# How Global-Scale Personal Lighwaves are Transforming Scientific Research

**Distinguished Lecturer Series**
**Department of Computer Science**
**University of California, Davis**
**March 8, 2007**

**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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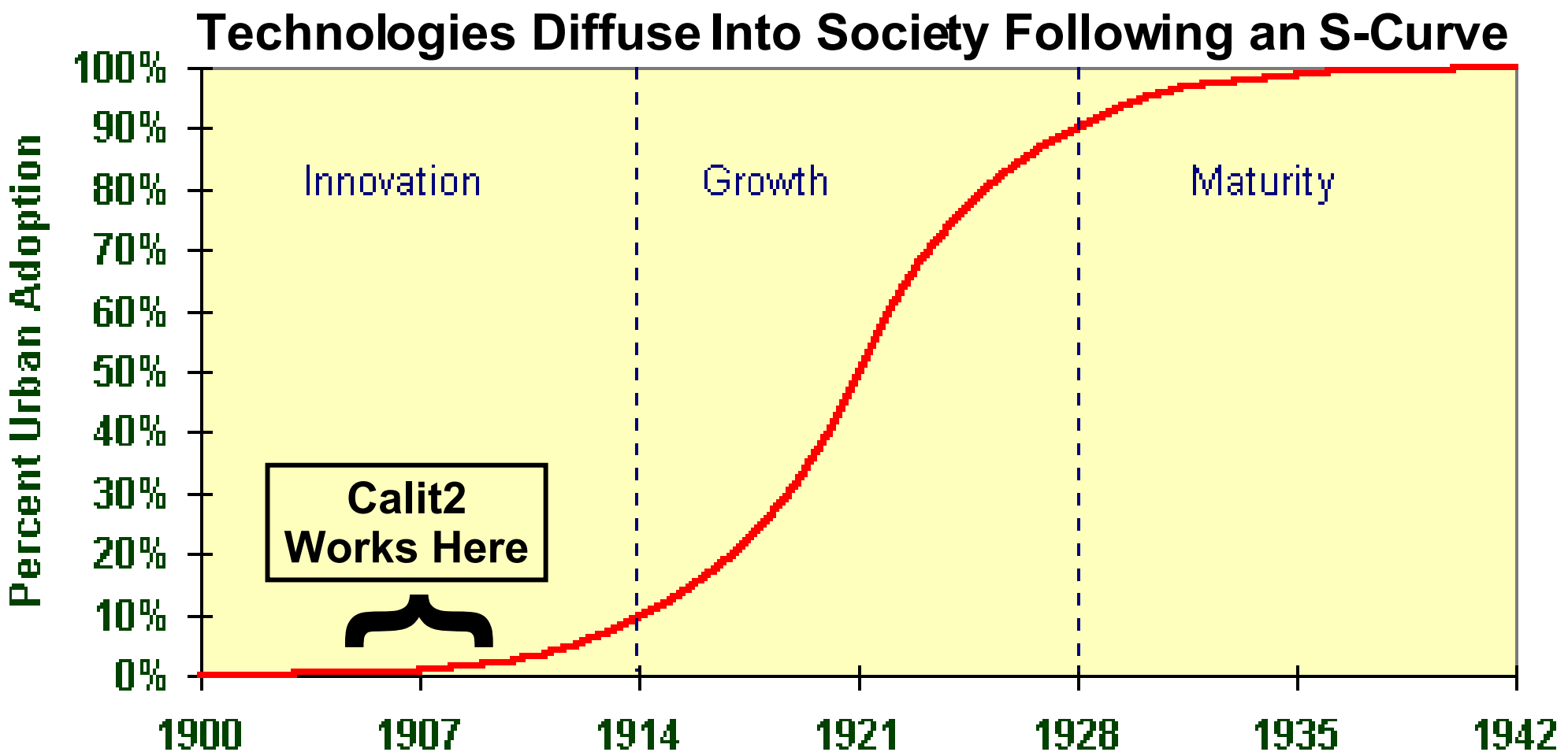
# Abstract

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 beginning to acquire access to high bandwidth lightwaves (termed "lambdas") on fiber optics through the National LambdaRail and the Global Lambda Integrated Facility. These user controlled 1- or 10- Gbps lambdas are providing direct access to global data repositories, scientific instruments, and computational resources from the researcher's Linux clusters in their campus laboratories. This necessitates a new alliance between campus network administrators and high end users to create dedicated lightpaths across and beyond campuses, in addition to traditional shared Internet networks. These dedicated connections have a number of significant advantages over shared internet connections, including high bandwidth, 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 how these user configurable LambdaGrid "metacomputer" global platforms open new frontiers in digital cinema, earth sciences, interactive ocean observatories, and marine microbial metagenomics.

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# Calit2 "Lives in the Future" By Building Systems of Emerging Disruptive Technologies

## Co-Evolution of Personal Automobile and Highway/Petroleum Infrastructure




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Source: Harry Dent, The Great Boom Ahead

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# Two New Calit2 Buildings Provide ~340,000 GSF and New Laboratories for "Living in the Future"




- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks
  - International Conferences and Testbeds
- New Laboratories
  - Nanotechnology
  - Virtual Reality, Digital Cinema



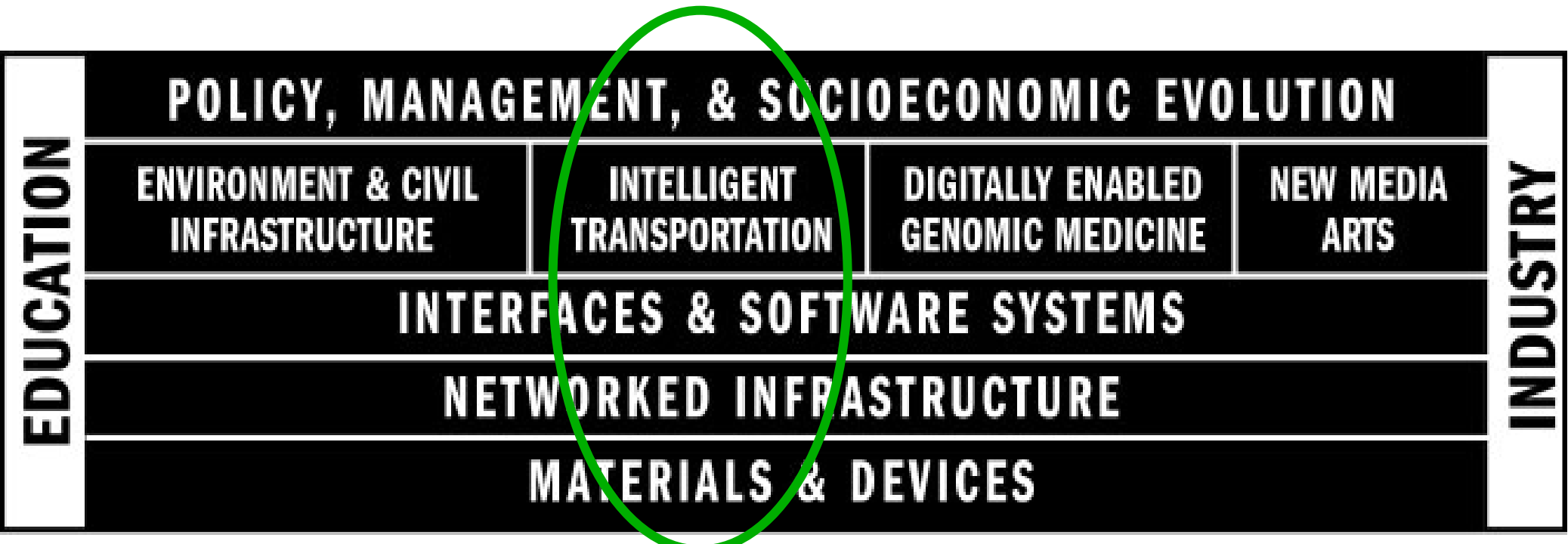

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**Preparing for a World in Which Distance is Eliminated…**

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# Calit2--A Systems Approach to the Future of the Internet and its Transformation of Our Society

**Calit2 Has Assembled a Complex Social Network of Over 350 UC San Diego & UC Irvine Faculty Working in Multidisciplinary Teams With Staff, Students, Industry, and the Community**




**Integrating Technology Consumers and Producers Into "Living Laboratories"**

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**www.calit2.net**

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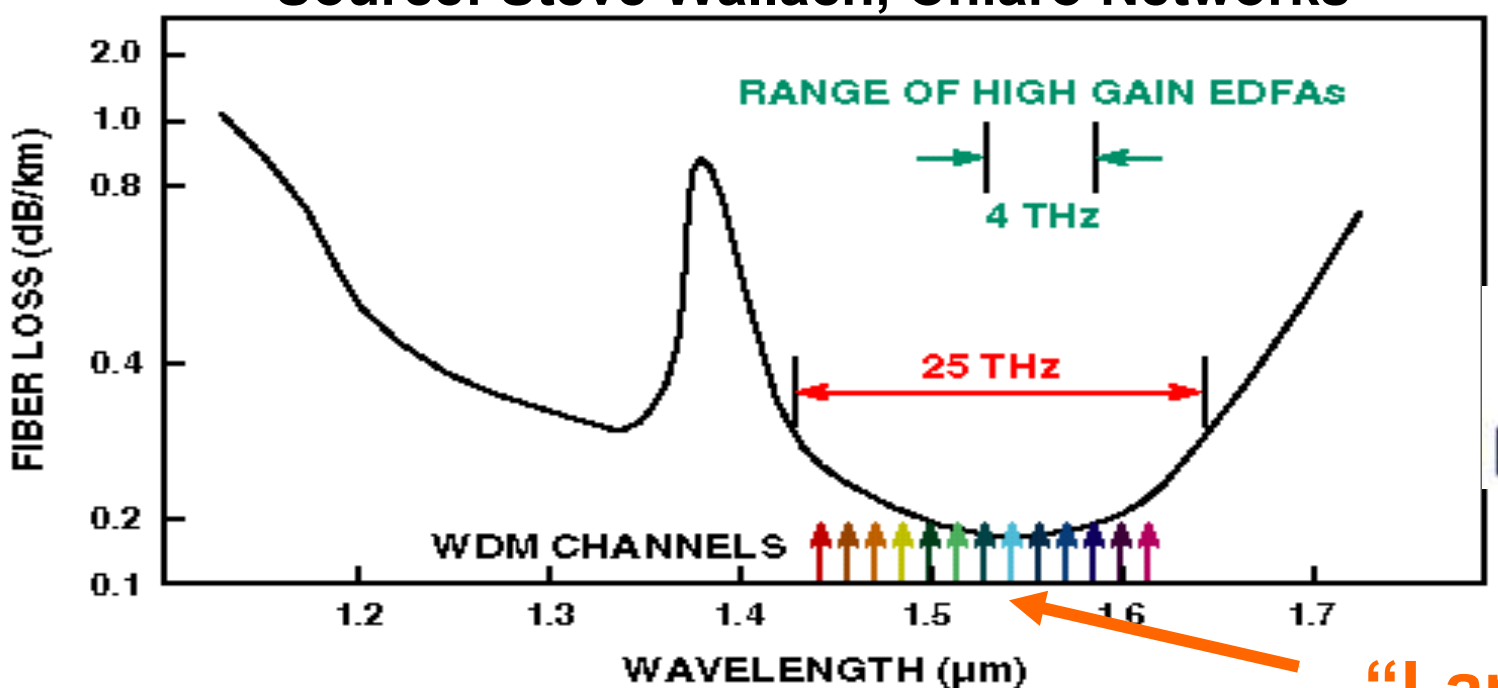
# Dedicated Optical Channels Makes High Performance Cyberinfrastructure Possible

## WAVELENGTH DIVISION MULTIPLEXING (WDM)

**10 Gbps per User ~ 200x Shared Internet Throughput**

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

**Source: Steve Wallach, Chiaro Networks**




CHIARO

**"Lambdas"**

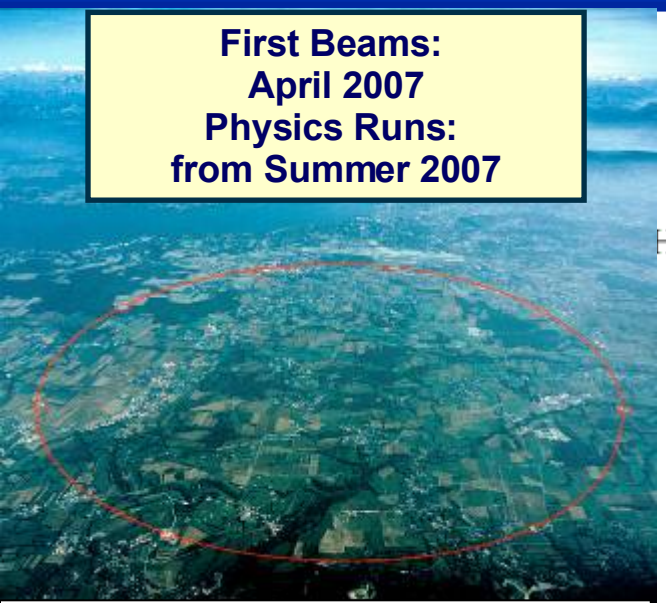
**Parallel Lambdas are Driving Optical Networking The Way Parallel Processors Drove 1990s Computing**

