"Metacomputer Architecture of the Global LambdaGrid: How Personal Light Paths are Transforming e-Science"

Invited Talk

Departments of Computer Science / Physics and Astronomy

University of Missouri@Columbia

Columbia, MO

May 15, 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

UCSD

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Abstract

I will describe my research in metacomputer architecture, a term I coined in 1988, in which one builds virtual ensembles of computers, storage, networks, and visualization devices into an integrated system. Working with a set of colleagues, I have driven development in this field through national and international workshops and conferences, including SIGGRAPH, Supercomputing, and iGrid. Although the vision has remained constant over nearly two decades, it is only the recent availability of dedicated optical paths, or lambdas, that has enabled the vision to be realized. 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 my current research in the four grants in which I am PI or co-PI, OptIPuter, Quartzite, LOOKING, and CAMERA, which both develop the computer science of LambdaGrids, but also couple intimately to the application drivers in biomedical imaging, ocean observatories, and marine microbial metagenomics.

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Metacomputer: Four Eras

- The Formative Years (1965-1985)
- The Early Days (1985-1995)
- The Emergence of the Grid (1995-2000)
- From Grid to LambdaGrid (2000-2005)
- The OptIPlanet Collaboratory (2005-2010)

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TV and Movies of 40 Years Ago Envisioned Telepresence Displays







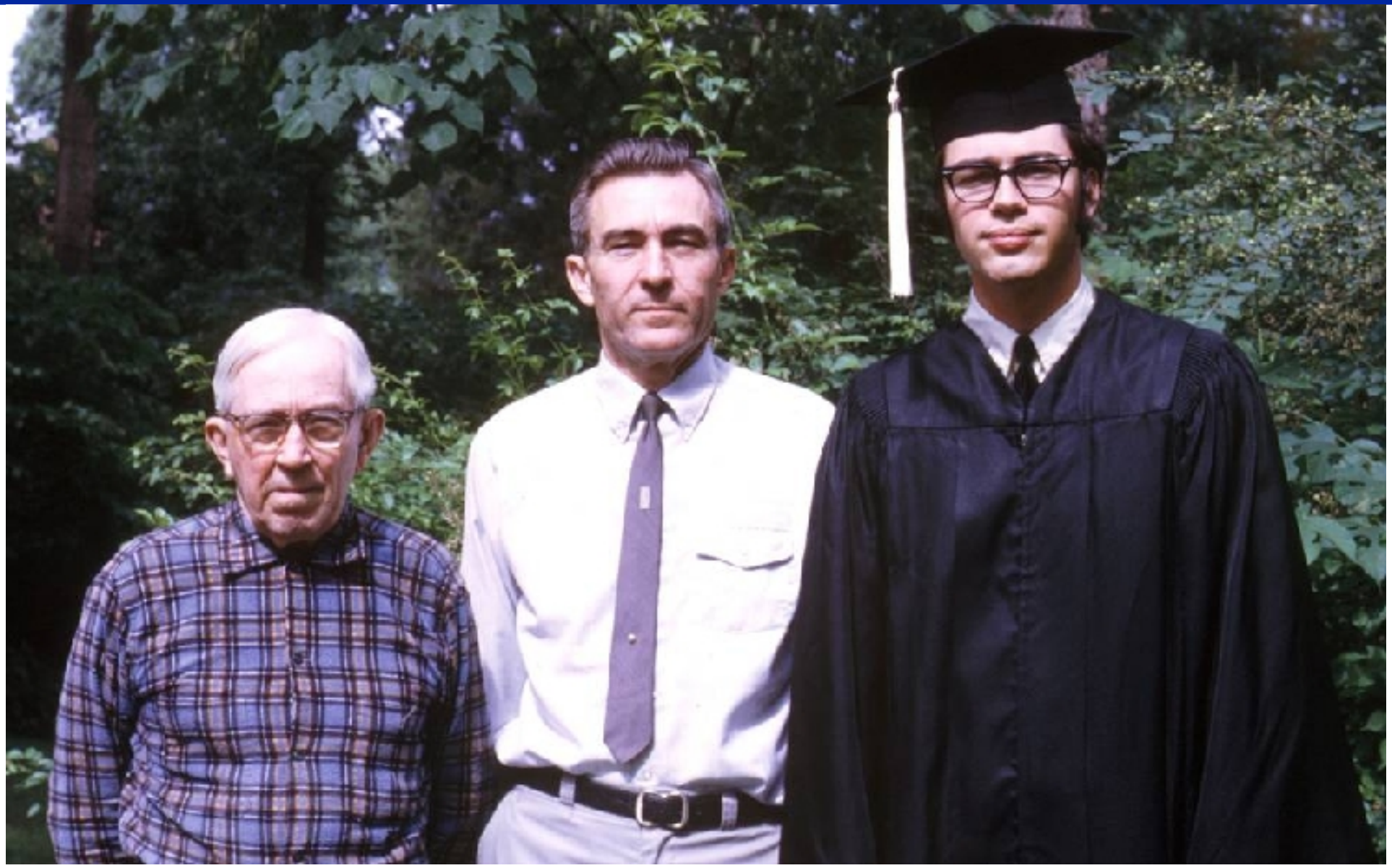


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Source: Star Trek 1966-68; Barbarella 1968

it²

MU Graduation 1970

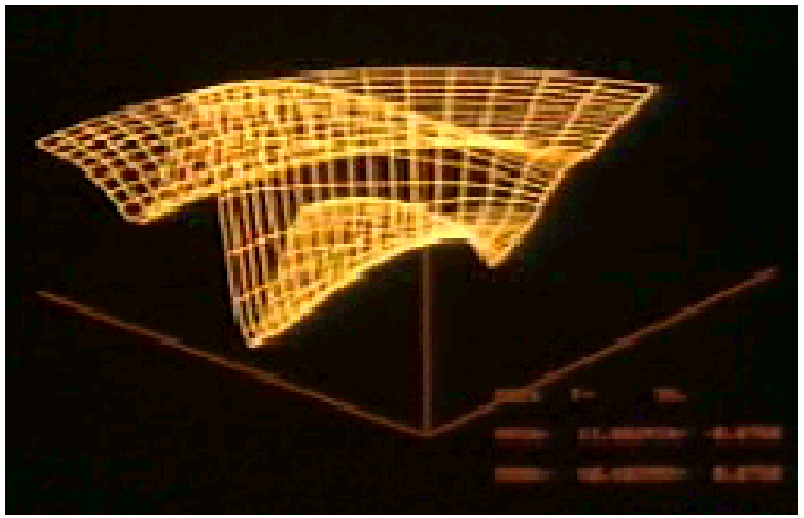


Grandpa Father Me

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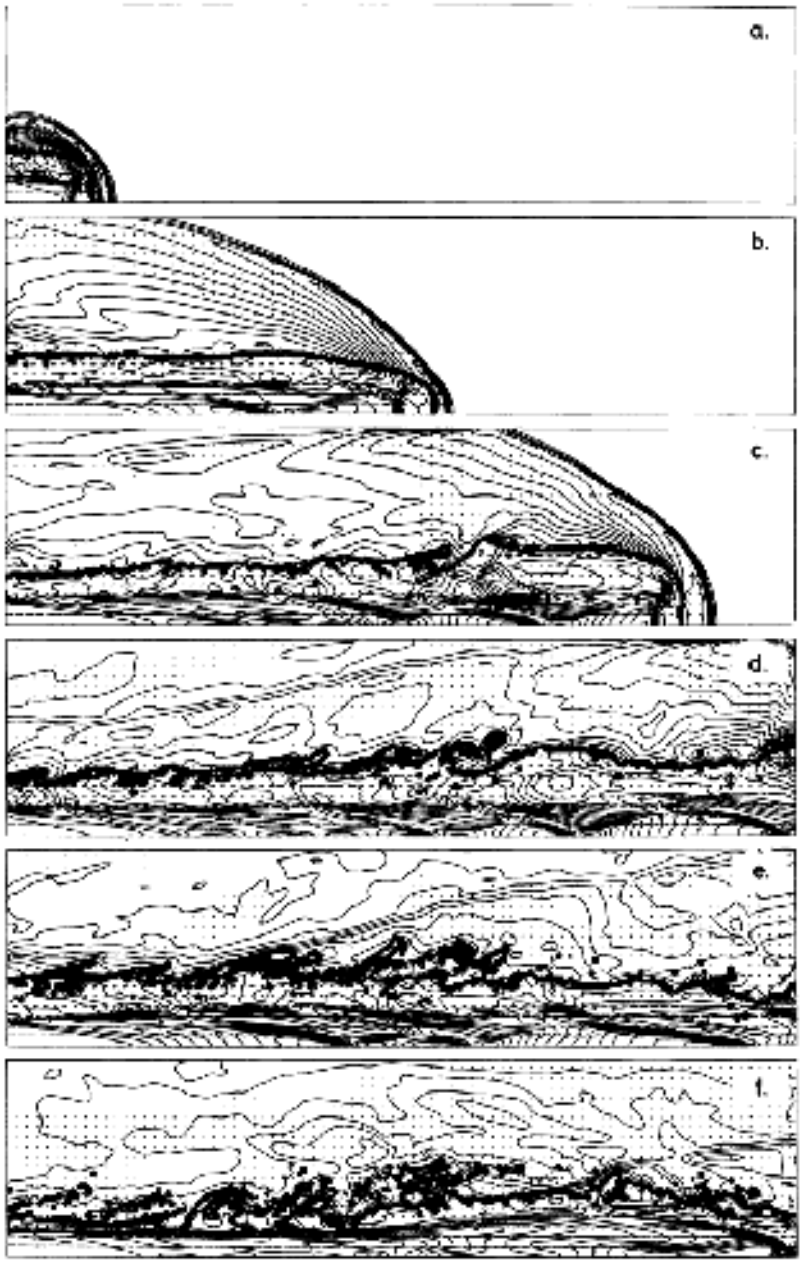
My Early Research was on Computational Astrophysics Before There Were National Supercomputer Centers

