The OptIPuter as a Prototype for CalREN-XD

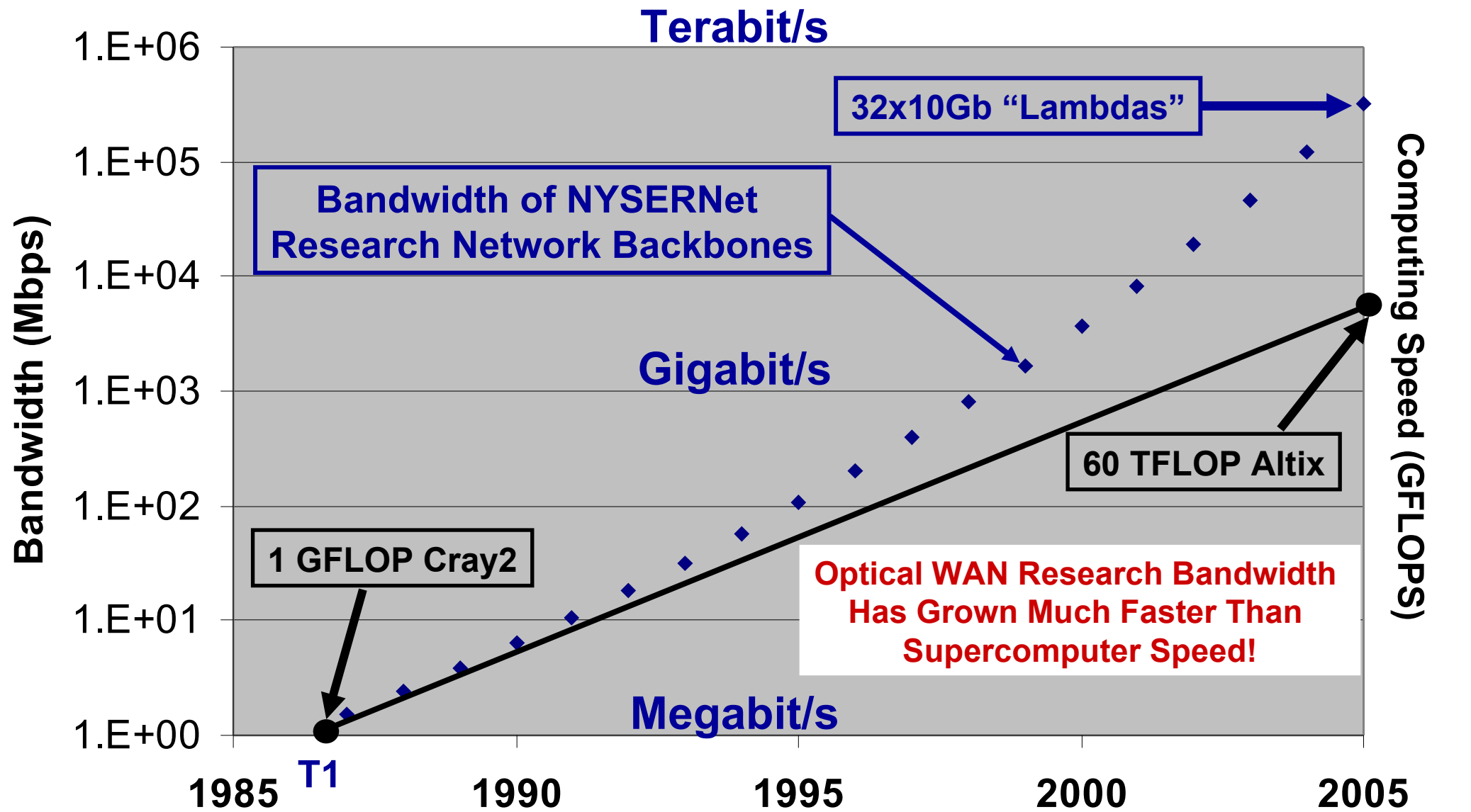
Briefing to the CalREN-XD Subcommittee
CENIC Board
July 29, 2005

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

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



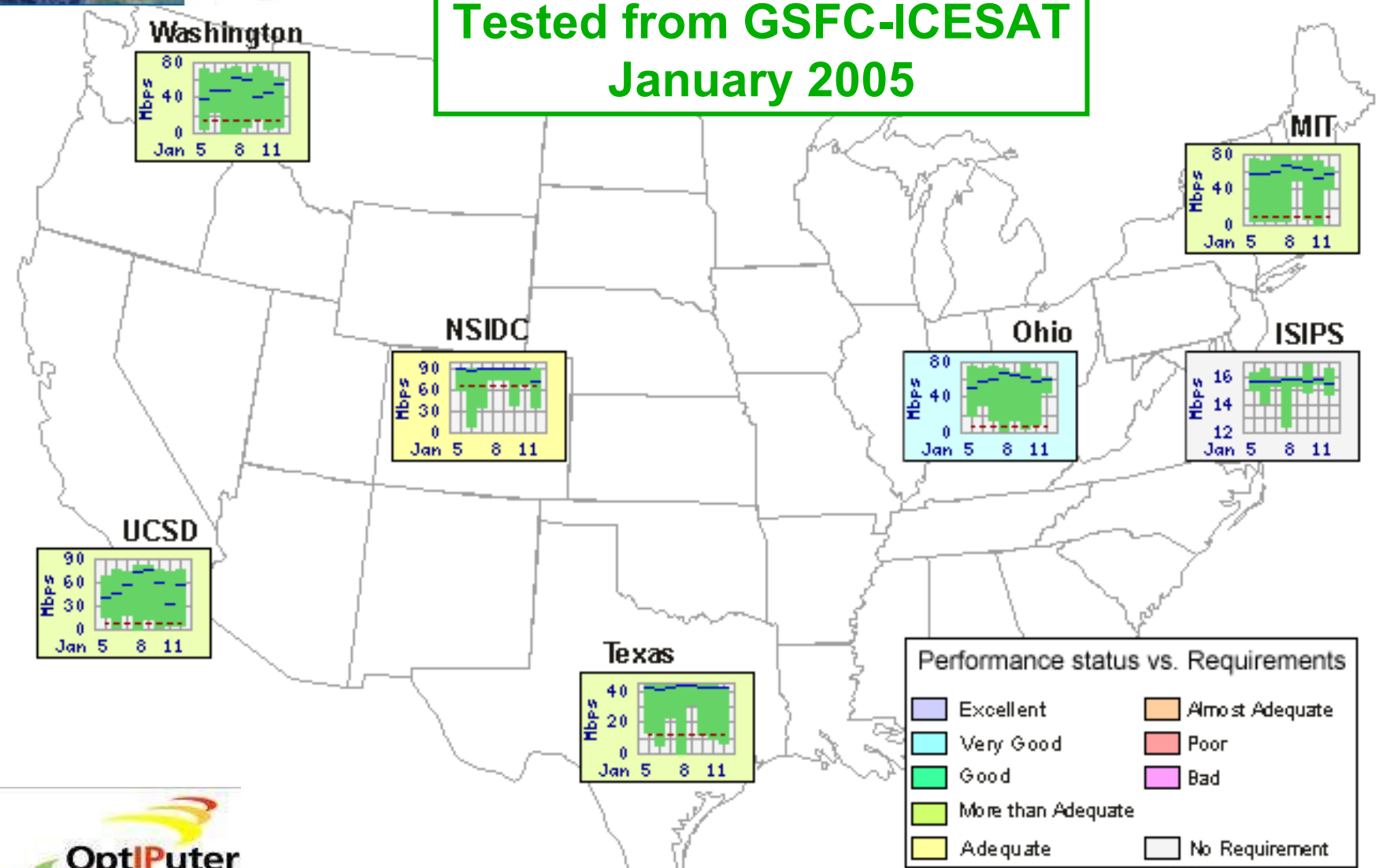
Network Data Source: Timothy Lance, President, NYSERNet

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



ENSIGHT Active Testing ICESat Destinations

Tested from GSFC-ICESAT January 2005

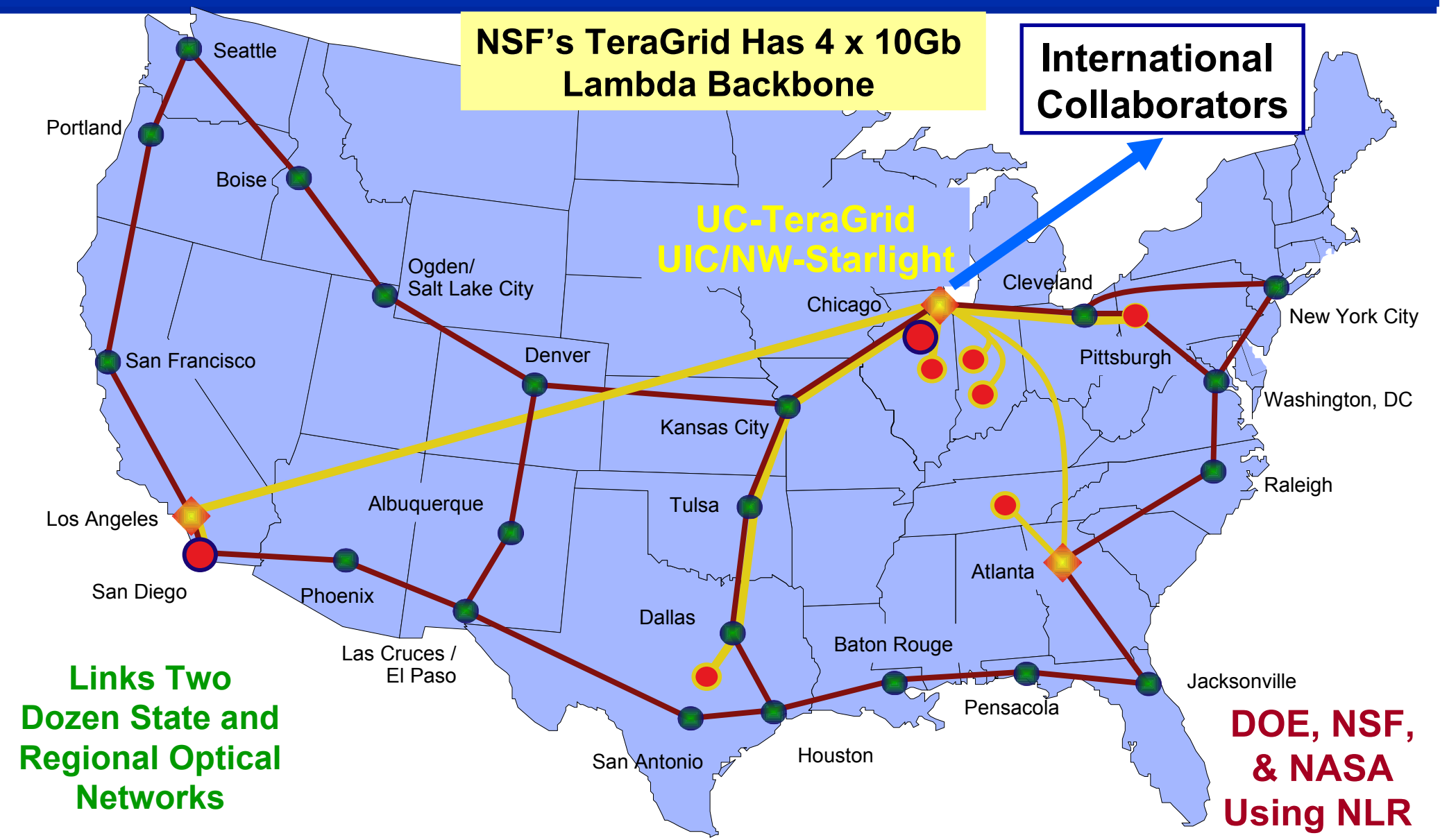


http://ensight.eos.nasa.gov/Missions/icesat/index.shtml

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National Lambda Rail (NLR) and TeraGrid Provides Researchers a Cyberinfrastructure Backbone



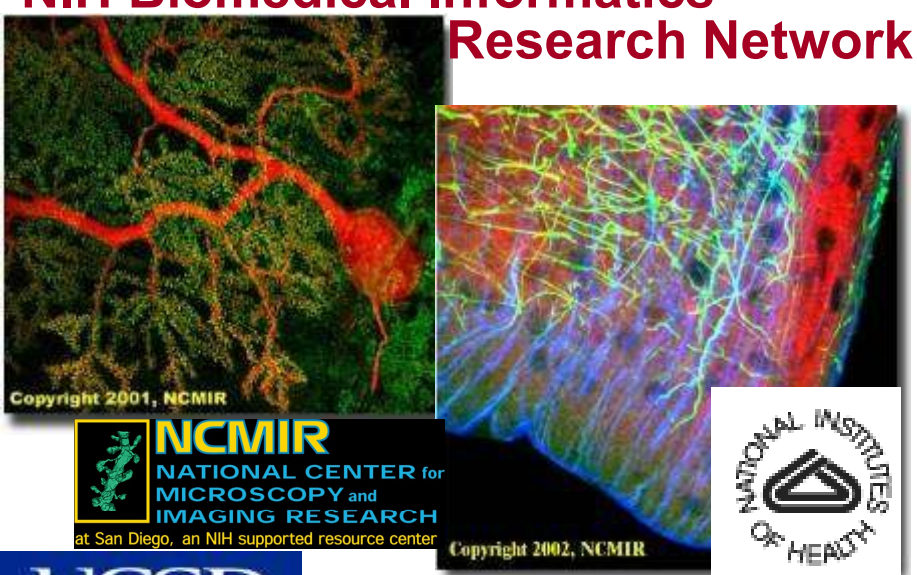
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The OptIPuter Project – A Model of Cyberinfrastructure Partnerships