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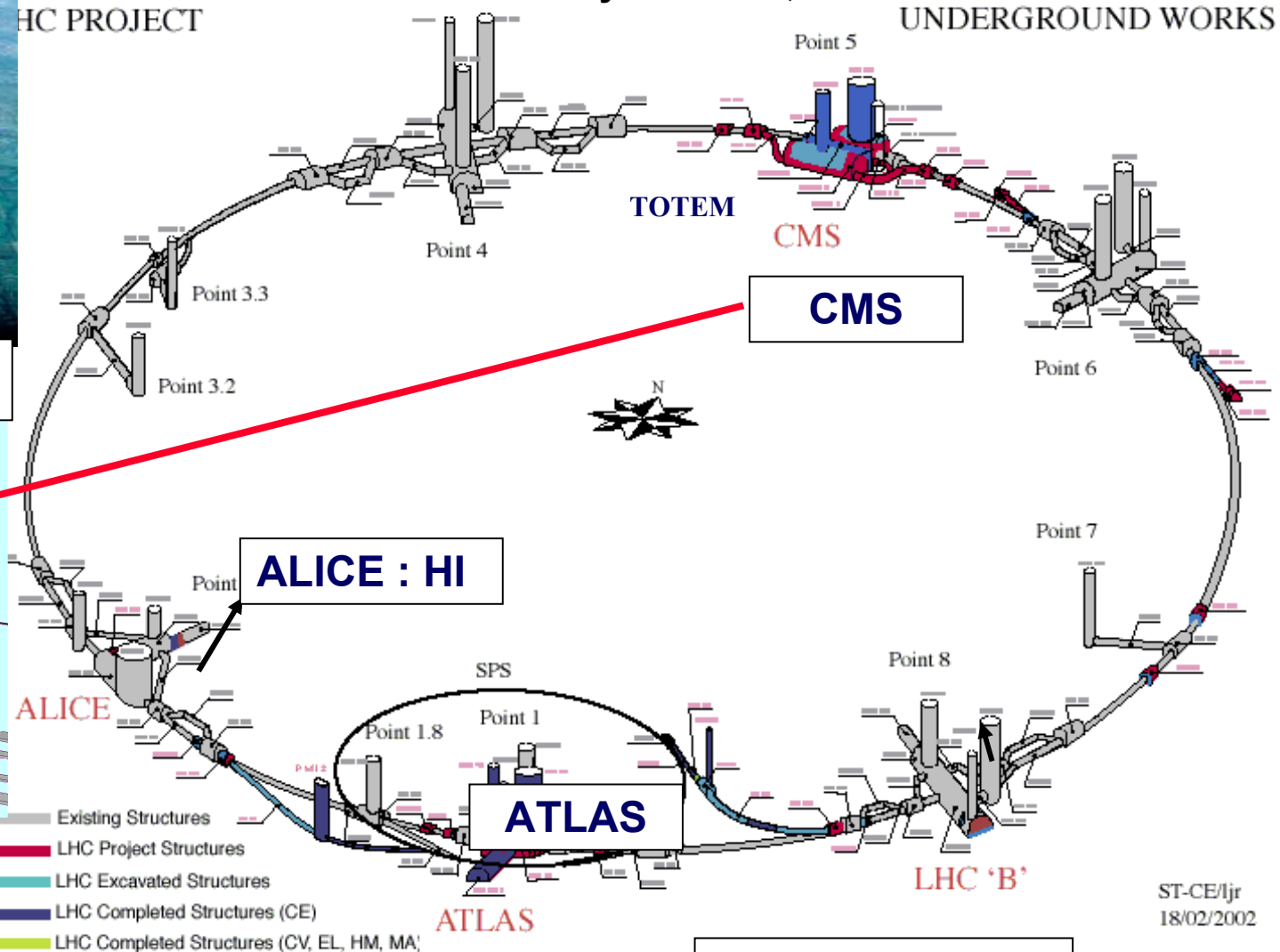
# Large Hadron Collider (LHC)
# e-Science Driving Global Cyberinfrastructure

**First Beams:**
**April 2007**
**Physics Runs:**
**from Summer 2007**

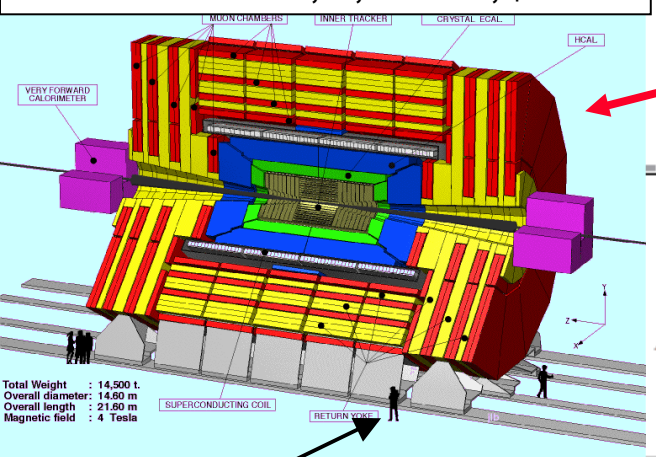


- **pp $\sqrt{s}$ =14 TeV L=$10^{34}$ cm$^{-2}$ s$^{-1}$**
- **27 km Tunnel in Switzerland & France**

**Source: Harvey Newman, Caltech**




**LHC CMS detector**
**15m X 15m X 22m,12,500 tons, $700M**




human (for scale)

**CMS**

**ALICE : HI**

**ATLAS**

**LHCb: B-physics**

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**Source: Bill Johnson, DoE**

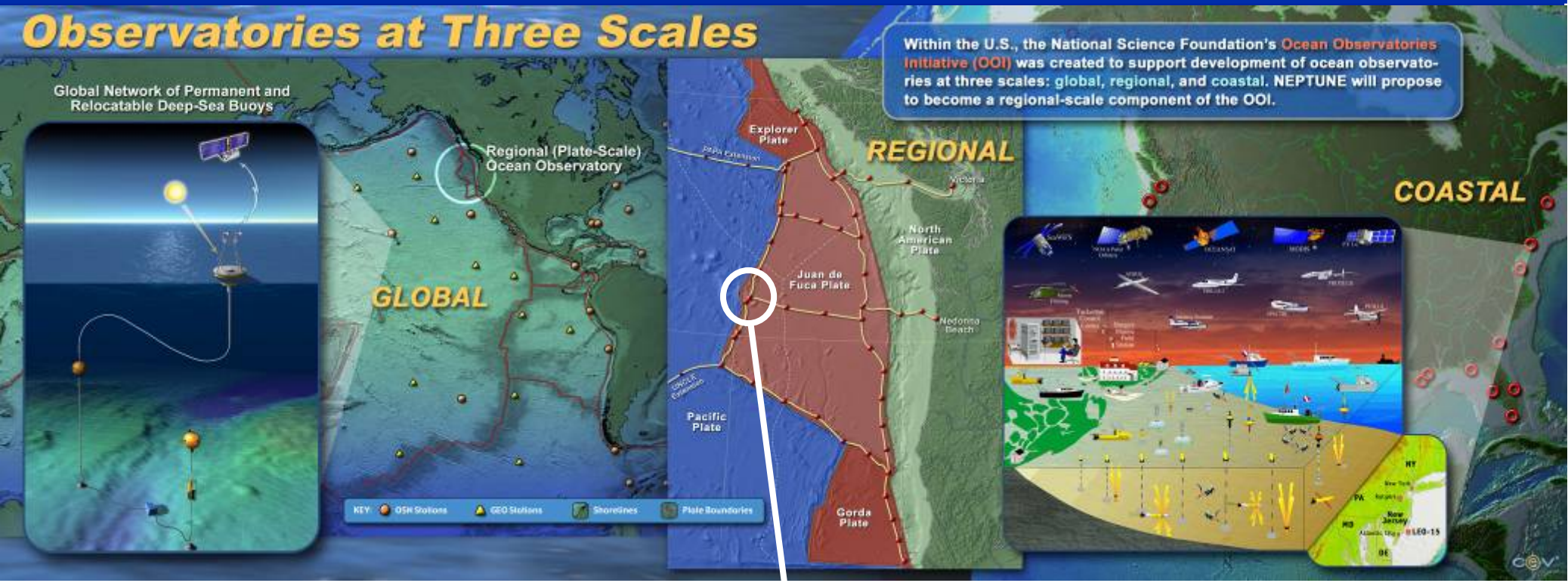
# High Energy and Nuclear Physics
# A Terabit/s WAN by 2013!

| Year | Production | Experimental | Remarks |
|---|---|---|---|
| 2001 | 0.155 | 0.622-2.5 | SONET/SDH |
| 2002 | 0.622 | 2.5 | SONET/SDH<br>DWDM; GigE Integ. |
| 2003 | 2.5 | 10 | DWDM; 1 + 10 GigE<br>Integration |
| 2005-6 | 10-20 | 2-4 X 10 | λ Switch;<br>λ Provisioning |
| 2007-8 | 30-40 | ~100 or<br>2 X 40 Gbps | 1st Gen. λ Grids |
| 2009-10 | 60-80 | ~5 X 40 or<br>~2 X 100 | 40 or 100 Gbps λ<br>Switching |
| 2011-12 | ~5 X 40 or<br>~2 X 100 | ~25 X 40 or<br>~10 X 100 | 2nd Gen λ Grids<br>Terabit Networks |
| 2013-14 | ~Terabit | ~MultiTbps | ~Fill One Fiber |

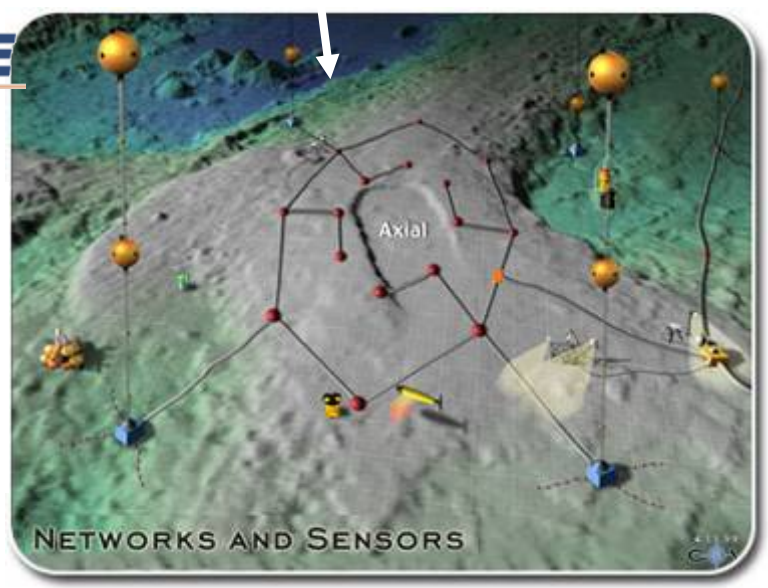
Source: Harvey Newman, Caltech

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# NSF's Ocean Observatories Initiative (OOI) Envisions Global, Regional, and Coastal Scales




NEPTUNE




LEO15 Inset Courtesy of Rutgers University, Institute of Marine and Coastal Sciences

NSF

ocean research interactive ORION observatory networks

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# Gigabit Fibers on the Ocean Floor -- Controlling Sensors and HDTV Cameras Remotely




**LOOKING is Driven By NEPTUNE CI Requirements**

**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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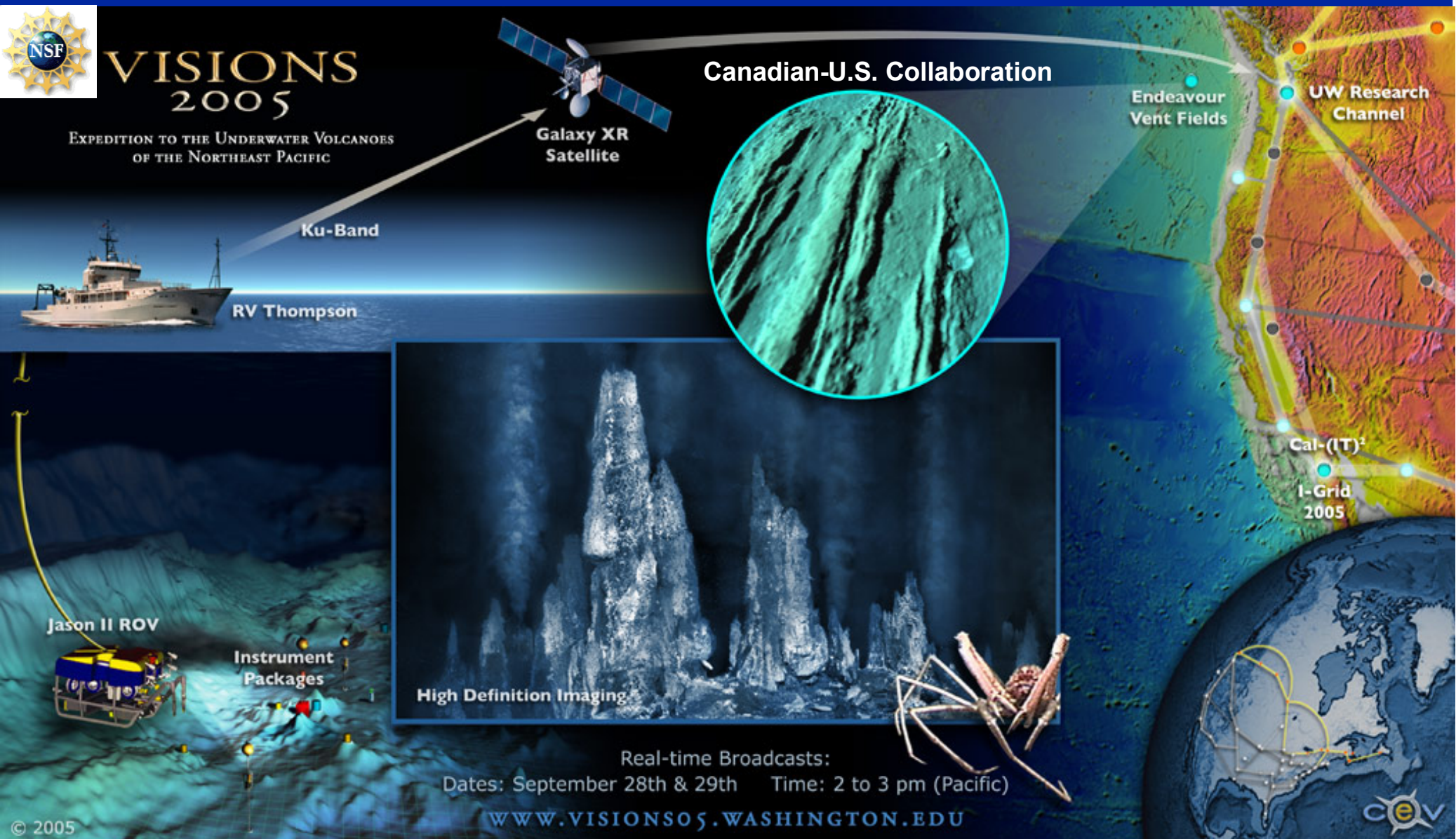
NSF

ocean research interactive ORION observatory networks

**Making Management of Gigabit Flows Routine**

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




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Source John Delaney & Deborah Kelley, UWash

