"Positioning University of California Information Technology for the Future: State, National, and International IT Infrastructure Trends and Directions."

Invited Talk

The Vice Chancellor of Research and Chief Information Officer Summit

“Information Technology Enabling Research at the University of California”

Oakland, CA

February 15, 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

OptIPuter

it²

A Once in Two-Decade Transition from Computer-Centric to Net-Centric Cyberinfrastructure

Bandwidth is getting cheaper faster than storage.
Storage is getting cheaper faster than computing.
Exponentials are crossing.

"A global economy designed
to waste transistors, power, and silicon area
-and conserve bandwidth above all-
is breaking apart and reorganizing itself
to waste bandwidth
and conserve power, silicon area, and transistors."
George Gilder Telecosm (2000)

OptIPuter

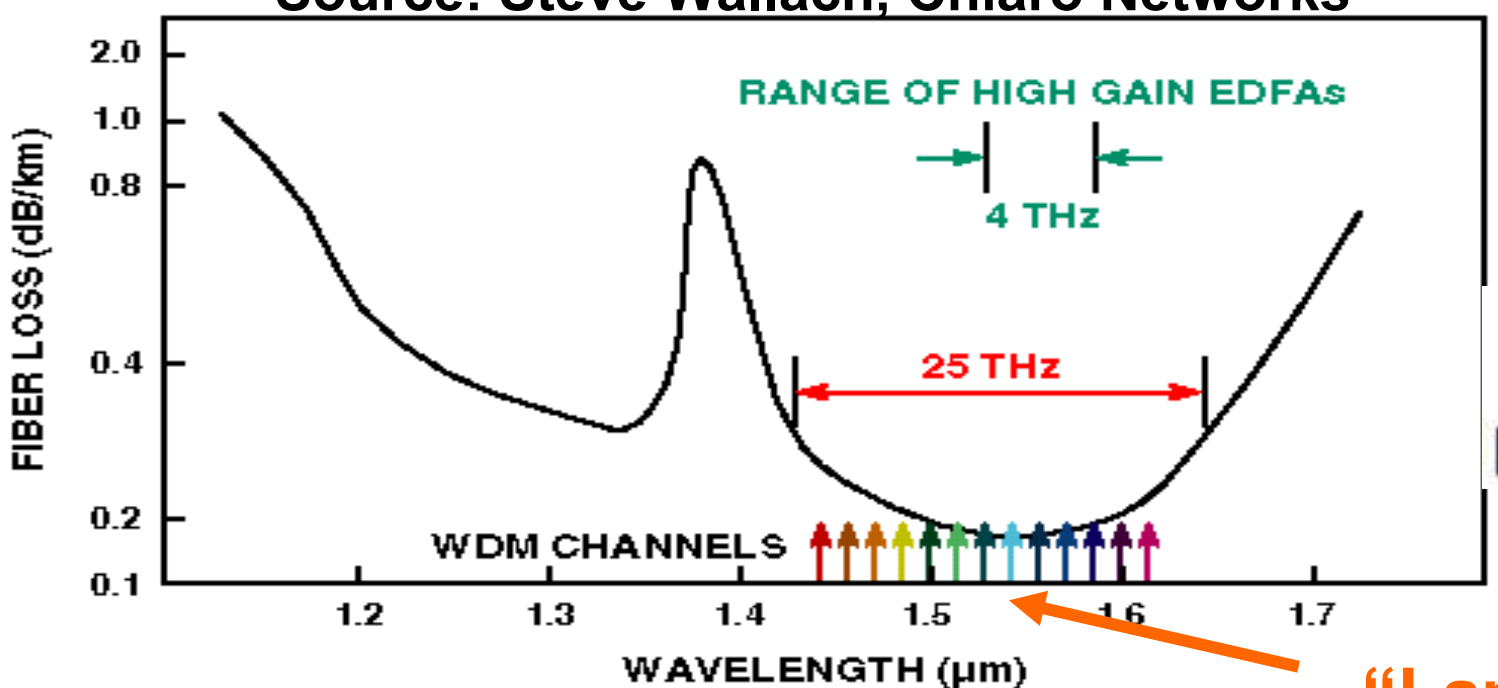
it²

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

WAVELENGTH DIVISION MULTIPLEXING (WDM)

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

Source: Steve Wallach, Chiaro Networks



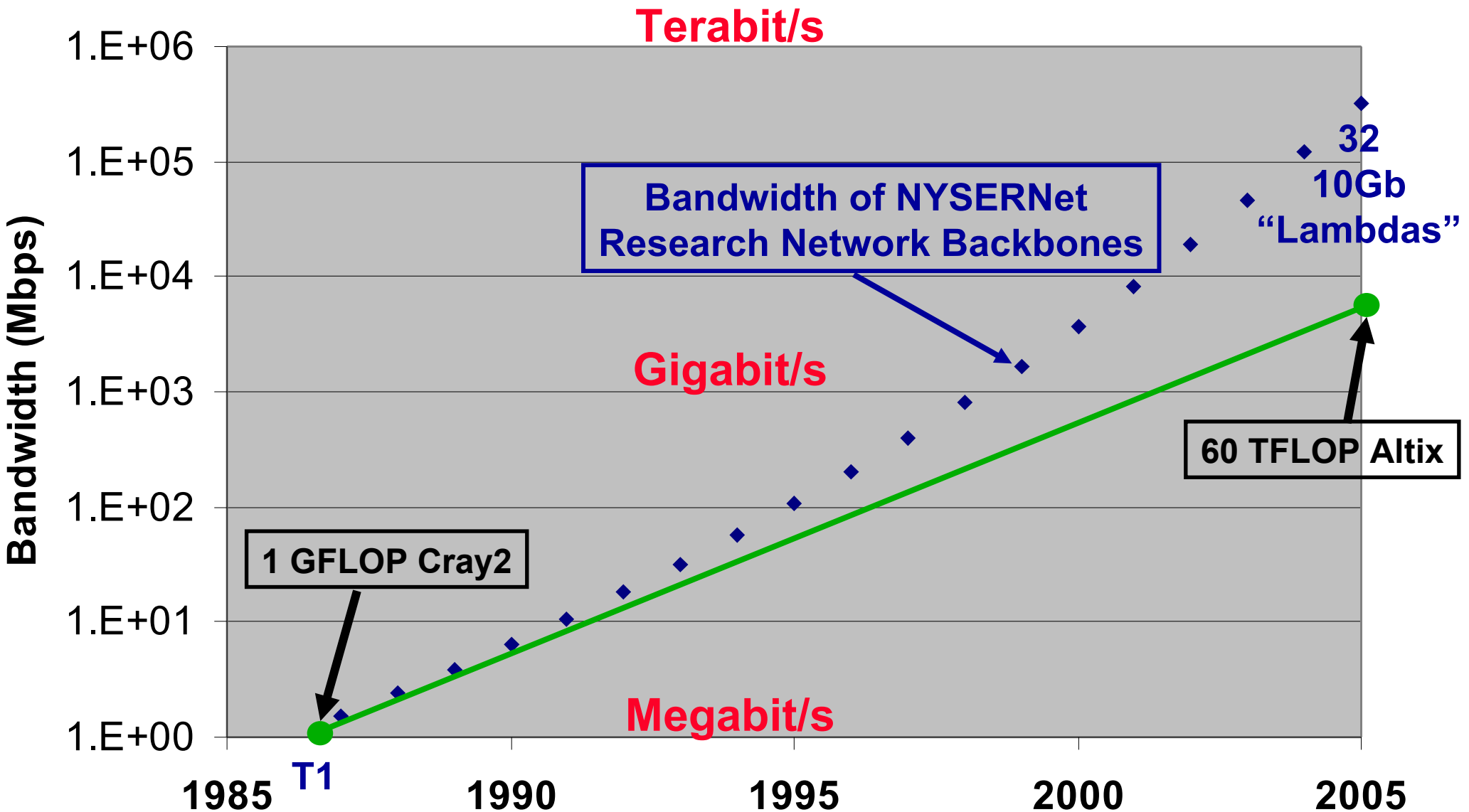
CHIARO

"Lambdas"

OptIPuter

it²

Optical WAN Research Bandwidth Has Grown Much Faster than Supercomputer Speed!

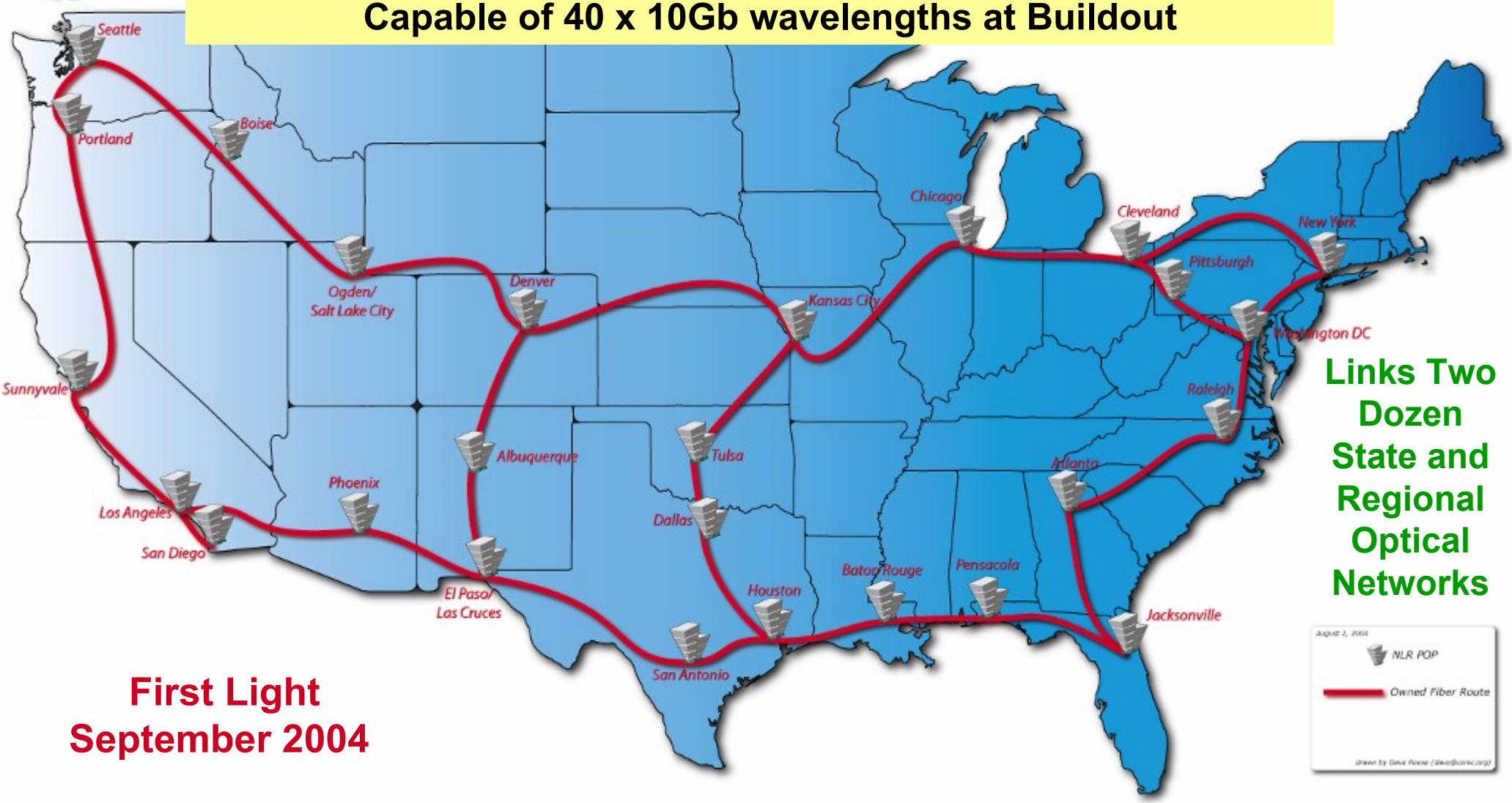


Source: Timothy Lance, President, NYSERNet

NLR Will Provide an Experimental Network Infrastructure for U.S. Scientists & Researchers

"National LambdaRail" Partnership

Serves Very High-End Experimental and Research Applications
4 x 10Gb Wavelengths Initially
Capable of 40 x 10Gb wavelengths at Buildout