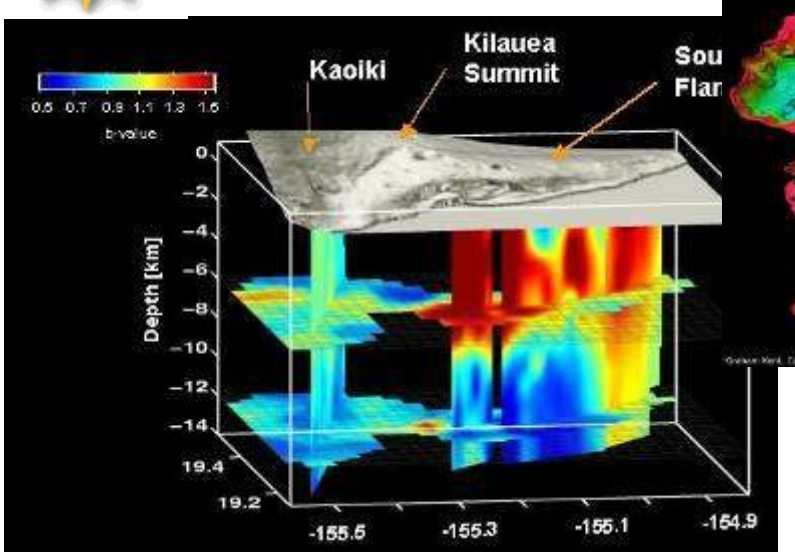
- **NSF Large Information Technology Research Proposal**
  - Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
  - Partnering Campuses: USC, SDSU, NW, TA&M, UvA, SARA, NASA
- **Industrial Partners**
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- **$13.5 Million Over Five Years**
- **Linking User's Linux Clusters to Remote Science Resources**

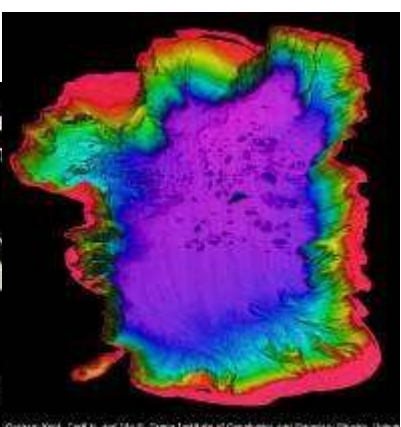
NIH Biomedical Informatics Research Network



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

NSF EarthScope and ORION





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

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What is the OptIPuter?

- **Optical networking, Internet Protocol, Computer Storage, Processing and Visualization Technologies**
  - Dedicated Light-pipe (One or More 1-10 Gbps WAN Lambdas)
  - Links Linux Cluster End Points With 1-10 Gbps per Node
  - Clusters Optimized for Storage, Visualization, and Computing
  - Does NOT Require TCP Transport Layer Protocol
  - Exploring Both Intelligent Routers and Passive Switches

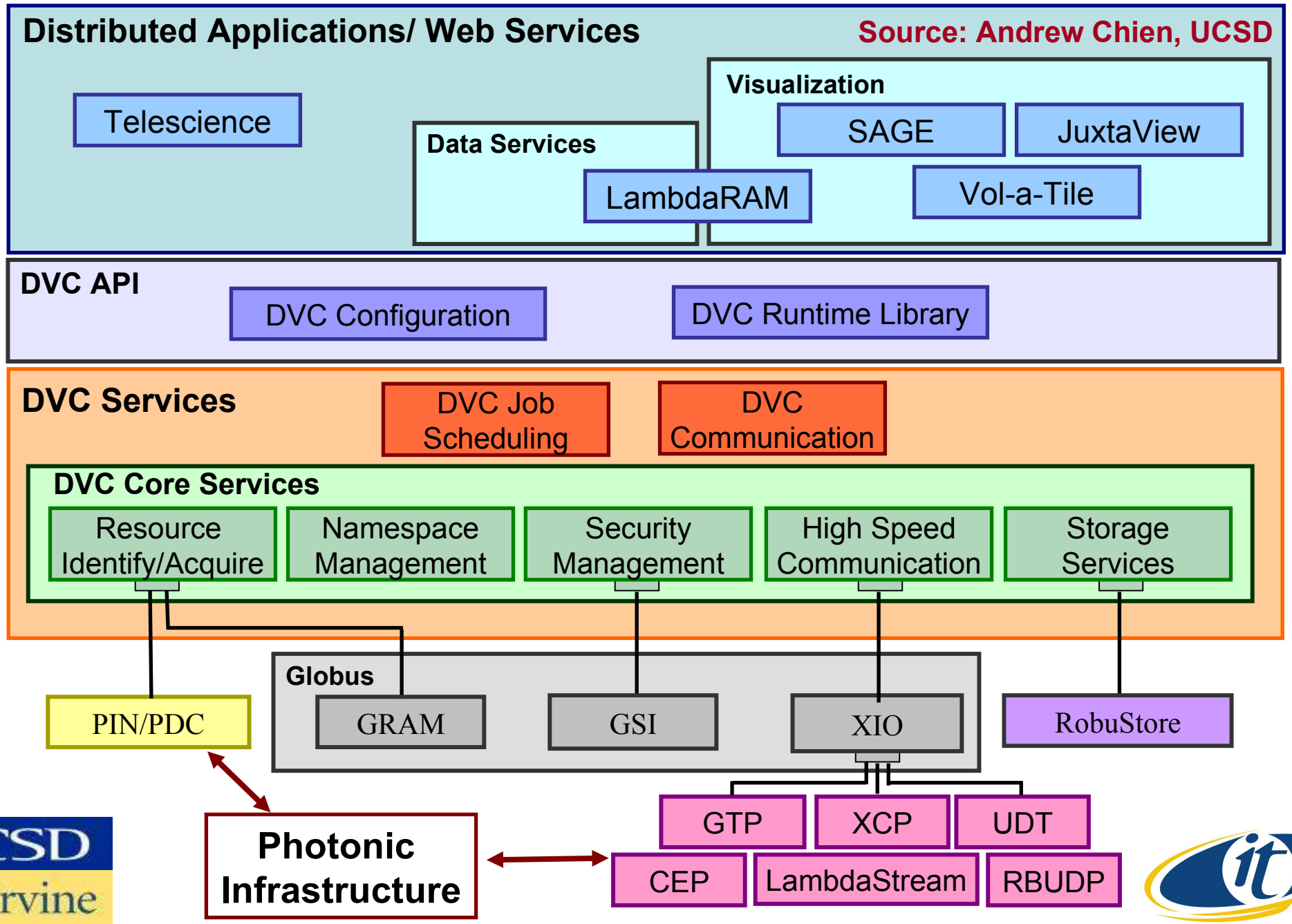
- **Applications Drivers:**
  - Interactive Collaborative Visualization of Large Remote Data Objects
    - Earth and Ocean Sciences
    - Biomedical Imaging

- **The OptIPuter Exploits a New World in Which the Central Architectural Element is Optical Networking, NOT Computers - Creating "SuperNetworks"**

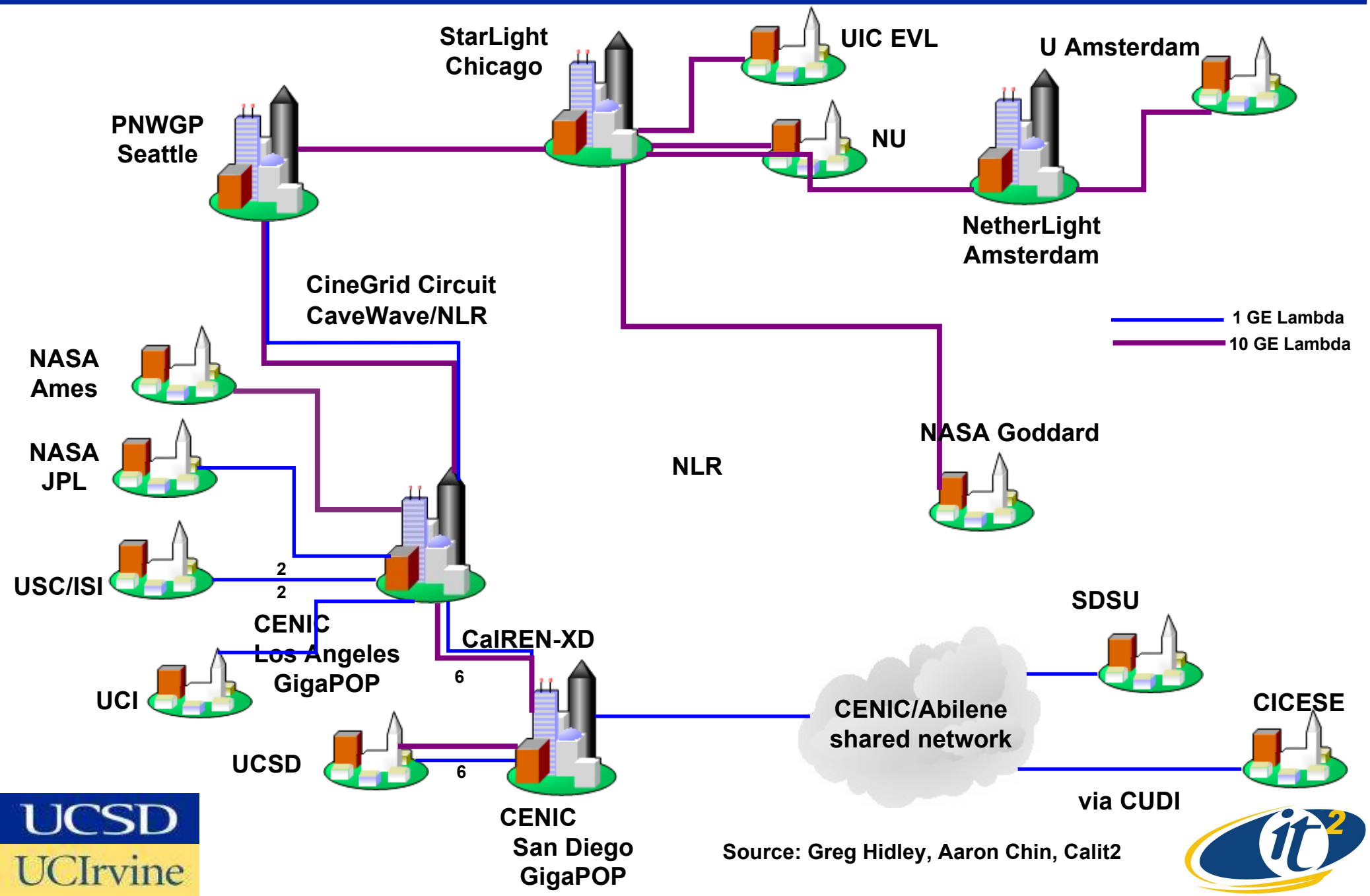
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OptIPuter Middleware Architecture-- The Challenge of Transforming Grids into LambdaGrids



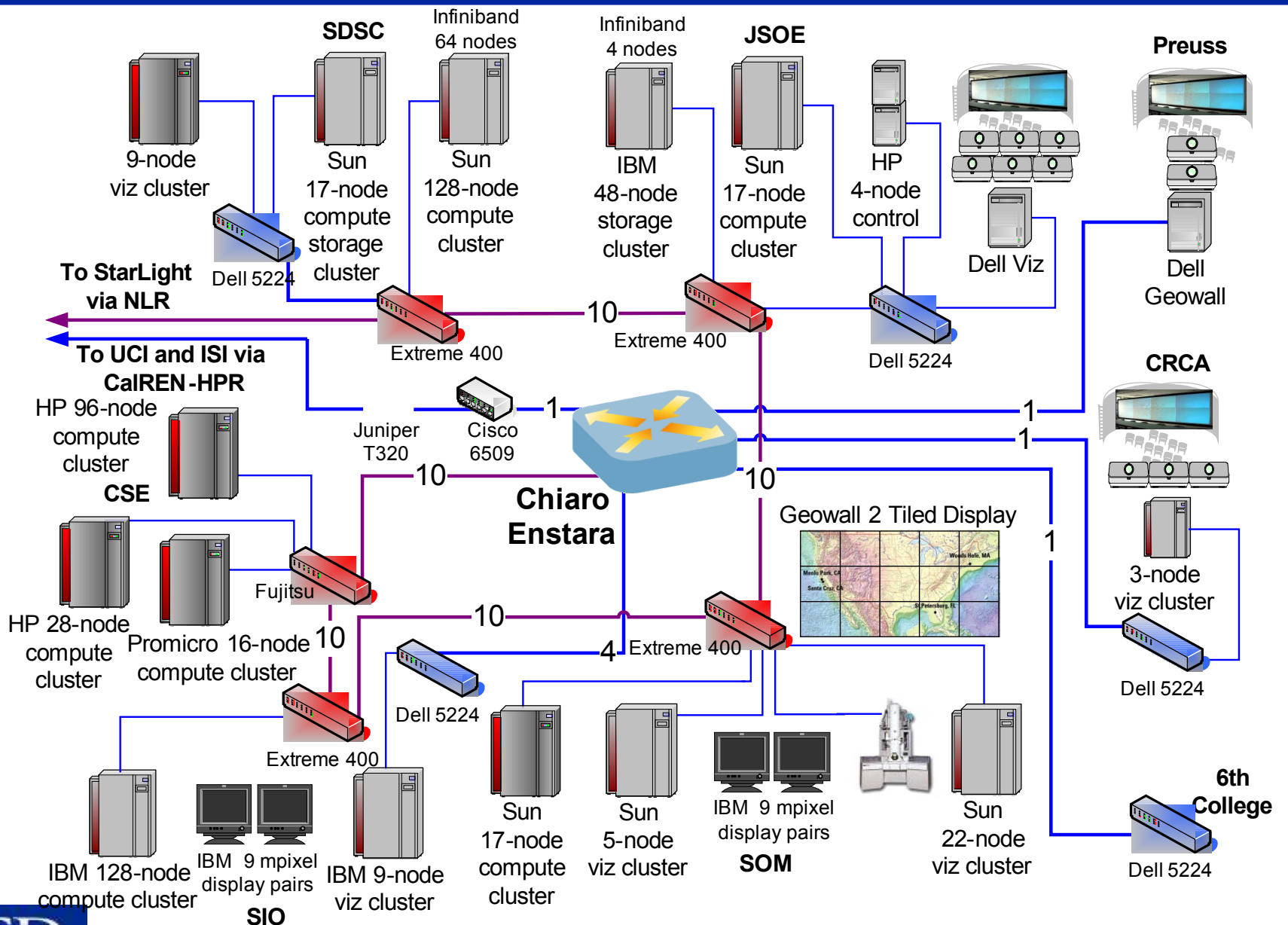
The OptIPuter LambdaGrid is Rapidly Expanding