# High Definition Still Frame of Hydrothermal Vent Ecology 2.3 Km Deep



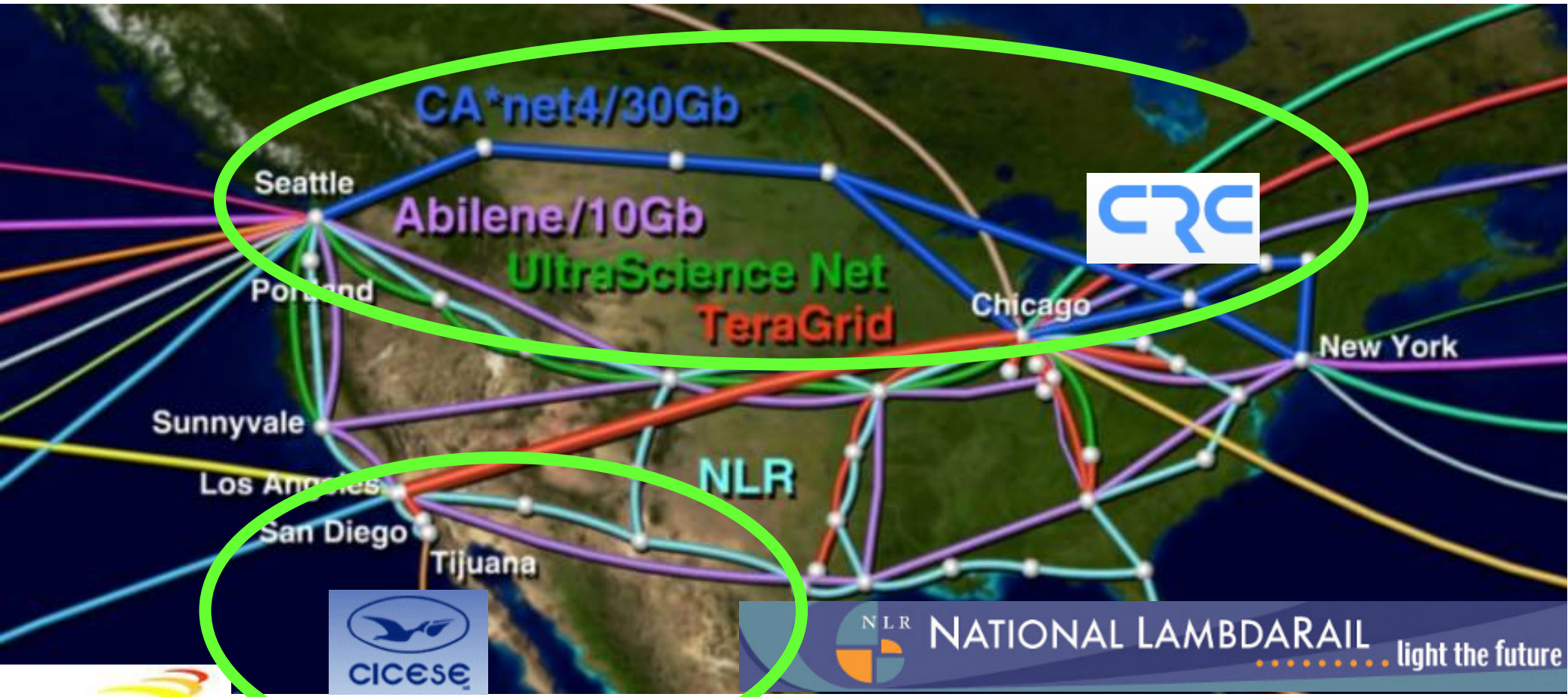

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**White Filamentous Bacteria on 'Pill Bug' Outer Carapace**

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# Creating a North American Superhighway for High Performance Collaboration

**Canada's CRC was Connected via CANARIE to Calit2 in June 2006**
**Next Step is Connecting Mexico's CICESE to Calit2 within Six Months**




OptIPuter

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cudi

cenic
Corporation for Education Network Initiatives in California

CANARIE

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# Calit2 Has Become a Global Hub for Optical 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**

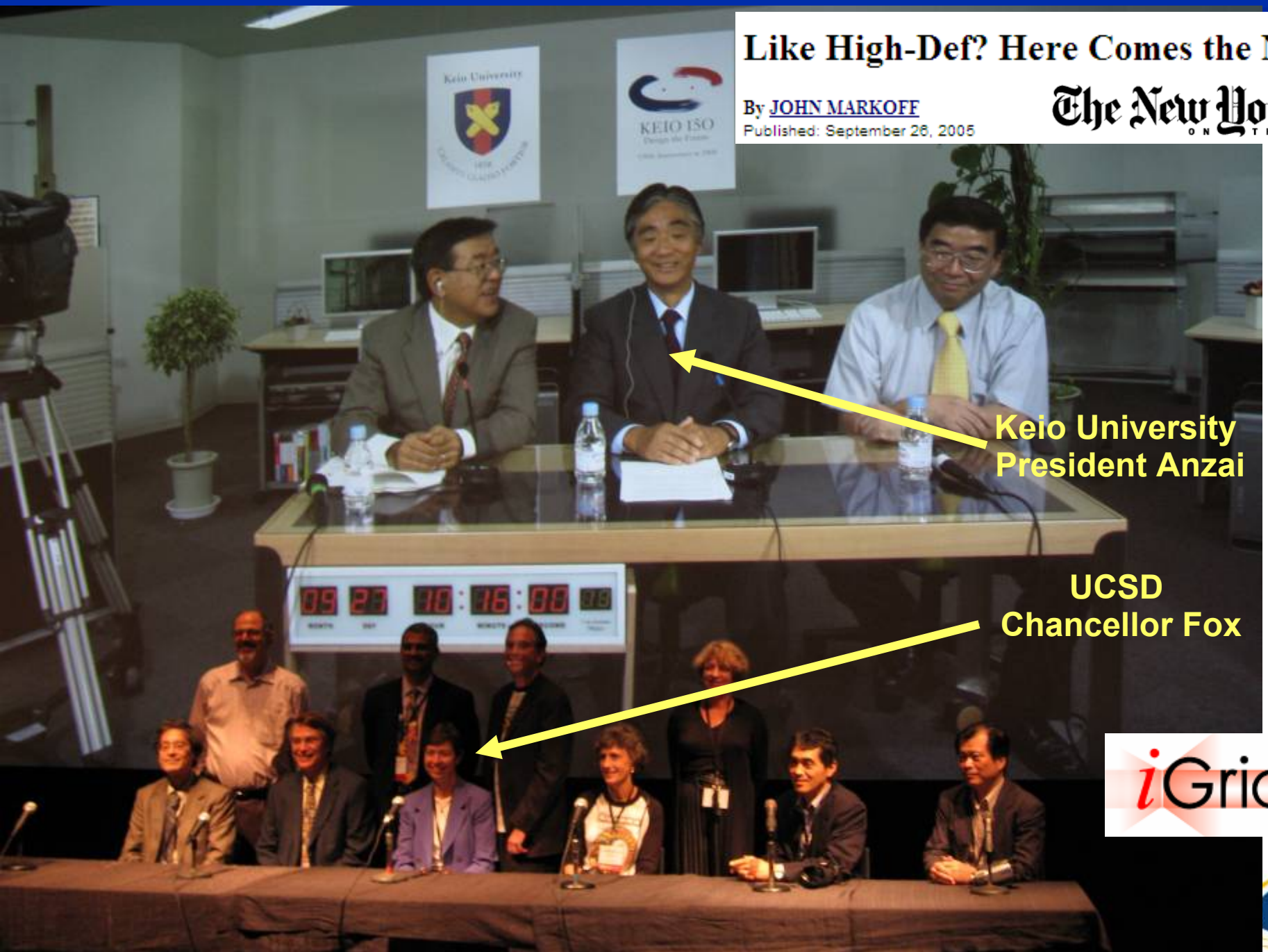
**Calit2 @ University of California, San Diego**

**California Institute for Telecommunications and Information Technology**



**21 Countries Driving 50 Demonstrations**
**1 or 10Gbps to Calit2@UCSD Building**
**Sept 2005**

# iGrid Lambda Digital Cinema Streaming Services: Telepresence Meeting in Calit2 Digital Cinema Auditorium




**Lays Technical Basis for Global Digital Cinema**

**Sony NTT SGI**

iGrid 2005

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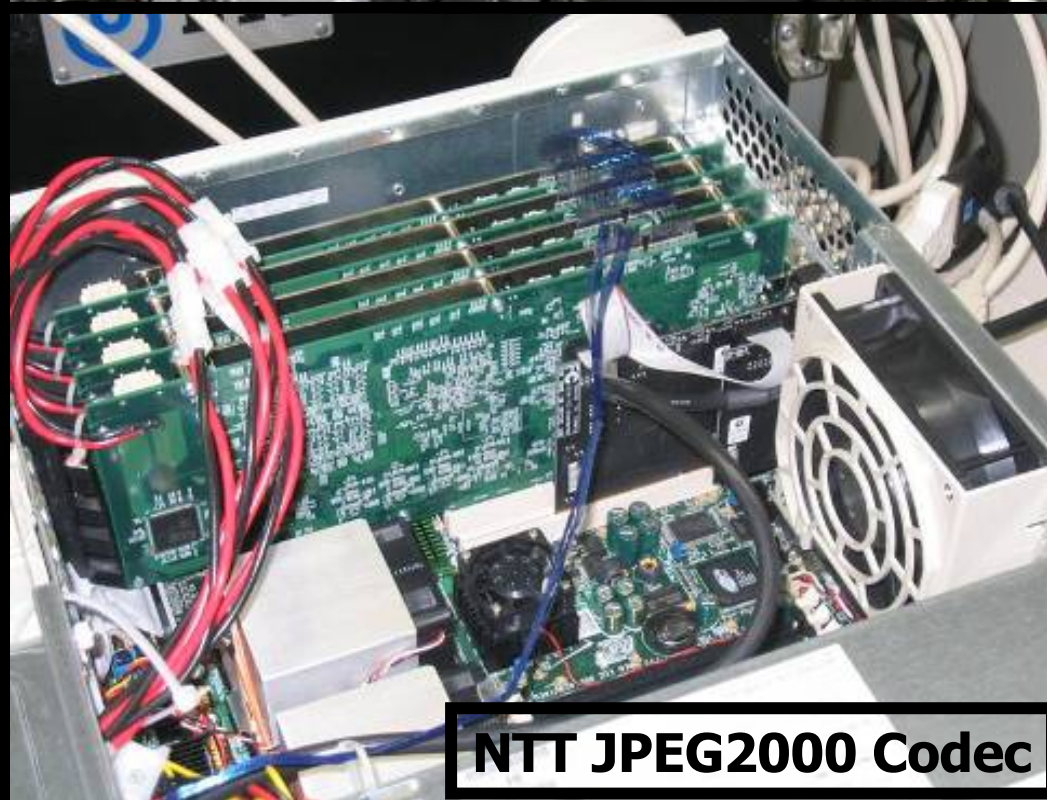
# The CineGrid Node at Keio University, Tokyo Japan