Links Two Dozen State and Regional Optical Networks

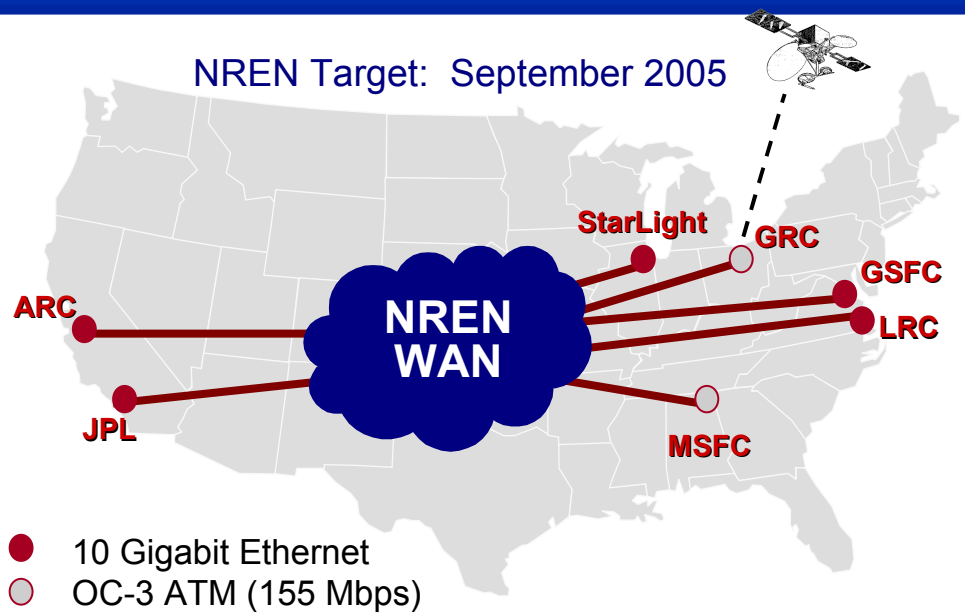
First Light September 2004

For more information regarding NLR see http://www.nlr.net or contact info@nlr.net

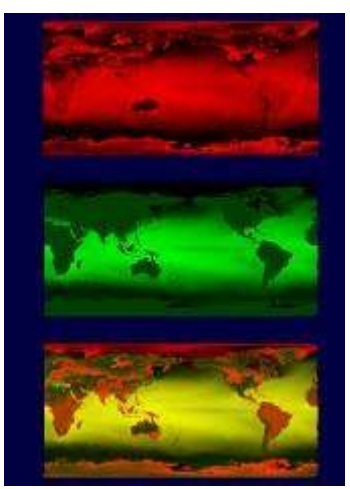
NASA Research and Engineering Network Lambda Backbone Will Run on CENIC and NLR

- NREN Goal
  - Provide a Wide Area, High-speed Network for Large Data Distribution and Real-time Interactive Applications
  - Provide Access to NASA Research & Engineering Communities - Primary Focus: Supporting Distributed Data Access to/ from Project Columbia





- Sample Application: Estimating the Circulation and Climate of the Ocean (ECCO)
  - ~78 Million Data Points
  - 1/6 Degree Latitude-Longitude Grid
  - Decadal Grids ~ 0.5 Terabytes / Day
  - Sites: NASA JPL, MIT, NASA Ames



- **Next Steps**
  - **1 Gbps (JPL to ARC) Across CENIC (February 2005)**
  - **10 Gbps ARC, JPL & GSFC Across NLR (May 2005)**
  - **StarLight Peering (May 2005)**
  - **10 Gbps LRC (Sep 2005)**



OptIPuter

Source: Kevin Jones, Walter Brooks, ARC

Lambdas Provide Global Access to Large Data Objects and Remote Instruments

Global Lambda Integrated Facility (GLIF)
Integrated Research Lambda Network



OptIPuter

Visualization courtesy of
Bob Patterson, NCSA

it2

A Necessary Partnership:
Campus IT Specialists and Faculty, Staff, and Students

Source: Enabling the future: IT at Purdue

Enabling learning, discovery, and engagement is more than just offering compute cycles.

It requires creating a collaborative environment where

IT specialists collaborate with faculty, staff, & students

so that computing is transparent."

-- James Bottum,

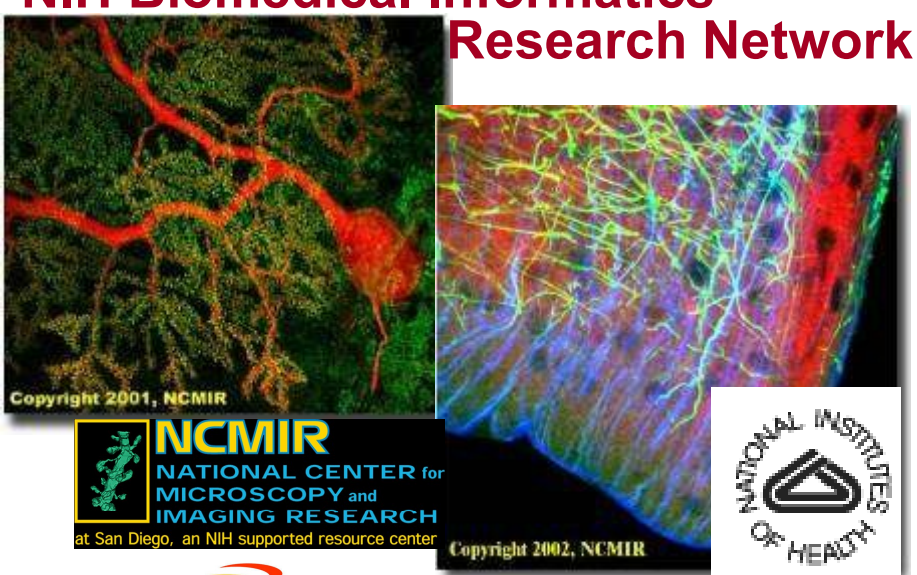
VP for Information Technology, CIO,

Purdue University

The OptIPuter Project – A Model of Cyberinfrastructure Partnerships

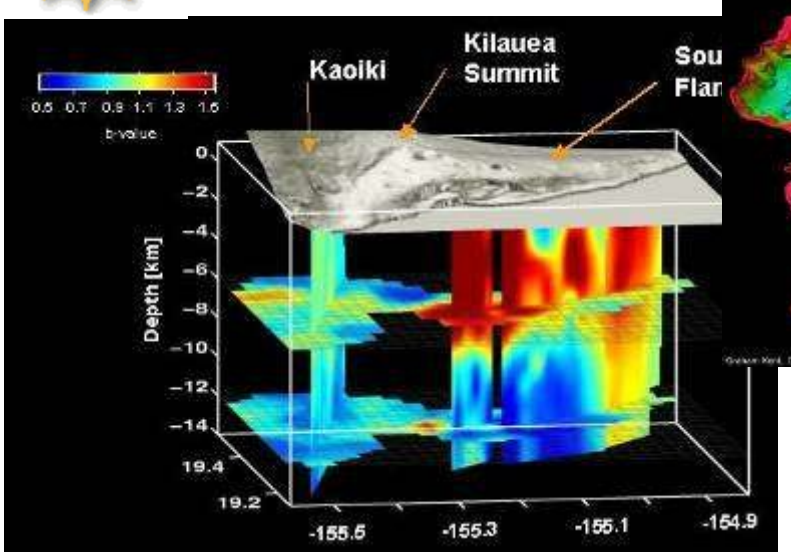
- **NSF Large Information Technology Research Proposal**
  - Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
  - Partnering Campuses: USC, SDSU, NW, TA&M, UvA, SARA, NASA
- **Industrial Partners**
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- **$13.5 Million Over Five Years**
- **Driven by Global Scale Science Projects**

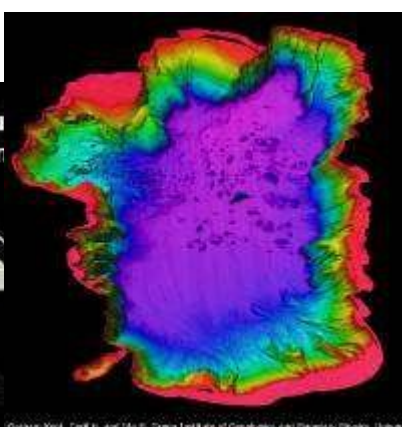
NIH Biomedical Informatics Research Network



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

NSF EarthScope and ORION





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

OptIPuter SDSC it2

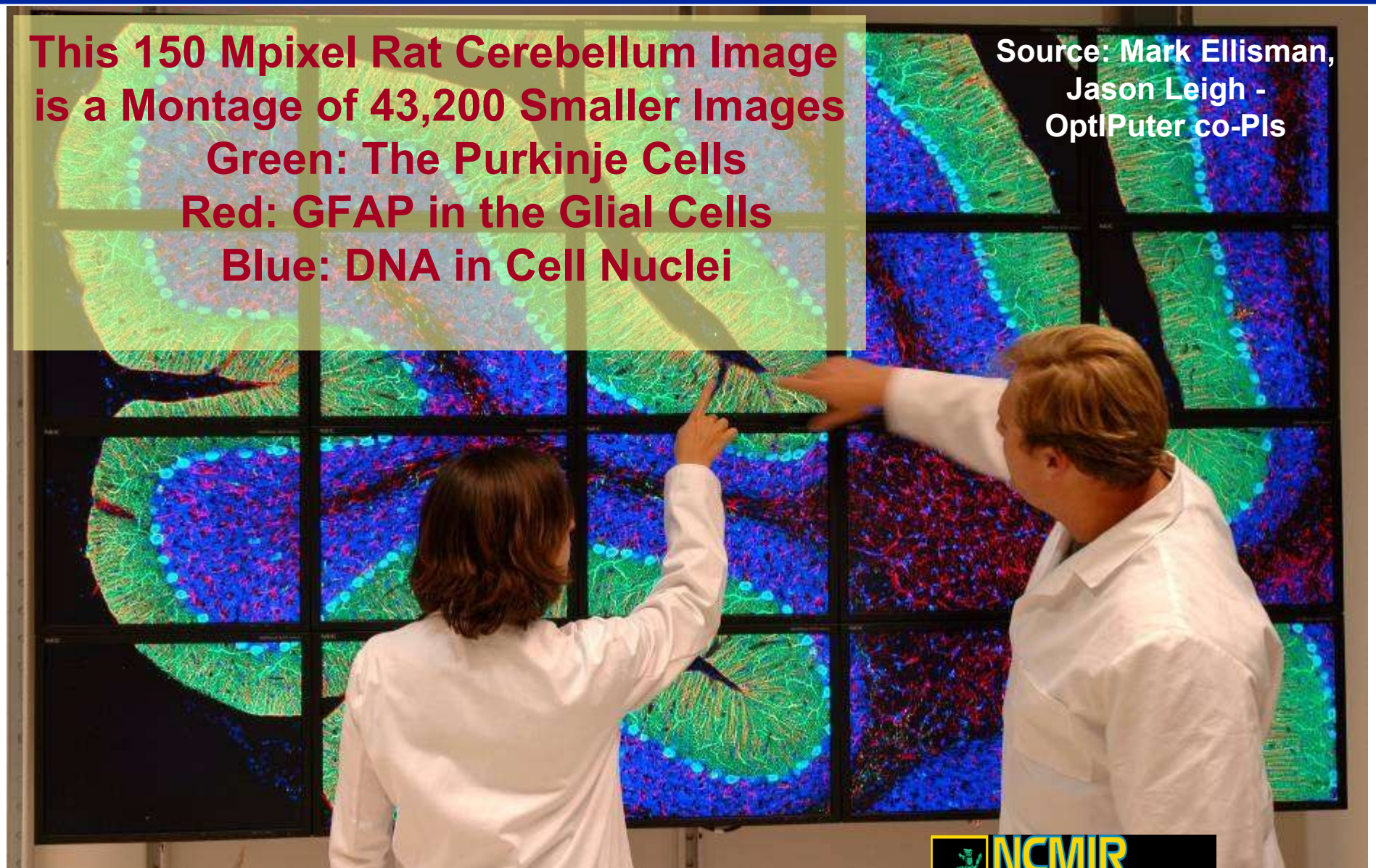
Optical Networking, Internet Protocol, Computer
Bringing the Power of Lambdas to Users

- **Extending Grid Middleware to Control:**
  - Clusters Optimized - Storage, Visualization, & Computing
    - Linux Clusters With 1 or 10 Gbps I/O per Node
    - Scalable Visualization Displays with OptIPuter Clusters
  - Jitter-Free, Fixed Latency, Predictable Optical Circuits
    - One or Parallel Dedicated Light-Pipes
      - 1 or 10 Gbps WAN Lambdas
    - Uses Internet Protocol, But Does NOT Require TCP
    - Exploring Both Intelligent Routers and Passive Switches
- **Applications Drivers:**
  - Earth and Ocean Sciences
  - Biomedical Imaging