Source: Greg Hidley, Aaron Chin, Calit2

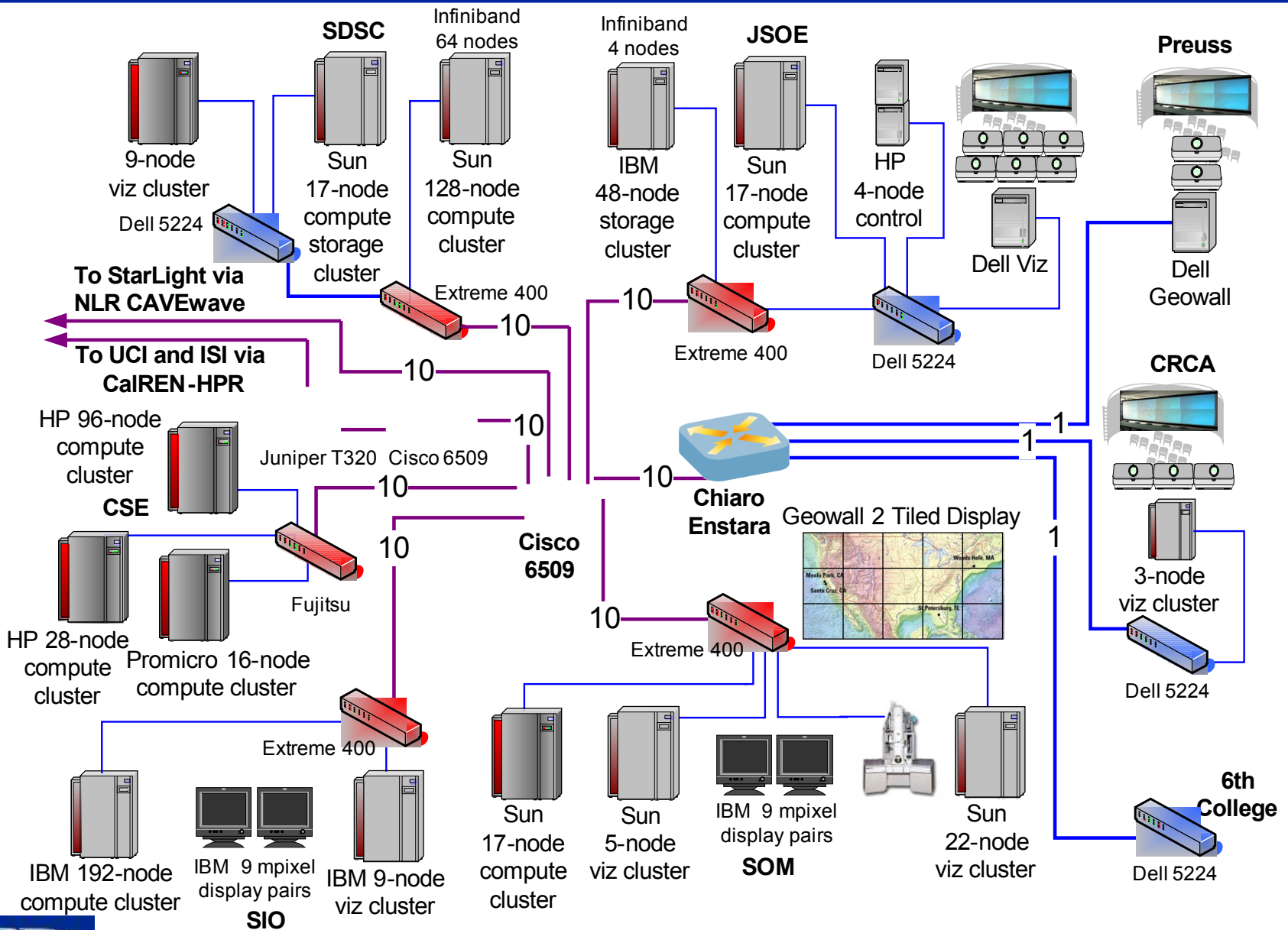
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UCSD Packet Test Bed
OptIPuter Year 2 – Ring Configuration



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UCSD Packet Test Bed
OptIPuter Year 3 – Star Configuration



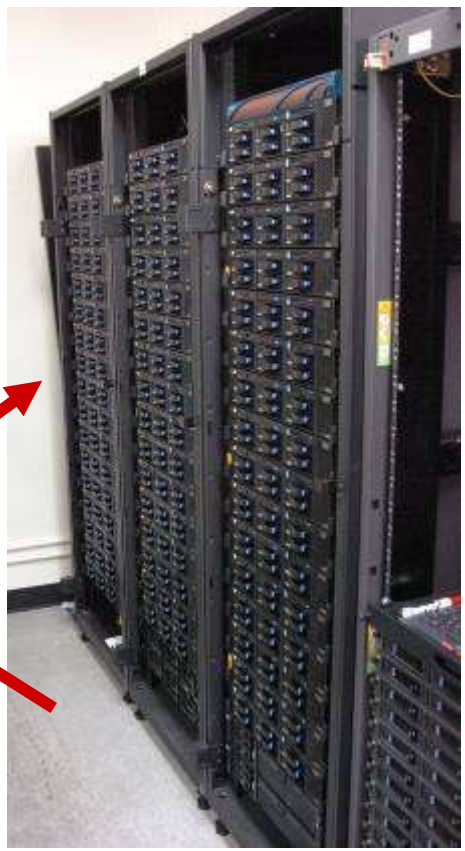
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UCSD Campus LambdaStore Architecture
Dedicated Lambdas to Labs Creates Campus LambdaGrid

SIO Ocean Supercomputer

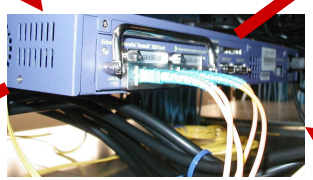


IBM Storage Cluster



Streaming Microscope





Extreme Switch with
2 Ten Gbps Uplinks









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Source: Phil Papadopoulos,
SDSC, Calit2

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The Calit2@UCSD Building is Designed for Extremely High Bandwidth

1.8 Million Feet of Cat6 Ethernet Cabling



Photo: Tim Beach, Calit2

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

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Calit2 Partnering with CENIC and Campuses

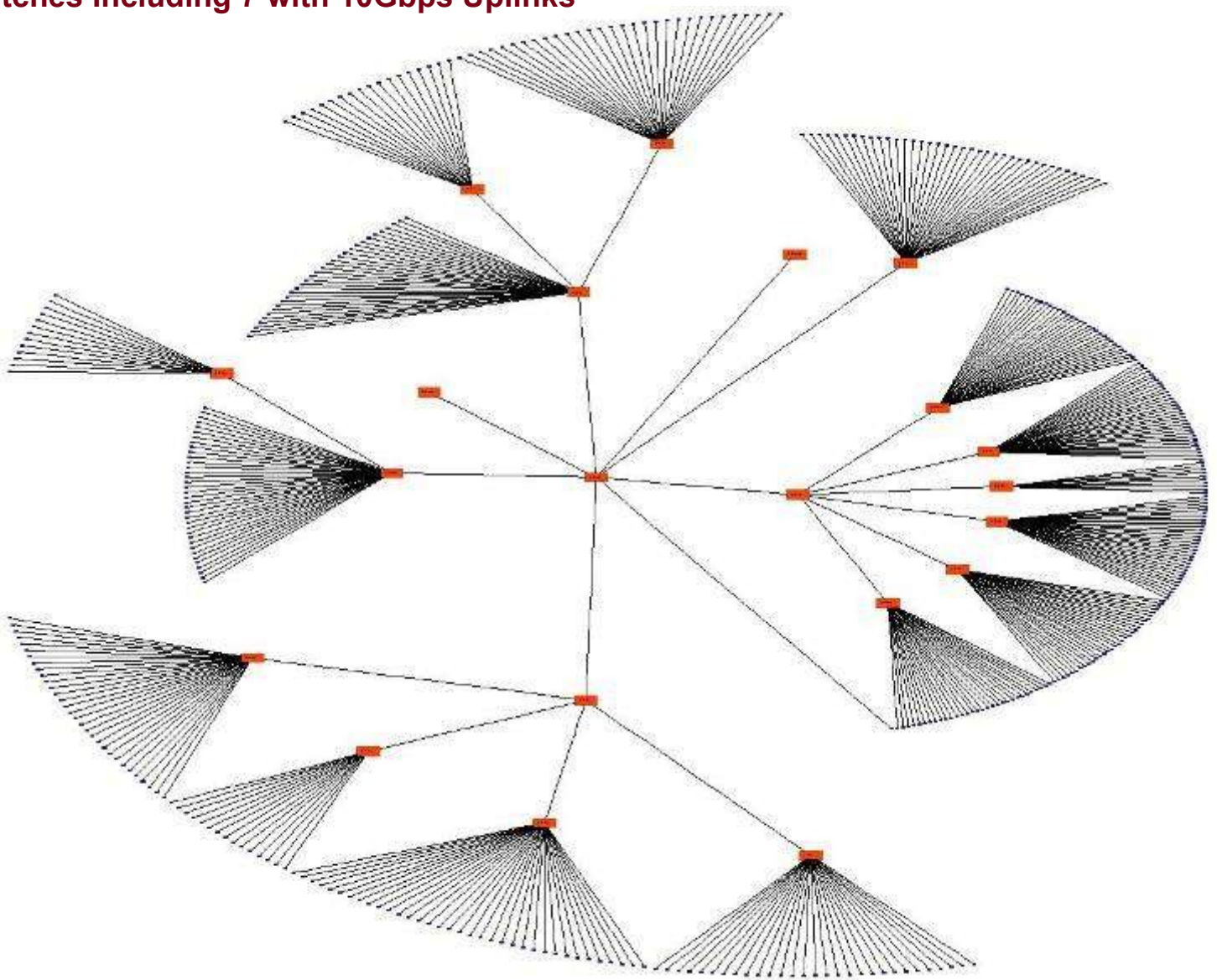
- **OptIPuter**
  - Campus Donated Multiple Single Mode Fiber Pairs Between Major OptIPuter Labs For Research
  - Campus Provided Routable IP Space for OptIPuter, Allowing for Easier Network Expansion
  - Campus Agreed to House and Monitor the Core Networking Gear While the New Calit2 Building is Being Built
- **CalREN-HPR**
  - Campus Provided Connectivity to the CalREN-HPR
  - Calit2 Provided Funding to Upgrade CalREN-HPR Access to 10GE
  - Other UC Campuses are Now Following Suit with UCLA Expected to Upgrade this Summer
- **CalREN-XD**
  - Campus Funded About 50% of the Dedicated 1GE Connections to UC Irvine and the University of Southern California (ISI)
  - It was the First XD Deployment for CENIC
  - Planning Underway for XD to be Extended UC Wide

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UCSD OptIPuter Network Discovery

Picture Below Displays ~500 Hosts (Including ~300 Shared)
80 Gbps Cisco 6509 backbone in the Core
> 20 Switches Including 7 with 10Gbps Uplinks



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Year 3 Plans: Enhance Campus OptIPuter

- A Substantial Portion of the Physical Build Completes in Year 2
  - Endpoints, Cross-campus Fiber, Commodity Endpoints
- Increase Campus Bandwidth
  - Work Towards More Extensive 10GigE Integration
    - Optiputer HW Budget Limited In Year 3, Focus is on Network Extension
  - Connect Two Campus Sites with 32-node Clusters At 10GigE
    - 3:1 Campus Bisection Ratio
- Add/Expand a Moderate Number of new Campus Endpoints
  - Add New Endpoints Into The Chiaro Network
    - UCSD Sixth College
    - JSOE (Engineering) Collaborative Visualization Center
    - New Calit2 Research Facility
  - Add 3 General-purpose Sun Opteron Clusters at Key Campus Sites (Compute and Storage); Clusters Will All Have PCI-X (100 Mhz, 1Gbps)
  - Deploy Infiniband on Our IBM Storage Cluster and on a Previously-Donated Sun 128-node Compute Cluster
- Complete Financial Acquisition of the Chiaro Router

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Year Three Goals
Integrate New NSF Quartzite MRI

- **Goal -- integration of Packet-based (SoCal) and Circuit-based (Illinois) Approaches a Hybrid System**
  - Add Additional O-O-O Switching Capabilities Through a Commercial (Glimmerglass) All-optical Switch and the Lucent (Pre-commercial) Wavelength Selective Switch
  - Begin CWDM or DWDM Deployment to Extend Optical Paths Around UCSD and Provide Additional Bandwidth
  - Add Additional 10GigE in Switches and Cluster Node NICs