Eppley and Smarr 1977



Hawley and Smarr 1985





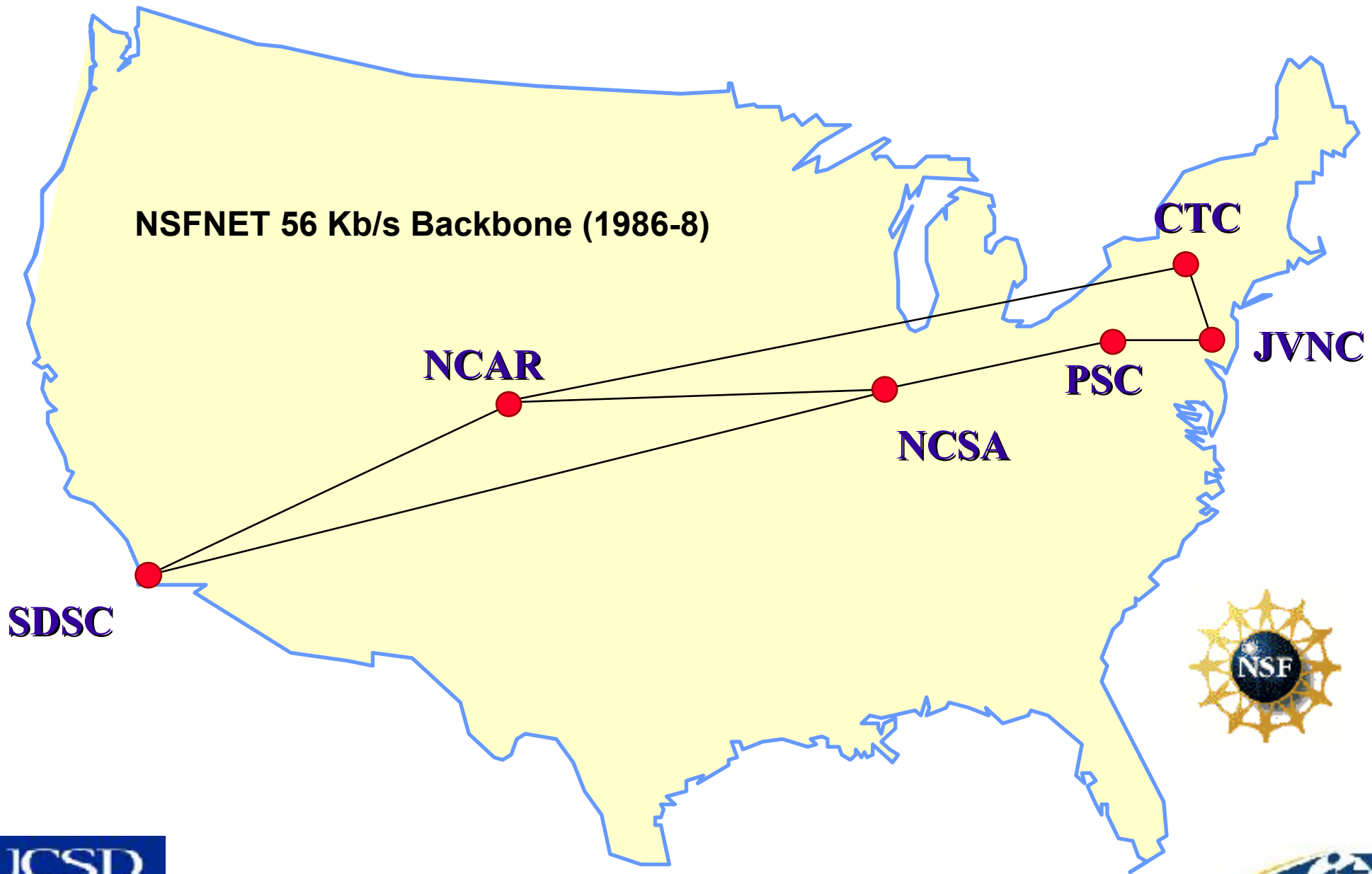
Norman, Winkler, Smarr, Smith 1982

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Metacomputer:
The Early Days (1985-1995)

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The First Metacomputer: NSFnet and the Six NSF Supercomputers



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NCSA Telnet--"Hide the Cray"
One of the Inspirations for the Metacomputer



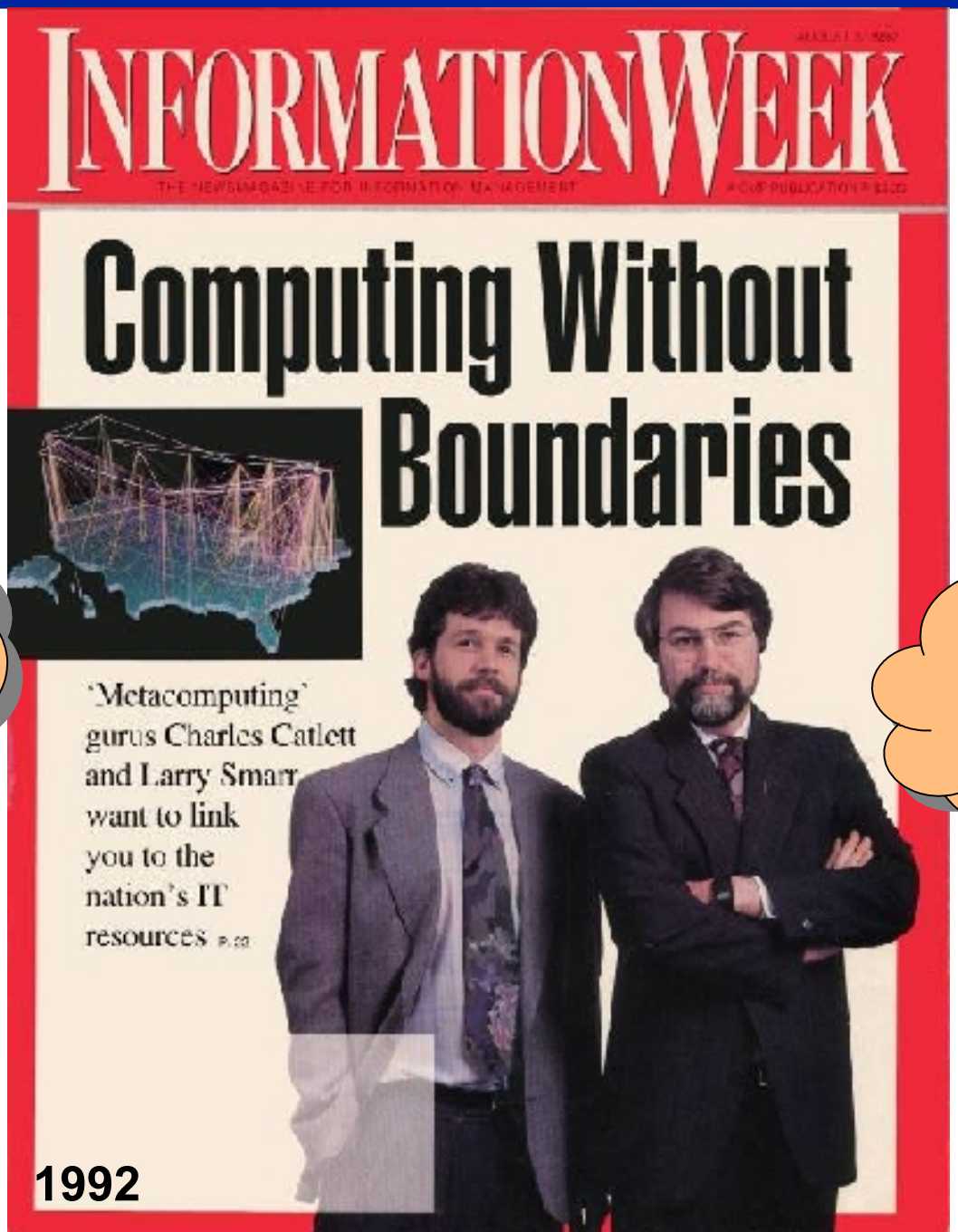
John Kogut Simulating
Quantum Chromodynamics
He Uses a Mac—The Mac Uses the Cray

- **NCSA Telnet -- Interactive Access**
  - From Macintosh or PC Computer
  - To Telnet Hosts on TCP/IP Networks
- **Allows for Simultaneous Connections**
  - To Numerous Computers on The Net
  - Standard File Transfer Server (FTP)
  - Lets You Transfer Files to and from Remote Machines and Other Users

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Source: Larry Smarr 1985

From Metacomputer to TeraGrid and OptIPuter: 15 Years of Development



"Metacomputer" Coined by Smarr in 1988

TeraGrid PI

OptIPuter PI

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Long-Term Goal: Dedicated Fiber Optic Infrastructure
Using Analog Communications to Prototype the Digital Future

"What we really have to do is eliminate distance between individuals who want to interact with other people and with other computers."
— Larry Smarr, Director, NCSA

SIGGRAPH 1989







"We're using satellite technology…to demo what It might be like to have high-speed fiber-optic links between advanced computers in two different geographic locations."

— Al Gore, Senator
Chair, US Senate Subcommittee on Science, Technology and Space

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The Bellcore VideoWindow -- A Working Telepresence Experiment



(1989)

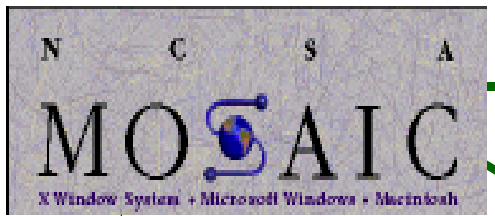
"Imagine sitting in your work place lounge having coffee with some colleagues. Now imagine that you and your colleagues are still in the same room, but are separated by a large sheet of glass that does not interfere with your ability to carry on a clear, two-way conversation. Finally, imagine that you have split the room into two parts and moved one part 50 miles down the road, without impairing the quality of your interaction with your friends."

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Source: Fish, Kraut, and Chalfonte-CSCW 1990 Proceedings

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NCSA Mosaic, a Module in *NCSA Collage* Desktop Collaboration Software, Led to the Modern Web World



Licensing

SPYGLASS

100 Commercial Licensees

NCSA Programmers

NETSCAPE

Microsoft Internet Explorer 4.0

1993

NCSA Collage

1990

CERN

The world's largest particle physics laboratory ... where the web was born!

NCSA HTTPd

Open Source

APACHE HTTP SERVER PROJECT

Mac OS X Server



IBM WebSphere Software



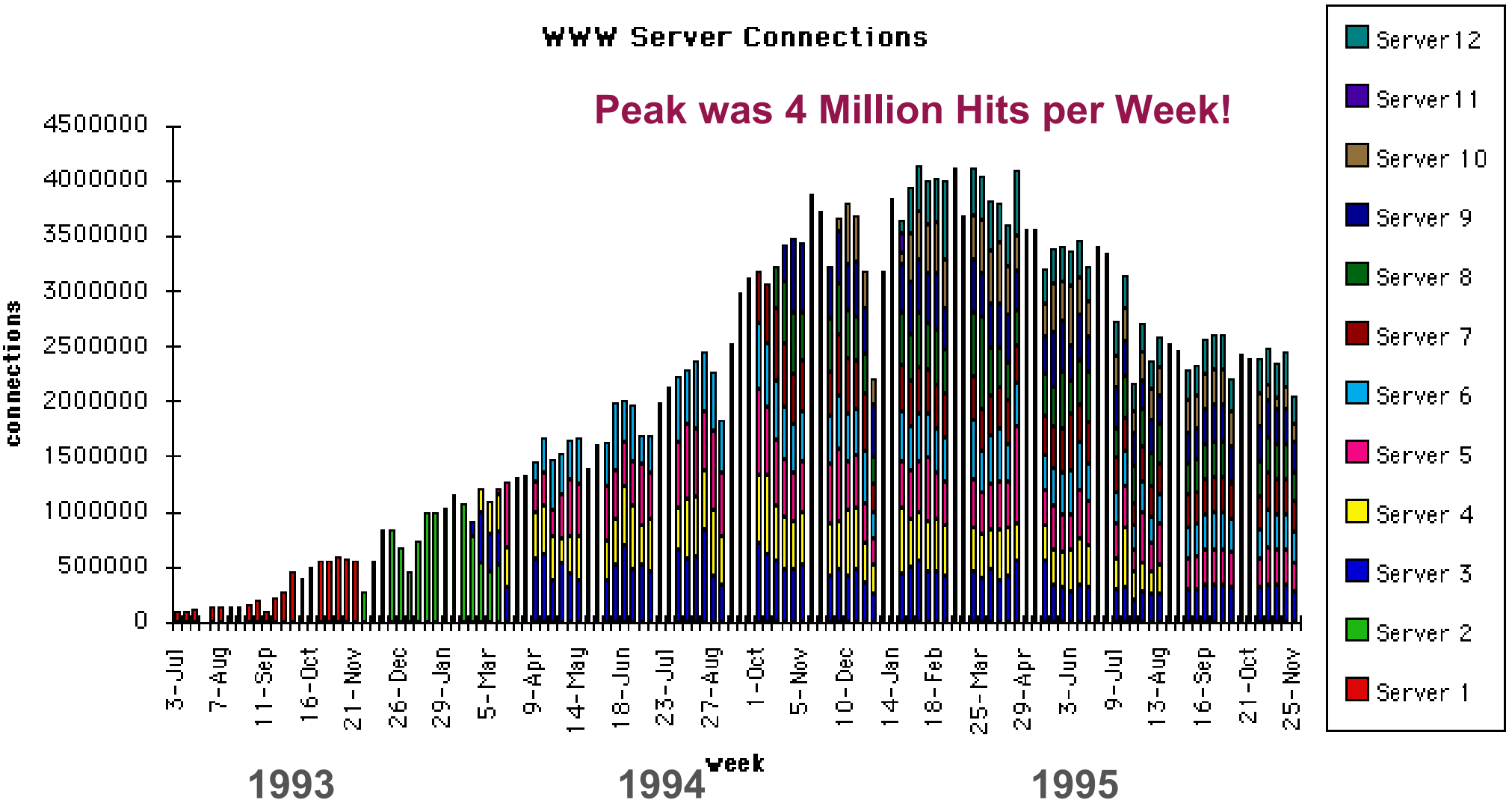
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Source: Larry Smarr