OptIPuter

it2

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



OptIPuter

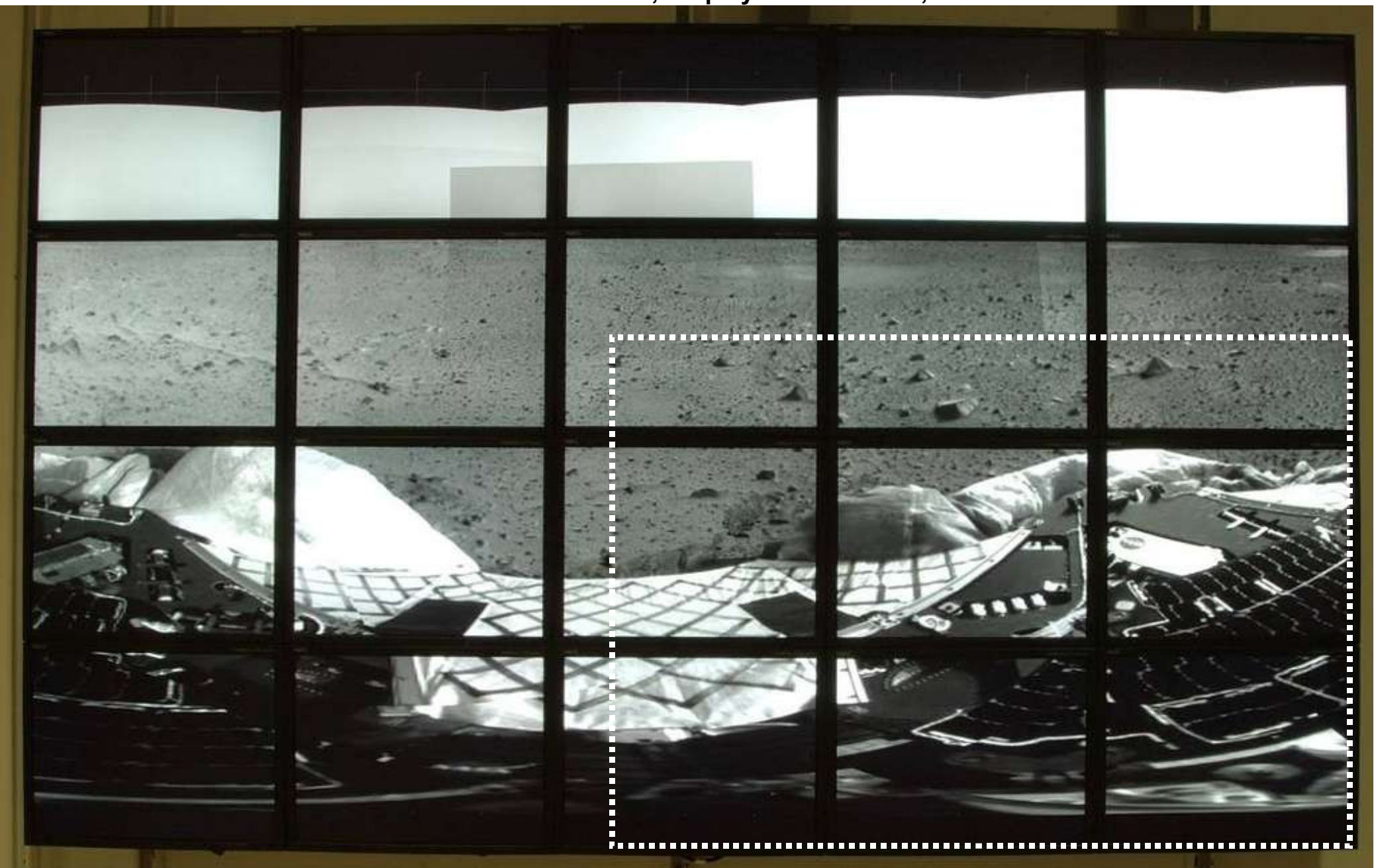
40 MPixel Display Driven By a 20-Node
Sun Opteron Visualization Cluster

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

it2

Tiled Displays Allow for Both Global Context and High Levels of Detail—150 MPixel Rover Image on 40 MPixel OptIPuter Visualization Node Display

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"



Interactively Zooming In Using EVL's JuxtaView on NCMIR's Sun Microsystems Visualization Node

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"



Highest Resolution Zoom on NCMIR 40 MPixel OptIPuter Display Node

"Source: Data from JPL/Mica; Display UCSD NCMIR, David Lee"

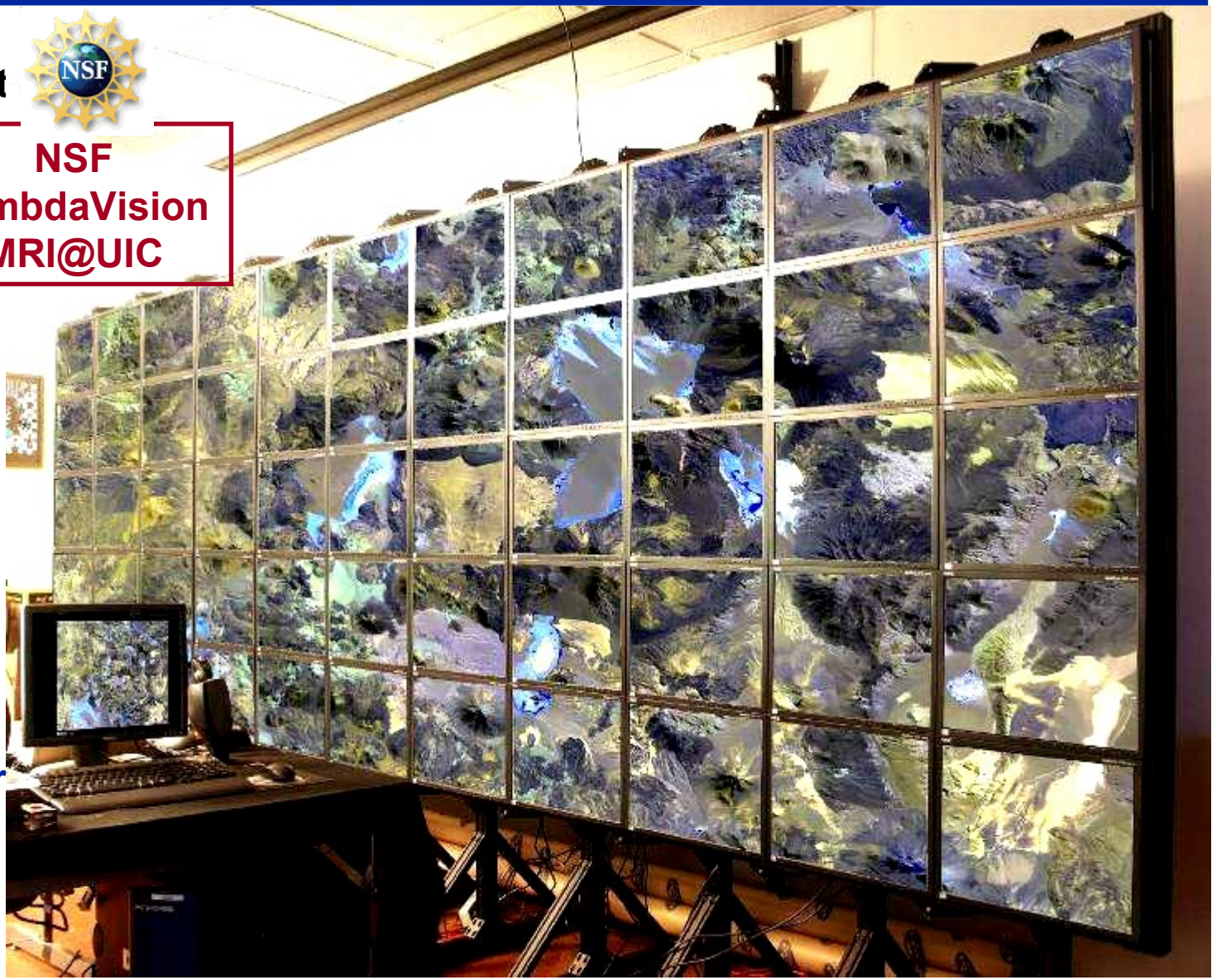


Currently Developing OptIPuter Software to Coherently Drive 100 Mpixel Displays

- Scalable Adaptive Graphics Environment (SAGE) Controls:

NSF
LambdaVision
MRI@UIC

- 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



OptIPuter

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

it2

UCSD is Prototyping a Campus-Scale OptIPuter



0.320 Tbps Backplane Bandwidth

Juniper T320

20X

6.4 Tbps Backplane Bandwidth



Chiaro Estara

To CENIC

SDSC

SDSC Annex

Engineering

High School

Medicine

Collocation

Earth Sciences

½ Mile

Campus Provided Dedicated Fibers Between Sites Linking Linux Clusters

UCSD Has ~ 50 Labs With Clusters

Source: Phil Papadopoulos, SDSC; Greg Hidley, Calit2

OptIPuter

it2

The Campus Role is Rapidly Evolving: Indiana University-A Leading Edge Campus

- The VP for Research & IT and CIO at Indiana U Has Established a Cyberinfrastructure Research Taskforce
  - Consists of ~ 25 Distinguished IU Faculty & Researchers
  - A Broad Array of Disciplines
  - Advise on Future Campus Research Cyberinfrastructure
- Top Priority Large Amounts of Data "Parking Space"
  - Instruments In Their Labs That Can Generate GB/Min
  - Access to Remote Federated Repositories
  - Interactive Visualization of Supercomputer Datasets
- 100-1000 TB Spinning Disk Managed Centrally
- 1-10 Gb/s Network Connections to Labs Needed

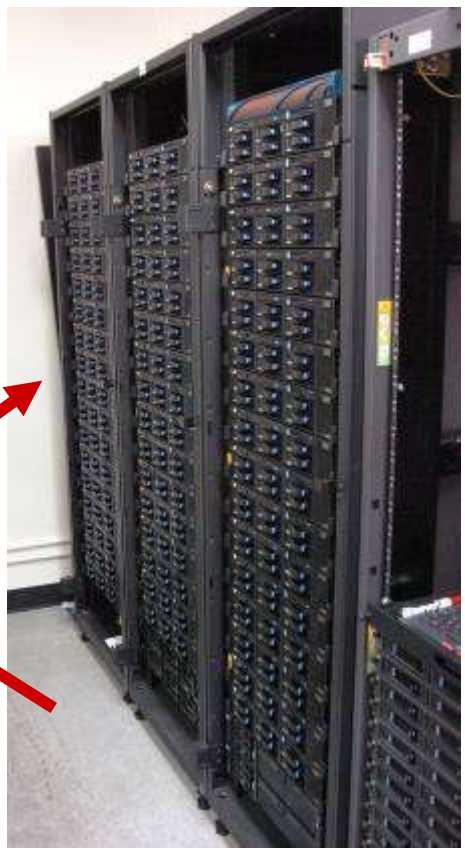
Source: Michael McRobbie, VP Research & IT, CIO
Indiana University

UCSD Campus LambdaStore Architecture
Dedicated Lambdas to Labs Creates Campus LambdaGrid