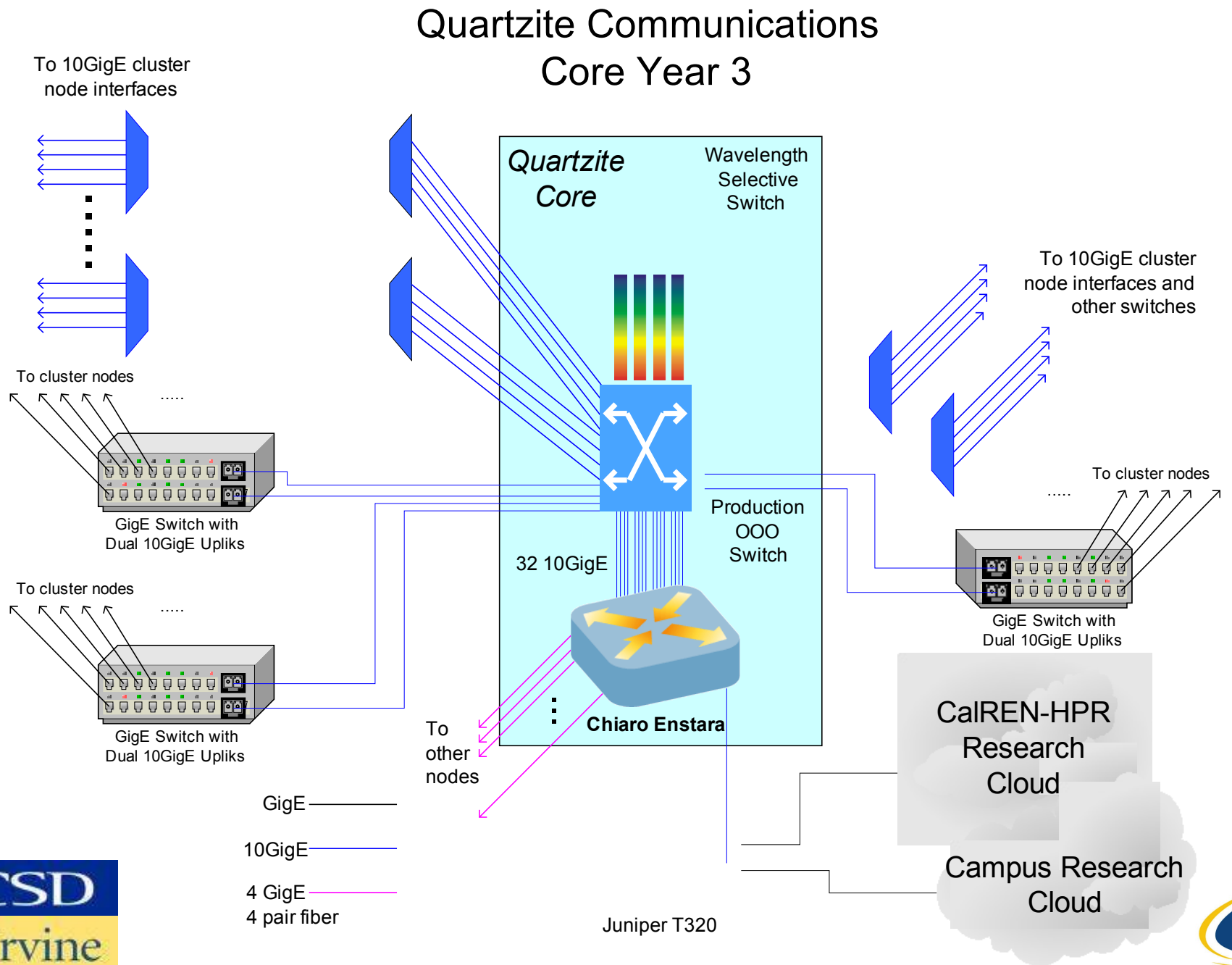
- **MRI Proposal (Quartzite, Recommended for Funding) Allows Us to Match the Network to the Number of Existing Endpoints**

- **This is a New Kind of Distributed Instrument**
  - 300+ Components Distributed Over the Campus
  - Simple and Centralized Control for Other Optiputer Users

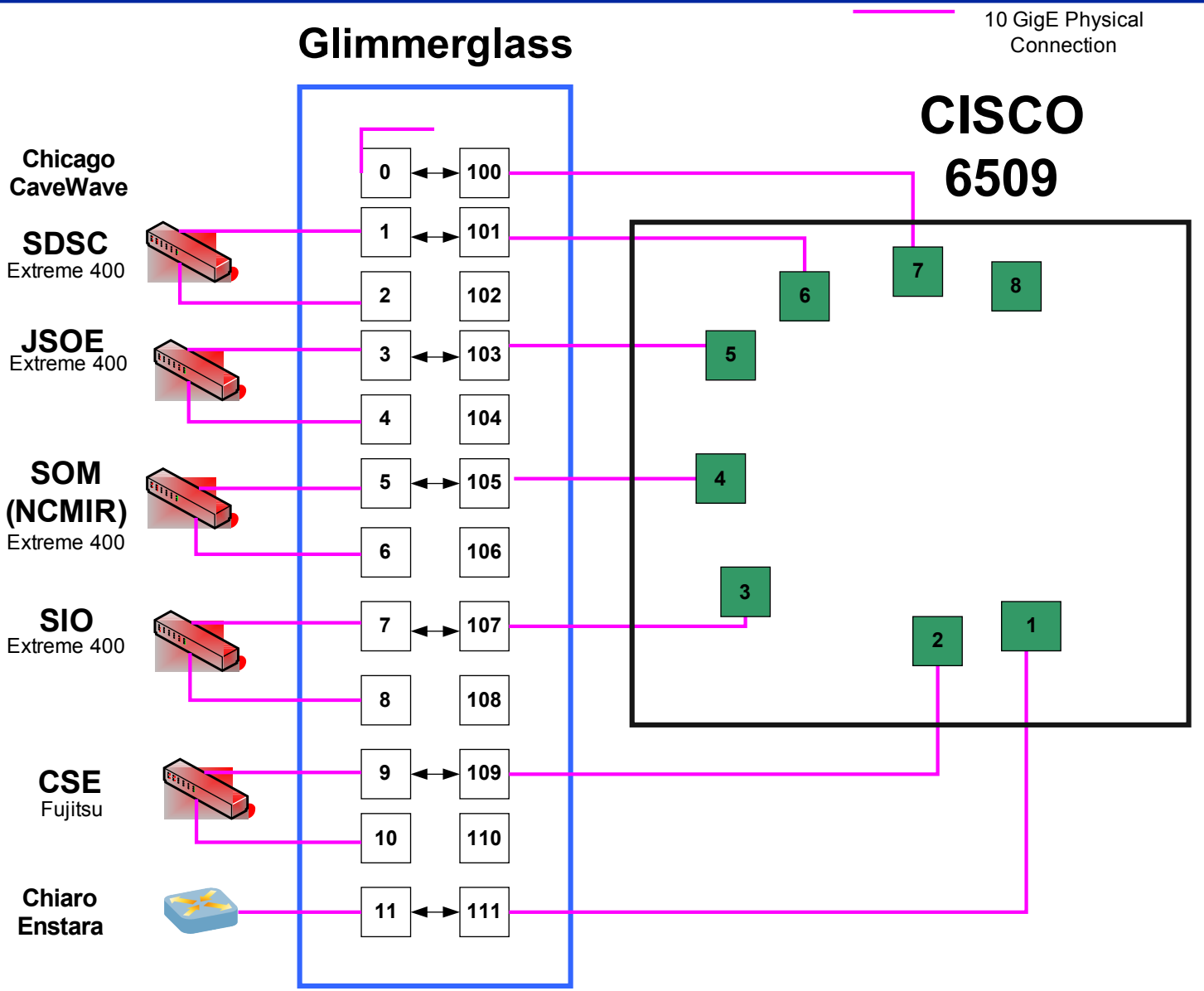
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UCSD Quartzite Core Year 3



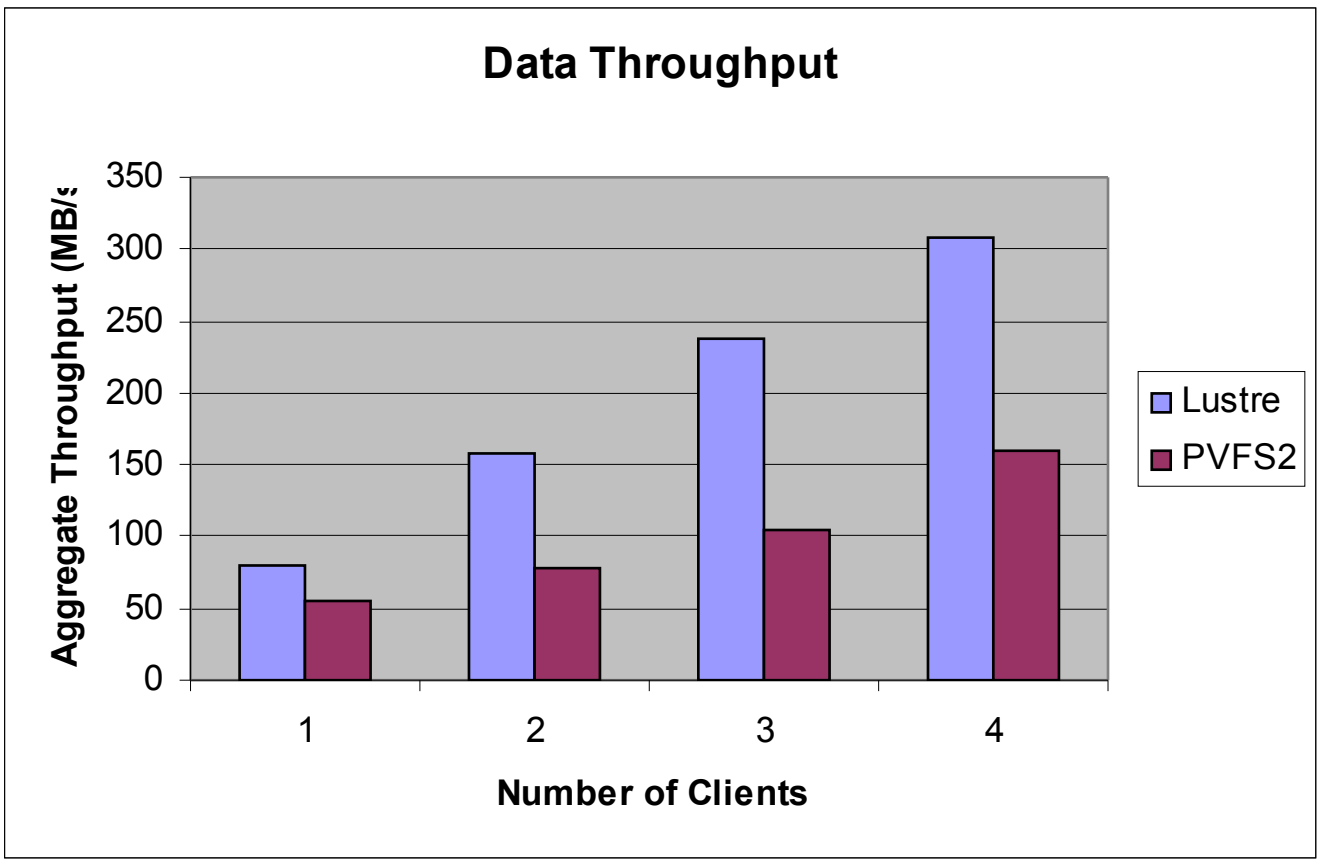
UCSD Glimmerglass



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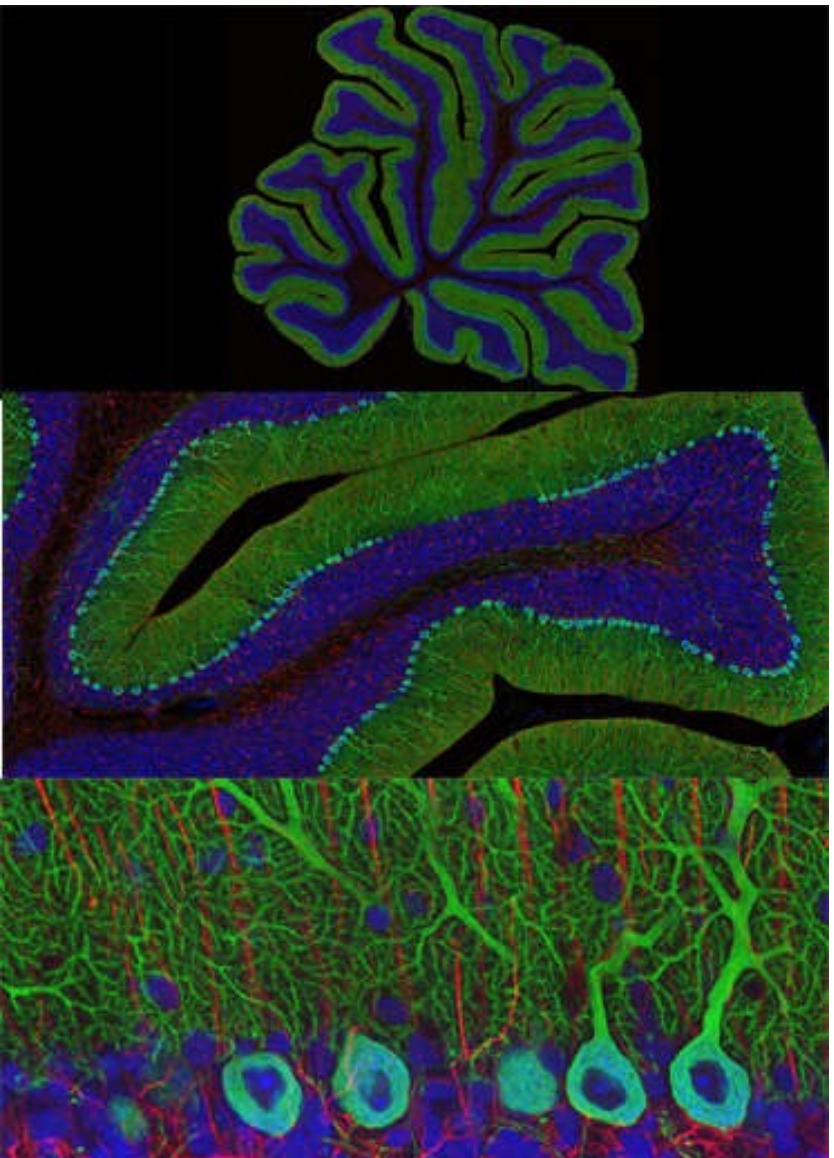
Lustre vs. PVFS2 Comparison

