virtualization at Cluster Level for Consolidation and Energy Efficiency

Source: Amin Vadhat, CSE, UCSD



Original Service

Usher



Virtualized Service

- Fault Isolation and Software Heterogeneity, Need to Provision for Peak Leads to:
  - Severe Under-Utilization
  - Inflexible Configuration
  - High Energy Utilization
- Usher / DieCast enable:
  - Consolidation onto Smaller Footprint of Physical Machines
  - Factor of 10+ Reduction in Machine Resources and Energy Consumption

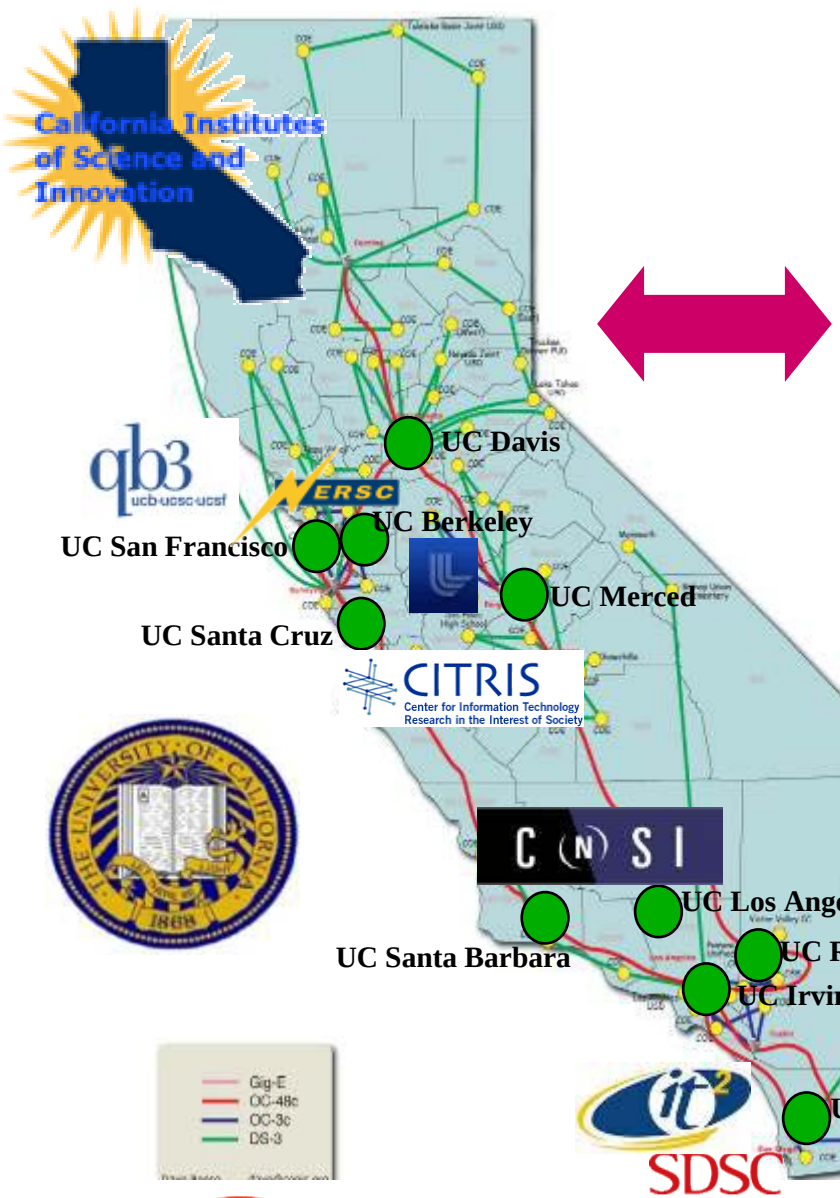
OptIPuter UCSDCSE Computer Science and Engineering