SIO Ocean Supercomputer

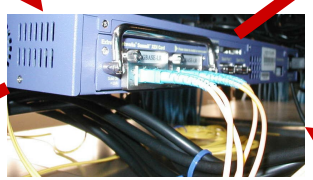


IBM Storage Cluster



Streaming Microscope









Extreme Switch with
2 Ten Gbps Uplinks





OptIPuter

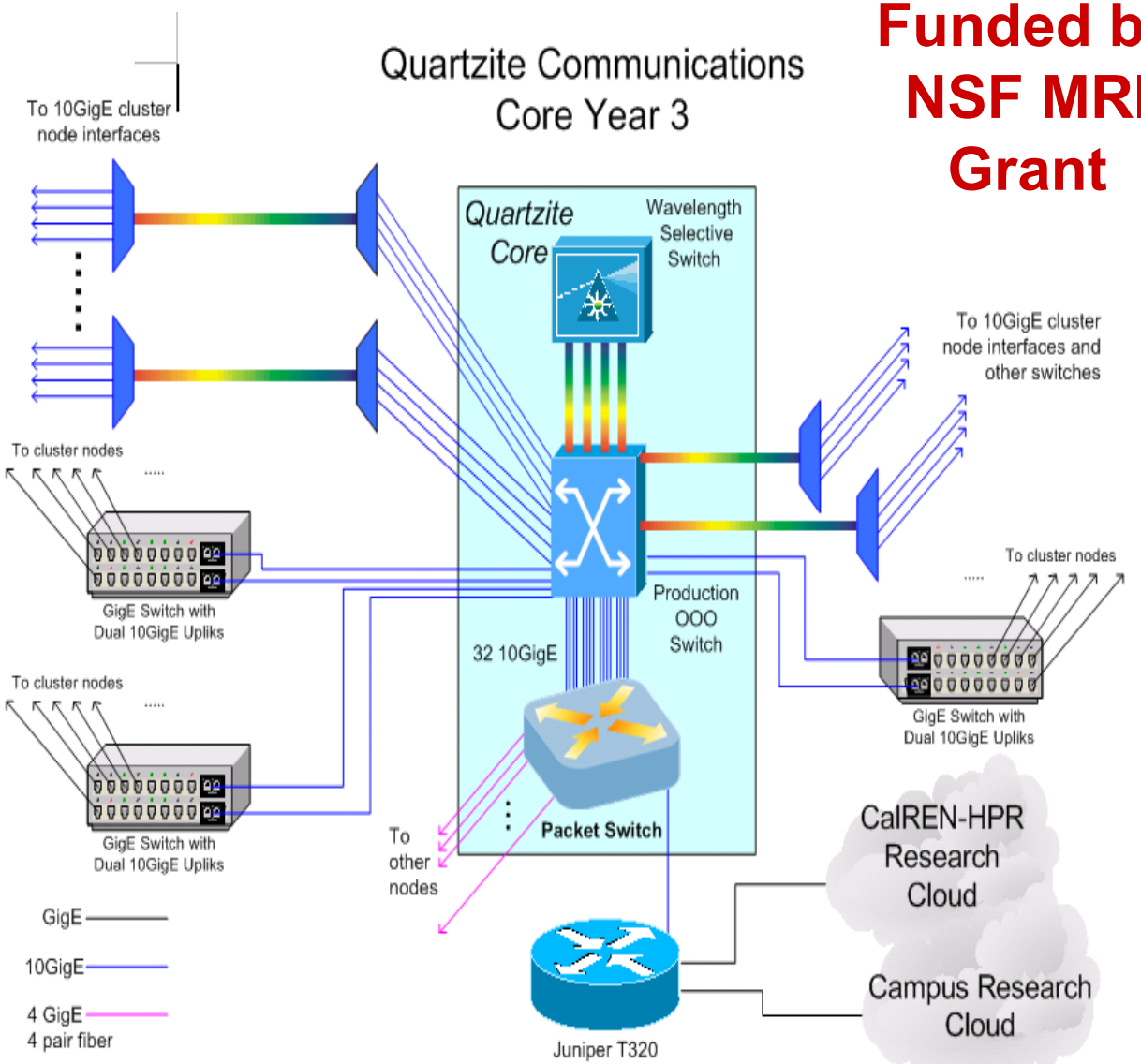
Source: Phil Papadopoulos, SDSC, Calit2

it2

The Optical Network Can be Routed or Switched:
The Optical Core of the UCSD Campus-Scale Testbed

Goals by 2007:
>= 50 endpoints at 10 GigE
>= 32 Packet switched
>= 32 Switched wavelengths
>= 300 Connected endpoints

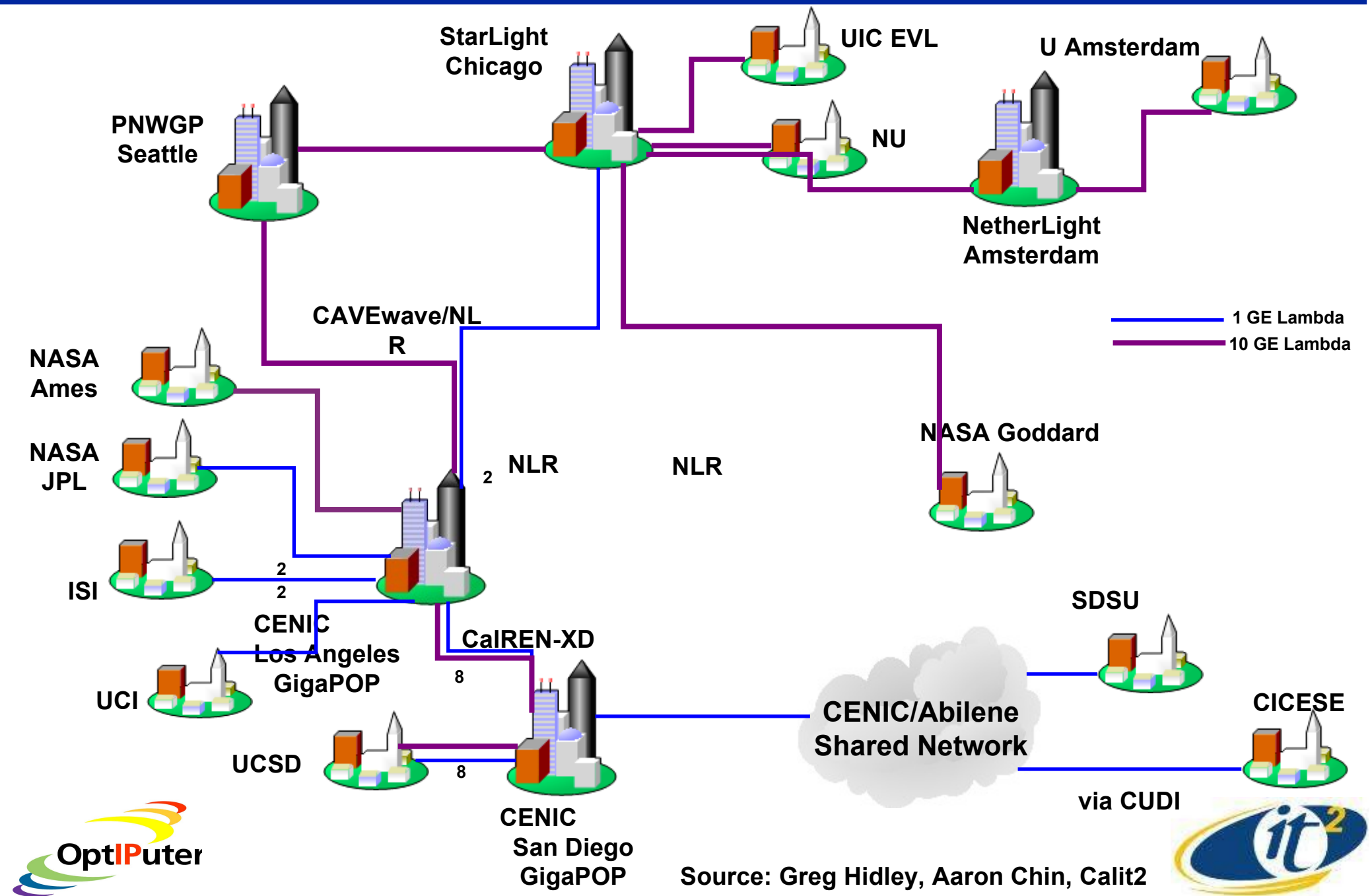
Approximately 0.5 TBit/s Arrive at the "Optical" Center of Campus
Switching will be a Hybrid Combination of:
Packet, Lambda, Circuit -- OOO and Packet Switches Already in Place



Funded by NSF MRI Grant

Source: Phil Papadopoulos, SDSC, Calit2

The OptIPuter LambdaGrid is Rapidly Expanding



The Cyberinfrastructure Conundrum:
New Levels of Partnering, Planning, and Funding are Required

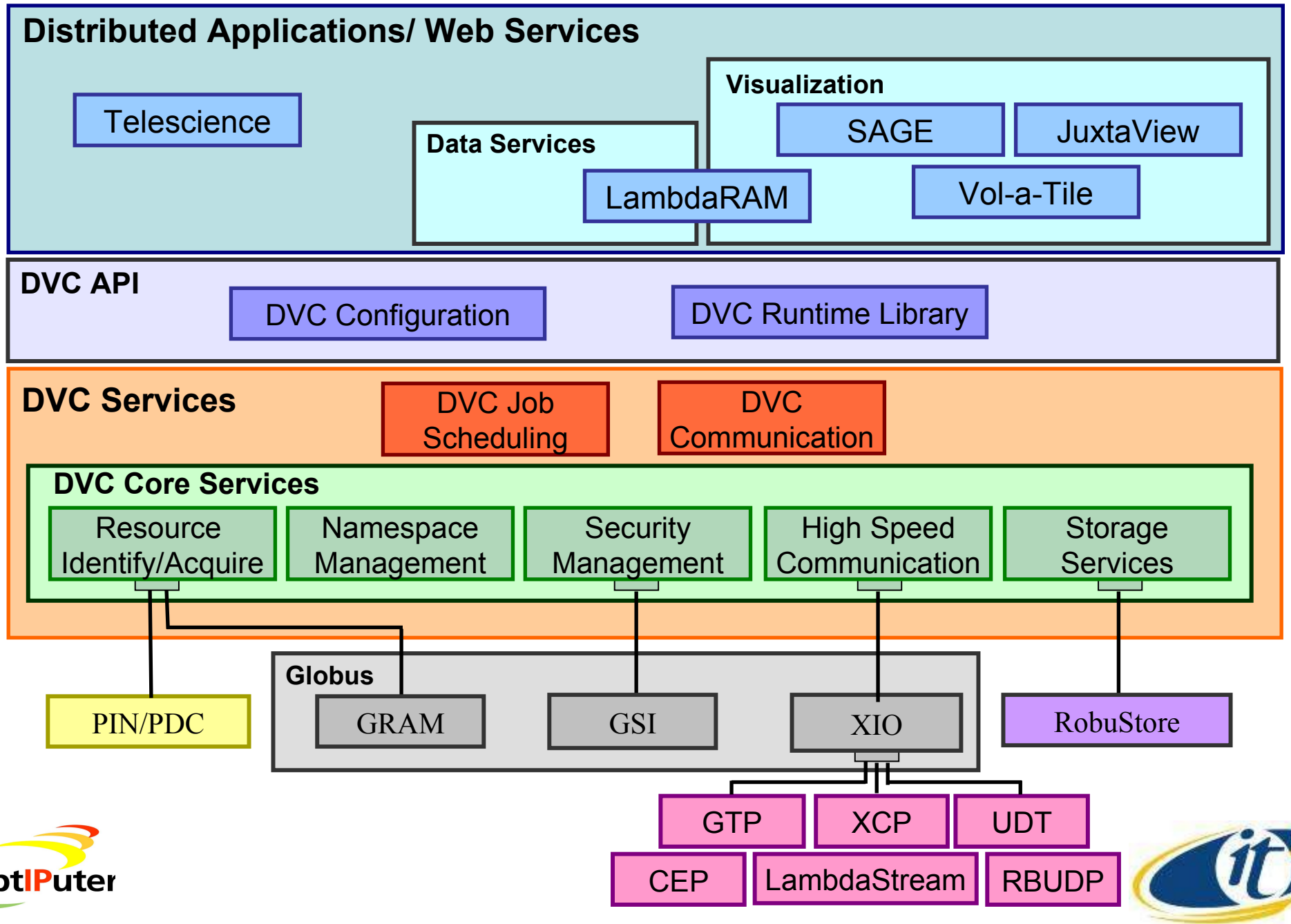
- NSF Needs to Fund Hardening of Research Software / Systems
- Regions and States Need to Fund Infrastructure to Link to National and International Systems
  - NLR, HOPI, GLIF
  - Proposed CENIC Statewide Summit on the Needs of High End Researchers
- Campus CIO's Need to Plan Jointly with Faculty Researchers
- Faculty Need to Submit Infrastructure Grants
- University Systems Need to Support Pathfinder Infrastructure
  - Only One CENIC Campus, UCSD, is Connected to HPR at 10Gbps
    - Both USC and UCLA Have Asked CENIC for 10Gb Pricing
  - The UC System Could be a Model for the Country (World?)

An Example in Progress:
Extending OptIPuter to UC Irvine

OptIPuter

it²

The OptIPuter is Primarily a Software Architecture Research Project –How to Harden and Support Users?