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NCSA Web Server Traffic Increase Led to NCSA Creating the First Parallel Web Server



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Data Source: Software Development Group, NCSA,
Graph: Larry Smarr

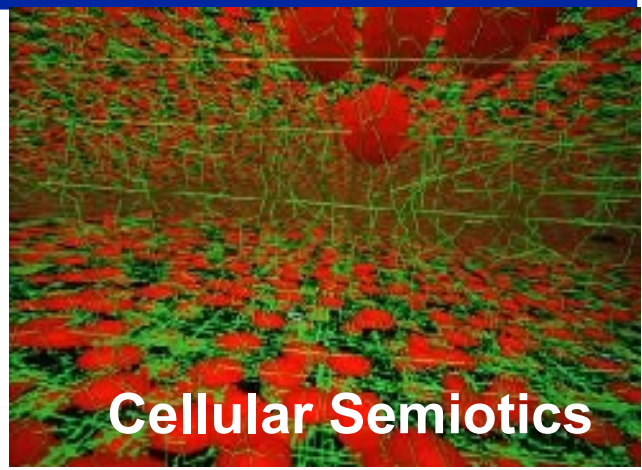
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Metacomputer: The Emergence of the Grid (1995-2000)

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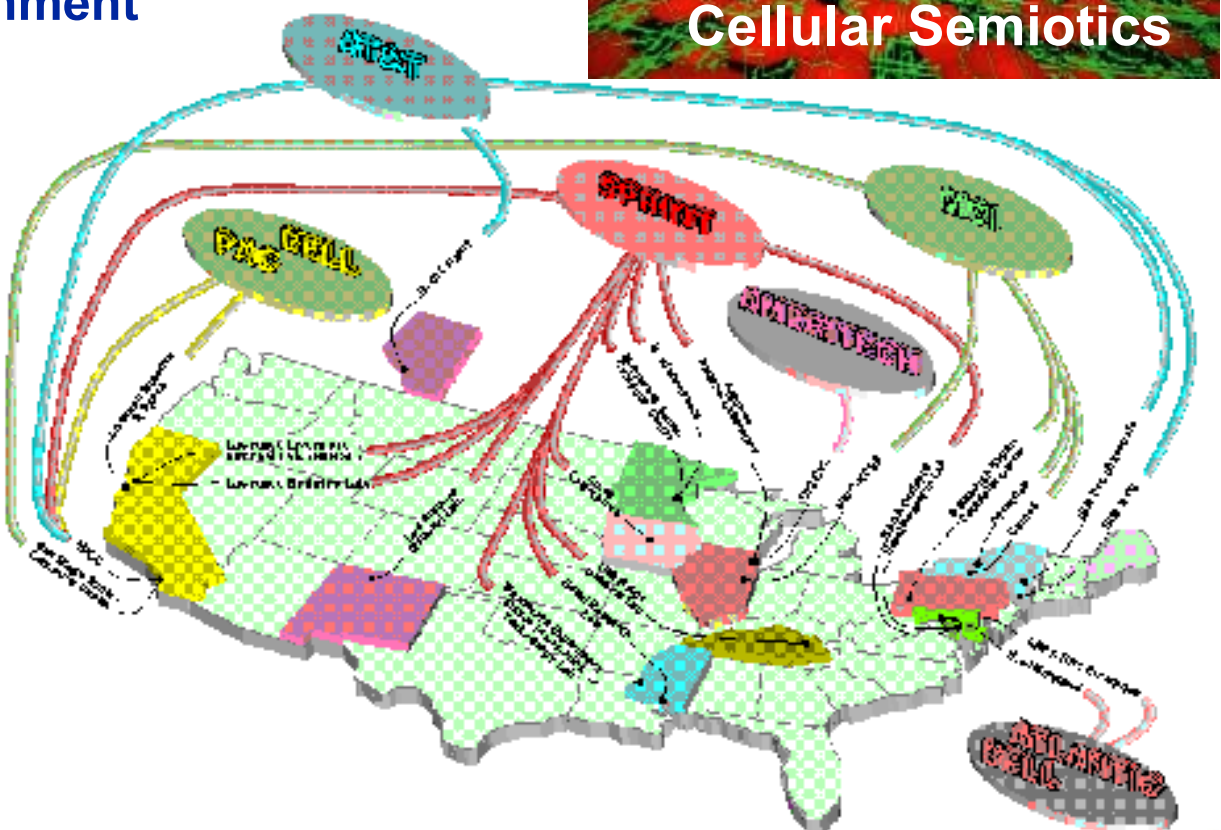
I-WAY Prototyped the National Metacomputer -- Supercomputing '95 I-WAY Project

- 60 National & Grand Challenge Computing Applications
- I-Way Featured:
  - IP over ATM with an OC-3 (155Mbps) Backbone
  - Large-Scale Immersive Displays
  - I-Soft Programming Environment
    - Led Directly to Globus



UIC mcs NCSA





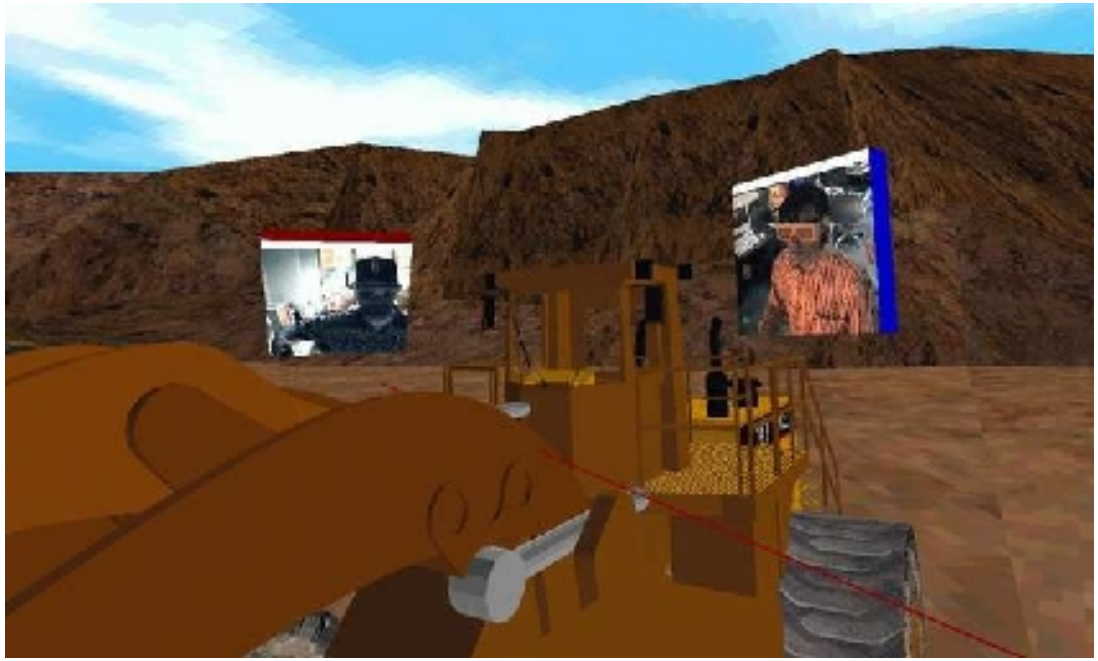
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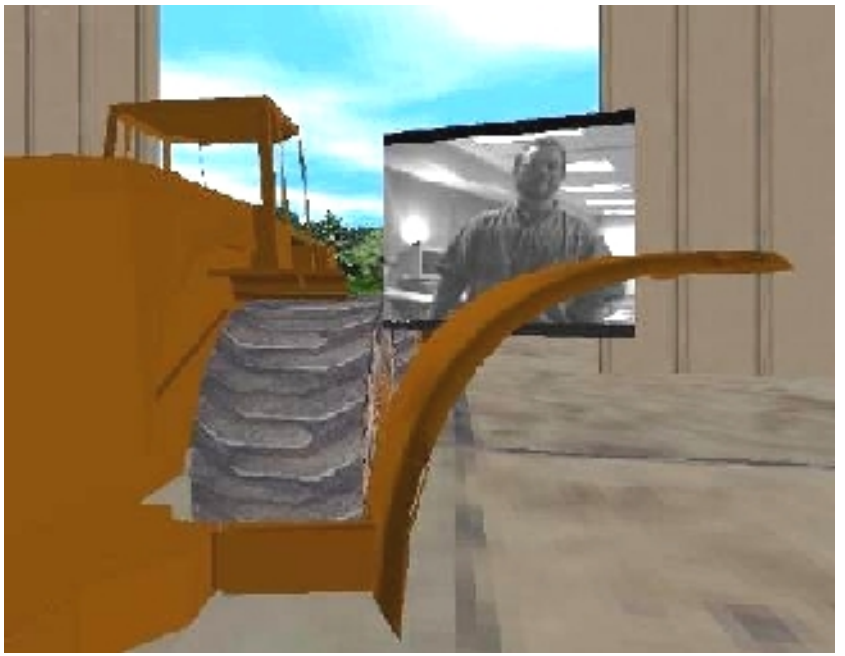
http://archive.ncsa.uiuc.edu/General/Training/SC95/GII.HPCC.html

Source: Larry Smarr, Rick Stevens, Tom DeFanti

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Caterpillar / NCSA: Distributed Virtual Reality for Global-Scale Collaborative Prototyping





NCSA™

Real Time Linked Virtual Reality and Audio-Video Between NCSA, Peoria, Houston, and Germany

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1996

www.sv.vt.edu/future/vt-cave/apps/CatDistVR/DVR.html

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Concept of NCSA Alliance National Technology Grid