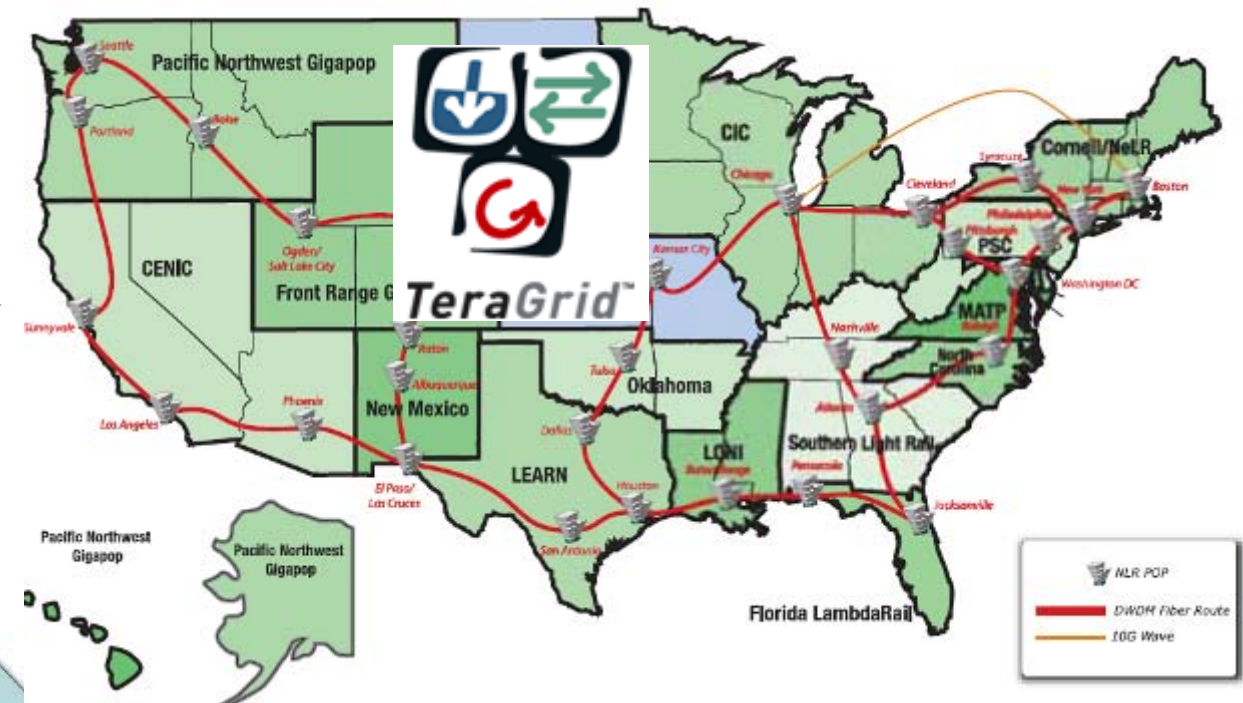
cns center for networked systems it²

Green ICT MOU Between
UCSD, Univ. British Columbia, and PROMPT



Creating a California Cyberinfrastructure of OptIPuter "On-Ramps" to NLR & TeraGrid Resources