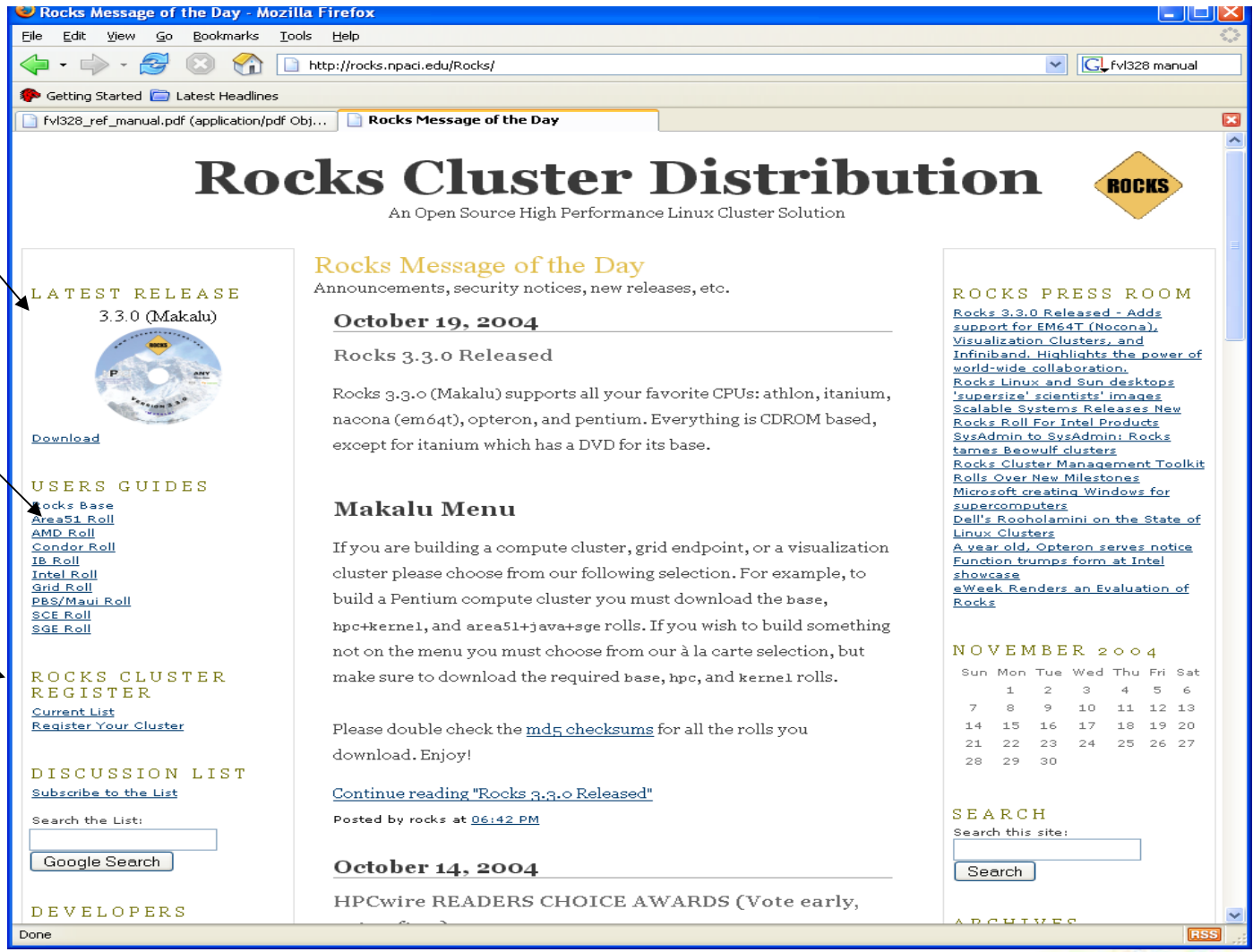
OptIPuter

OptIPuter Uses Rocks for Software Distribution

Campuses Should Support Standards-Based Cluster Software, So the Focus Can Turn to Cyberinfrastructure Integration

2004 Most Important Software Innovation
HPCwire Reader's Choice and Editor's Choice Awards

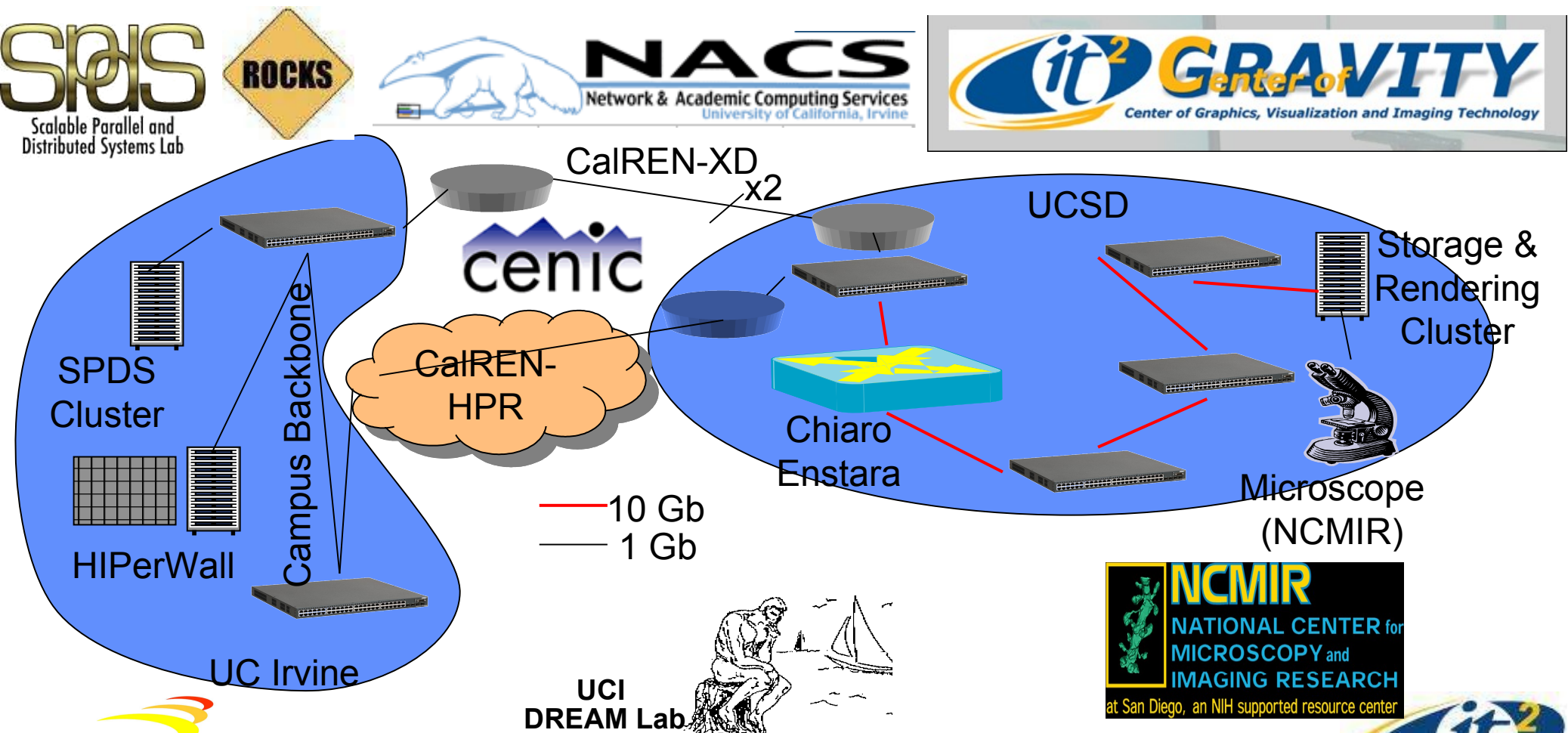
- Downloadable CDs
- Optional Components (rolls) OptIPuter Viz distribution
- Nearly 300 Rocks Clusters Around the World
- Active Discussion List (750+ people)



Source: Phil Papadopoulos, SDSC

UCI is Adding Real Time Control to the Calit2 OptIPuter Testbed

- **Application Development Experiments Requires Institutional Collaboration**
  - **An Experiment for Remote Access and Control within the UCI Campus**
  - **A Step Toward Preparation of an Experiment for Remote Access and Control of Electron Microscopes at UCSD-NCMIR**

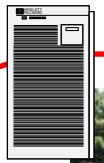


Source: Steve Jenks, Kane Kim, Falko Kuester UCI

Purdue University Shadow Net -
A Campus Dark Fiber Network Can Easily Support LambdaGrids



Computer Science

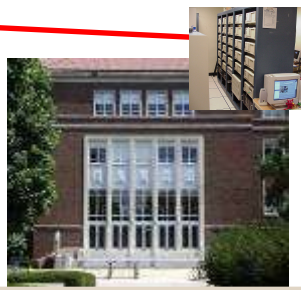


Krannert


High Performance Computing


Stewart Center

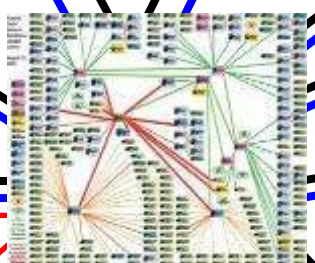

Purdue Memorial Union



Civil Engineering



Math


Dual Core Campus Backbone

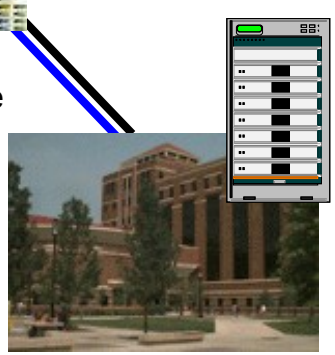


Birck Nanotechnology Center



Collaborator "X"

Commodity Internet, Internet 2, I-Light, NLR, etc.


Steven C. Beering Hall of Liberal Arts and Education

- Primary Network
  - Gigabit between buildings
  - 10/100 to desktop
  - Gig E on demand
- Shadow Network Providing Load Balancing and Redundancy
- Example of Data Flowing through Shadow Network

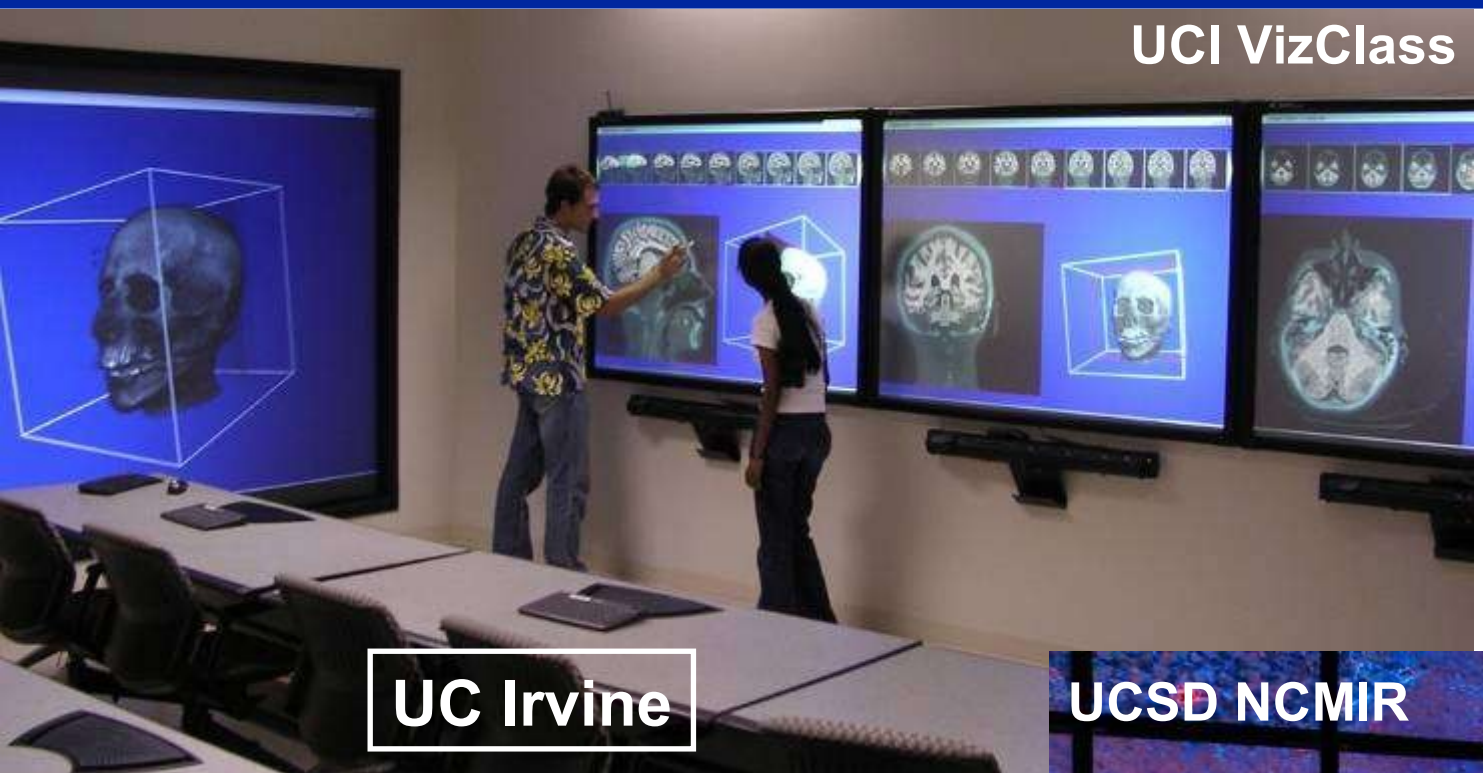
OptIPuter

Another Example is Georgia Tech

Source: Jim Bottum, CIO, Purdue U.