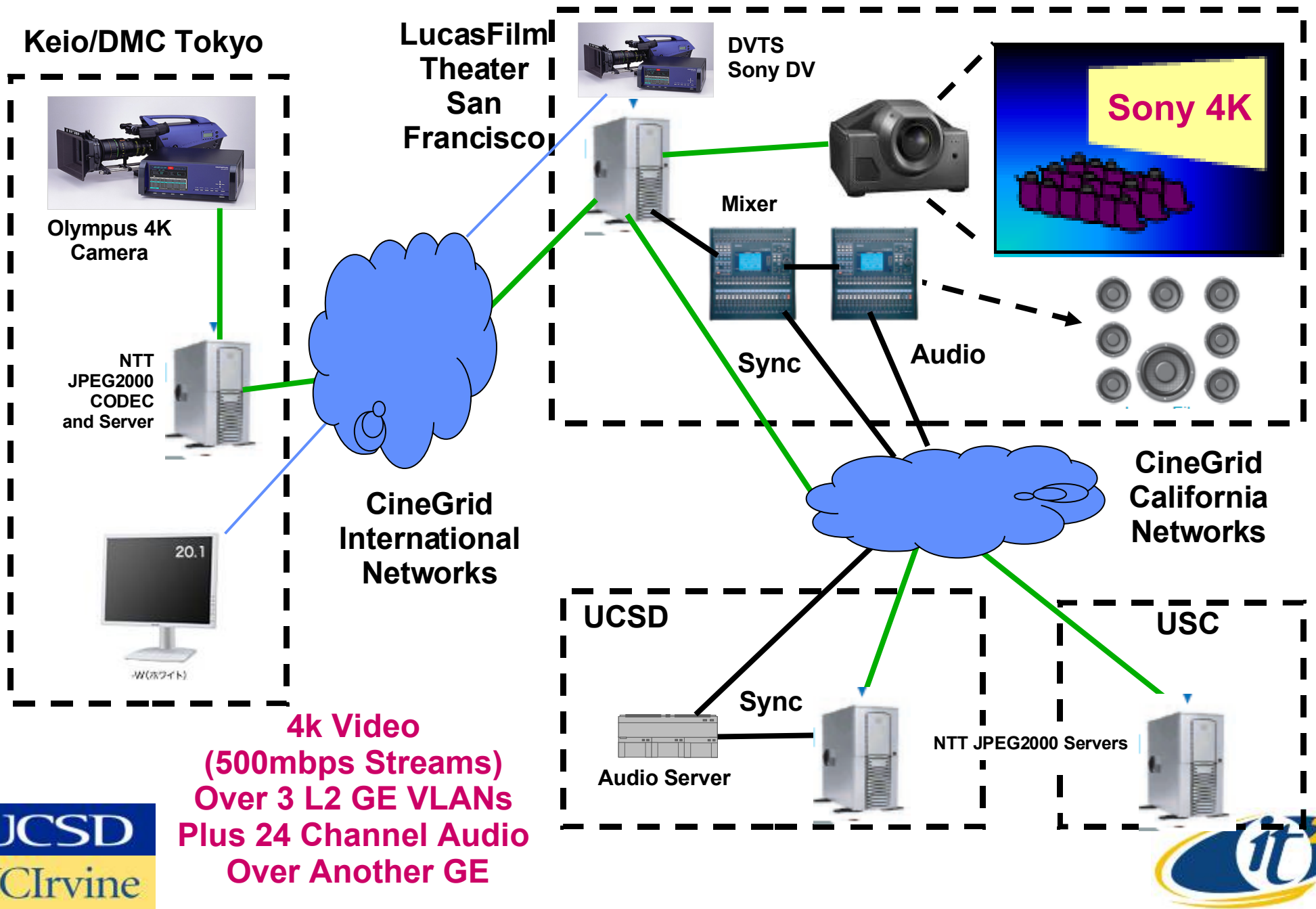




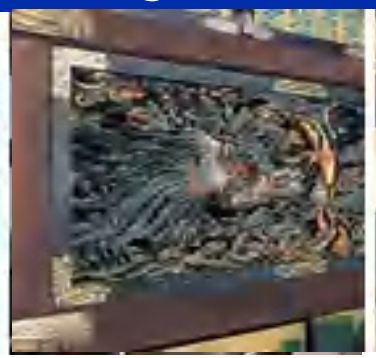
# Audio Engineering Society (AES)/LucasFilm

## Trans-Pacific CineGrid 4K Demonstration, October 8, 2006



# iGrid 2005
# Kyoto Nijo Castle









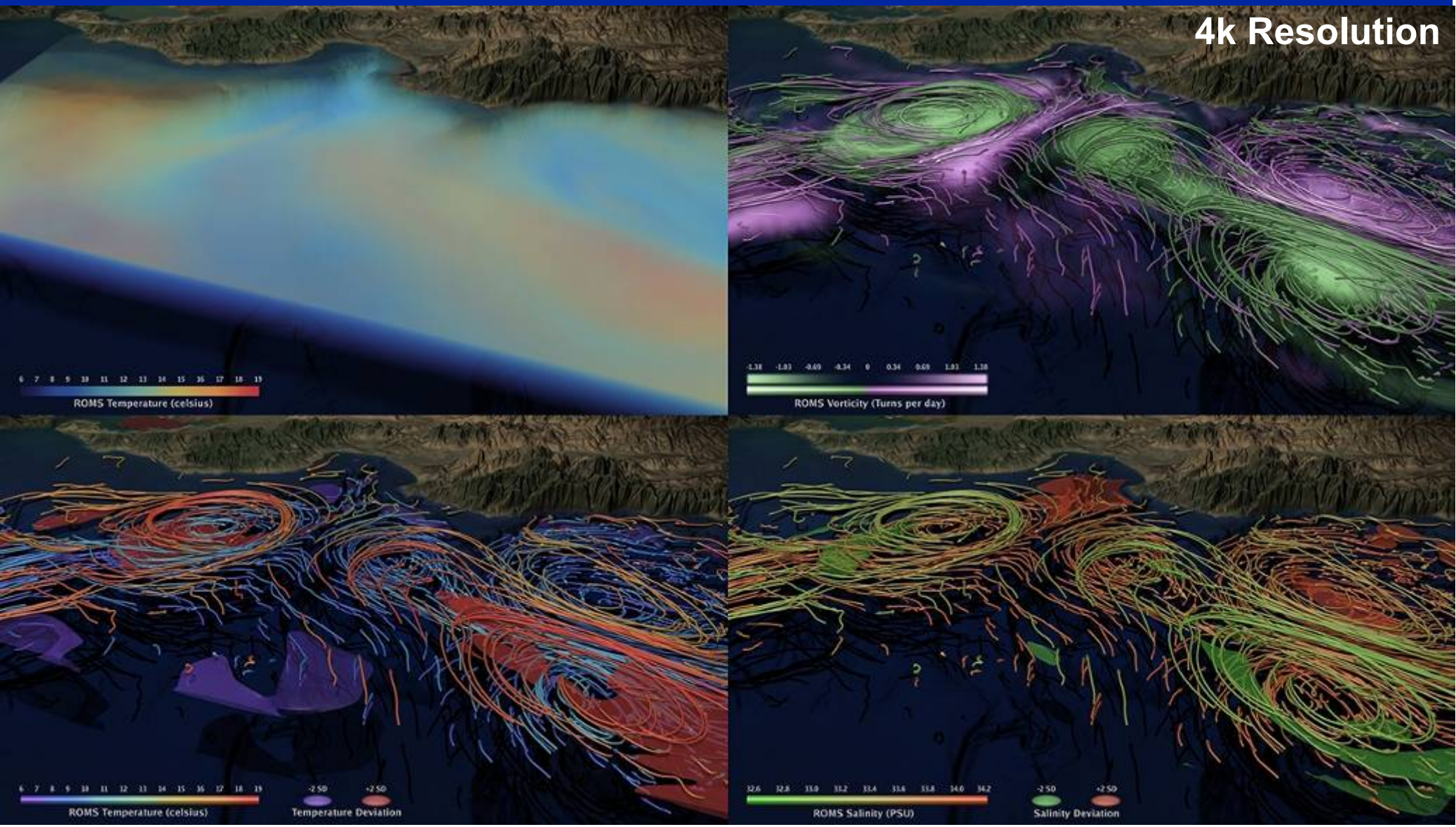
**Source: Toppan Printing**

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

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# The Synergy of Digital Art and Science
# Visualization of JPL Simulation of Monterey Bay




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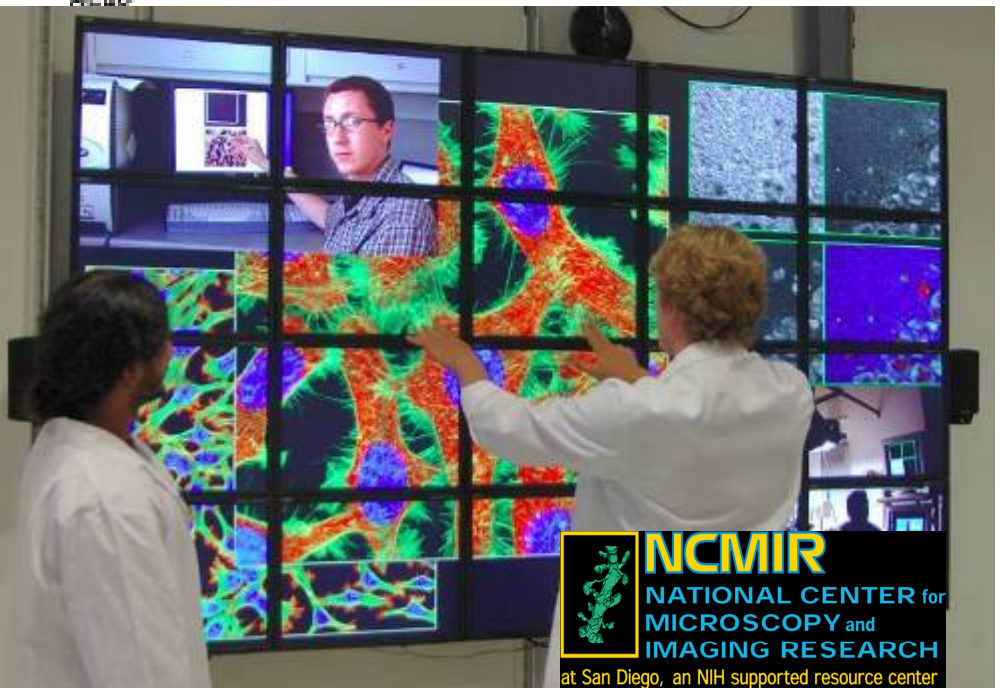
**Source: Donna Cox, Robert Patterson, NCSA**
**Funded by NSF LOOKING Grant**

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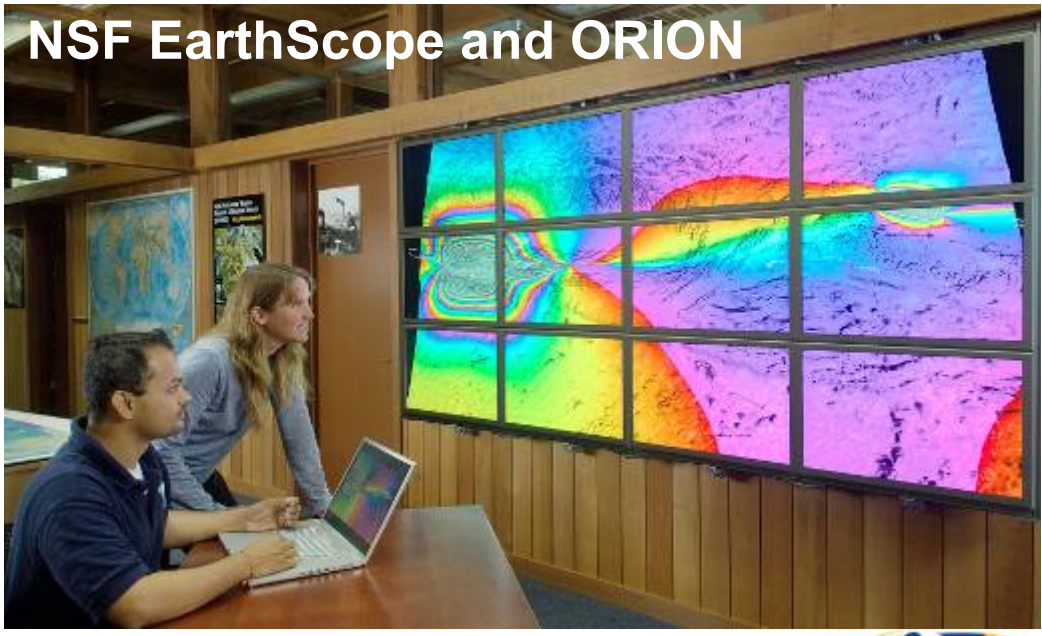
# The OptIPuter Project – Creating High Resolution Portals Over Dedicated Optical Channels to Global Science Data

- **NSF Large Information Technology Research Proposal**
  - Calit2 (UCSD, UCI) and UIC Lead Campuses—Larry Smarr PI
  - Partnering Campuses: SDSC, USC, SDSU, NCSA, NW, TA&M, UvA, SARA, NASA Goddard, KISTI, AIST, CRC(Canada), CICESE (Mexico)
- **Engaged Industrial Partners:**
  - IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent
- **$13.5 Million Over Five Years—Now In the Fifth Year**

NIH Biomedical Informatics Research Network

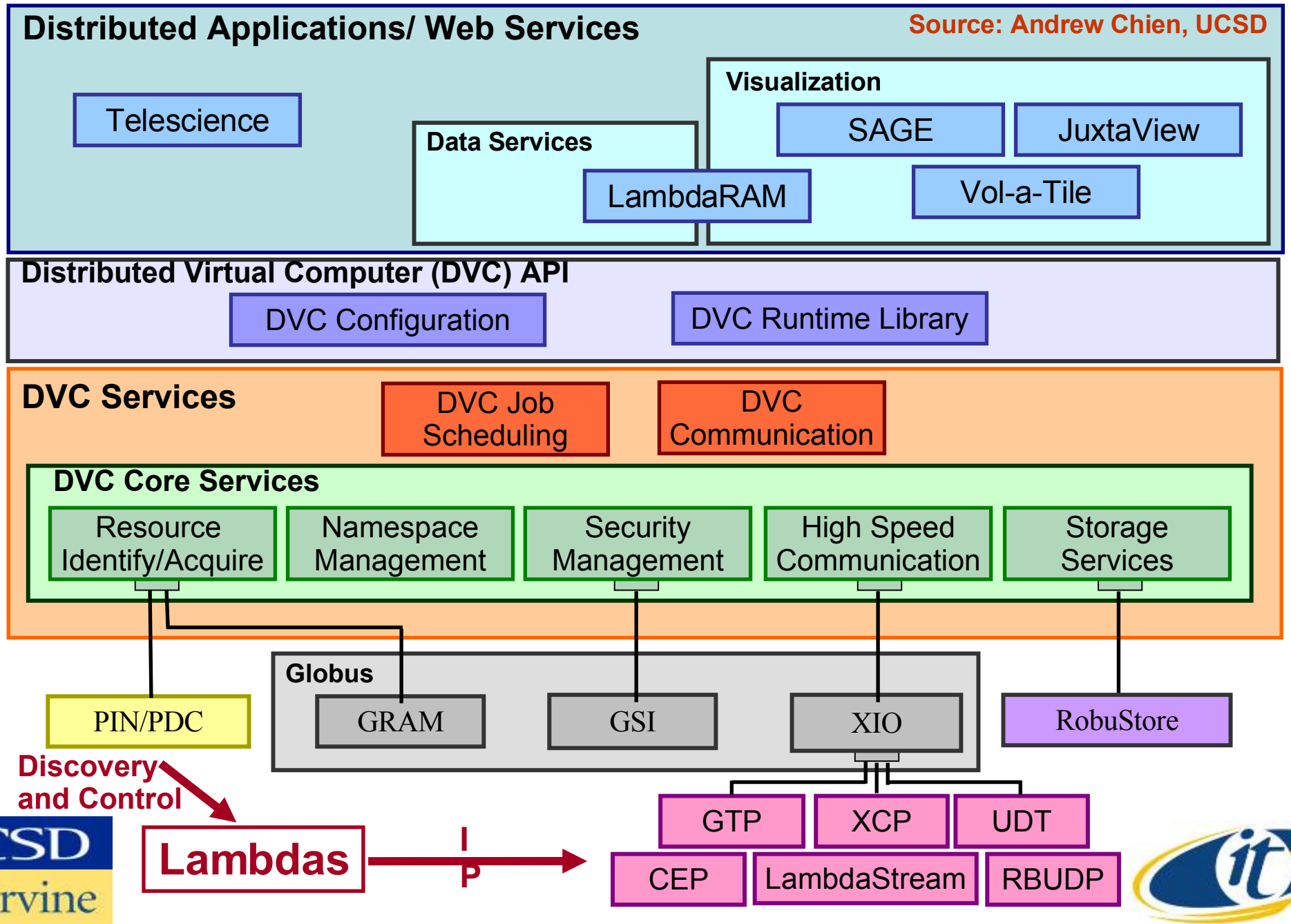



NSF EarthScope and ORION



SCRIPPS INSTITUTION OF OCEANOGRAPHY

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




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# 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