- 9 servers
  - 8 data, 1 meta-data
- Connected via dedicated GigE network
- Iozone tests with multiple clients accessing the same file (size 10/30 GB)
- Default setup for PVFS-2 and Lustre
- Optimal record size selected for PVFS2 comparison



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Brainywall – Predecessor to the Biowall

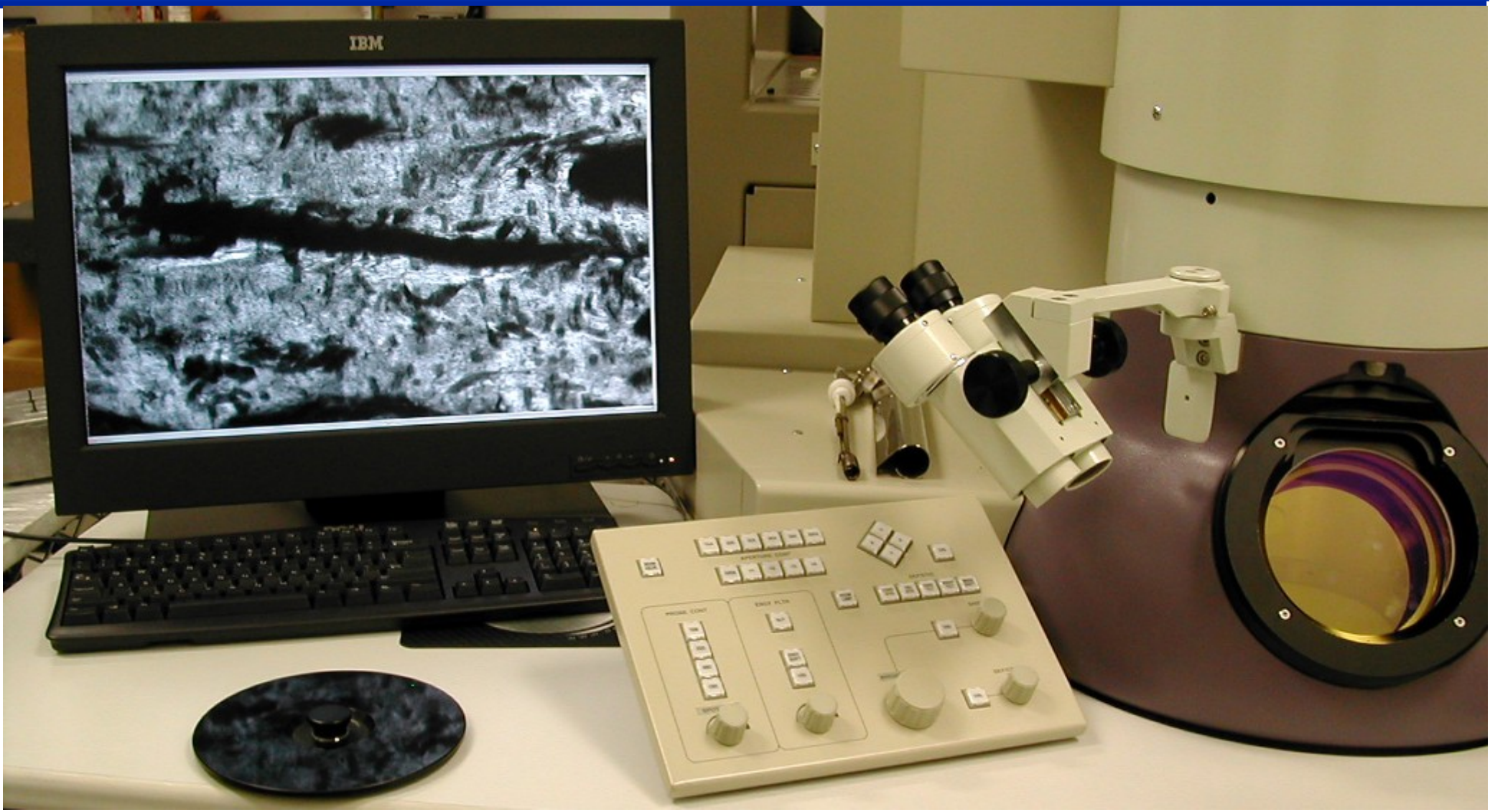


- Powered by a 5 node cluster
  - Four render nodes and one front-end
  - Each node drives one half of one display (1920x2400)
- Each display accepts 1-4 DVI inputs
  - Refresh rate is bound by number of DVI inputs.
    - Full resolution of the display at 60hz, exceeds the maximum bandwidth of the DVI specification.
    - Each additional DVI connection increases the refresh rate (2xDVI=20.1hz)/display
- 18 million pixels (9Mpixels/display)
- Single user station



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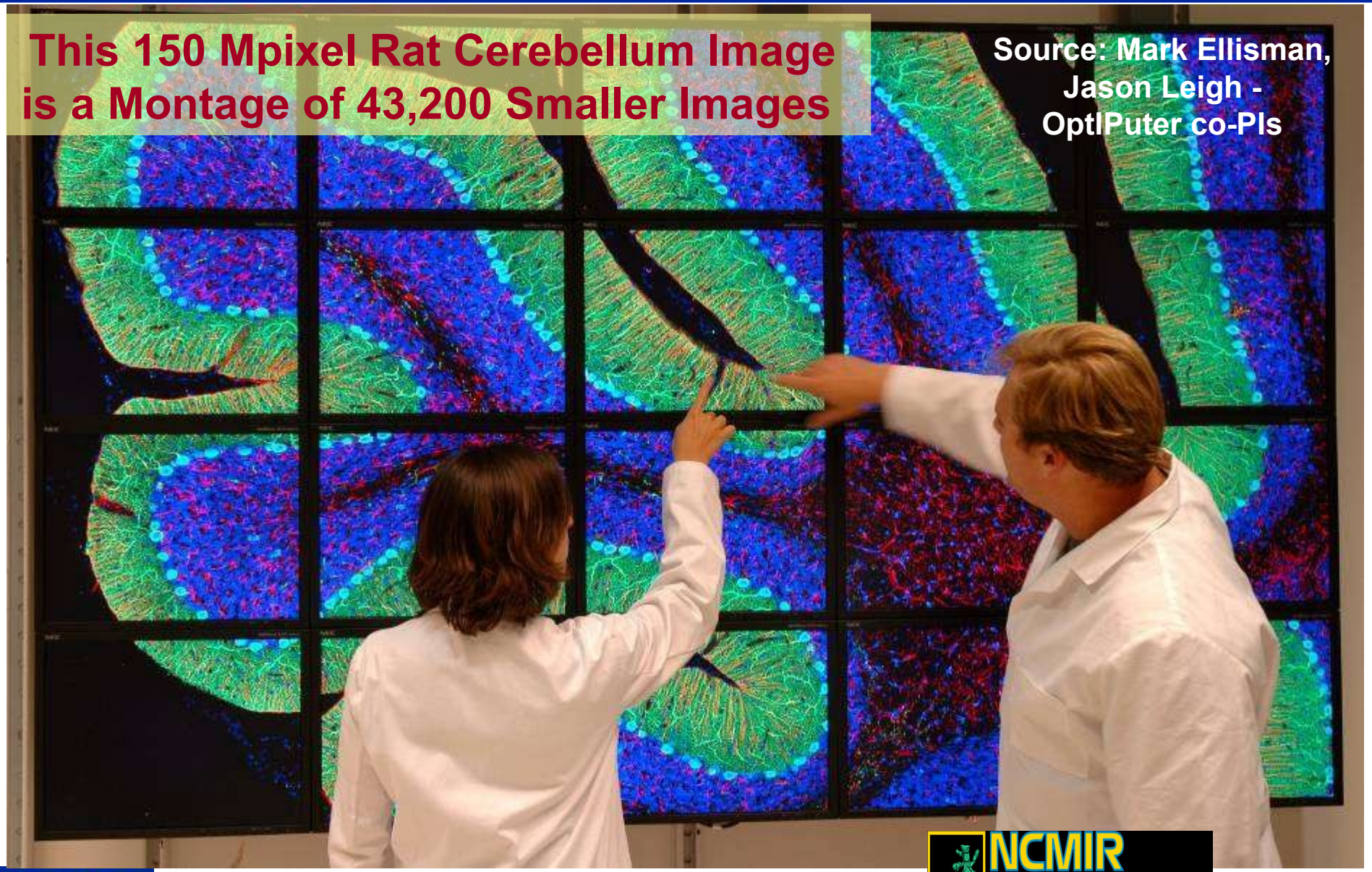
Electron Microscope Datasets: 2D



- High resolution 2D image acquired from the 4k x4k camera
- Displayed on an IBM T221 9 million pixel display, 3840x2400 QUXGAW resolution

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GeoWall2: OptIPuter JuxtaView Software for Viewing High Resolution Images on Tiled Displays



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40 MPixel Display Driven By a 20-Node Sun Opteron Visualization Cluster

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

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Currently Developing OptIPuter Software to Coherently Drive 100 MegaPixel Displays

- 55-Panel Display
  - 100 Megapixel
- Driven by 30 Dual-Opterons (64-bit)
- 60 TB Disk
- 30 10GE interfaces
  - 1/3 Tera bit/sec!
- Linked to OptIPuter
- We are Working with NASA ARC Hyperwall Team to Unify Software



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

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iCluster – ANFwall (Array Network Facility)



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16 MPixel Display (30” Apple Cinema) Driven by a 3-Node Dual G5 Visualization Cluster

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High Resolution Portals to Global Science Data -- 200 Million Pixels of Viewing Real Estate!



it² Center of GRAVITY
Center of Graphics, Visualization and Imaging Technology

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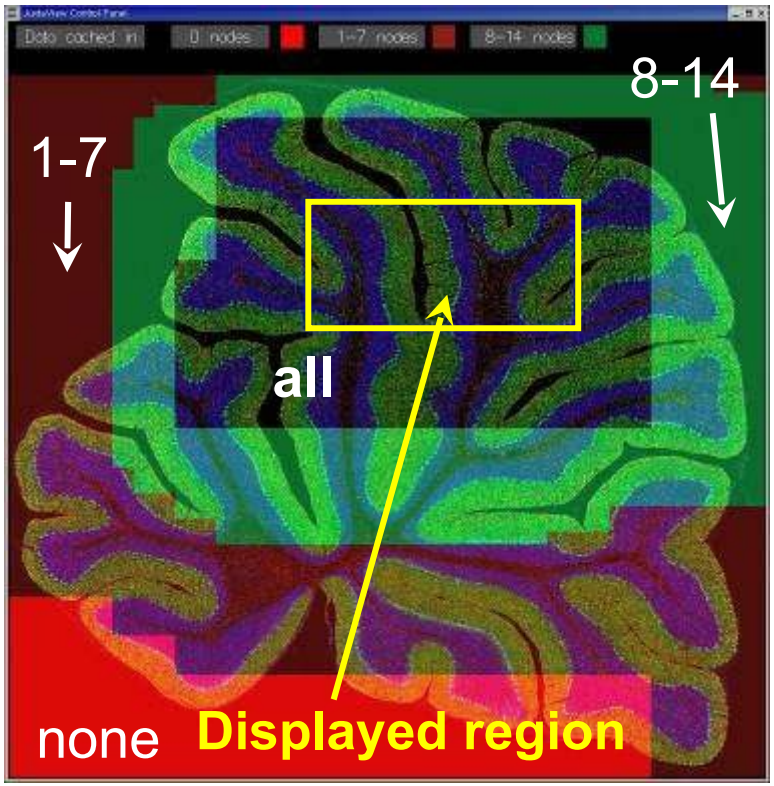
Source: Falko Kuester, Calit2@UCI
NSF Infrastructure Grant

it²

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

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Multiple HD Streams Over Lambdas Will Radically Transform Network Collaboration







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Establishing TelePresence Between AIST (Japan) and KISTI (Korea) and PRAGMA in Calit2@UCSD Building in 2006