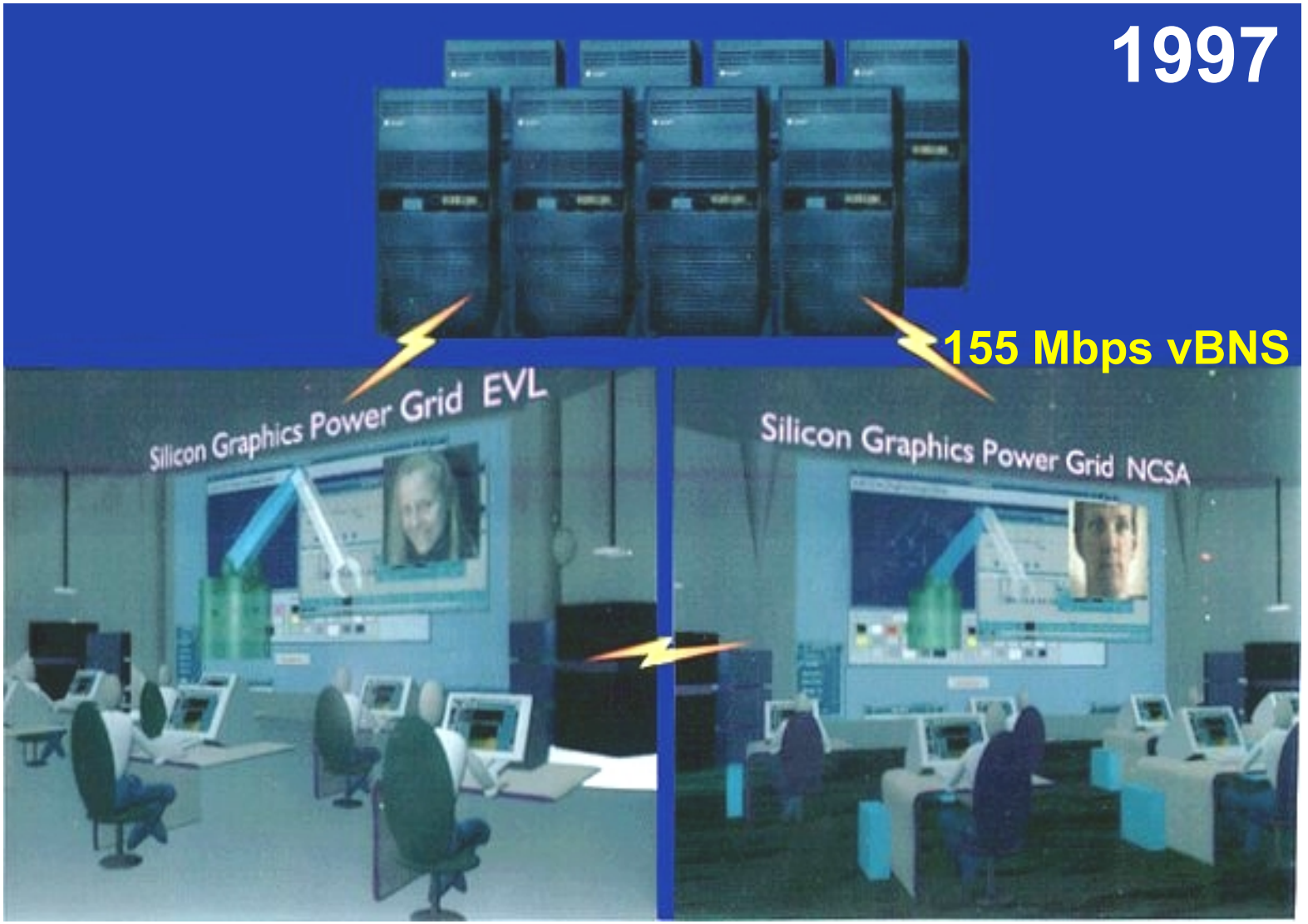
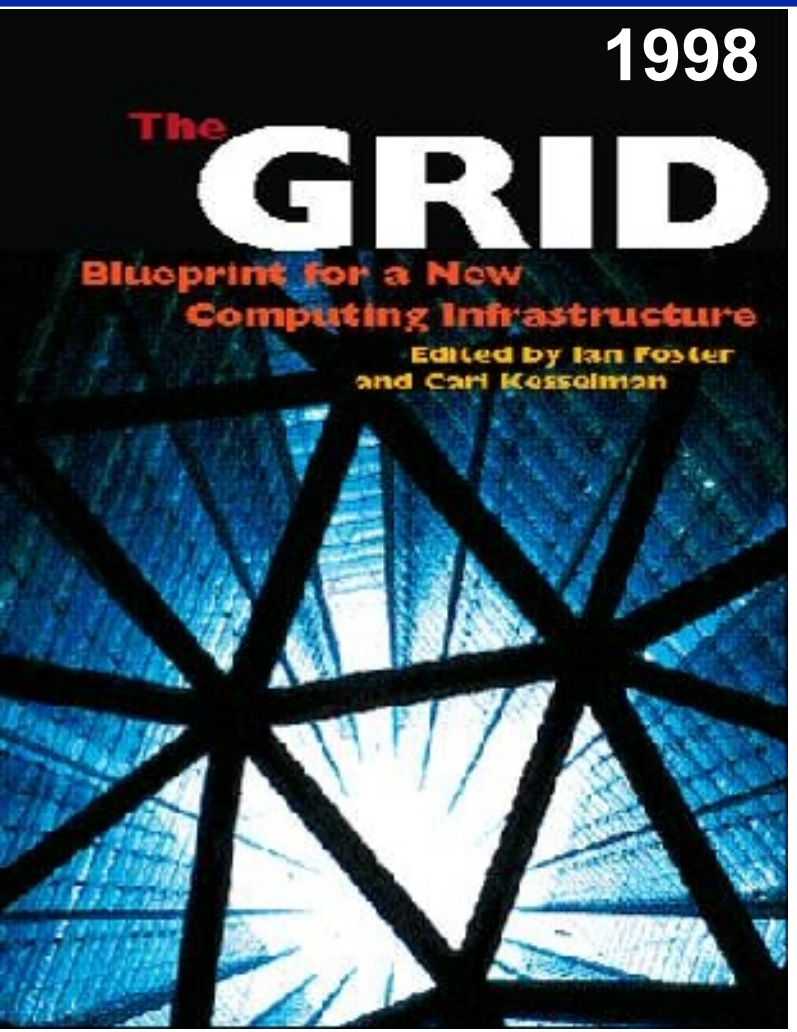


Image From LS Talk at Grid Workshop Argonne Sept. 1997

From Metacomputing to the Grid



"A source book for the history of the future" -- Vint Cerf

Science Portals & Workbenches

Twenty-First Century Applications

Access Grid

Computational Grid

Access Services & Technology

Computational Services

Grid Services
(resource independent)

Grid Fabric
(resource dependent)

Networking, Devices and Systems

Performance

Extending Collaboration From Telephone Conference Calls to Access Grid International Video Meetings



1999

Can We Create Realistic Telepresence Using Dedicated Optical Networks?

Access Grid Lead-Argonne

NSF STARTAP Lead-UIC's Elec. Vis. Lab

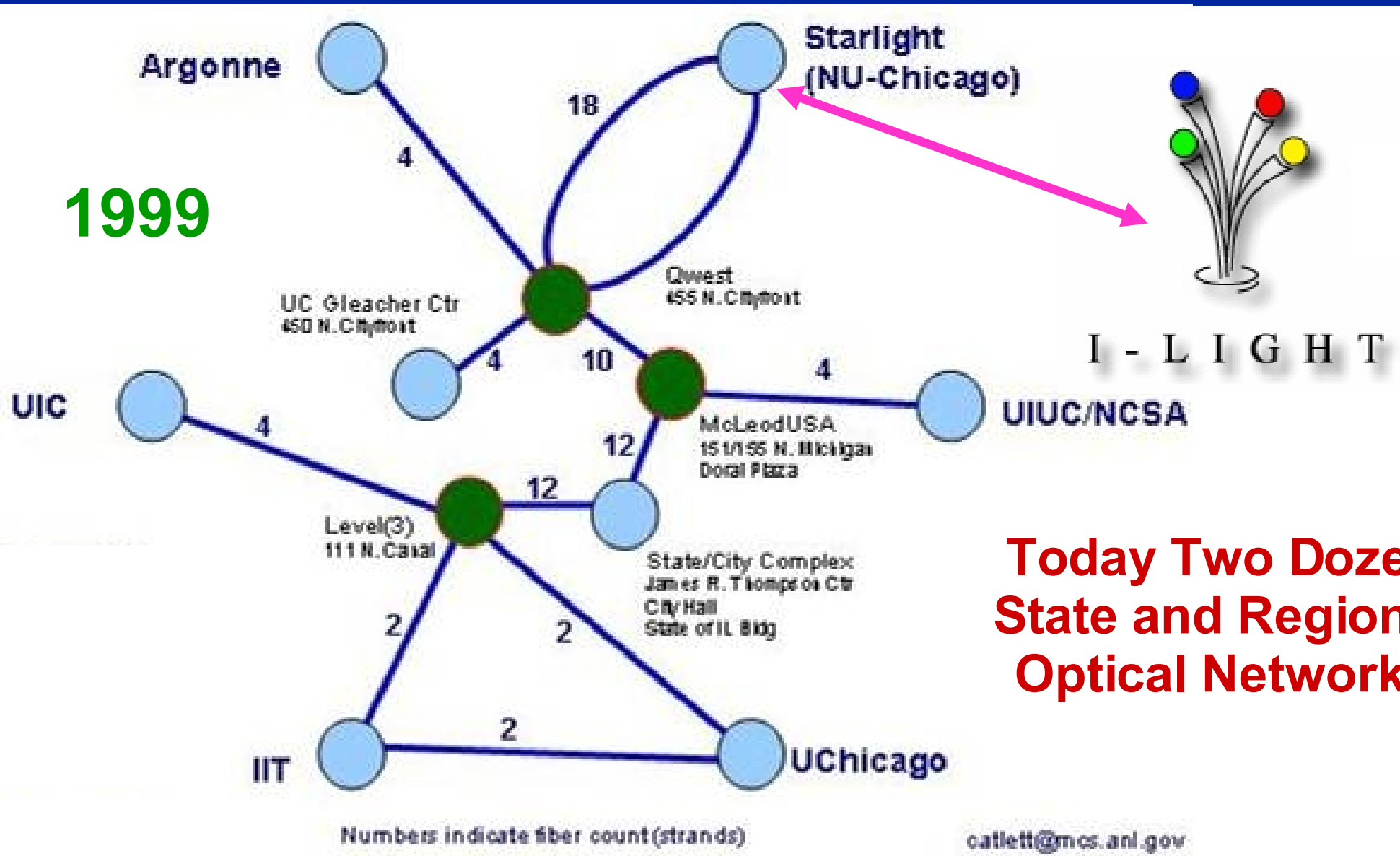
NCSA University of Illinois at Urbana-Champaign

National Computational Science ALLIANCE

Metacomputer:
From Grid to LambdaGrid (2000-2005)

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States are Acquiring Their Own Dark Fiber Networks -- Illinois's I-WIRE and Indiana's I-LIGHT



Today Two Dozen State and Regional Optical Networks

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Source: Larry Smarr, Rick Stevens, Tom DeFanti, Charlie Catlett