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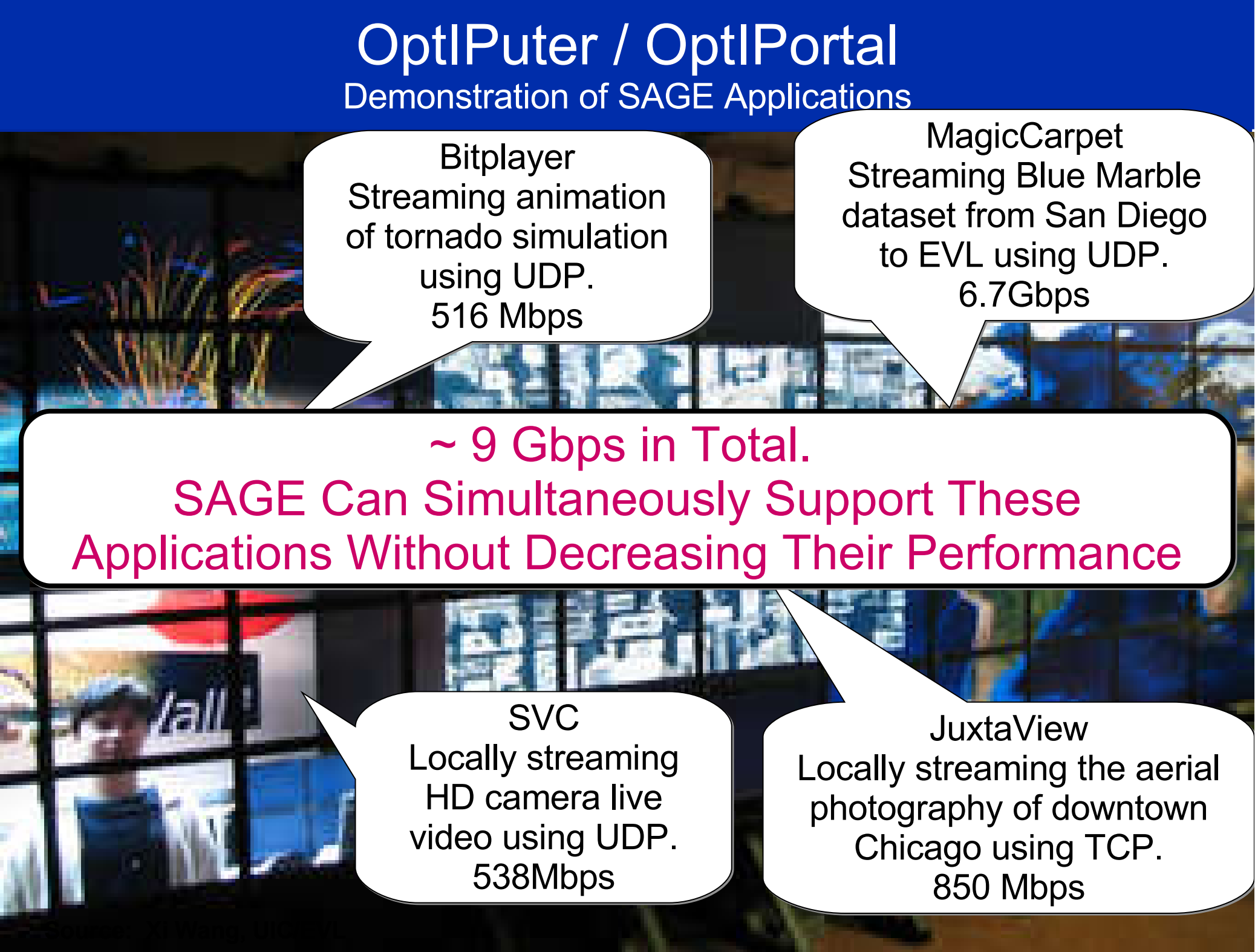
Powered by Rocks ROCKS

Source: Phil Papadopoulos SDSC, Calit2

it²

# OptIPuter / OptIPortal

## Demonstration of SAGE Applications



# SAGE OptIPortal Software: 10 Wireless Laptop Users All Pushing Their Desktops to the EVL OptIPortal--Goal is a Distributed Gigapixel in 2007



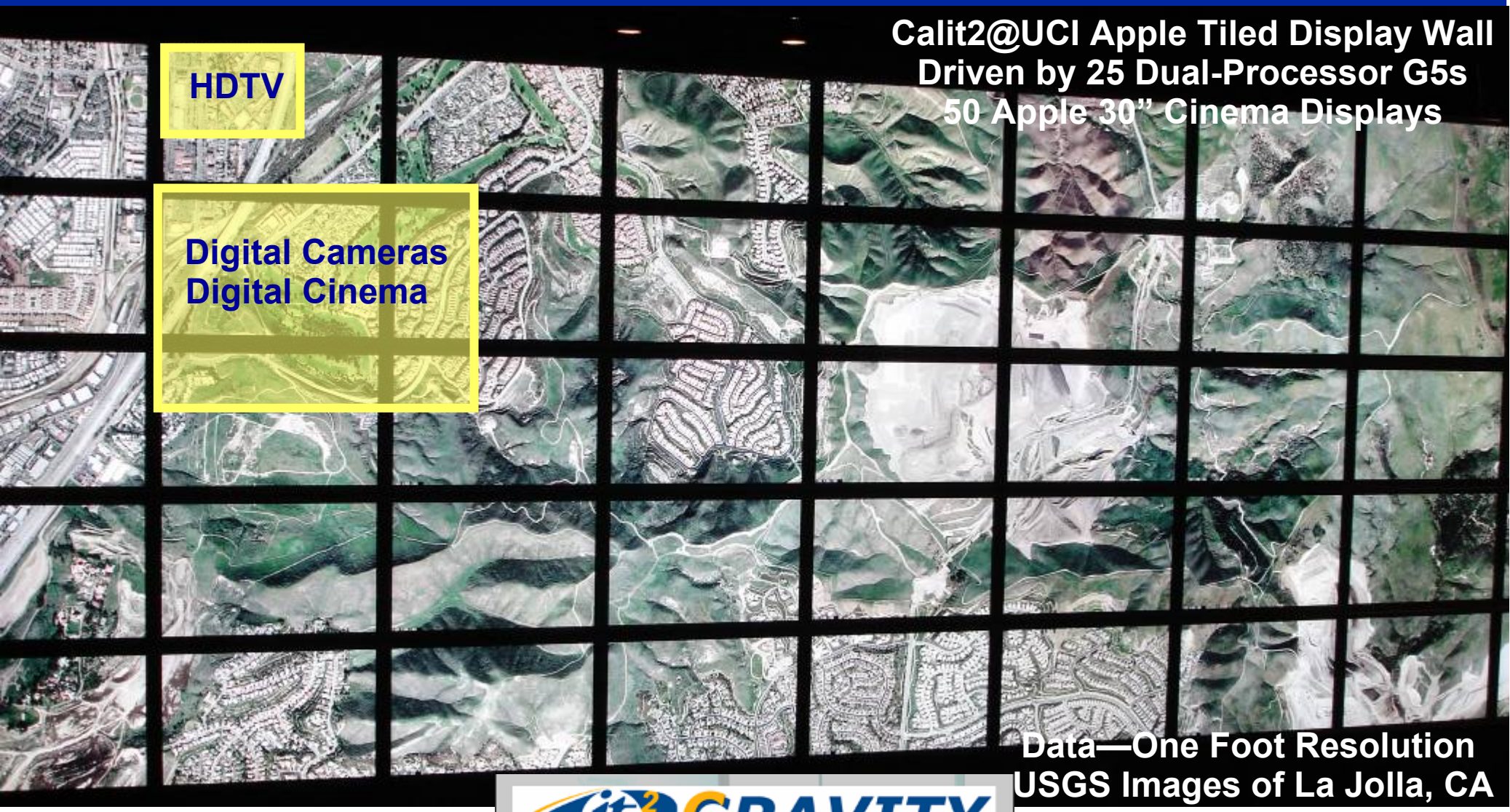
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**A possible model for 4K workflow?**

ource: Luc Renambot, EVL

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# The World's Largest Tiled Display Wall—Calit2@UCI's HIPerWall




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

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Source: Falko Kuester, Calit2@UCI
NSF Infrastructure Grant

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# Showing your Science at Meetings-- The Portable Mini-Mac Wall




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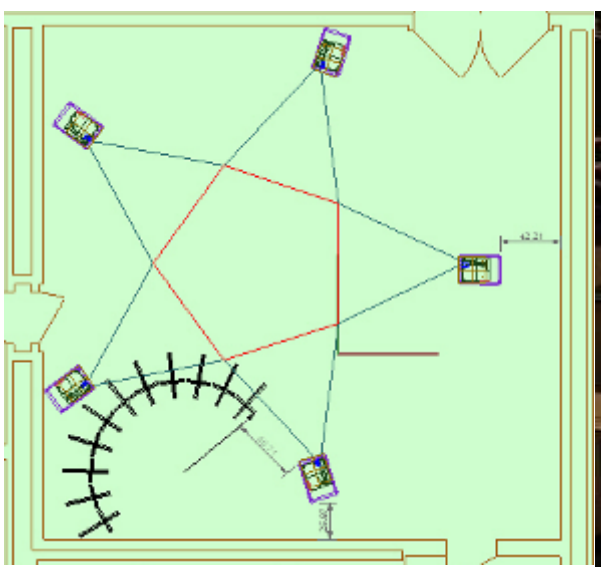
**ANL's Rick Stevens Studying Deep Sea Vent Ecology at Supercomputing '06**

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# Partnering with UIC Electronic Visualization Lab to Create Next Generation OptIPortals

- Varrier Autostereo Virtual Reality
  - Head-Tracked No Need for Glasses
  - 65 LCD Tiles
  - 45 Mpixels/eye of Visual Stereo
- PentaCAVE— High Definition Surround
  - Working Prototype 4 Mpixel Wall
  - Full Scale PentaCAVE Being Built
    - 6 JVC HD2K Projectors Per Wall
    - 30 Mpixel/eye of Stereo w/5-Walls