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



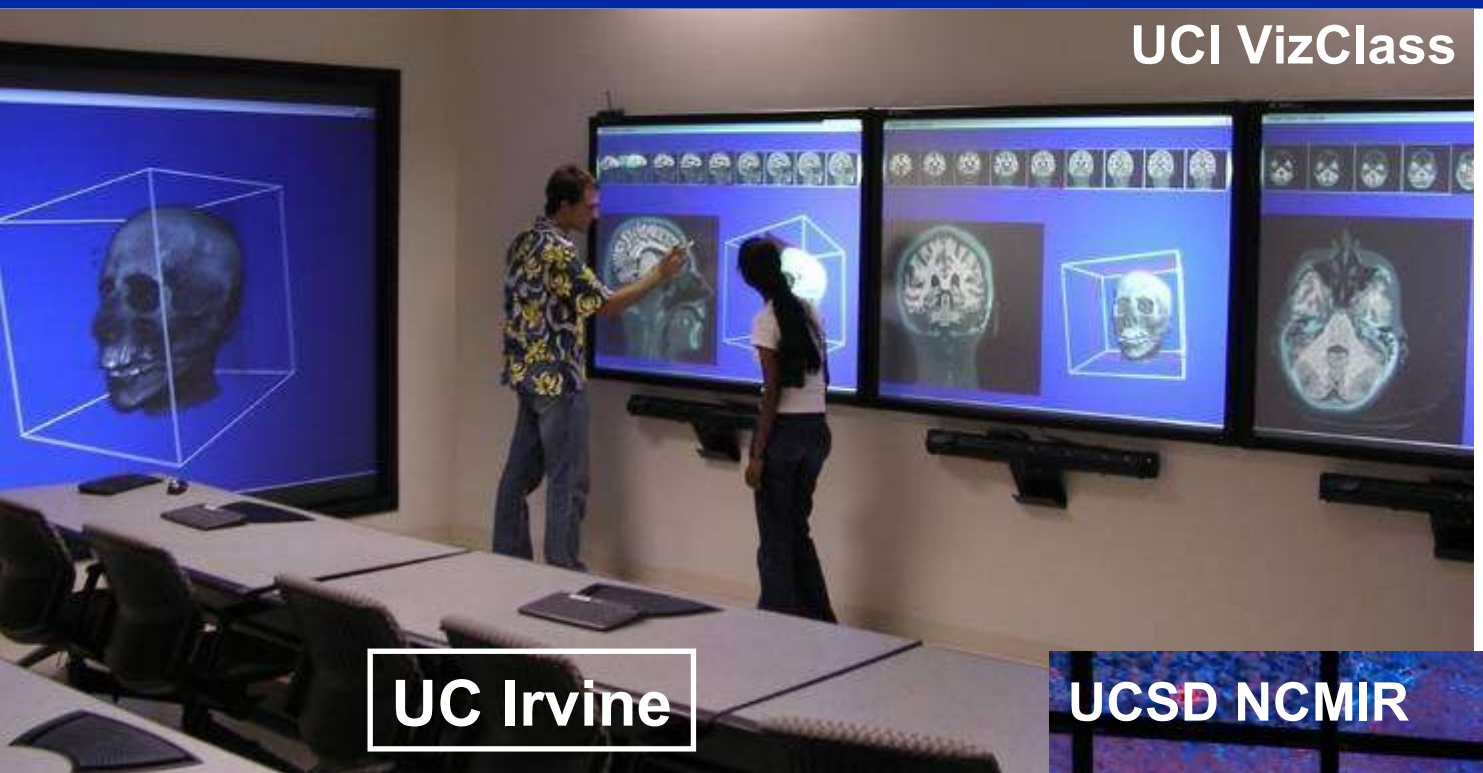
- **Over 1000 Researchers in Two Buildings**
  - Linked via Dedicated Optical Networks
  - International Conferences and Testbeds
- **New Laboratory Facilities**
  - Virtual Reality, Digital Cinema, HDTV
  - Nanotech, BioMEMS, Chips, Radio, Photonics



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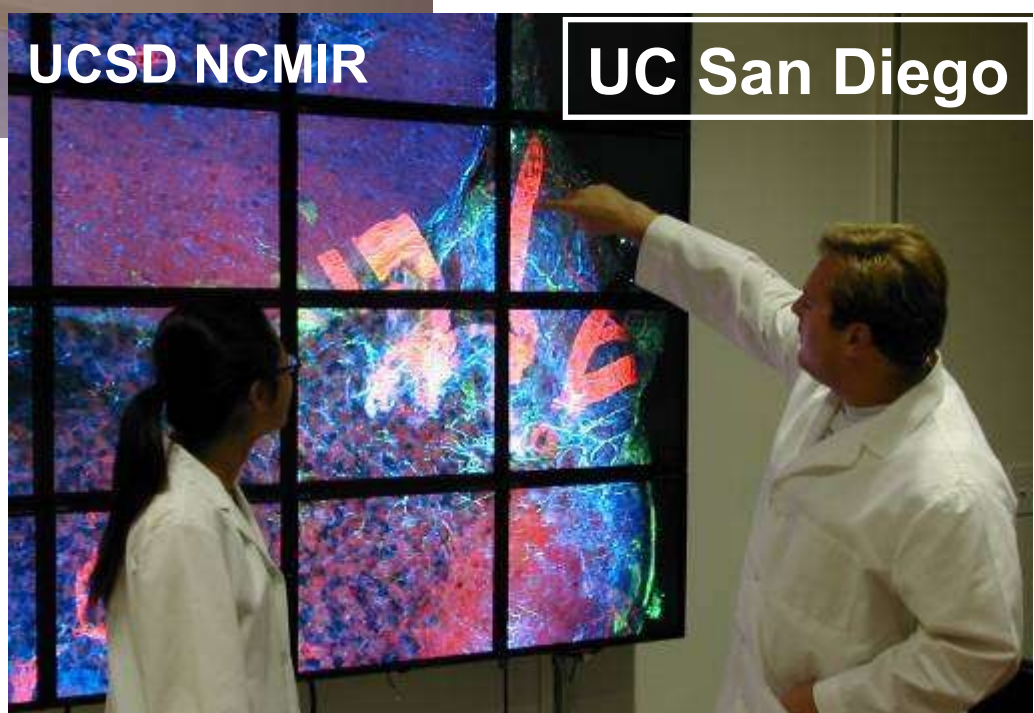
it2

Calit2 Collaboration Rooms Testbed
UCI to UCSD



Source: Falko Kuester, UCI
& Mark Ellisman, UCSD

OptIPuter



In 2005 Calit2 will Link Its Two Buildings via CENIC-XD Dedicated Fiber over 75 Miles Using OptIPuter Architecture to Create a Distributed Collaboration Laboratory

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SDSC/Calit2 Synthesis Center Will Be Moving from SDSC to Calit2 Building

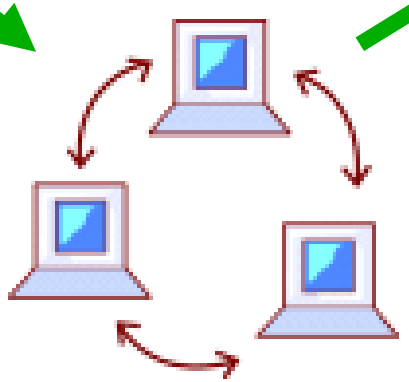


Collaboration to Set Up Experiments





Collaboration to Study Experimental Results



Collaboration to Run Experiments





Cyberinfrastructure for the Geosciences

www.geongrid.org

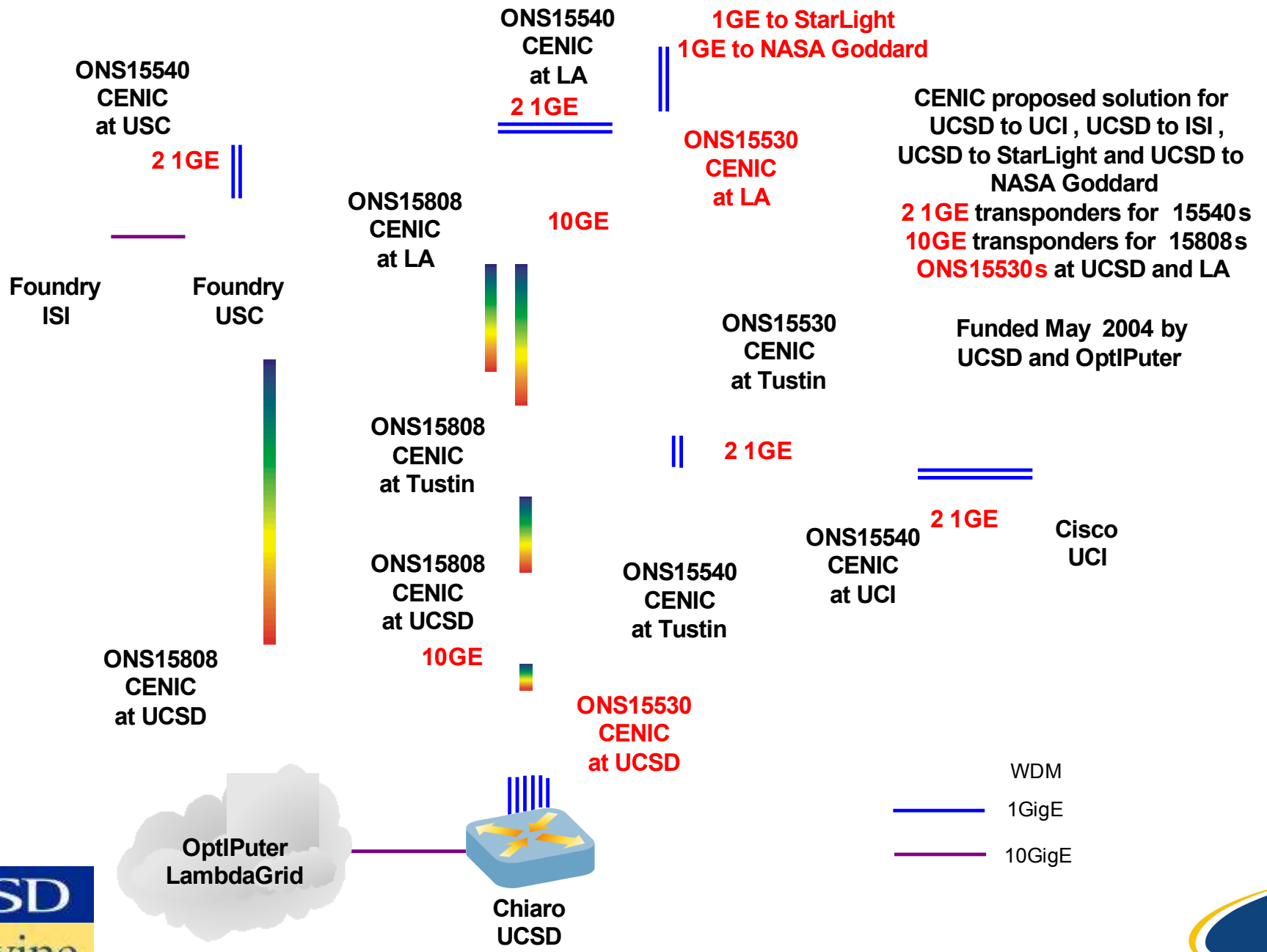
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SDSC
SAN DIEGO SUPERCOMPUTER CENTER

UC San Diego

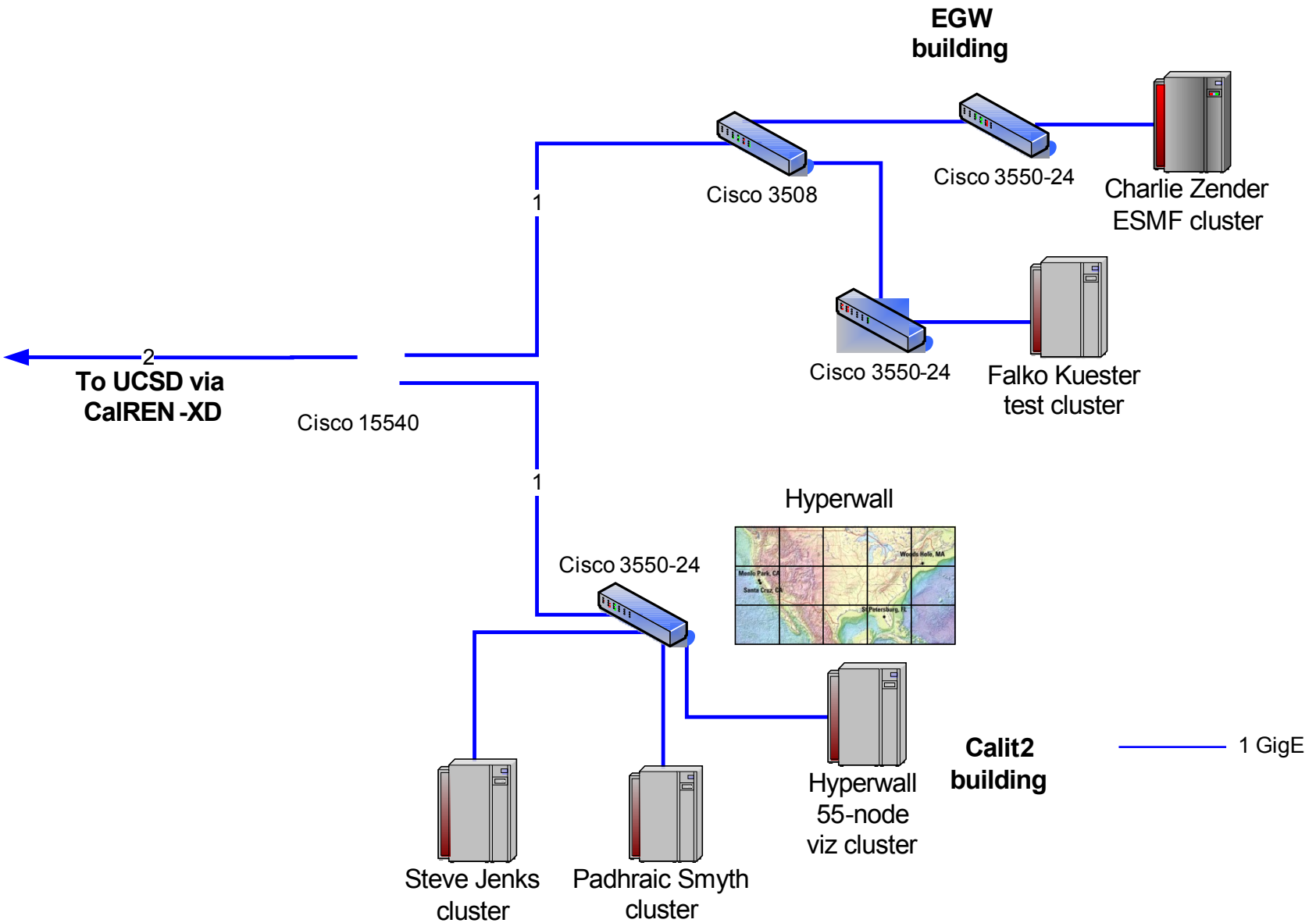
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Southern California CalREN-XD Build Out



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UC Irvine



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Applying OptIPuter Technologies to Support Global Change Research