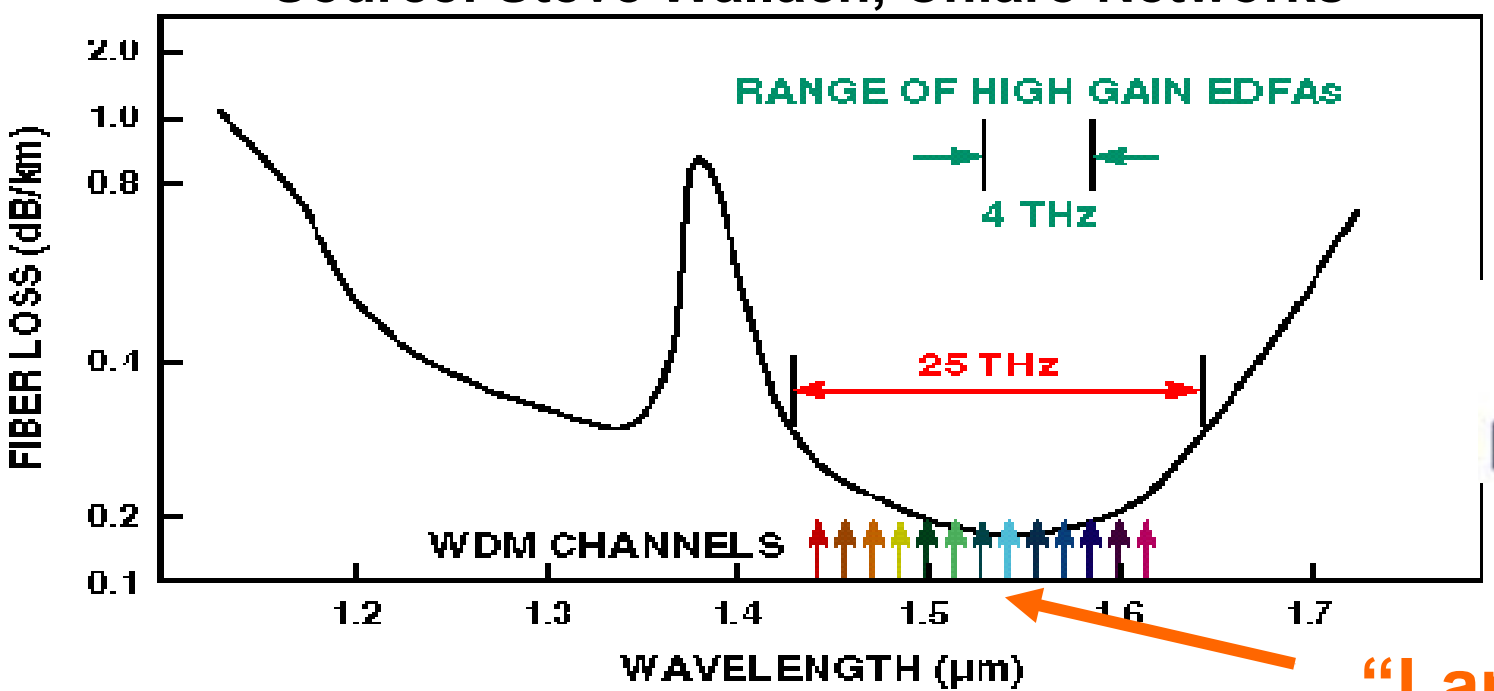
Dedicated Optical Channels Makes High Performance Cyberinfrastructure Possible

WAVELENGTH DIVISION MULTIPLEXING (WDM)

10 Gbps per User ~ 200x Shared Internet Throughput

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

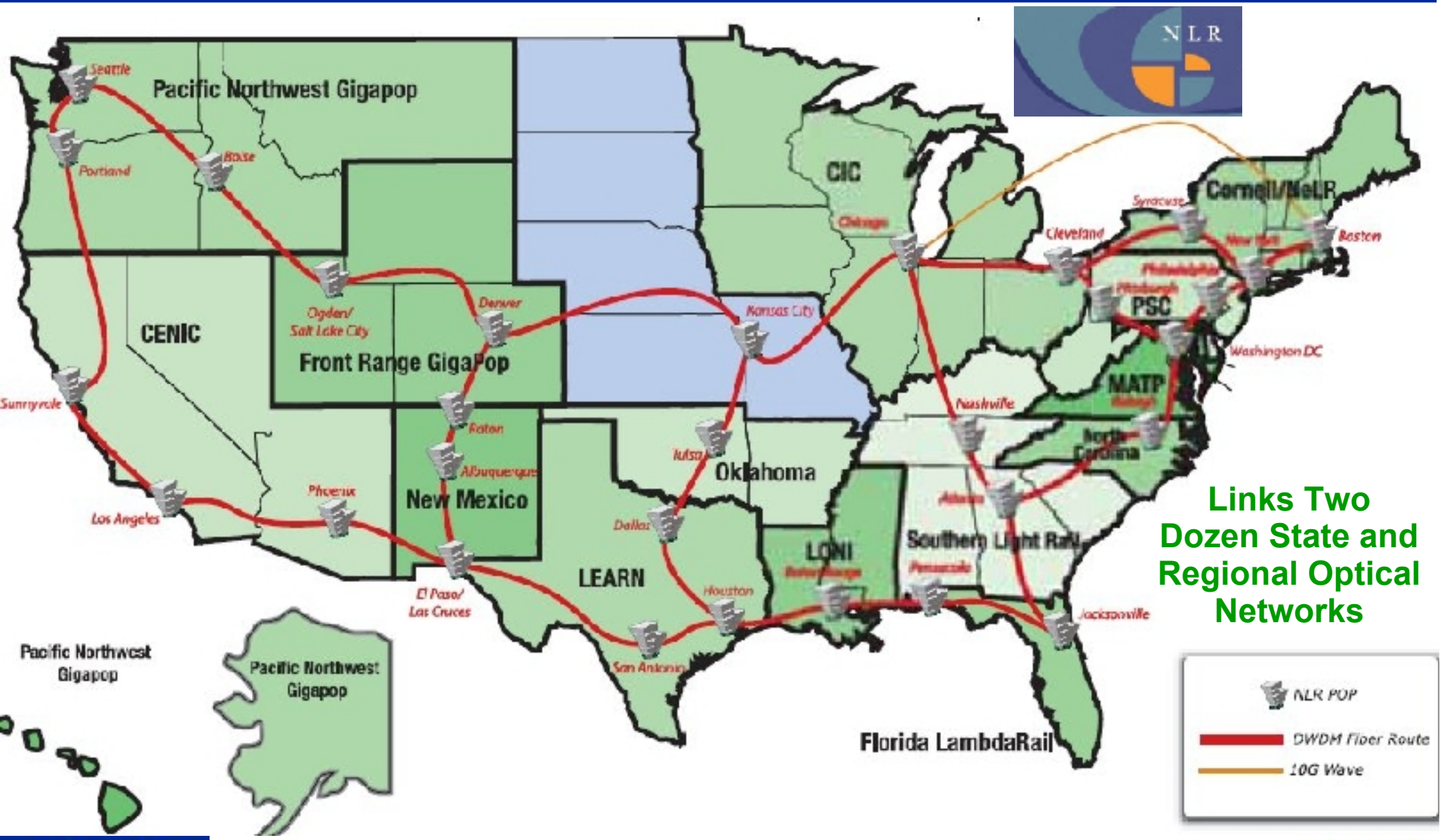
Source: Steve Wallach, Chiaro Networks



"Lambdas"

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

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

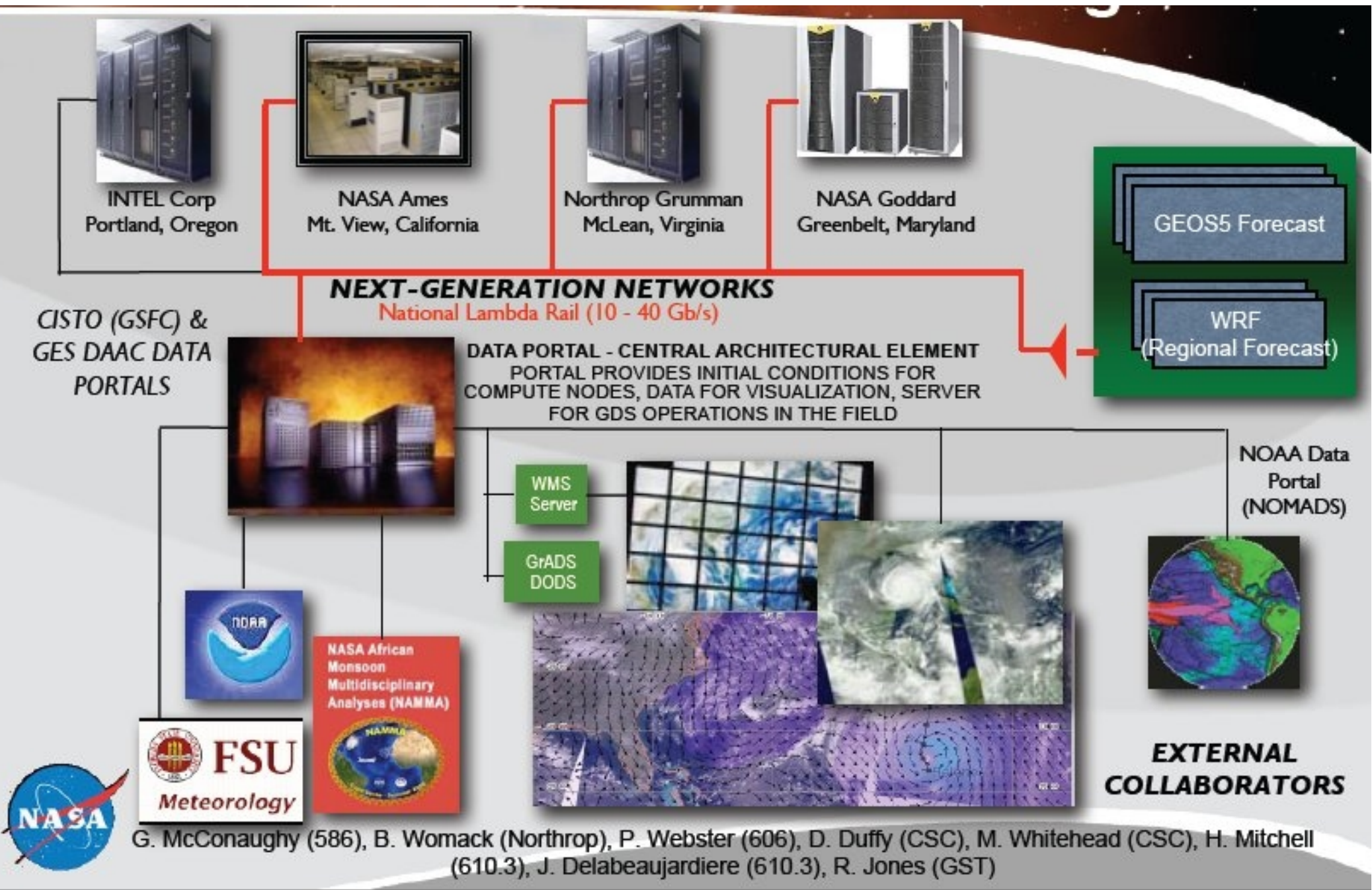


NLR 4 x 10Gb Lambdas Initially
Capable of 40 x 10Gb wavelengths at Buildout

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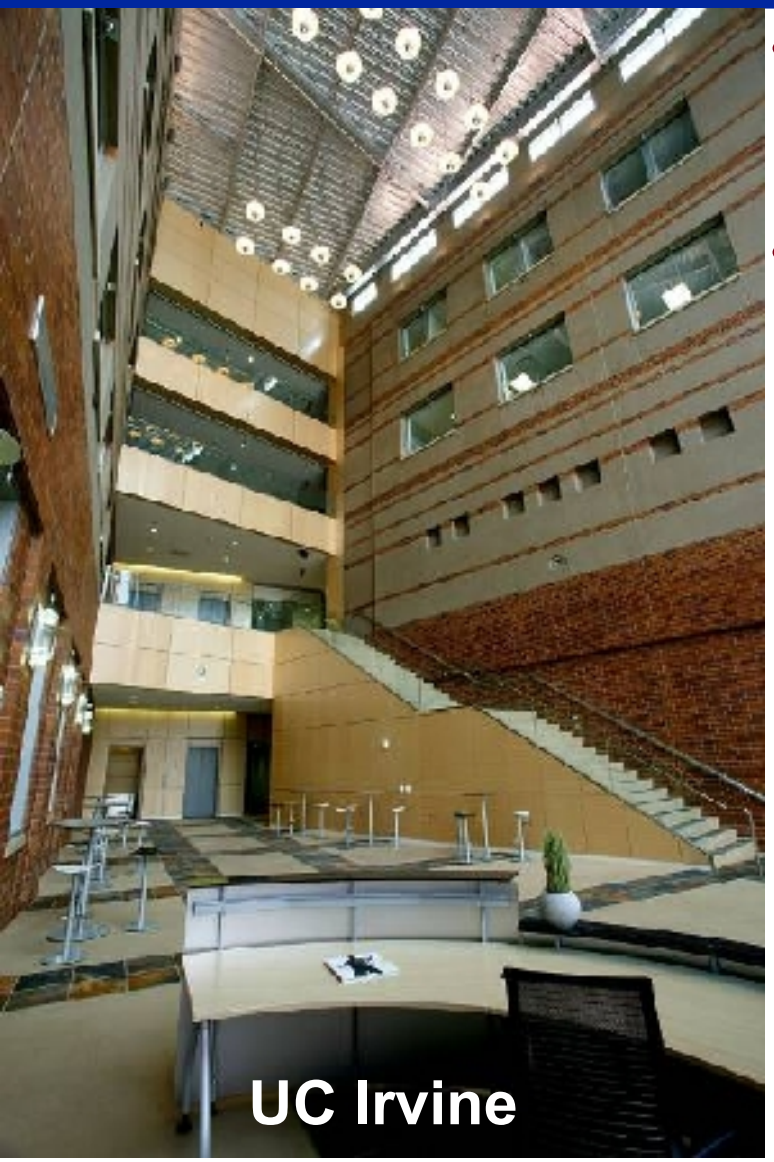
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Distributed Supercomputing: NASA MAP '06 System Configuration Using NLR