evl electronic visualization laboratory

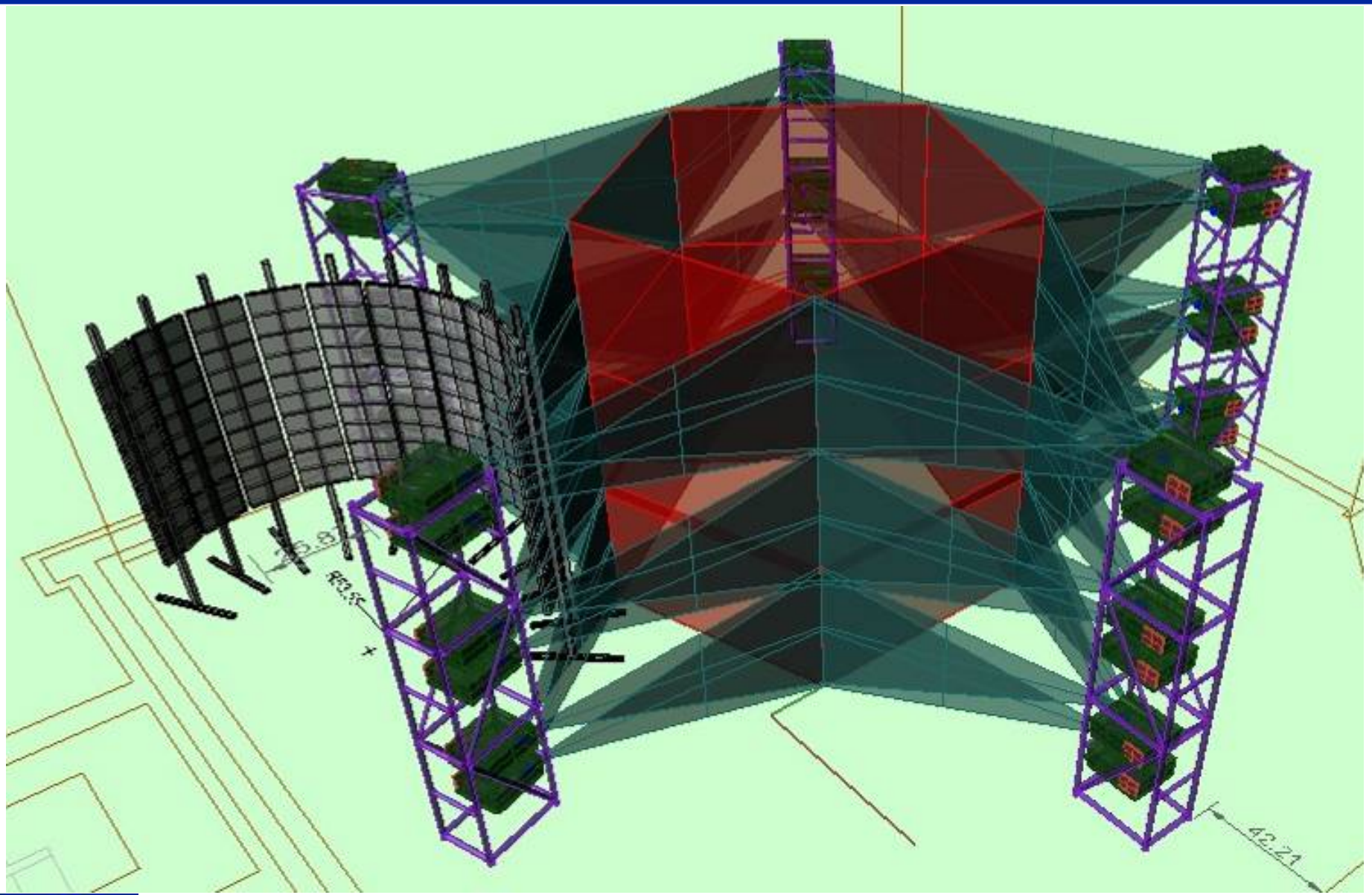
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Dan Sandin, Greg Dawe, Tom Peterka, Tom DeFanti, Jason Leigh, Jinghua Ge, Javier Girado, Bob Kooima, Todd Margolis, Lance Long, Alan Verlo, Maxine Brown, Jurgen Schulze, Qian Liu, Ian Kaufman, Bryan Glogowski

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# Varrier and StarCAVE in Calit2 Immersion Visualization Room Summer 2007



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

## National LambdaRail
## Direct Connect
## Computation and Storage Complex

Funded by: Gordon and Betty Moore Foundation

PI Larry Smarr

Joint Partnership of:

UCSD
UCIrvine

**Announced January 17, 2006**
**$24.5M Over Seven Years**

# Building On Centers of Excellence and Achievement













Powered by Rocks







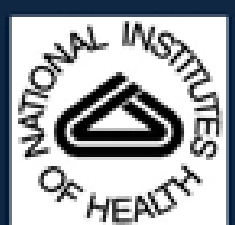






The Scripps Genome Center

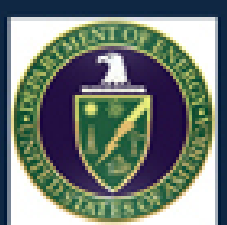
## Supported by:












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# Marine Genome Sequencing Project – Measuring the Genetic Diversity of Ocean Microbes










MARINE MICROBIOLOGY INITIATIVE

Gordon and Betty MOORE FOUNDATION

**Sorcerer II Data Will Double Number of Proteins in GenBank!**

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

Gordon and Betty MOORE FOUNDATION

**Sargasso Sea Data**

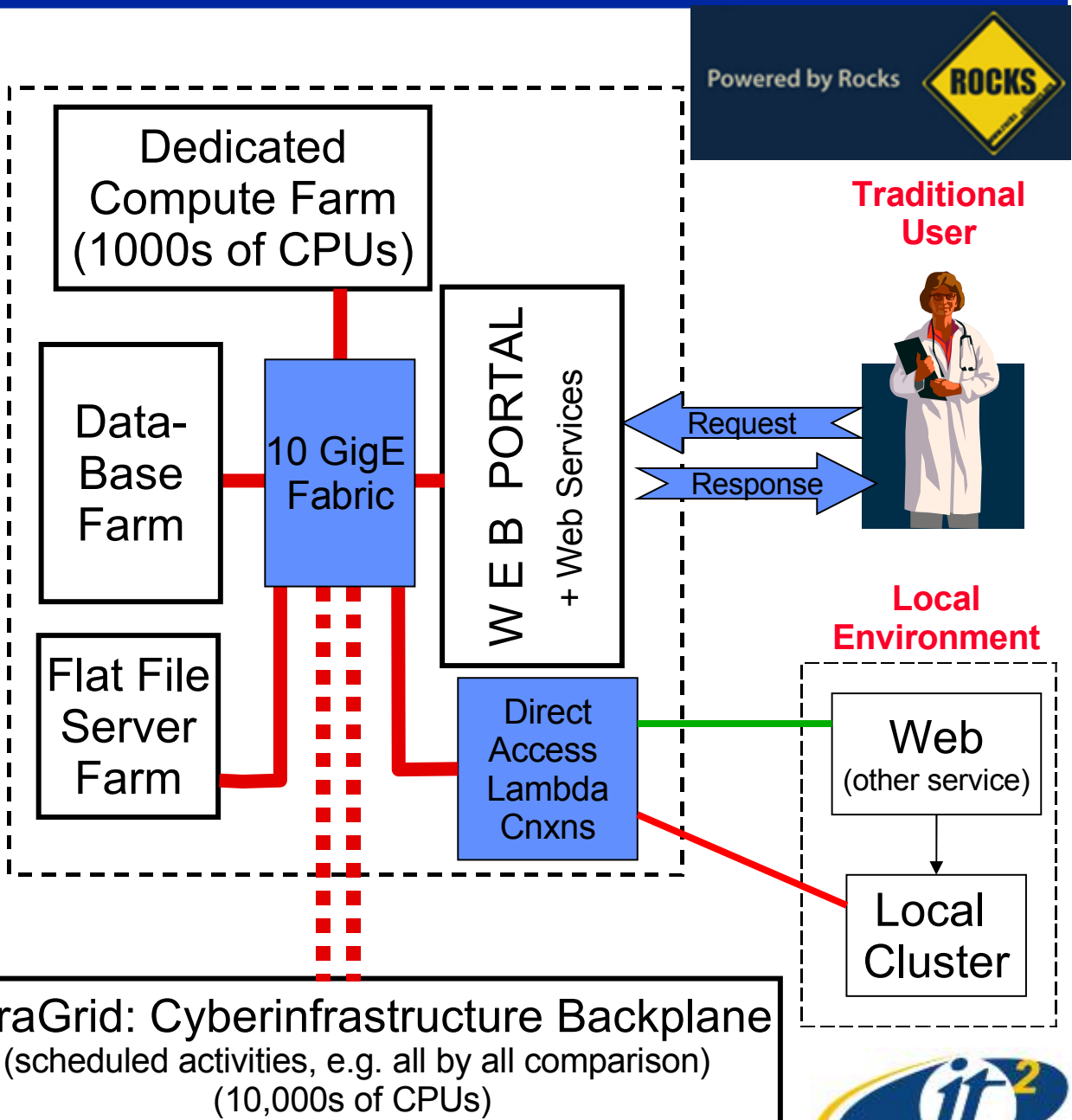
**Sorcerer II Expedition (GOS)**

**JGI Community Sequencing Project**

**Moore Marine Microbial Project**

**NASA and NOAA Satellite Data**

**Community Microbial Metagenomics Data**




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

CENTER FOR EARTH OBSERVATIONS & APPLICATIONS

SCRIPPS INSTITUTION OF OCEANOGRAPHY

SDSC SAN DIEGO SUPERCOMPUTER CENTER

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# Calit2 CAMERA Production
# Compute and Storage Complex is On-Line

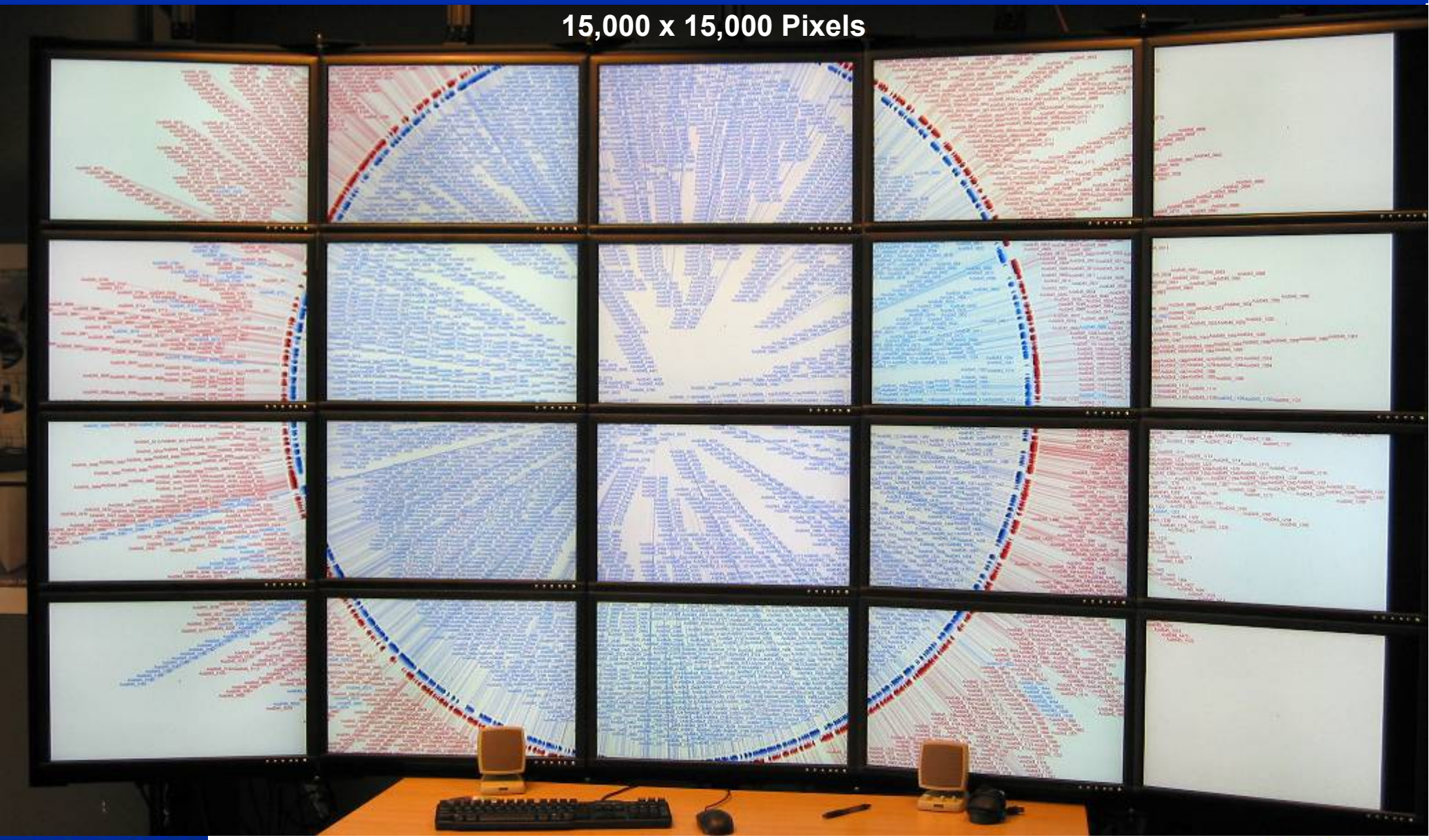



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camera
Marine Microbial Ecology

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# Use of OptIPortal to Interactively View Microbial Genome




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Source: Raj Singh, UCSD

Acidobacteria bacterium Ellin345 (NCBI)
Soil Bacterium 5.6 Mb

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# Use of OptIPortal to Interactively View Microbial Genome