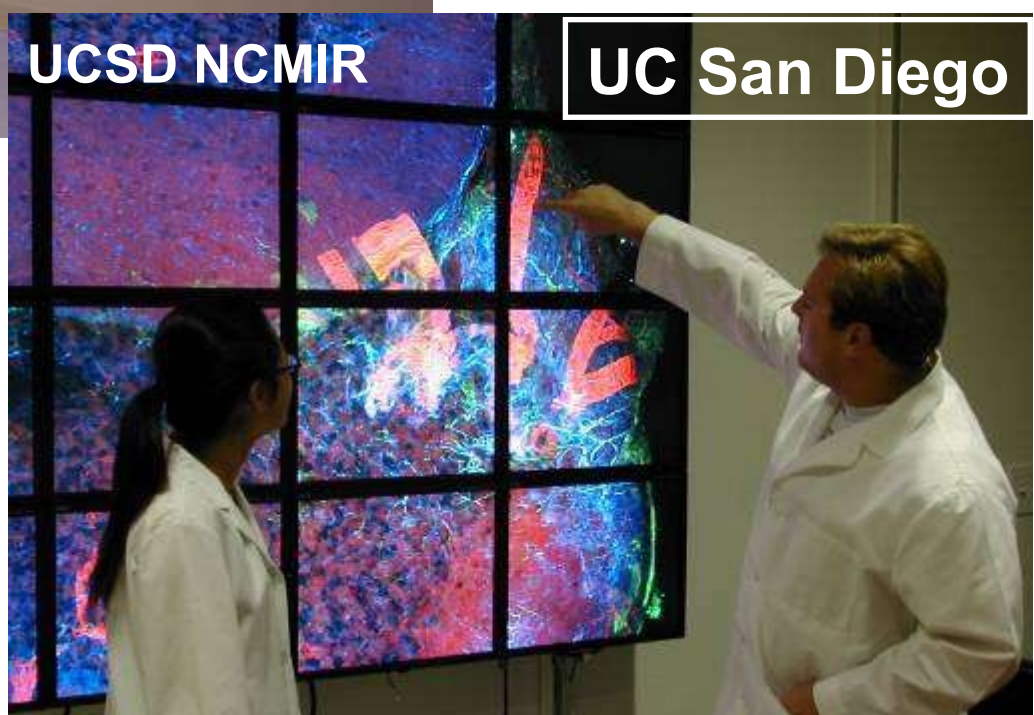
it2

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

OptIPuter

Multiple HD Streams Over Lambdas Will Radically Transform Campus Collaboration







OptIPuter

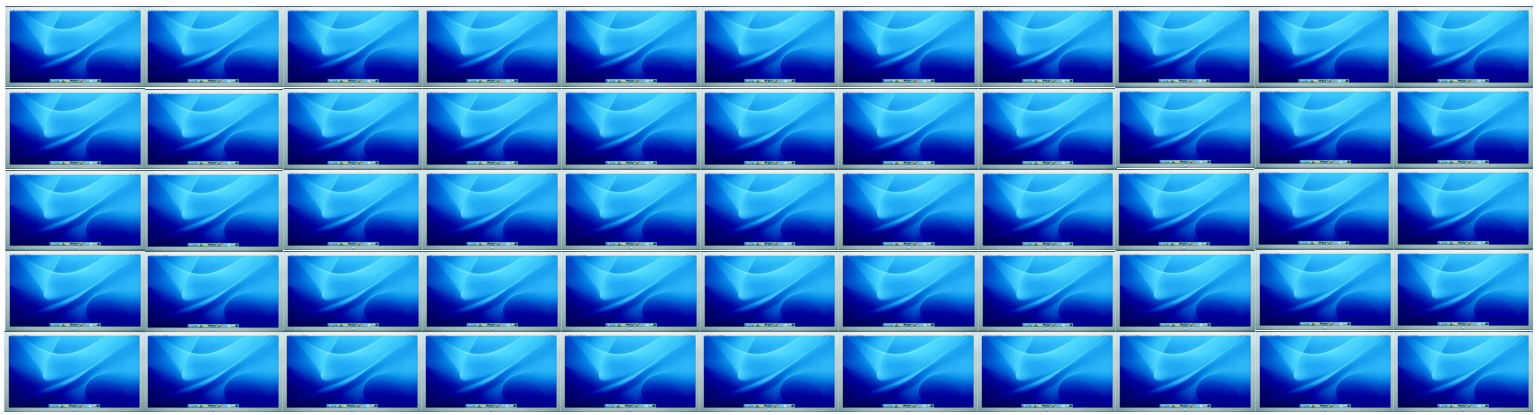
Source: U Washington Research Channel

it2

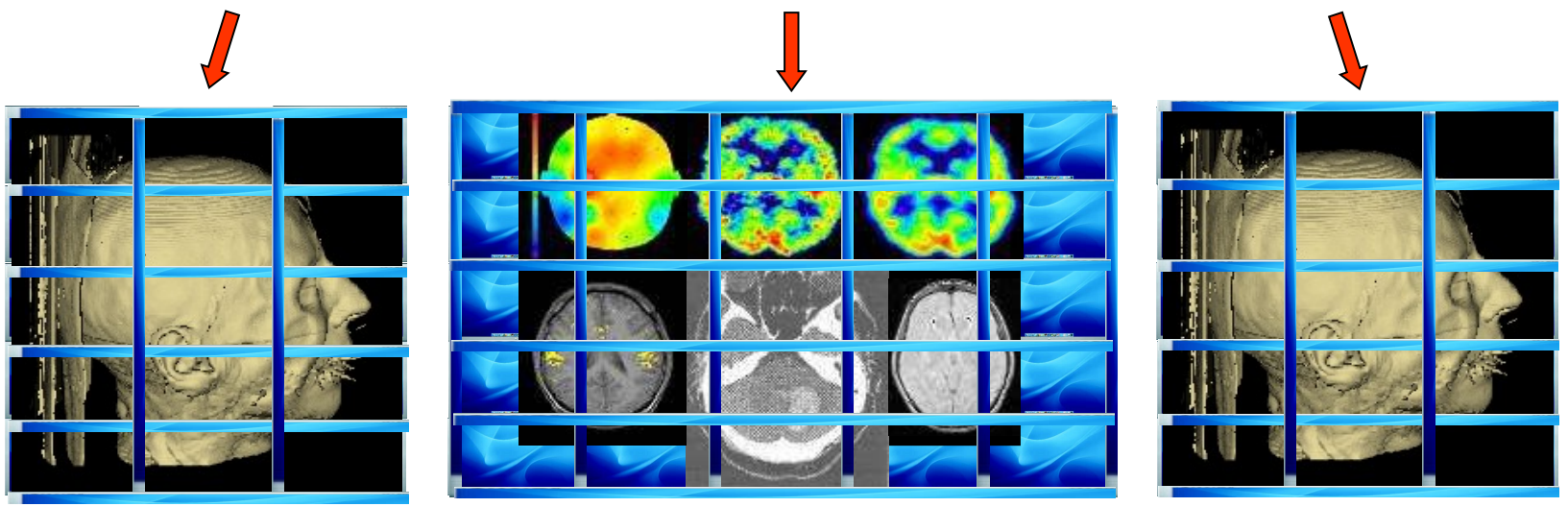
Calit2@UCI HiPerWall will be Linked by OptIPuter to Similar Walls at UCSD and UIC

100 Mpixels

Source: Falko Kuester, UCI



Funded by NSF MRI



OptIPuter

Three Classes of LambdaGrid Applications

- Browsing & Analysis of Multiple Large Remote Data Objects
- Assimilating Data—Linking Supercomputers with Data Sets
- Interacting with Coastal Observatories

OptIPuter

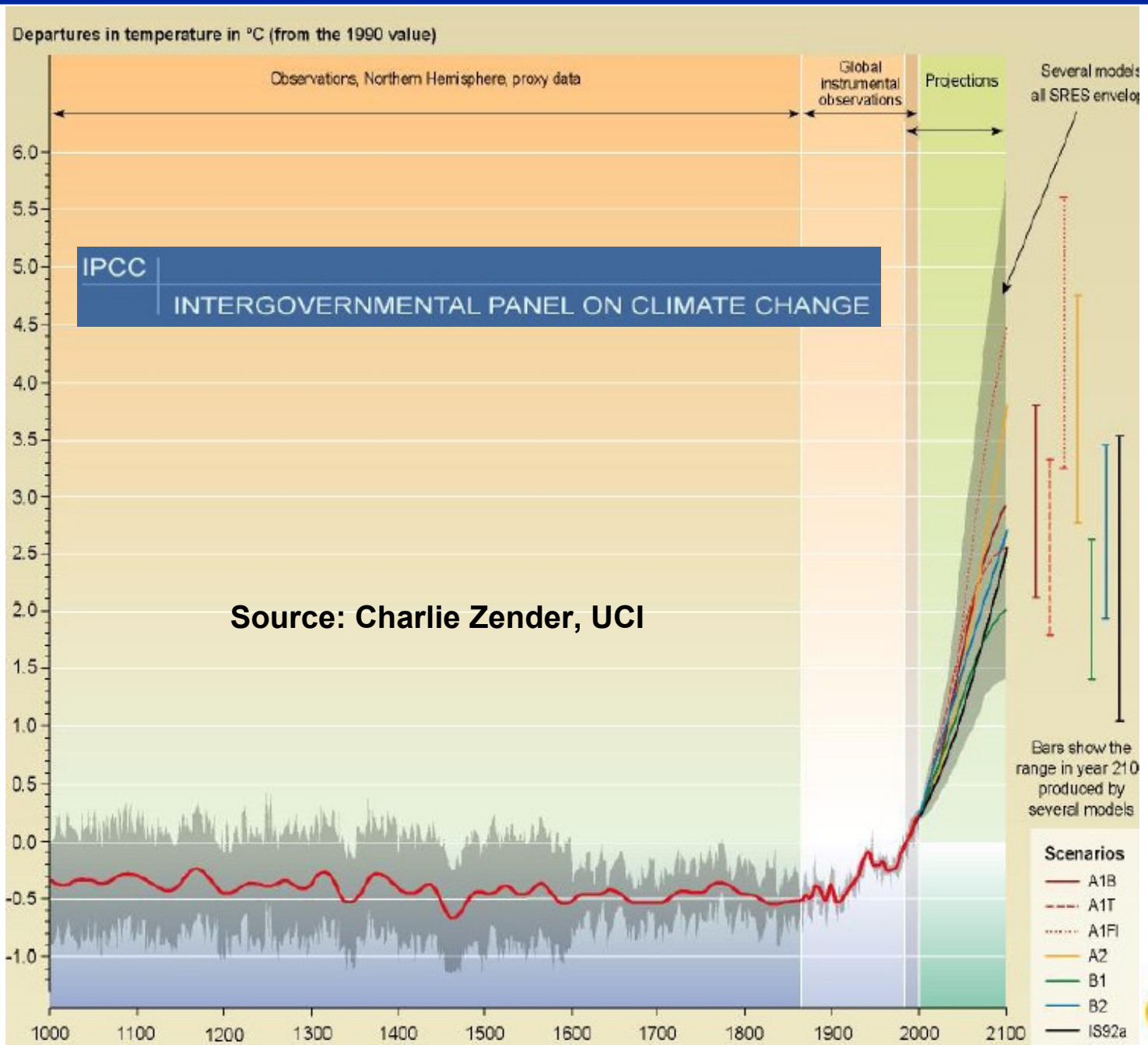
it²

Applying OptIPuter Technologies to Support Global Change Research

- **UCI Earth System Science Modeling Facility (ESMF)**
  - NSF's CISE Science and Engineering Informatics Program Funded ESMF and Calit2 to Improve Distributed Data Reduction & Analysis
    - Calit2 and UCI is Adding ESMF to the OptIPuter Testbed
    - Link to Calt2@UCI HiPerWall
    - Funding UCSD OptIPuter co-PI Phil Papadopoulos' Team
- **ESMF Challenge:**
  - Extend the NCO netCDF Operators Over Calit2 OptIPuter Testbed
    - Exploit MPI-Grid and OPeNDAP
  - Test DDRA on TBs of Data Stored Across the OptIPuter (at UCI and UCSD) and the Earth System Grid (LBNL, NCAR, and ORNL)
- **The Resulting Scientific Data Operator LambdaGrid Toolkit will Support the Next Intergovernmental Panel on Climate Change (IPCC) Assessment Report**