- UCI Earth System Science Modeling Facility (ESMF)
  - Calit2 is Adding ESMF to the OptIPuter Testbed
- ESMF Challenge:
  - Improve Distributed Data Reduction and Analysis
  - Extending the NCO netCDF Operators
    - Exploit MPI-Grid and OPeNDAP
  - Link IBM Computing Facility at UCI over OptIPuter to:
    - Remote Storage
      - at UCSD
      - Earth System Grid (LBNL, NCAR, ONRL) over NLR
- The Resulting Scientific Data Operator LambdaGrid Toolkit will Support the Next Intergovernmental Panel on Climate Change (IPCC) Assessment Report

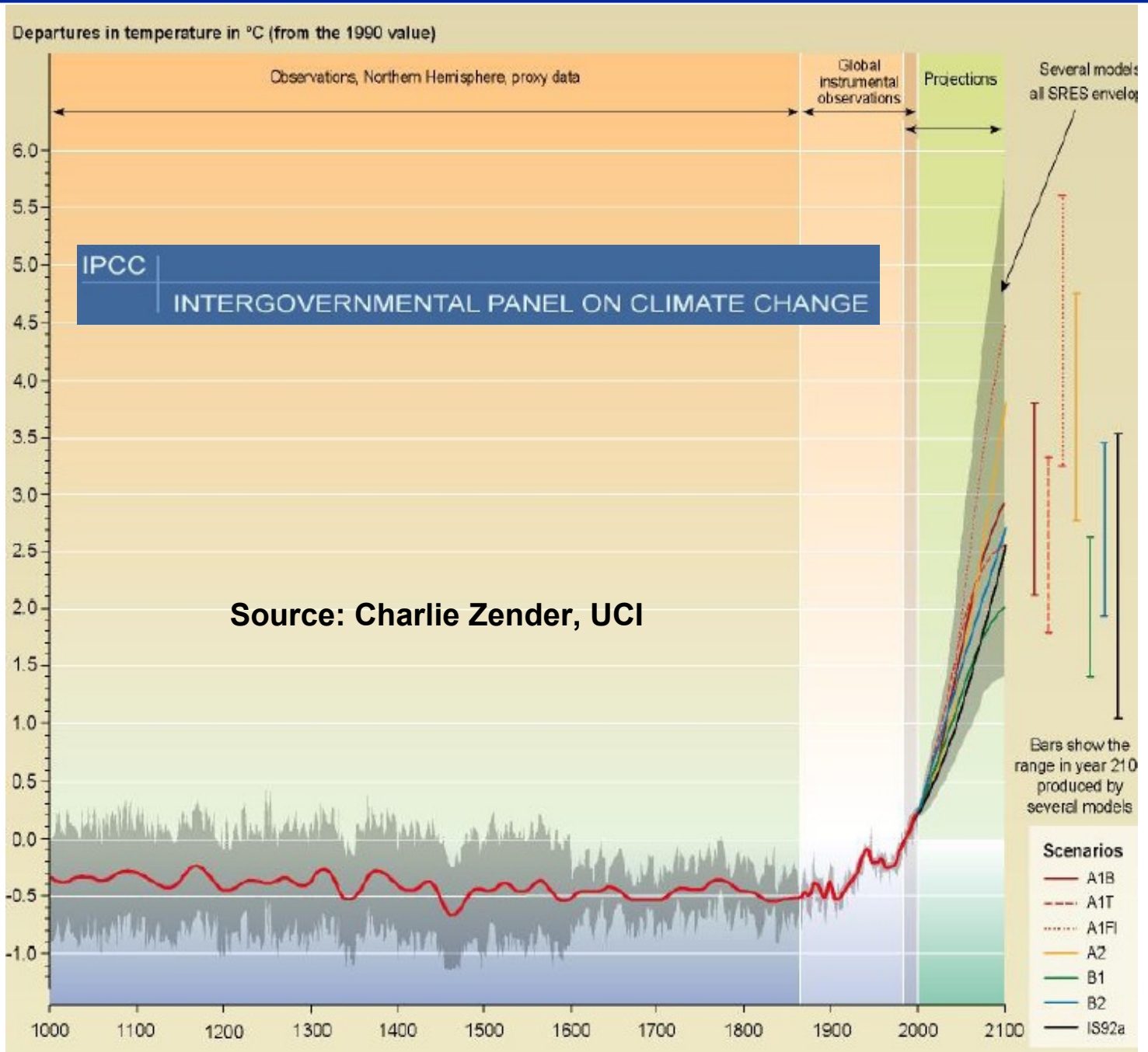


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Source: Charlie Zender, UCI

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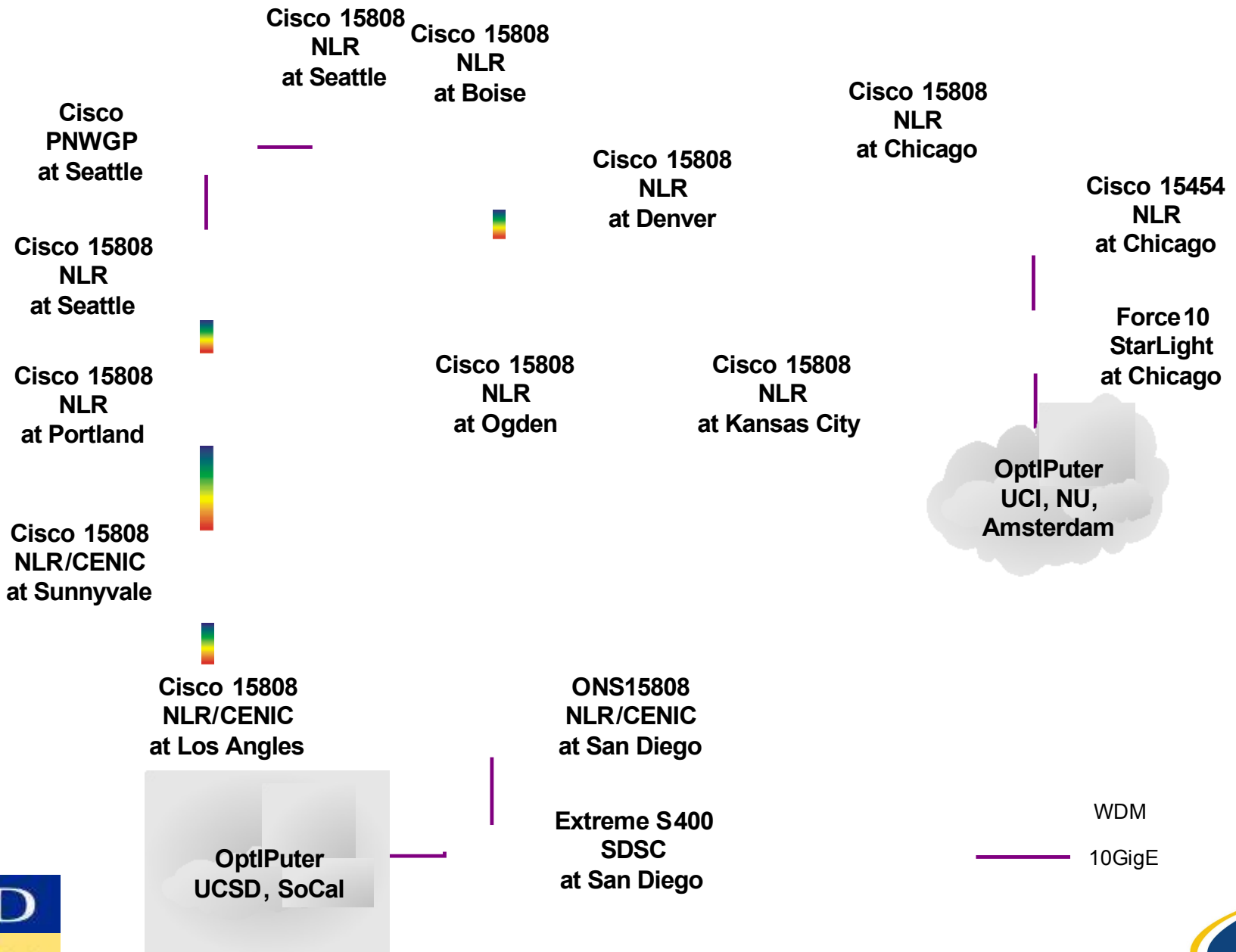
Variations of the Earth Surface Temperature Over One Thousand Years



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NLR CAVEwave



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10GE OptIPuter CAVEWAVE Helped Launch the National LambdaRail