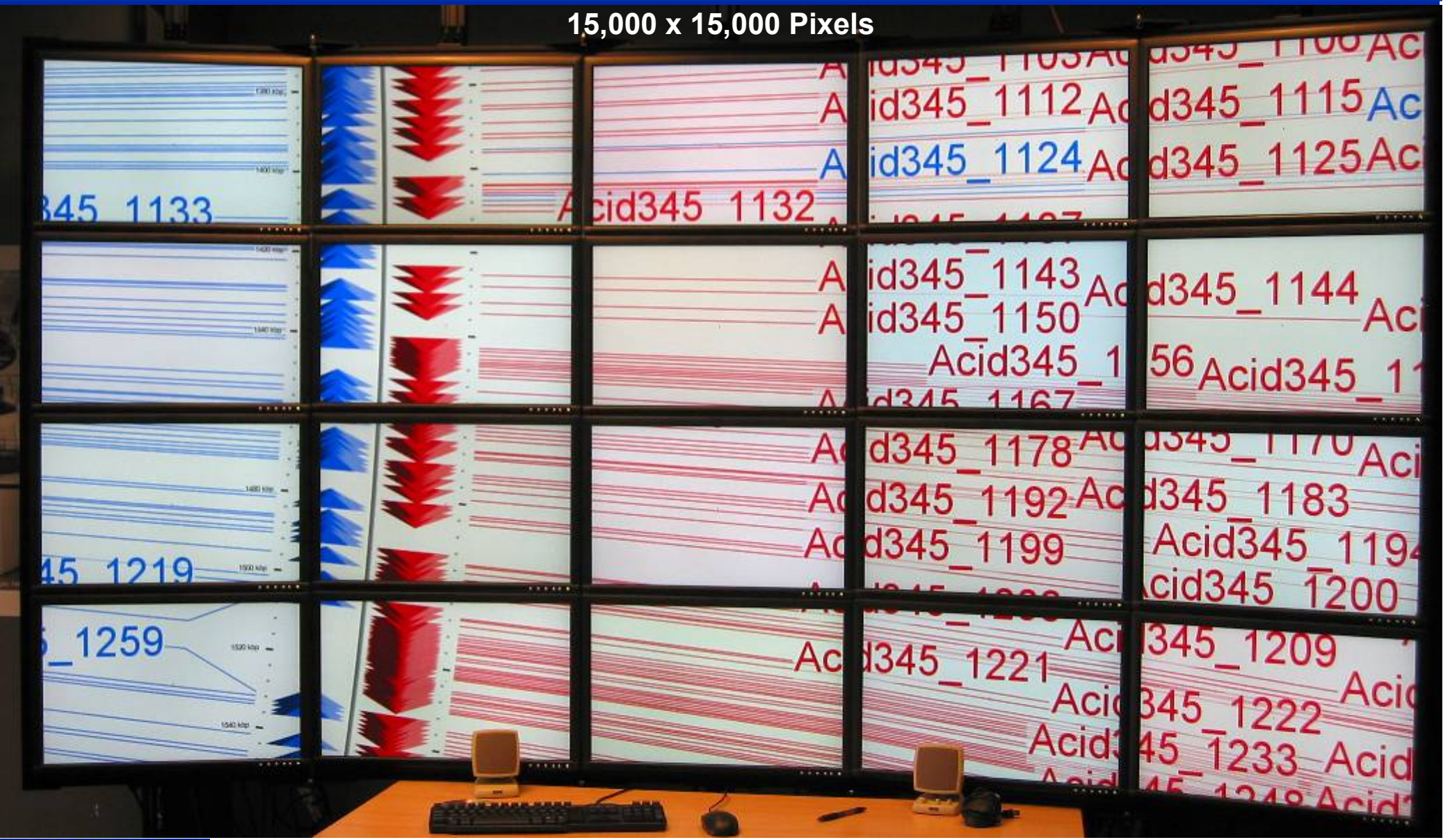

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Source: Raj Singh, UCSD

Acidobacteria bacterium Ellin345 (NCBI)
Soil Bacterium 5.6 Mb

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# Use of OptIPortal to Interactively View Microbial Genome




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Source: Raj Singh, UCSD

Acidobacteria bacterium Ellin345 (NCBI)
Soil Bacterium 5.6 Mb

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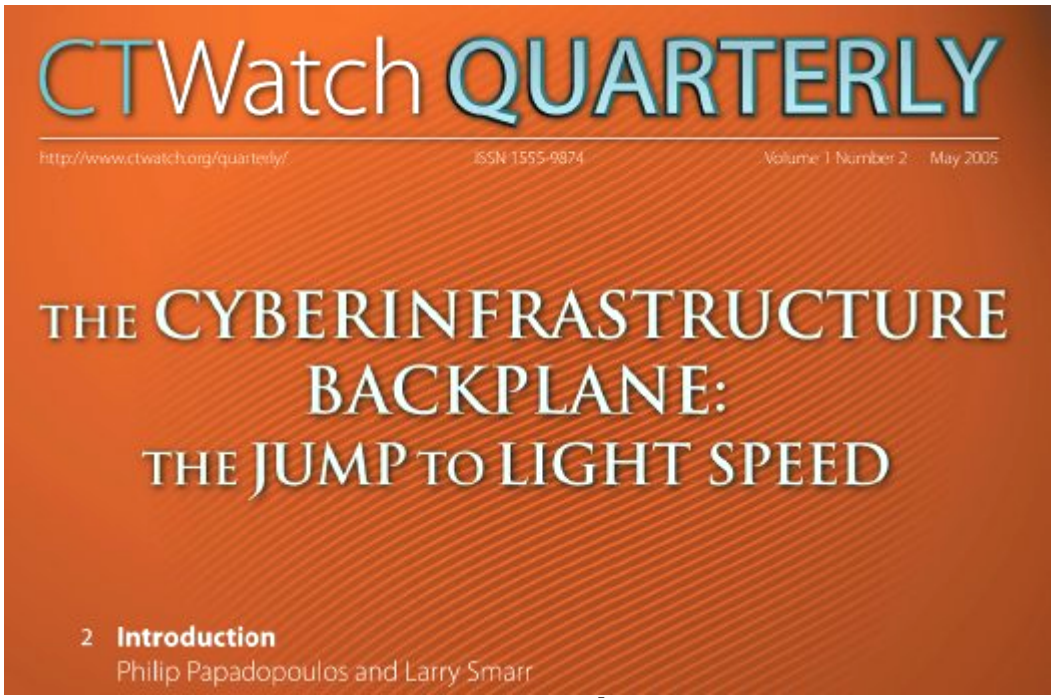
# Calit2 is Now OptIPuter Connecting Remote OptIPortal Moore-Funded Microbial Researchers via NLR



# How Do You Get From Your Lab to the National LambdaRail?

**"Research is being stalled by 'information overload,' Mr. Bement said, because data from digital instruments are piling up far faster than researchers can study. In particular, he said, campus networks need to be improved. High-speed data lines crossing the nation are the equivalent of six-lane superhighways, he said. But networks at colleges and universities are not so capable. "Those massive conduits are reduced to two-lane roads at most college and university campuses," he said. Improving cyberinfrastructure, he said, "will transform the capabilities of campus-based scientists."**

**-- Arden Bement, the director of the National Science Foundation**

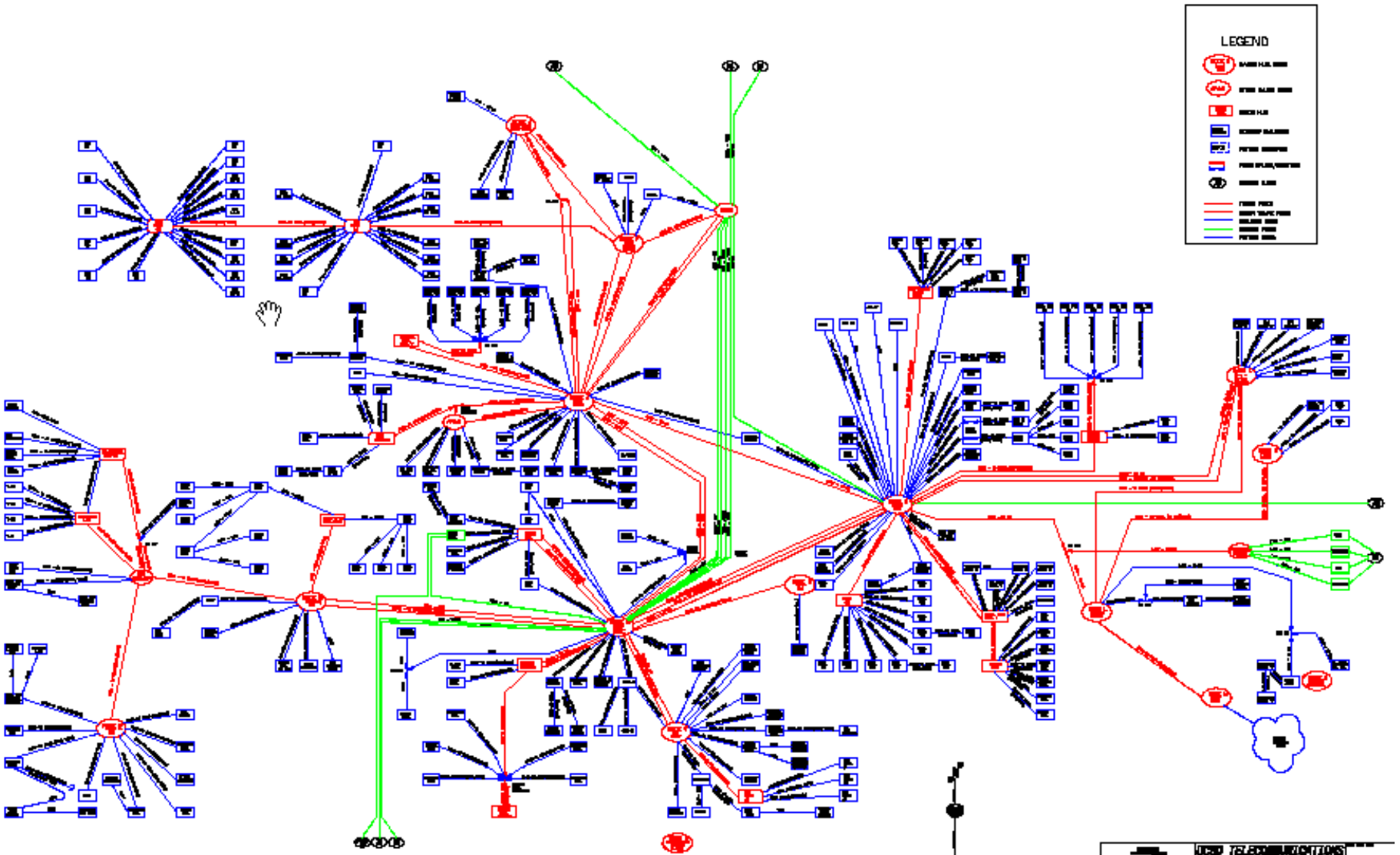



www.ctwatch.org

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# To Build a Campus Dark Fiber Network—First, Find Out Where All the Campus Conduit Is!




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# UCSD is Prototyping a Campus-Scale OptIPuter

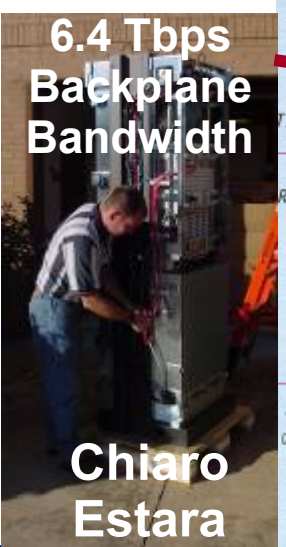


0.320 Tbps Backplane Bandwidth

Juniper T320

20X

6.4 Tbps Backplane Bandwidth



Chiaro Estara

To CENIC

SDSC

SDSC Annex

Engineering

High School

Medicine

Collocation

Earth Sciences

½ Mile

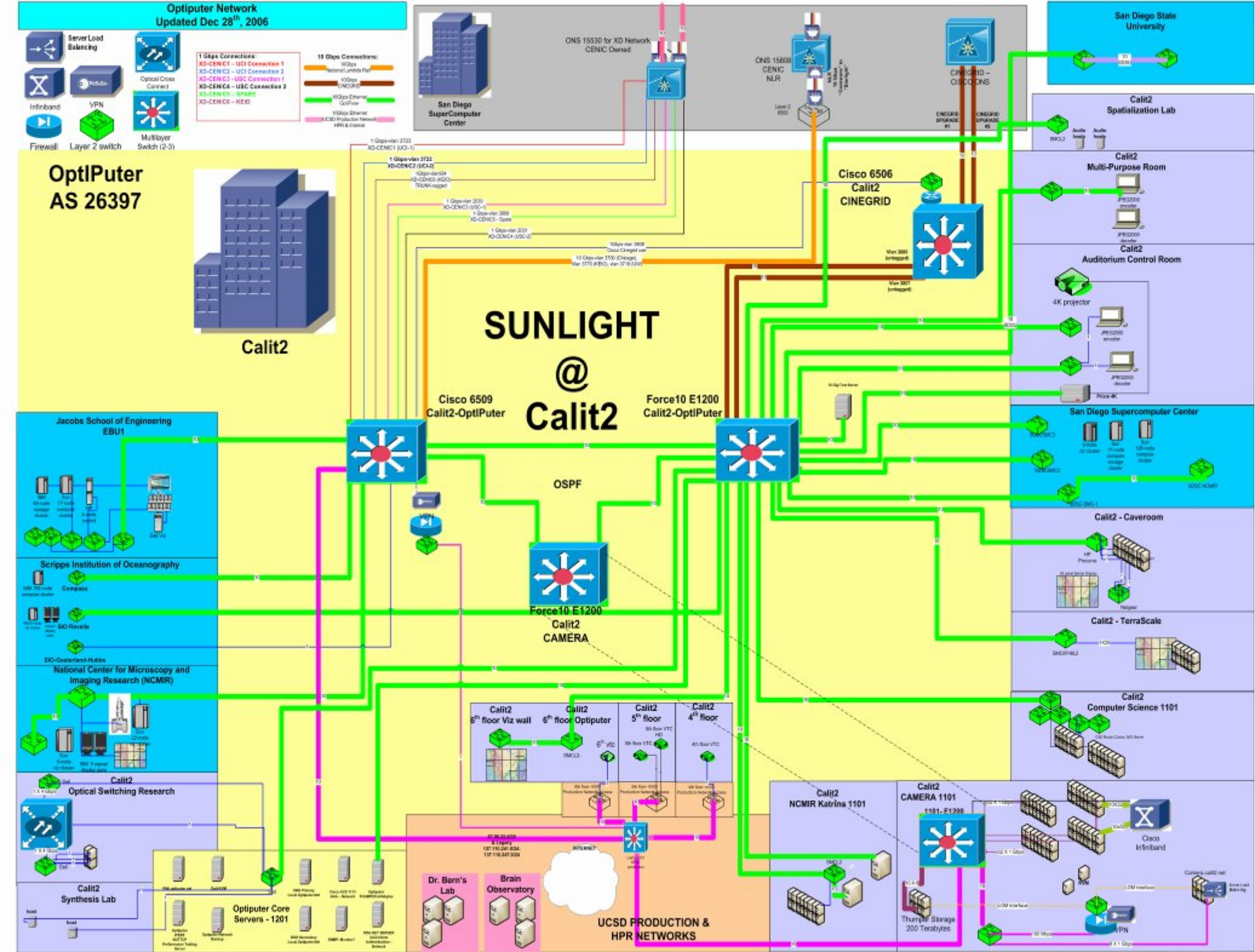
**Dedicated Fibers Between Sites Link Linux Clusters**