G. McConaughy (586), B. Womack (Northrop), P. Webster (606), D. Duffy (CSC), M. Whitehead (CSC), H. Mitchell (610.3), J. Delabeaujardiere (610.3), R. Jones (GST)

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

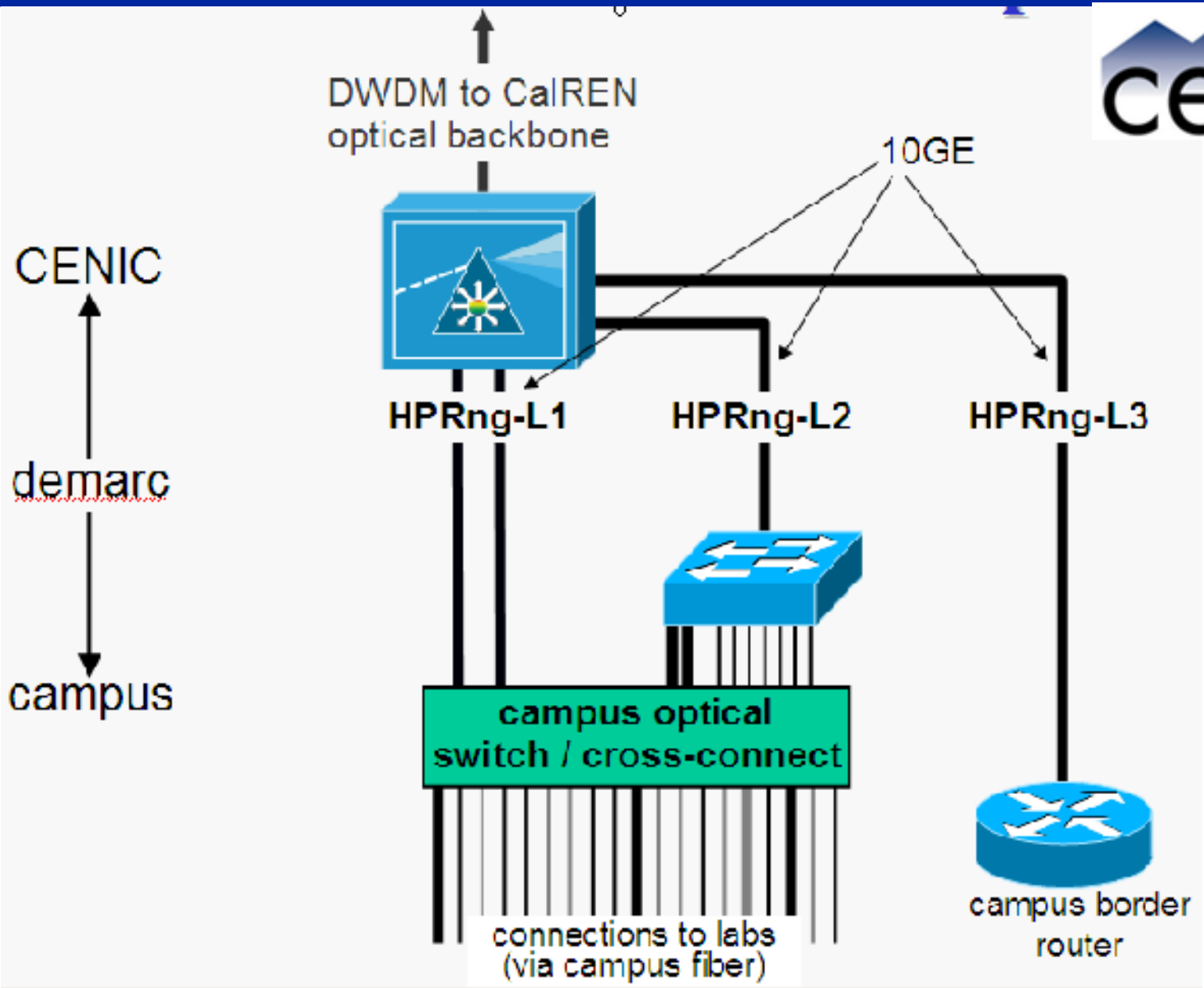


www.calit2.net

Preparing for a World in Which Distance is Eliminated…

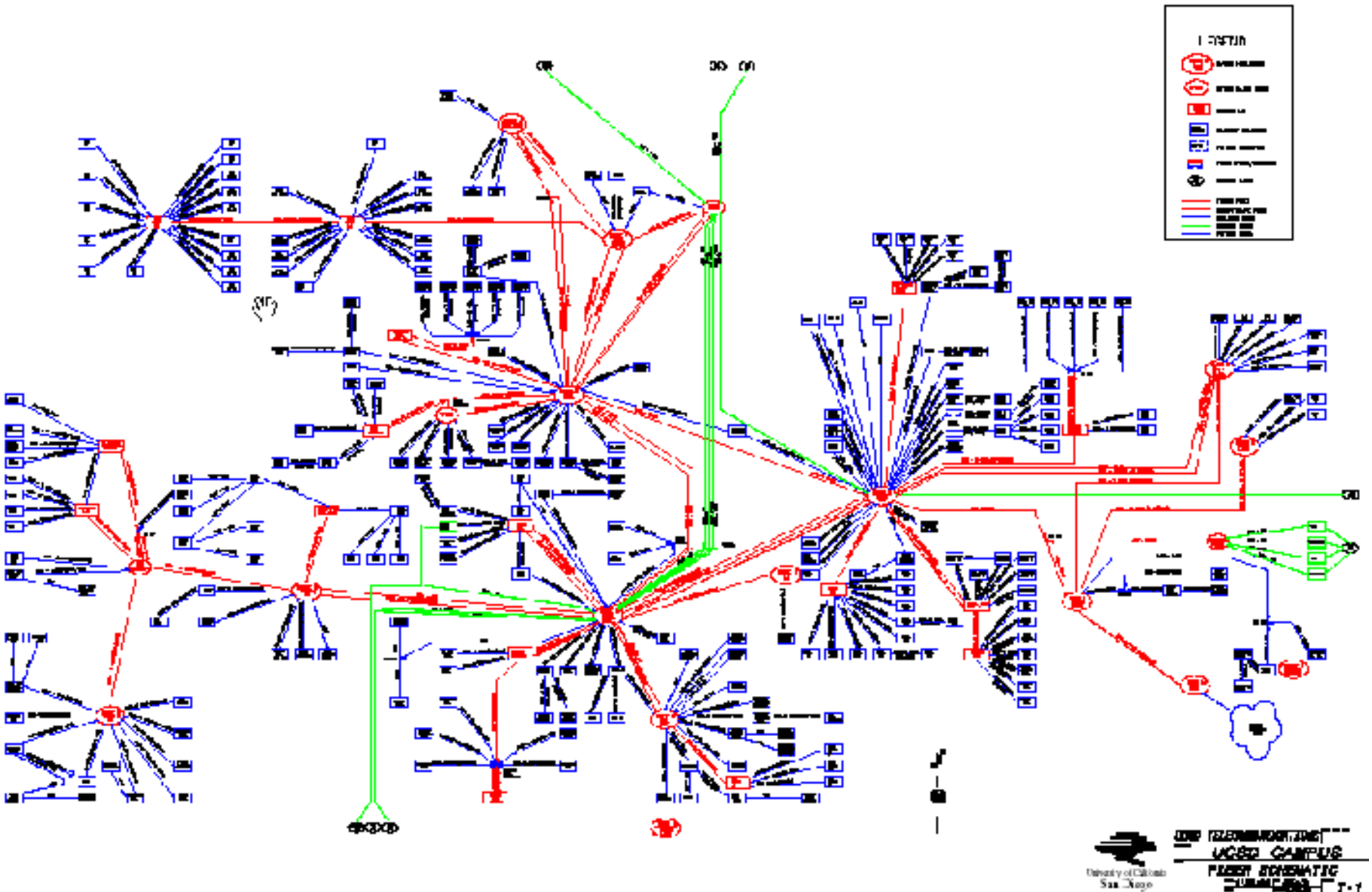
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Campus Preparations Needed to Accept CENIC CalREN Handoff to Campus