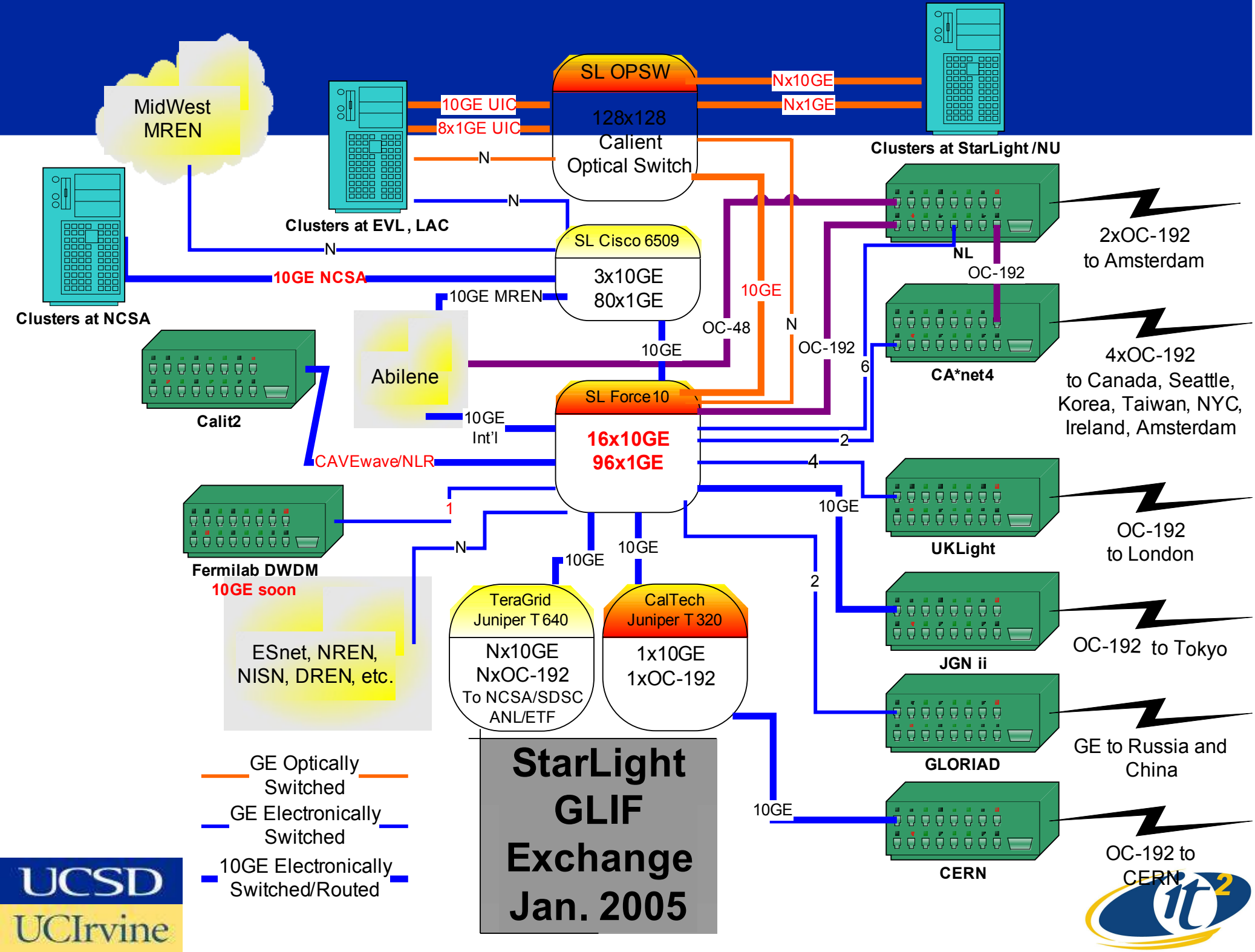


Next Step: Coupling NASA Centers to NSF OptIPuter

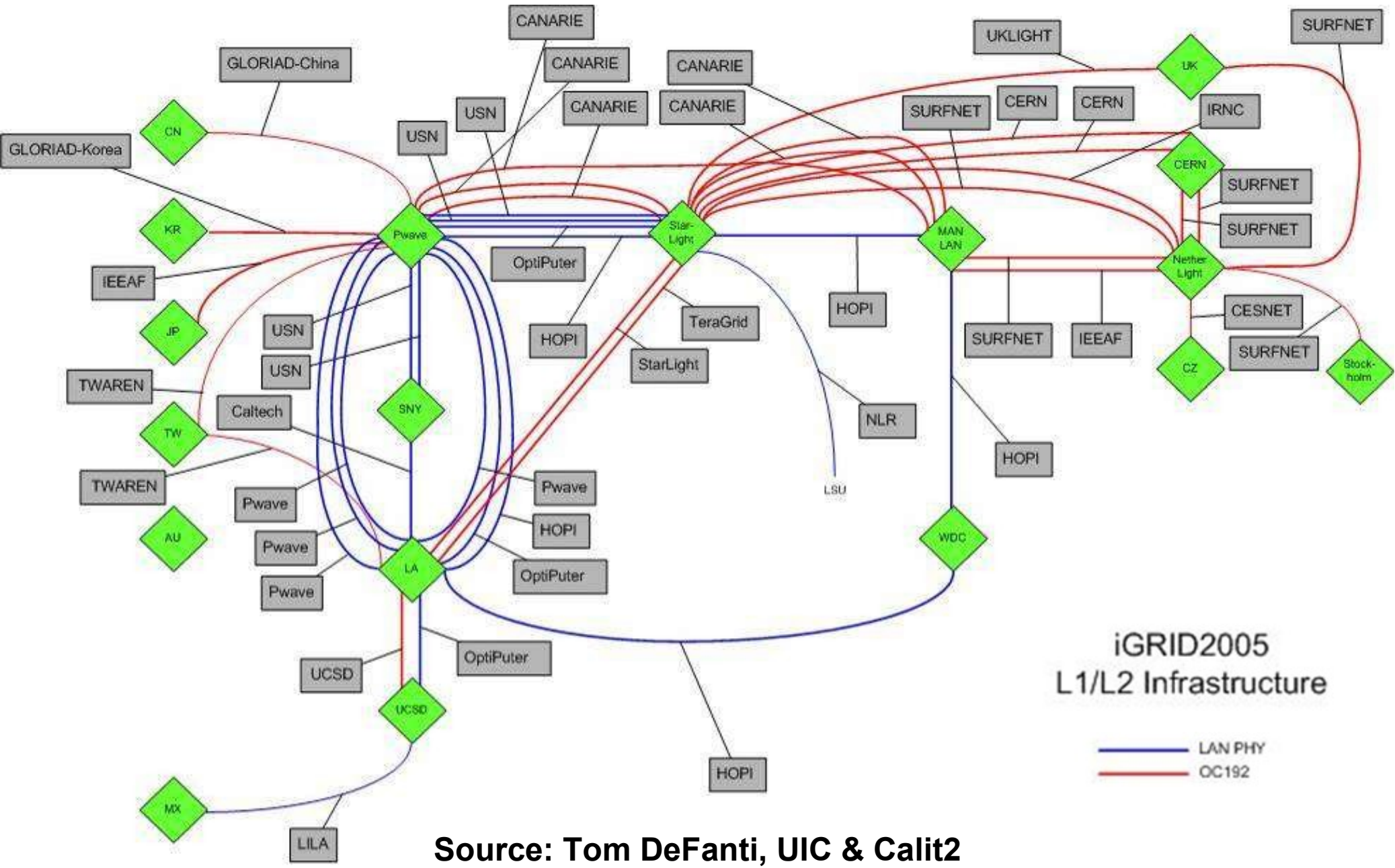
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NASA

Source: Tom DeFanti, OptIPuter co-PI


MidWest MREN
SL OPSW
128x128 Calient Optical Switch
10GE UIC
8x1GE UIC
Nx10GE
Nx1GE
Clusters at StarLight /NU
Clusters at EVL, LAC
N
Clusters at NCSA
10GE NCSA
SL Cisco 6509
3x10GE
80x1GE
10GE MREN
10GE
OC-48
10GE
N
OC-192
6
NL
OC-192
2xOC-192
to Amsterdam
CA*net4
4xOC-192
to Canada, Seattle, Korea, Taiwan, NYC, Ireland, Amsterdam
Abilene
Calit2
SL Force10
16x10GE
96x1GE
10GE Int'l
CAVEwave/NLR
2
4
10GE
UKLight
OC-192
to London
1
N
10GE
10GE
2
Fermilab DWDM
10GE soon
TeraGrid Juniper T640
Nx10GE
NxOC-192
To NCSA/SDSC ANL/ETF
CalTech Juniper T320
1x10GE
1xOC-192
JGN ii
OC-192 to Tokyo
ESnet, NREN, NISN, DREN, etc.
GLORIAD
GE to Russia and China
10GE
CERN
OC-192 to CERN
GE Optically Switched
GE Electronically Switched
10GE Electronically Switched/Routed
StarLight GLIF Exchange Jan. 2005
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The International Lambda Fabric
Being Assembled to Support iGrid Experiments



Source: Tom DeFanti, UIC & Calit2

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

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

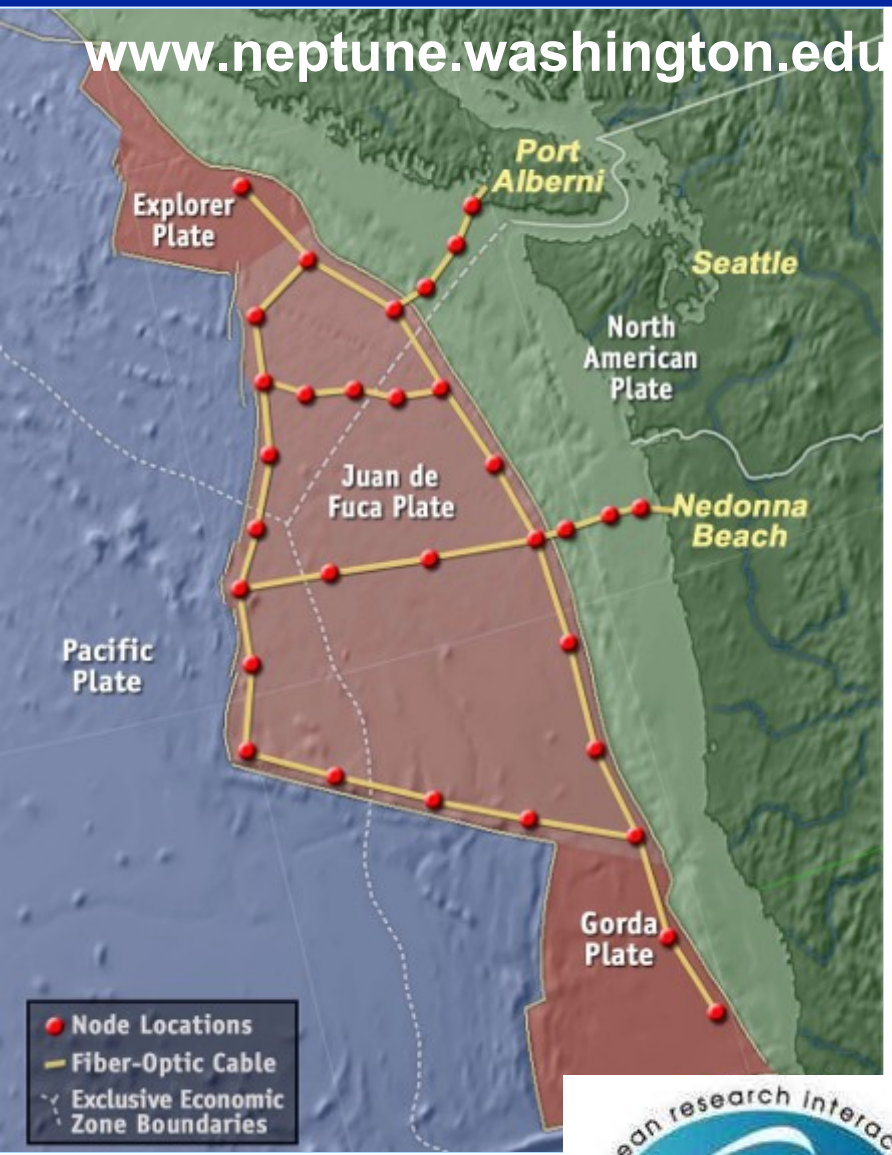
SC|05 Gateway to Discovery

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

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UCIrvine
NSF
ocean research interactive ORION observatory networks
it2

Goal – From Expedition to Cable Observatories with Streaming Stereo HDTV Robotic Cameras

http://disney.go.com/disneypictures/aliensofthedeep/alienseduguide.pdf

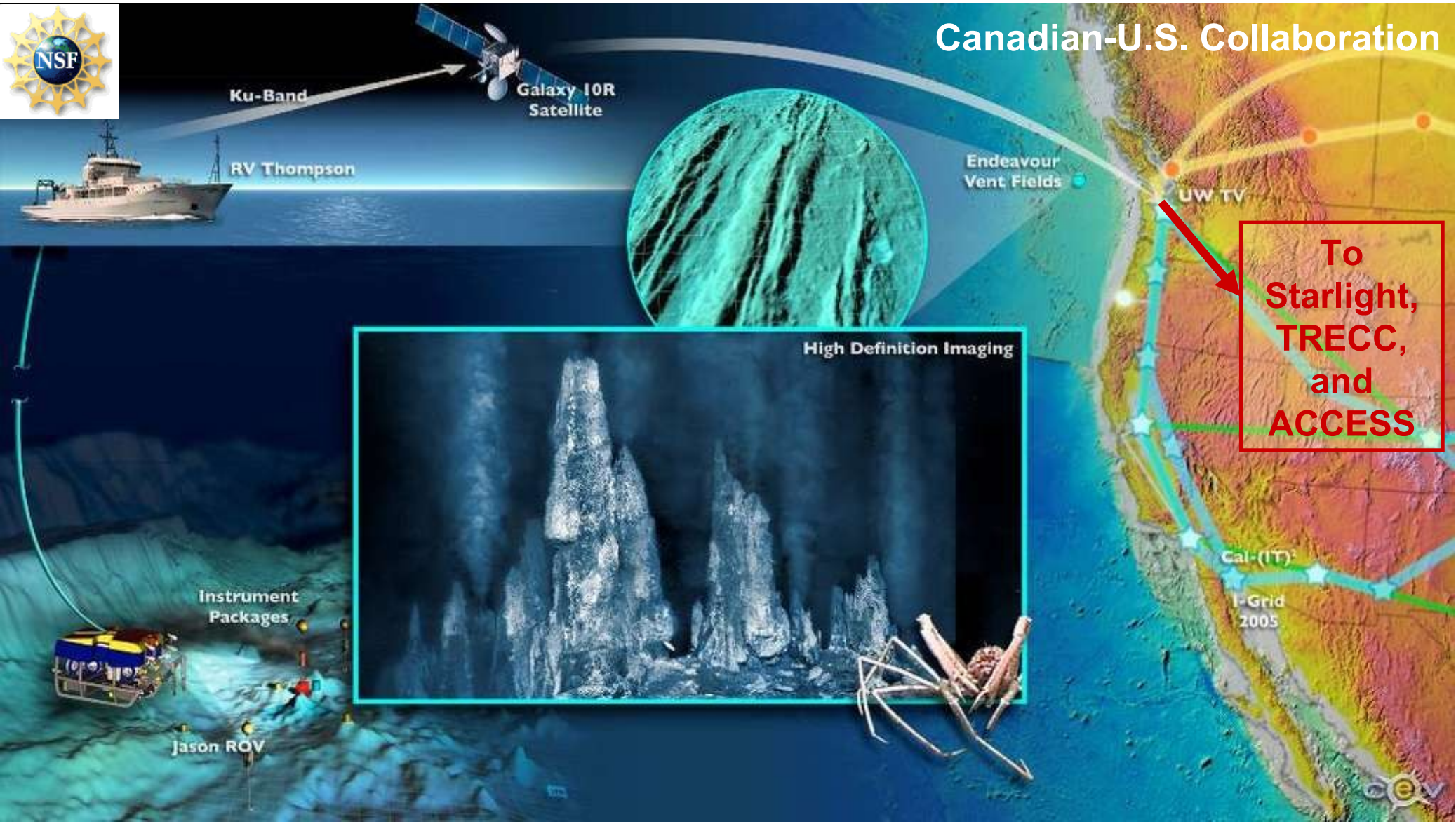




Scenes from The Aliens of the Deep, Directed by James Cameron & Steven Quale

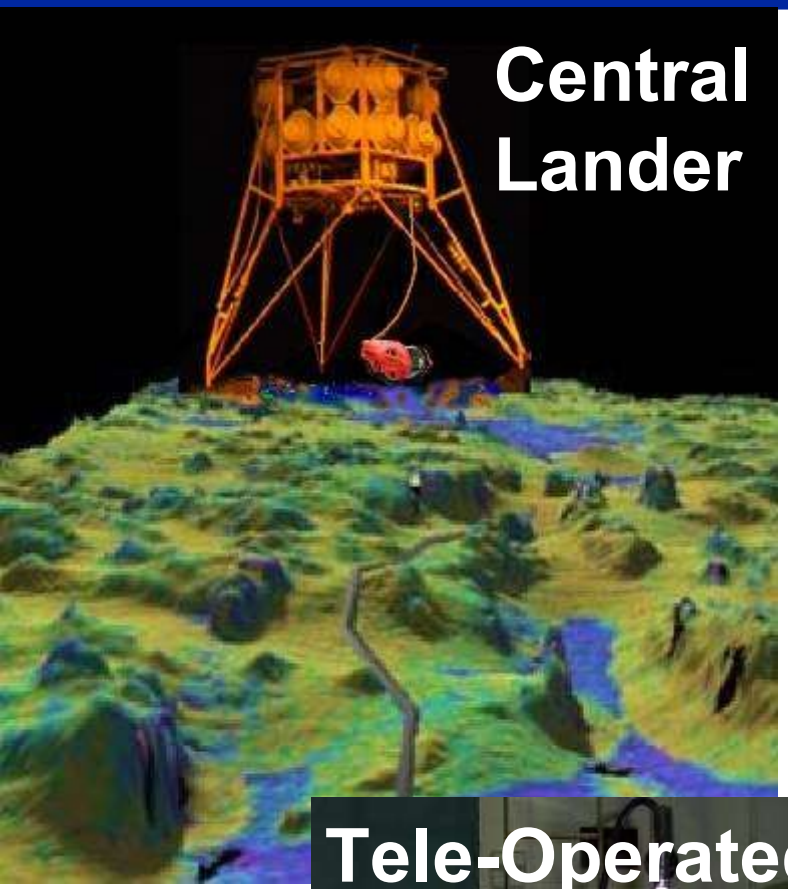
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Proposed UW/Calit2 Experiment for iGrid 2005 – Remote Interactive HD Imaging of Deep Sea Vent



Source John Delaney & Deborah Kelley, UWash

Monterey Bay Aquarium Research Institute (MBARI) Cable Observatory Testbed – LOOKING Living Lab





Source: Jim Bellingham, MBARI

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