Source: Charlie Zender, UCI

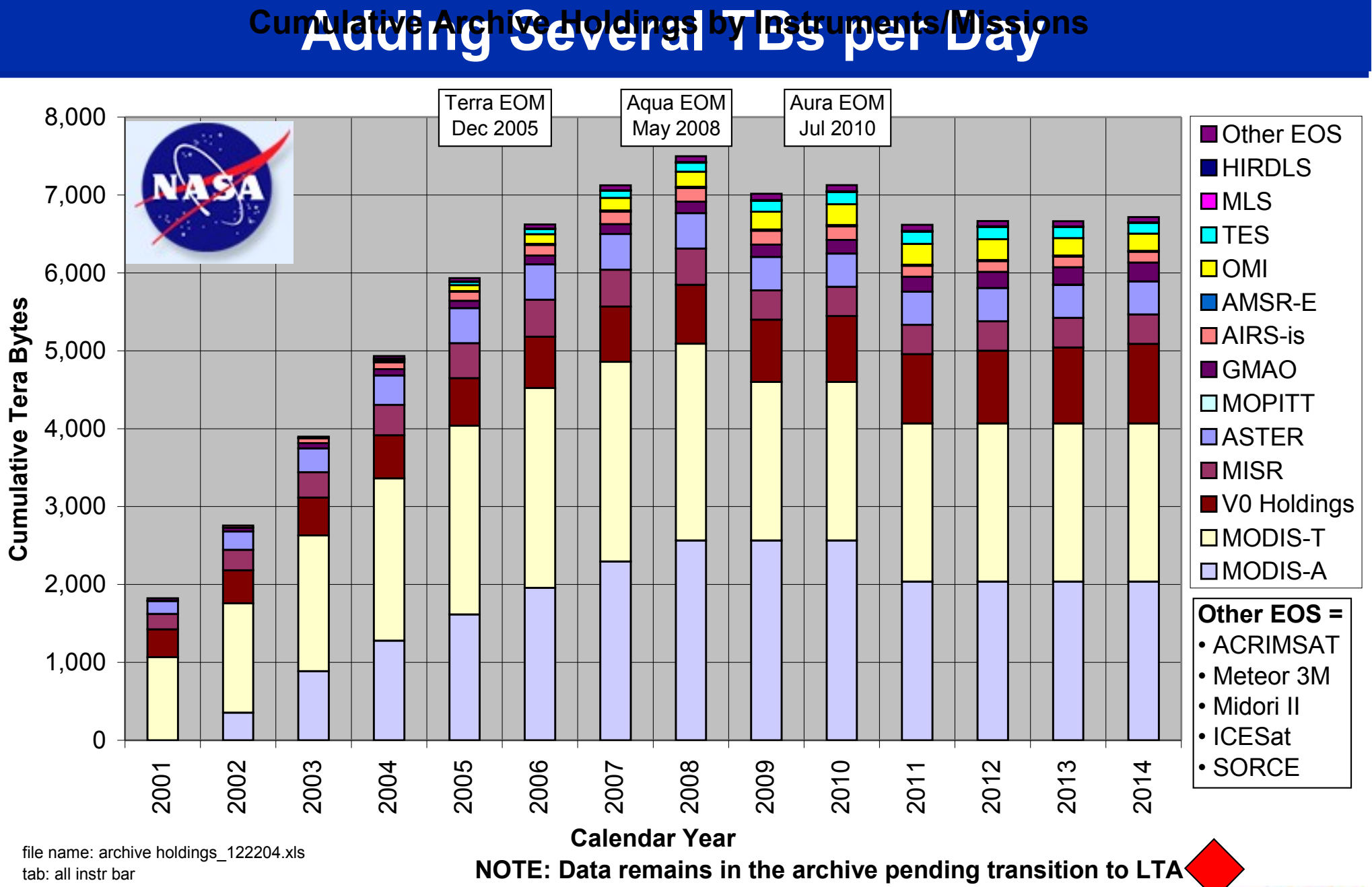
Variations of the Earth Surface Temperature Over One Thousand Years



OptIPuter

it2

Cumulative Earth Observing System Archive -- Adding Several TBs per Day



file name: archive holdings_122204.xls
tab: all instr bar

NOTE: Data remains in the archive pending transition to LTA

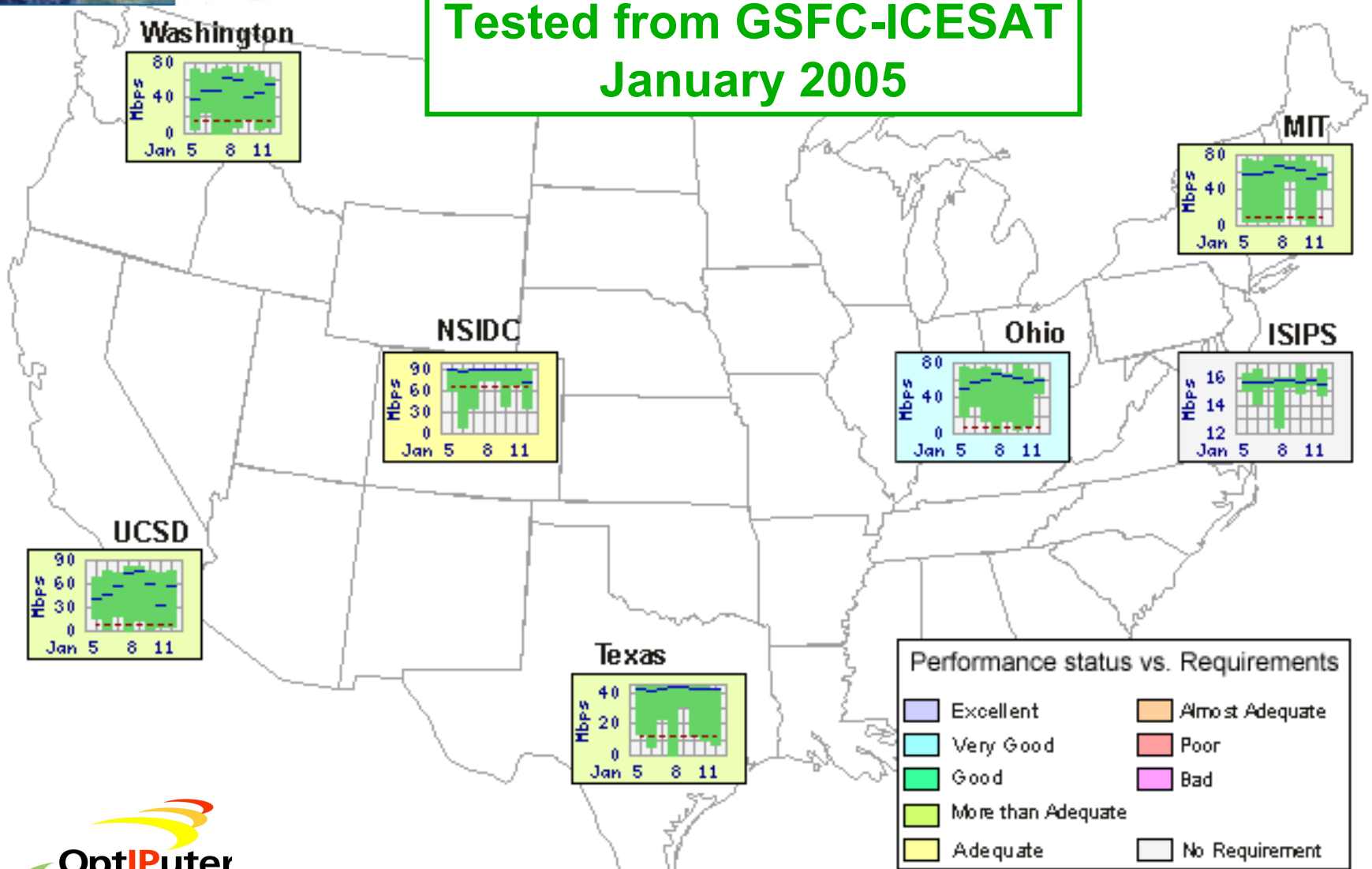
Source: Glenn Iona, EOSDIS Element Evolution Technical Working Group January 6-7, 2005

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

Interactive Retrieval and Hyperwall Display of Earth Sciences Images Using CENIC & NLR

Enables Scientists To Perform Coordinated Studies Of Multiple Remote-Sensing Datasets

Source: Milt Halem & Randall Jones, NASA GSFC & Maxine Brown, UIC EVL

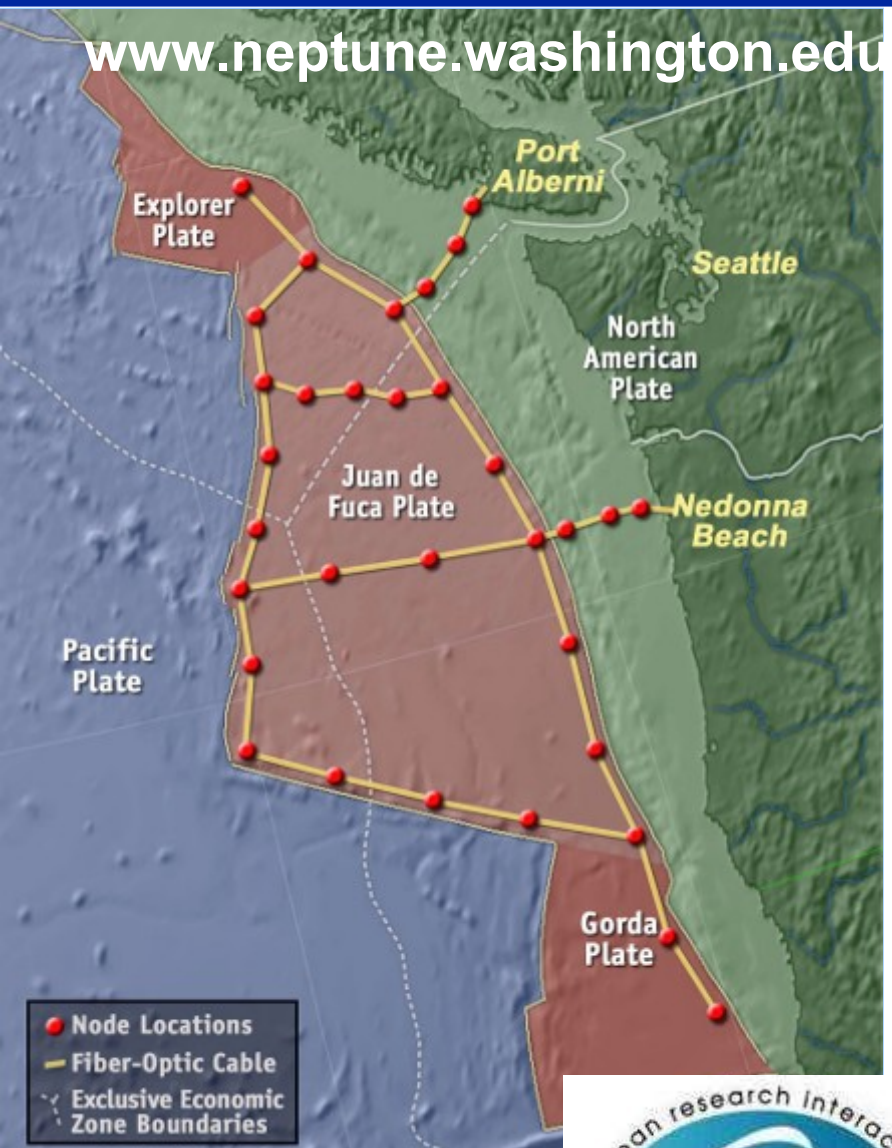




Earth Science Data Sets Created by GSFC's Scientific Visualization Studio were Retrieved Across the NLR in Real Time from OptIPuter Servers in Chicago and San Diego and from GSFC Servers in McLean, VA, and Displayed at the SC2004 in Pittsburgh

http://esdcd.gsfc.nasa.gov/LNetphoto3.html

New OptIPuter Application Driver: Gigabit Fibers on the Ocean Floor



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

- **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**
- **Goal: Prototype Cyberinfrastructure for NSF ORION**

LOOKING--
Integrate Instruments & Sensors
(Real Time Data Sources)
Into a LambdaGrid
Computing Environment
With Web Services Interfaces