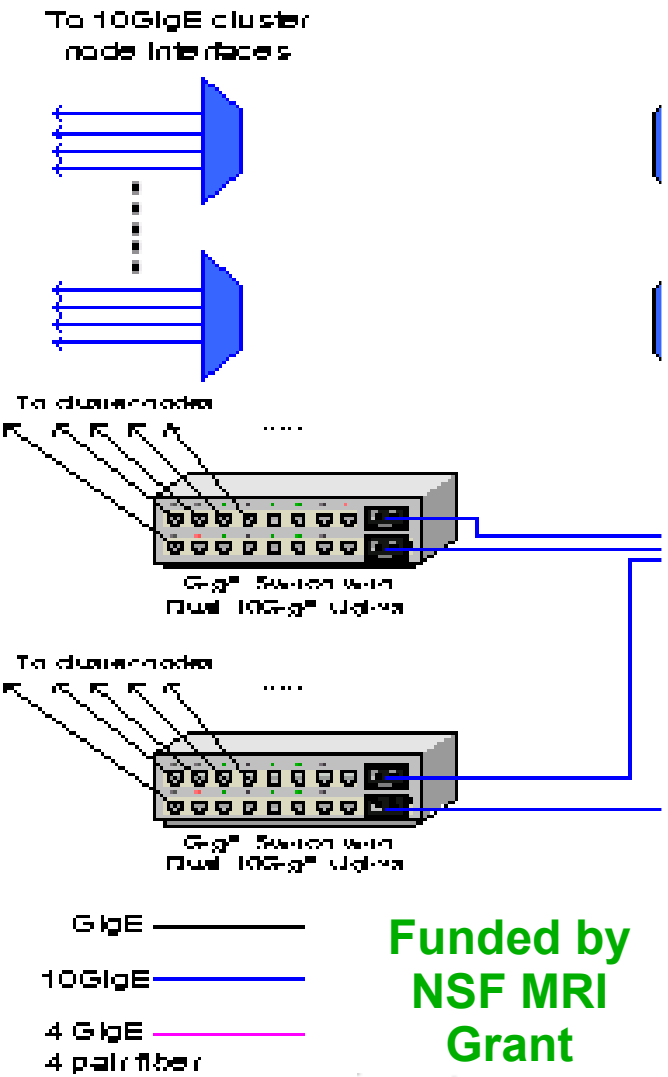
Source: Jim Dolgonas, CENIC

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



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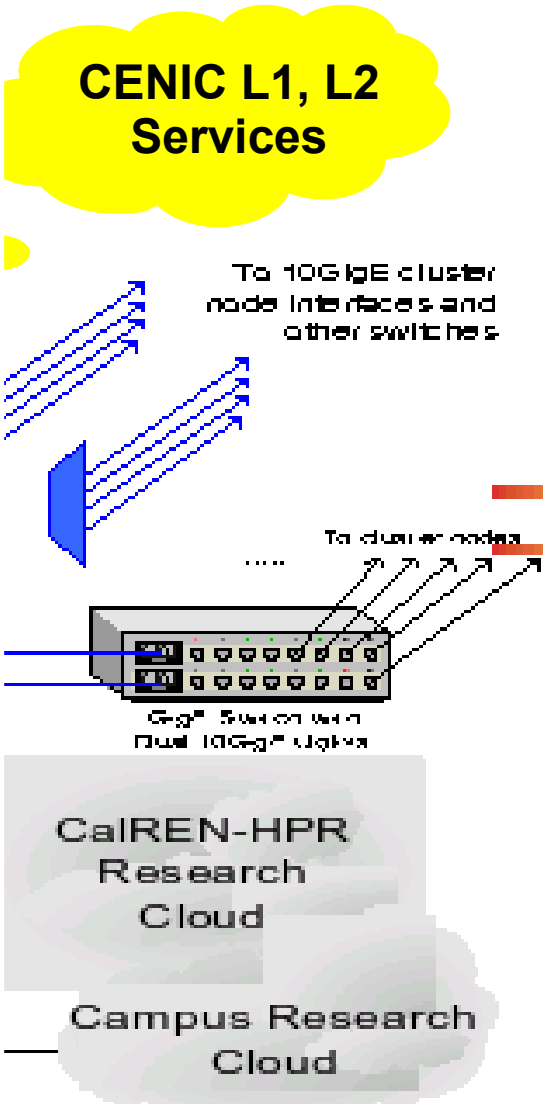
Current UCSD Experimental Optical Core: Ready to Couple to CENIC L1, L2, L3 Services



Goals by 2008:

- >= 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

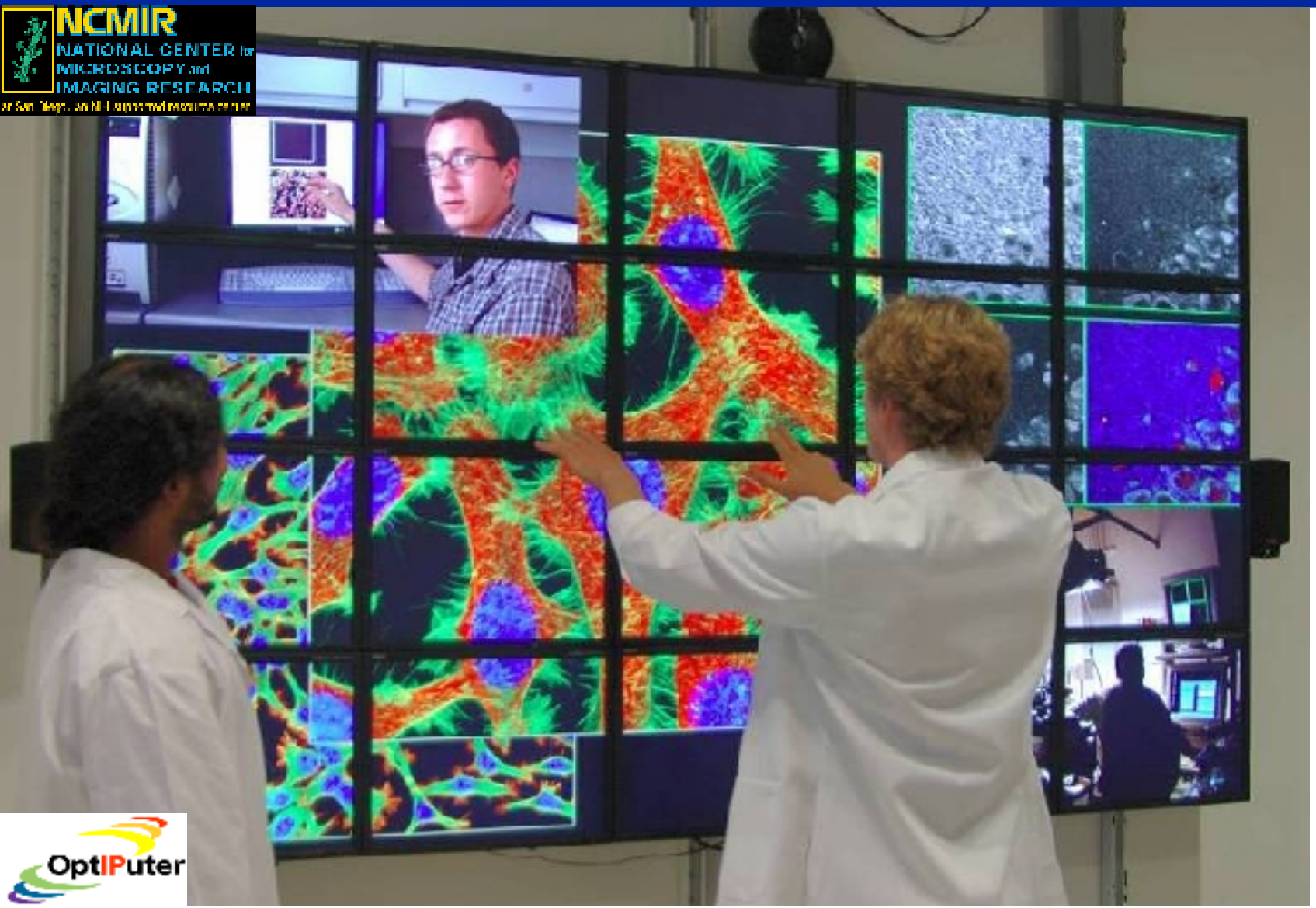


Funded by NSF MRI Grant

OptIPuter Border Router

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

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



Scalable Adaptive Graphics Environment (SAGE)

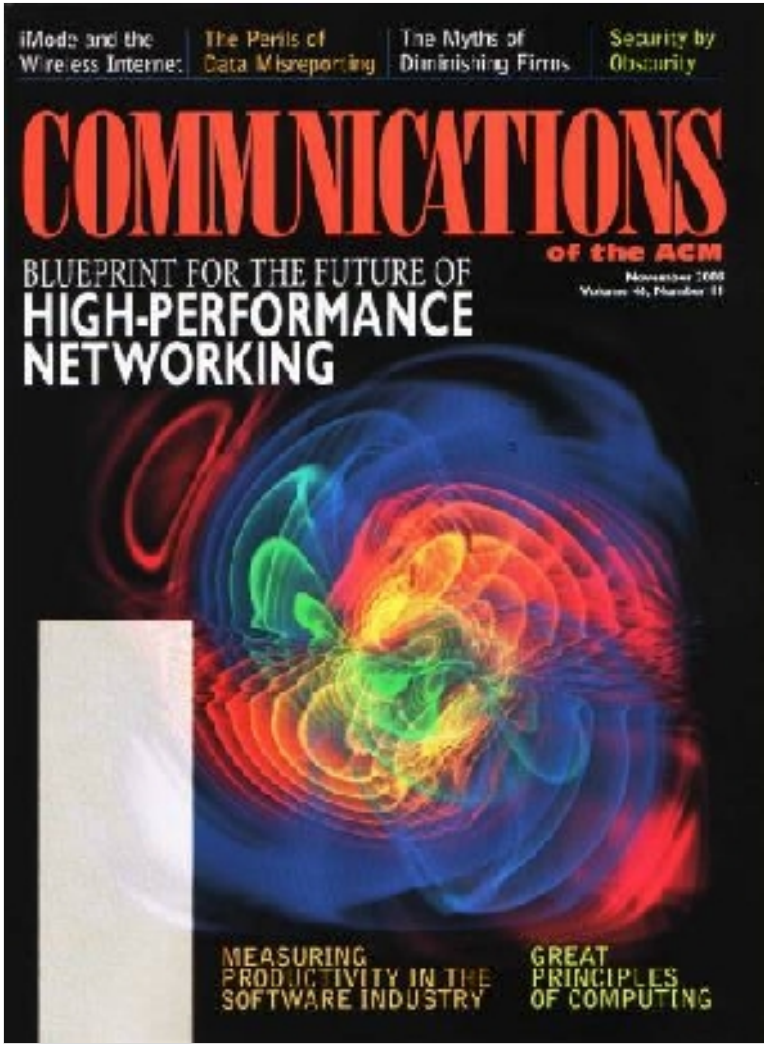
$13.5M Over Five Years

Picture Source: Mark Ellisman, David Lee, Jason Leigh

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

Special issue of Communications of the ACM (CACM): Blueprint for the Future of High-Performance Networking

- Introduction
  - Maxine Brown (guest editor)
- TransLight: A Global-scale LambdaGrid for e-Science
  - Tom DeFanti, Cees de Laat, Joe Mambretti, Kees Neggers, Bill St. Arnaud
- Transport Protocols for High Performance
  - Aaron Falk, Ted Faber, Joseph Bannister, Andrew Chien, Bob Grossman, Jason Leigh
- Data Integration in a Bandwidth-Rich World
  - Ian Foster, Robert Grossman
- The OptIPuter
  - Larry Smarr, Andrew Chien, Tom DeFanti, Jason Leigh, Philip Papadopoulos
- Data-Intensive e-Science Frontier Research
  - Harvey Newman, Mark Ellisman, John Orcutt