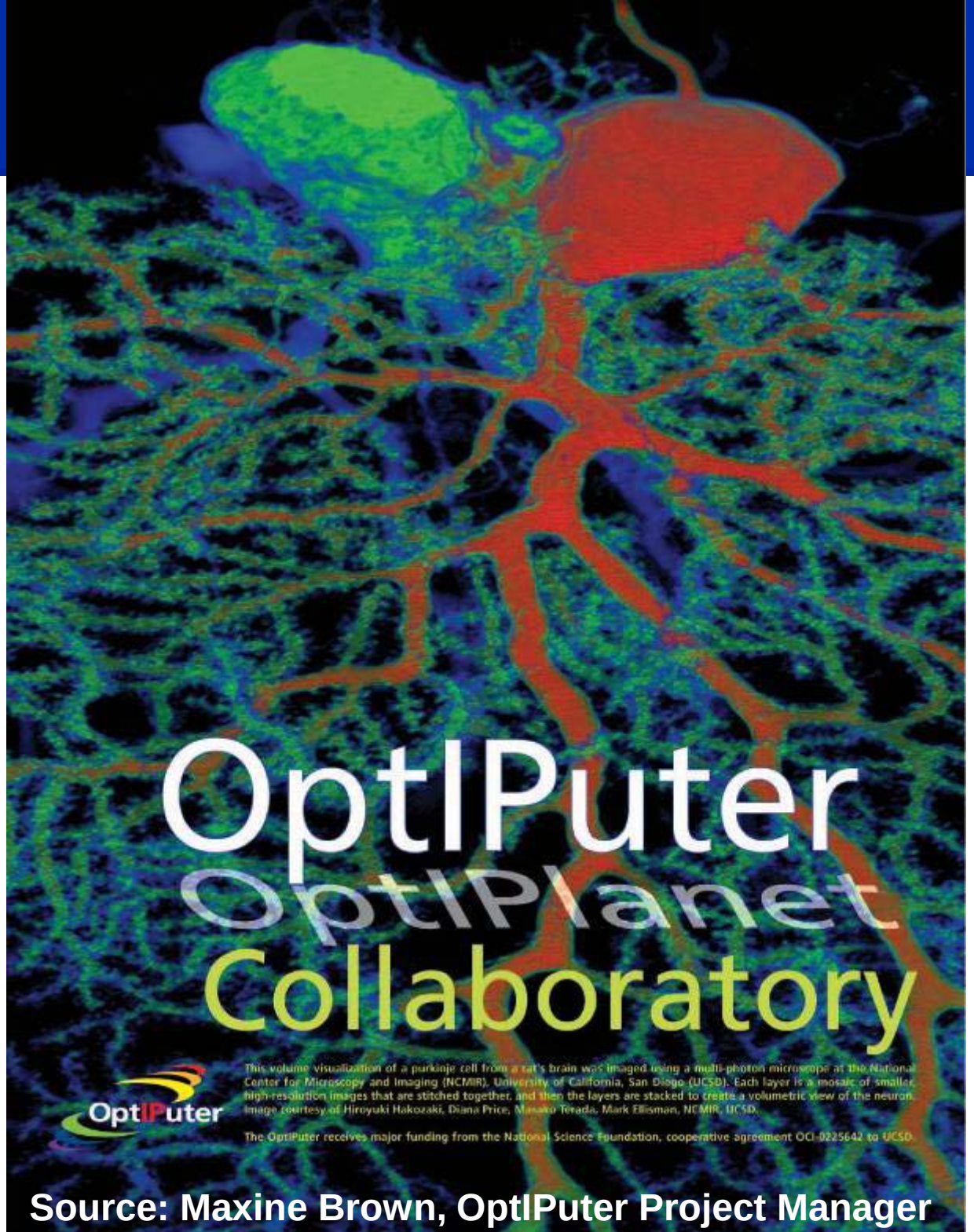


Creating a Critical Mass of OptIPuter End Users on a Secure LambdaGrid

CENIC Workshop at Calit2 Sept 15-16, 2008

OptIPuter

it2



Source: Maxine Brown, OptIPuter Project Manager

Green Initiative:

Can Optical Fiber Replace Airline Travel for Continuing Collaborations ?

Launch of the 100 Megapixel OzIPortal Over Qvidium Compressed HD on 1 Gbps CENIC/PW/AARNet Fiber