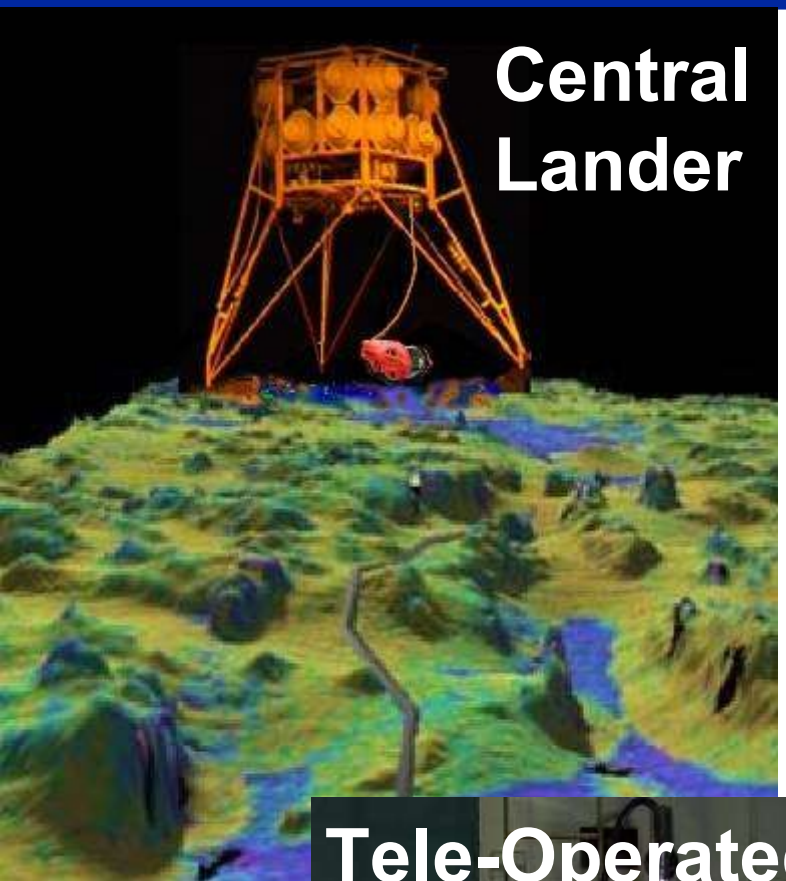
OptIPuter

NSF

ocean research interactive ORION observatory networks

it²

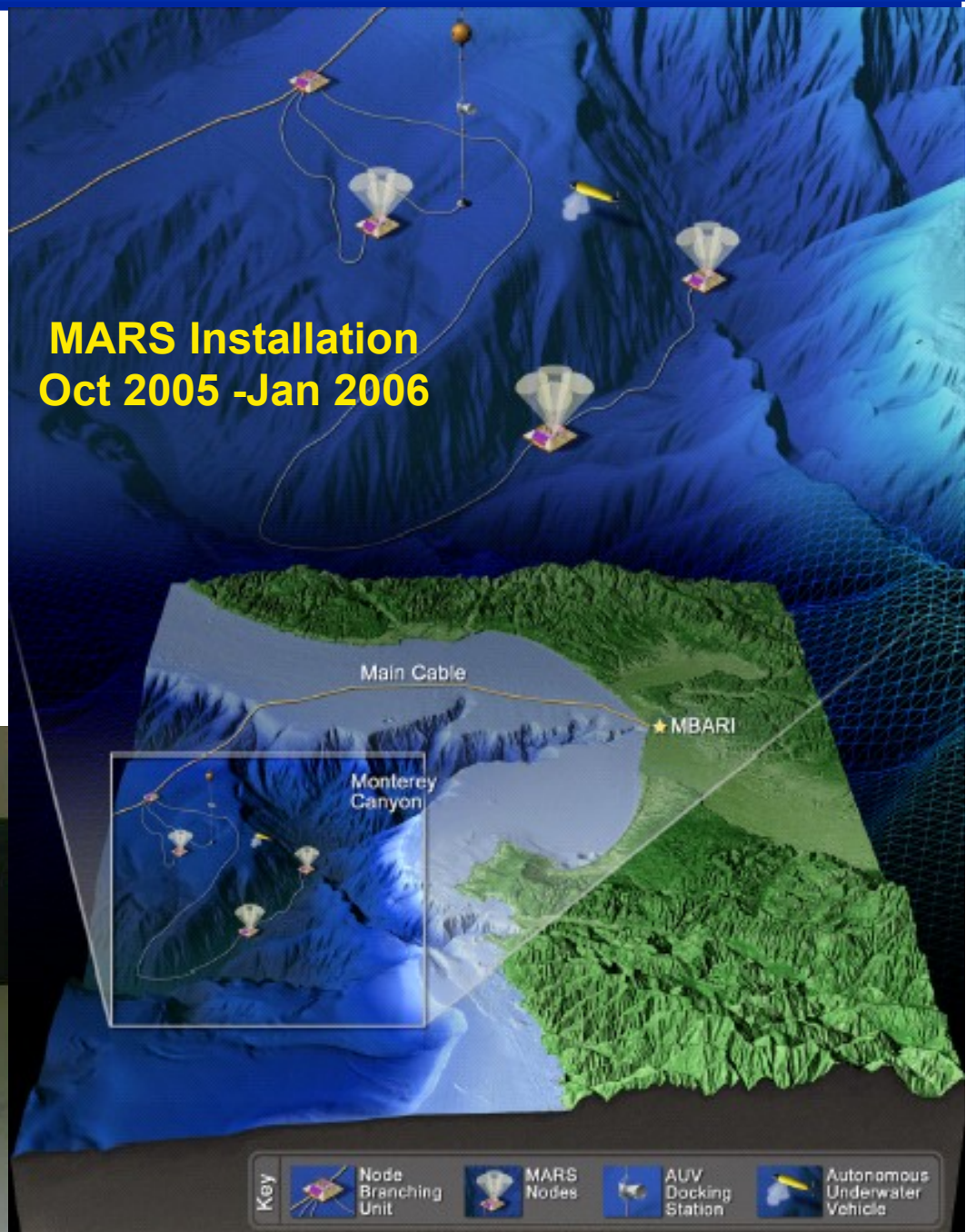
MARS New Gen Cable Observatory Testbed - Capturing Real-Time Basic Environmental Data





Source:
Jim
Bellingham,
MBARI

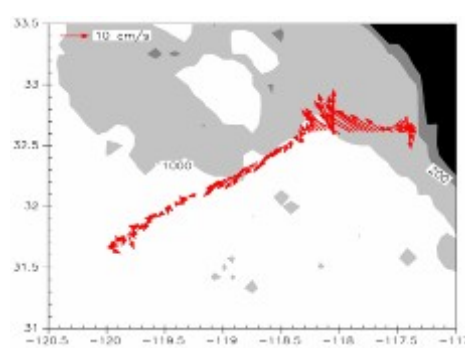
OptIPuter



LOOKING Builds on the Multi- Institutional SCCOOS Program, OptIPuter, and CENIC-XD

- **SCCOOS is Integrating:**
  - Moorings
  - Ships
  - Autonomous Vehicles
  - Satellite Remote Sensing
  - Drifters
  - Long Range HF Radar
  - Near-Shore Waves/Currents (CDIP)
  - COAMPS Wind Model
  - Nested ROMS Models
  - Data Assimilation and Modeling
  - Data Systems

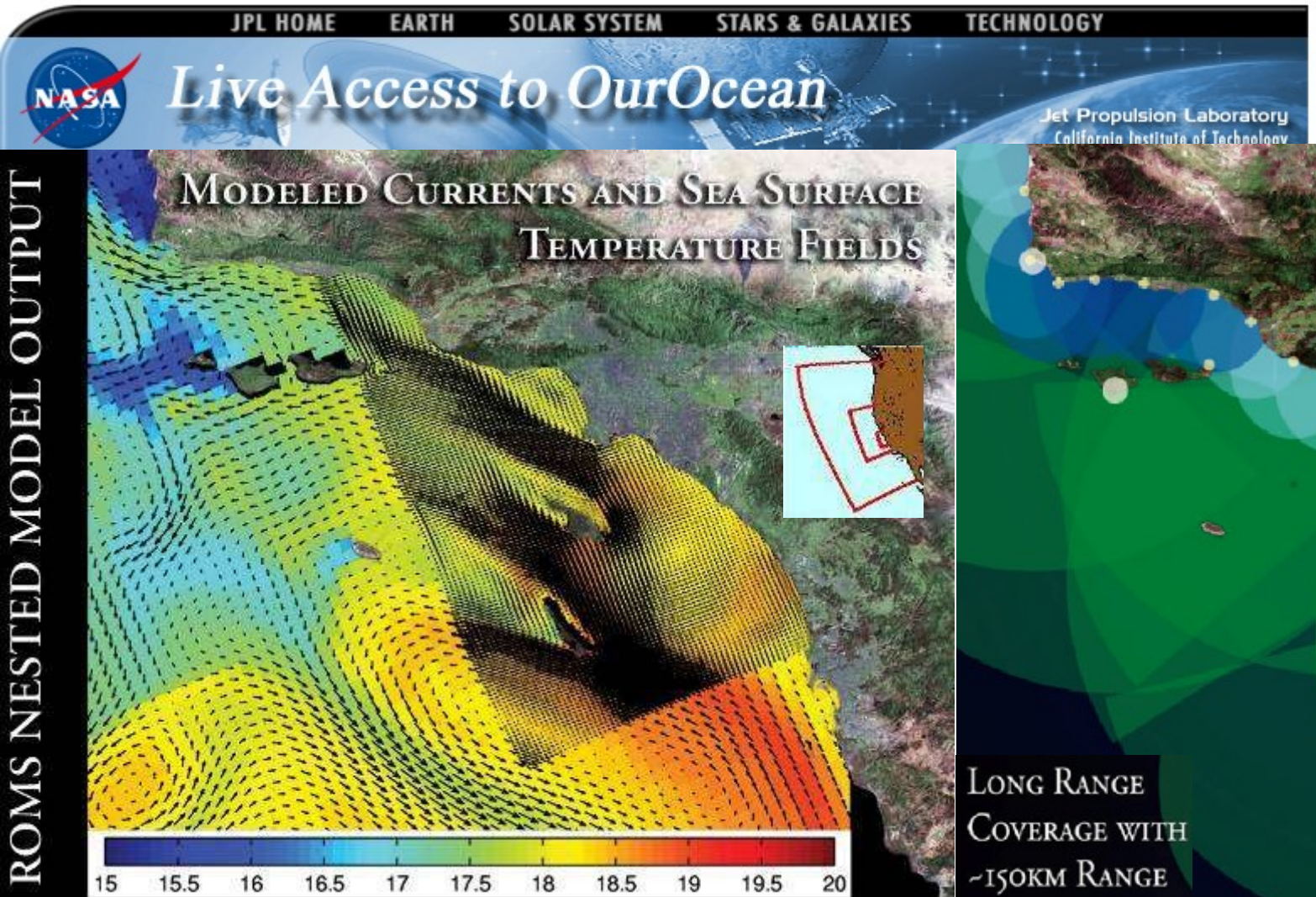




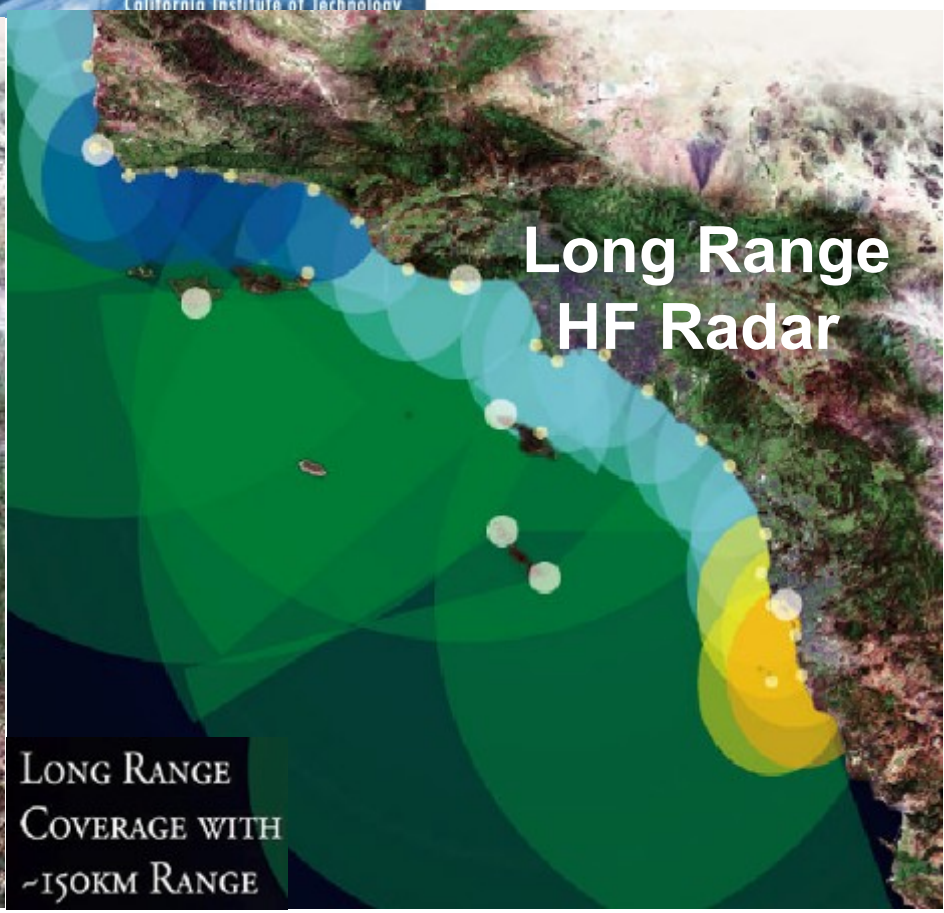


OptIPuter NSF ROADNet

Use OptIPuter to Couple Data Assimilation Models to Remote Data Sources and Analysis



Goal is Real Time Local Digital Ocean Models



JPL ONR MBARI

Regional Ocean Modeling System (ROMS)

http://ourocean.jpl.nasa.gov/

OptIPuter

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