**2003**

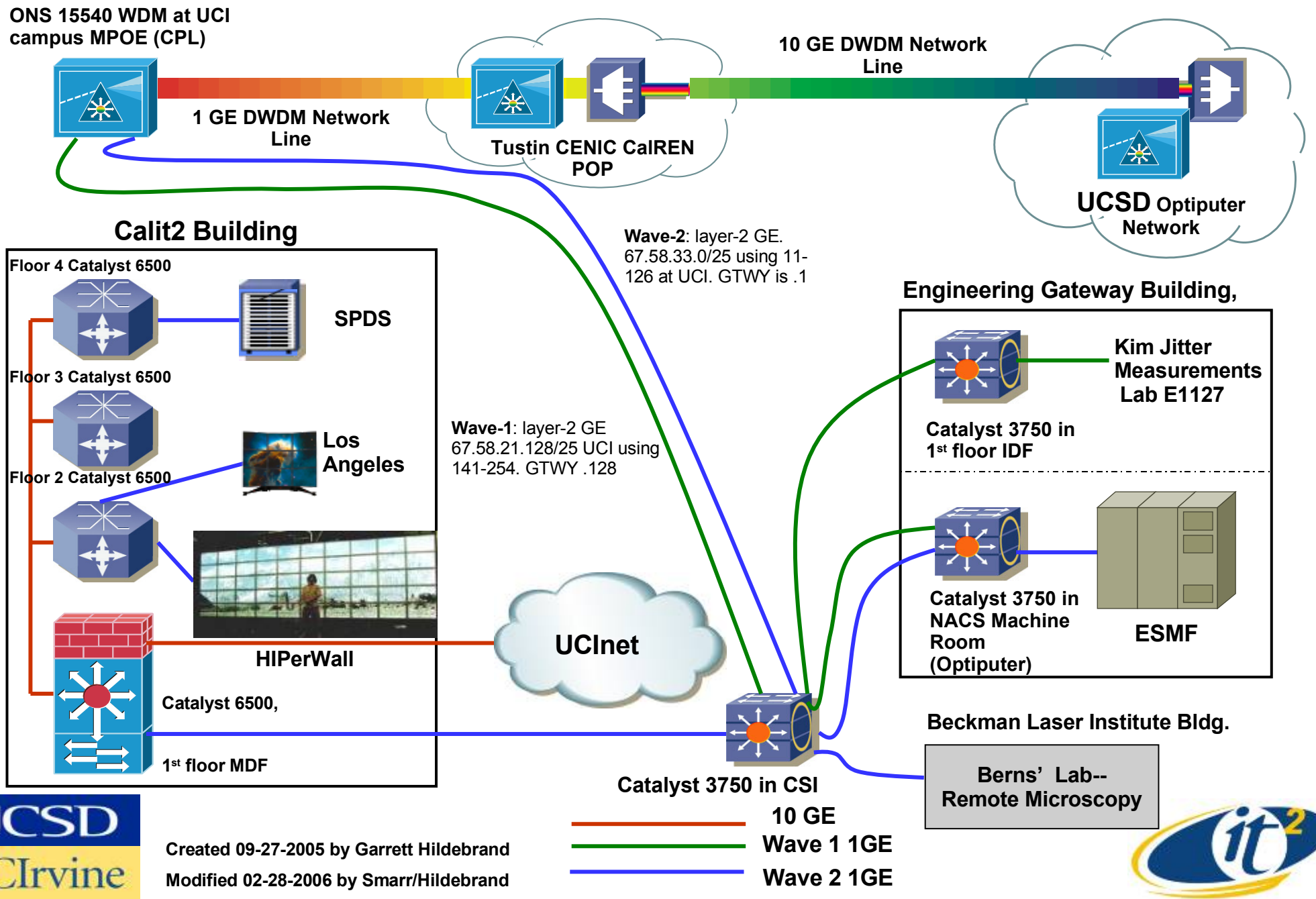
**Source:**
**Phil Papadopoulos, SDSC/Calit2;**
**Greg Hidley, Calit2**

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UCIrvine


Optiputer Network
Updated Dec 28th, 2006
Server Load Balancing
Optical Cross Connect
Infiniband
VPN
Firewall
Layer 2 switch
Multilayer Switch (2-3)
1 Gbps Connections:
XD-CENIC1 – UCI Connection 1
XD-CENIC2 – UCI Connection 2
XD-CENIC3 – USC Connection 1
XD-CENIC4 – USC Connection 2
XD-CENIC5 – SPARE
XD-CENIC6 – KEIO
10 Gbps Connections:
San Diego SuperComputer Center
ONS 15530 for XD Network
CENIC Owned
ONS 15808
CENIC
NLR
CINEGRID – CISCO ONS
San Diego State University
Calit2
Spatialization Lab
Calit2
Multi-Purpose Room
Calit2
Auditorium Control Room
4K projector
OptIPuter
AS 26397
Calit2
SUNLIGHT
@
Calit2
Cisco 6506
Calit2
CINEGRID
Cisco 6509
Calit2-OptIPuter
Force10 E1200
Calit2-OptIPuter
OSPF
Force10 E1200
Calit2
CAMERA
San Diego Supercomputer Center
Calit2 - Caveroom
Calit2 - TerraScale
Calit2
Computer Science 1101
Jacobs School of Engineering
EBU1
Scripps Institution of Oceanography
National Center for Microscopy and Imaging Research (NCMIR)
Calit2
6th floor Viz wall
Calit2
6th floor Optiputer
Calit2
5th floor
Calit2
4th floor
Calit2
Optical Switching Research
Calit2
NCMIR Katrina 1101
Calit2
CAMERA 1101
Cisco Infiniband
Thumper Storage
200 Terabytes
VPN
Calit2
Synthesis Lab
Optiputer Core
Servers - 1201
Dr. Bern's Lab
Brain Observatory
UCSD PRODUCTION &
HPR NETWORKS

# OptIPuter@UCI is Up and Working

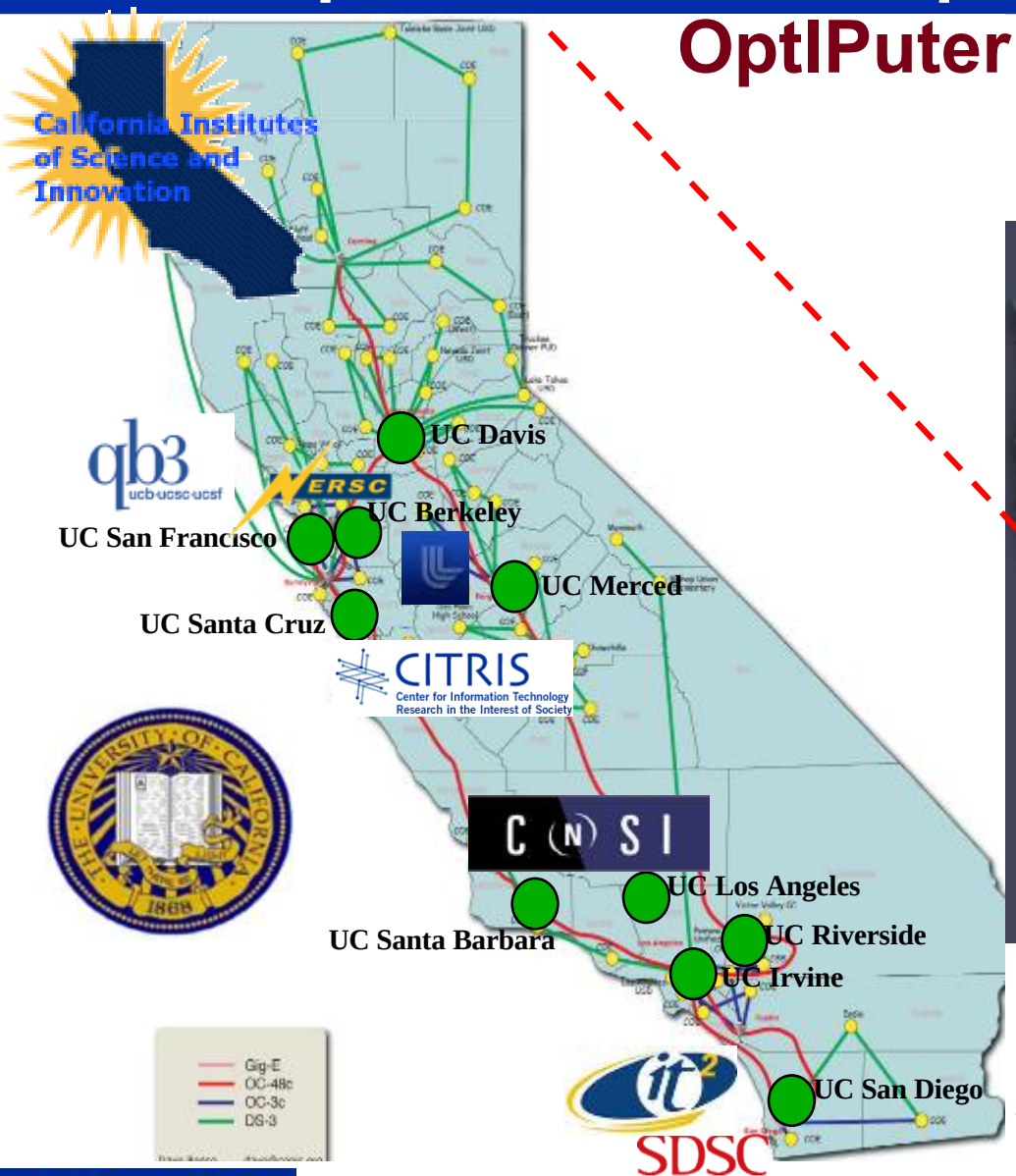



UCSD UCIrvine

Created 09-27-2005 by Garrett Hildebrand

Modified 02-28-2006 by Smarr/Hildebrand

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




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

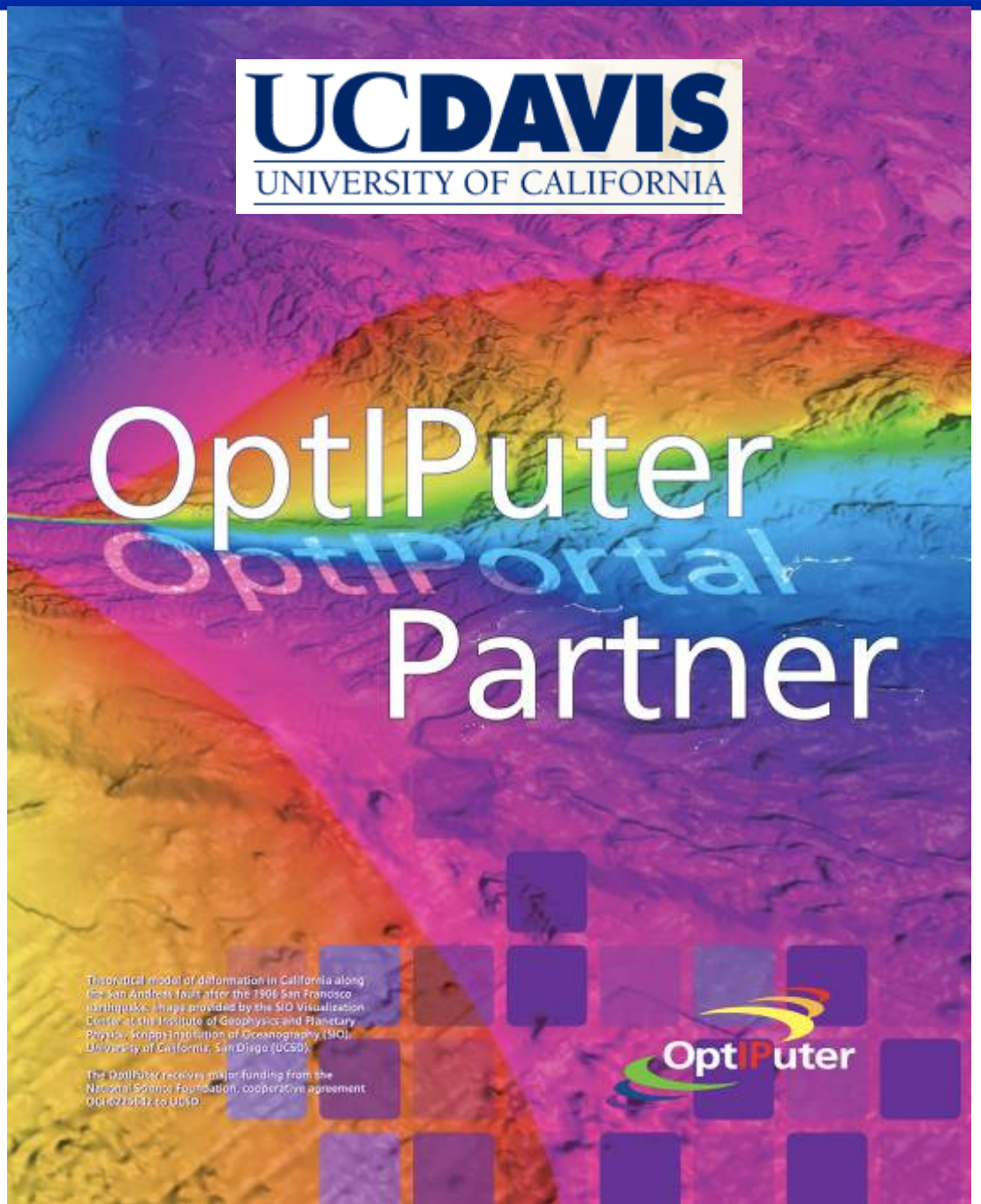



**Creating a Critical Mass of End Users on a Secure LambdaGrid**

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Source: Fran Berman, SDSC , Larry Smarr, Calit2

# Next Step…




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