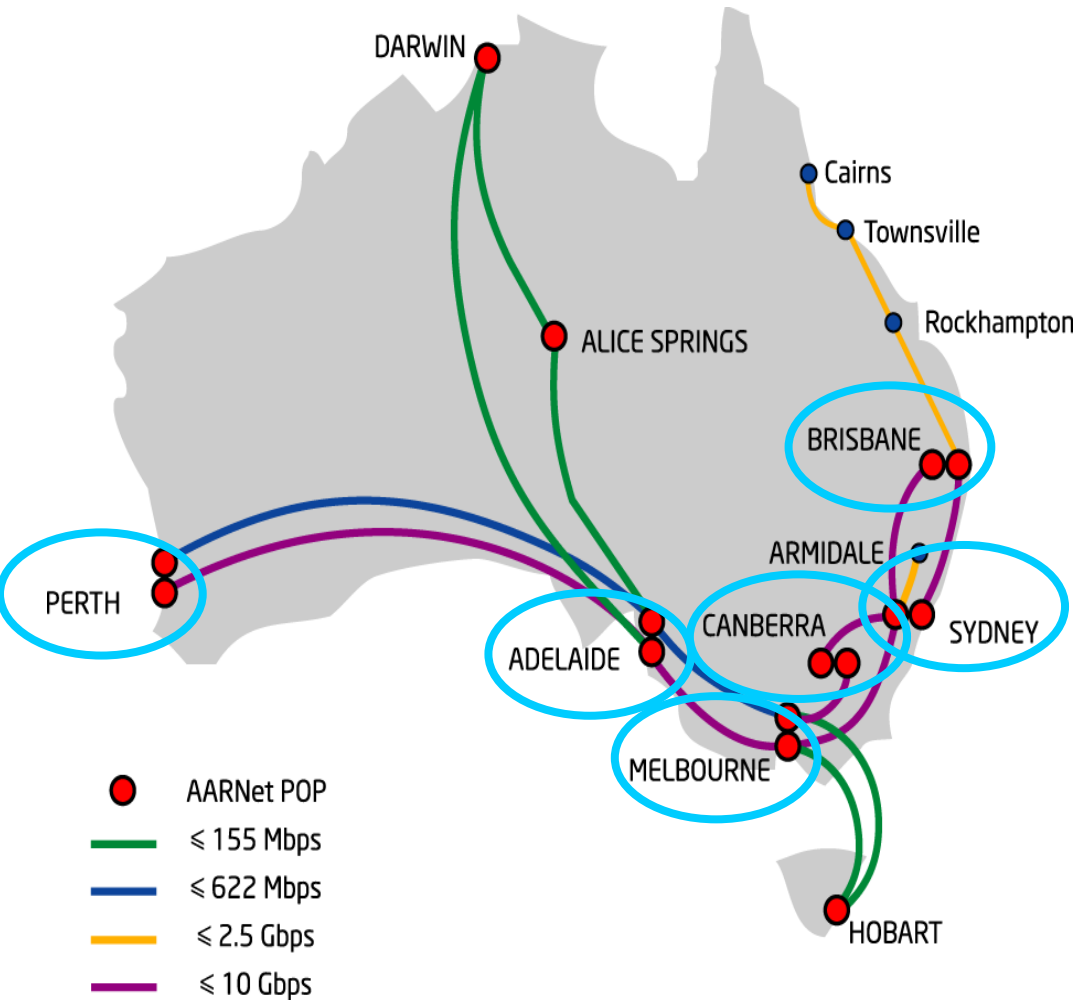


No Calit2 Person Physically Flew to Australia to Bring This Up!

Covise, Phil Weber, Jurgen Schulze, Calit2
CGLX, Kai-Uwe Doerr , Calit2
www.calit2.net/newsroom/release.php?id=1219

Smarr American Australian Leadership Dialogue OptIPlanet Collaboratory Lecture Tour October 2008

AARNet National Network



- Oct 2—University of Adelaide
- Oct 6—Univ of Western Australia
- Oct 8—Monash Univ.; Swinburne Univ.
- Oct 9—Univ. of Melbourne
- Oct 10—Univ. of Queensland
- Oct 13—Univ. of Technology Sydney
- Oct 14—Univ. of New South Wales
- Oct 15—ANU; AARNet; Leadership Dialogue Scholar Oration, Canberra
- Oct 16—CSIRO, Canberra
- Oct 17—Sydney Univ.

OptIPuter

AUSTRALIAN AMERICAN LEADERSHIP DIALOGUE

aarnet Australia's Academic and Research Network

it²

OptIPortals
Are Being Adopted Globally

And Today--
New Zealand's First OptIPortal!



TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

EVL's SAGE OptIPortal VisualCasting Multi-Site OptIPuter Collaboratory

CENIC CalREN-XD Workshop Sept. 15, 2008



At Supercomputing 2008 Austin, Texas November, 2008 SC08 Bandwidth Challenge Entry

On site:	Remote:
SARA (Amsterdam)	U of Michigan
GIST / KISTI (Korea)	UIC/EVL
Osaka Univ. (Japan)	U of Queensland
Masaryk Univ. (CZ), Calit2	Russian Academy of Science

Requires 10 Gbps Lightpath to Each Site

Uncompressed High Definition Video From Each Site

Source: Jason Leigh, Luc Renambot, EVL, UI Chicago