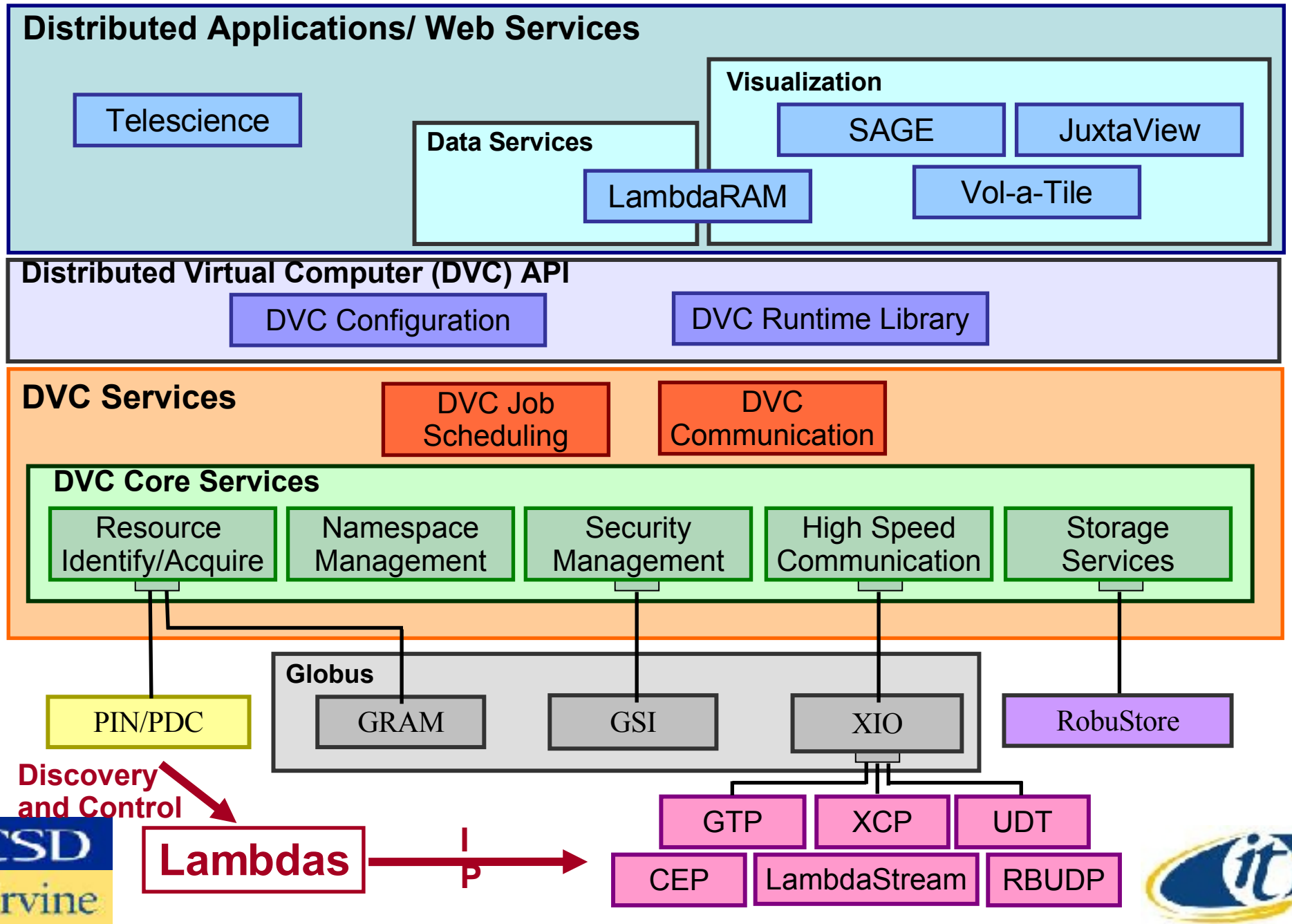


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Source: Special Issue of Comm. ACM 2003

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



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





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Powered by Rocks ROCKS

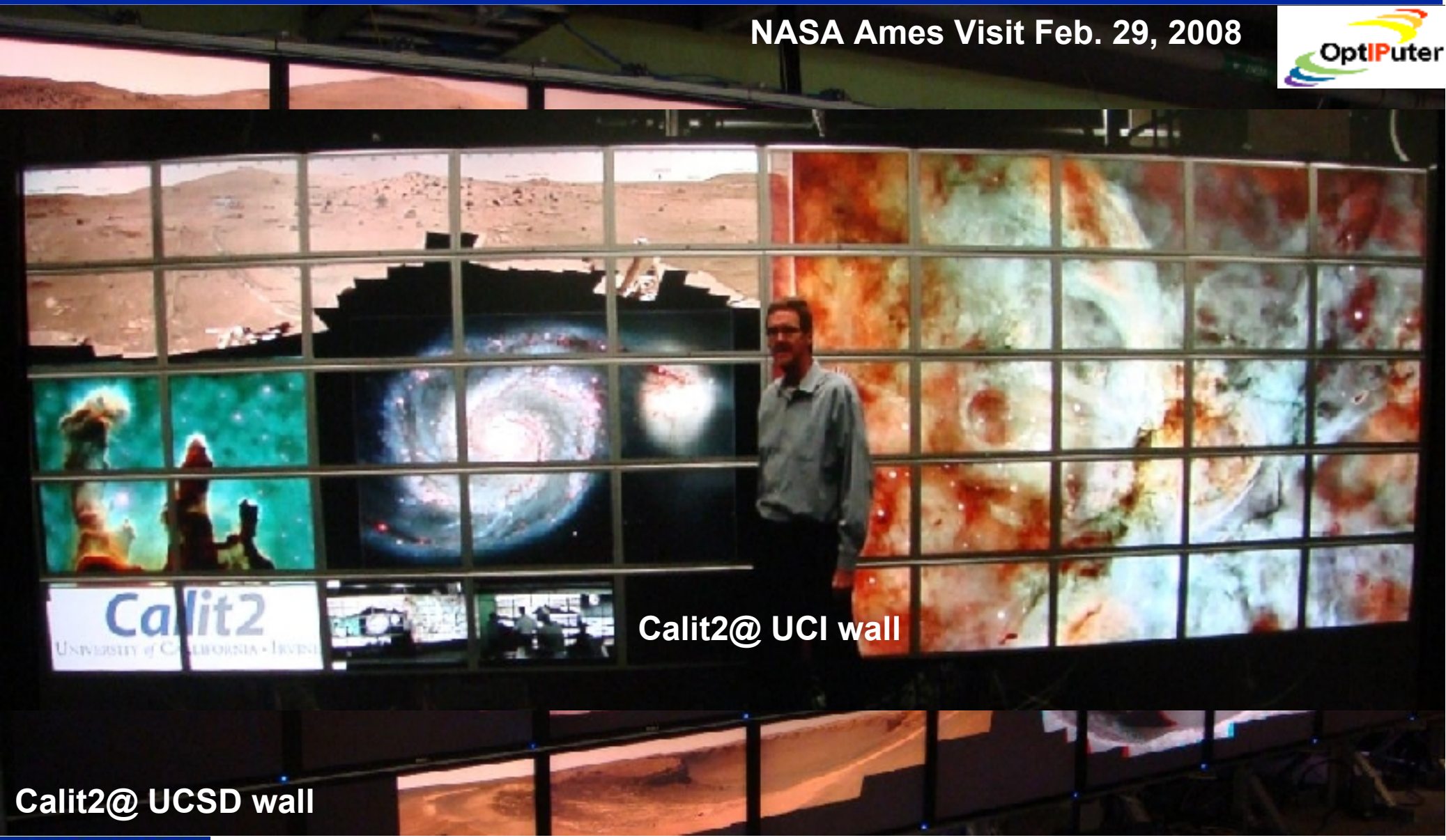
Source: Phil Papadopoulos SDSC, Calit2

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Metacomputer:
The OptIPlanet Collaboratory (2005-2010)

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The Calit2 200 Megapixel OptIPortals at UCSD and UCI Are Now a Gbit/s HD Collaboratory



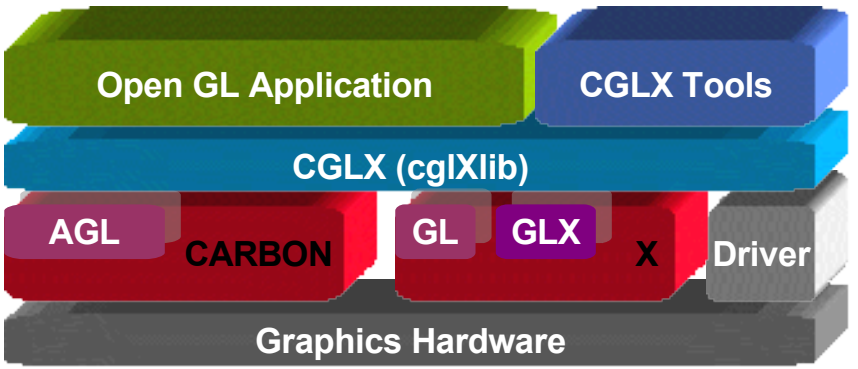
UCSD
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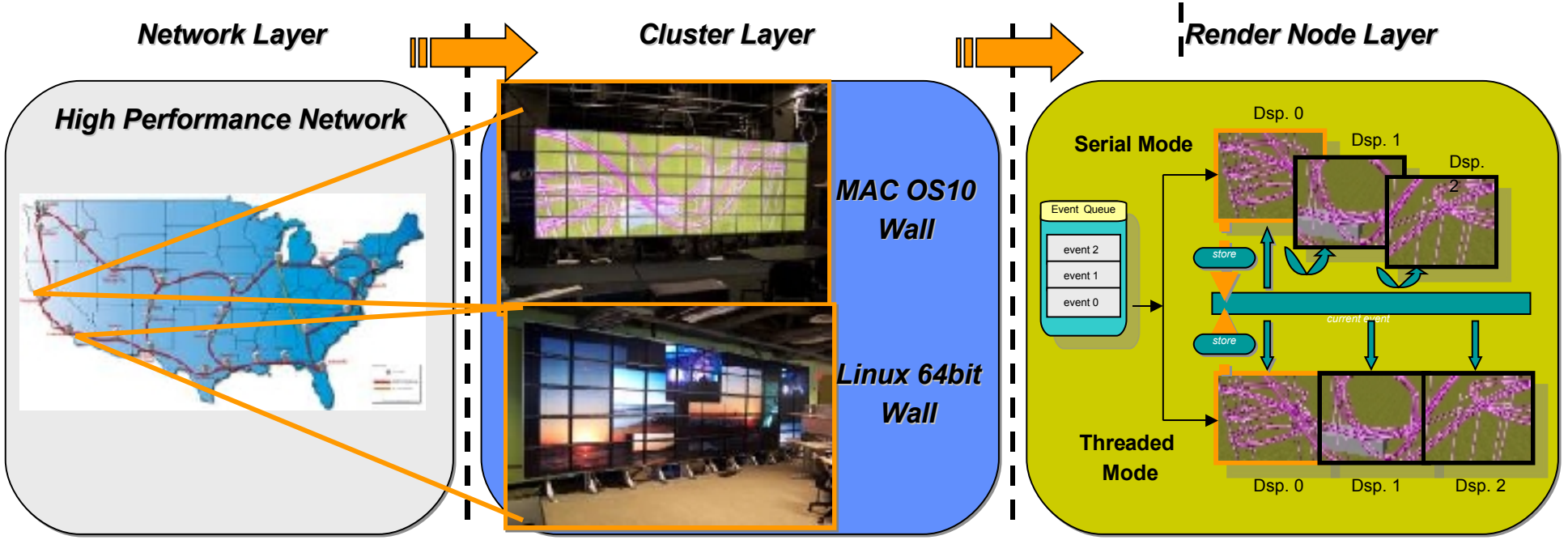
NASA Ames is Completing a 245 Mpixel Hyperwall as Project Columbia Interface

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Rocks/CGLX OptIPortal Uses OpenGL Hardware Accelerated

- **CGLX features:**
  - Cross-Platform Hardware Accelerated Rendering
  - Synchronized Multi-Layer OpenGL Context Support
  - Distributed Event Management
  - Scalable Multi Display Support





Source: Kai-Uwe Doerr, Falko Kuester, Calit2

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

Joint Partnership of:

UCSD
UCIrvine

PI Larry Smarr

The Genetic Diversity of Ocean Microbes Provides Novel Genetic Components for Bioengineering Clean Energy

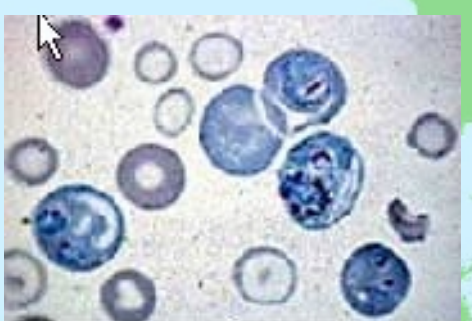
Plus 155 Marine Microbial Genomes



Each Sample ~2000 Microbial Species

Specify Ocean Data





Sorcerer II Data Will Double Number of Proteins in GenBank!

camera Marine Microbial Ecology

MARINE MICROBIOLOGY INITIATIVE

Gordon and Betty MOORE FOUNDATION

J. Craig Venter INSTITUTE

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Calit2's Direct Access Core Architecture
An OptIPuter Metagenomics Metacomputer

Sargasso Sea Data

Sorcerer II Expedition (GOS)

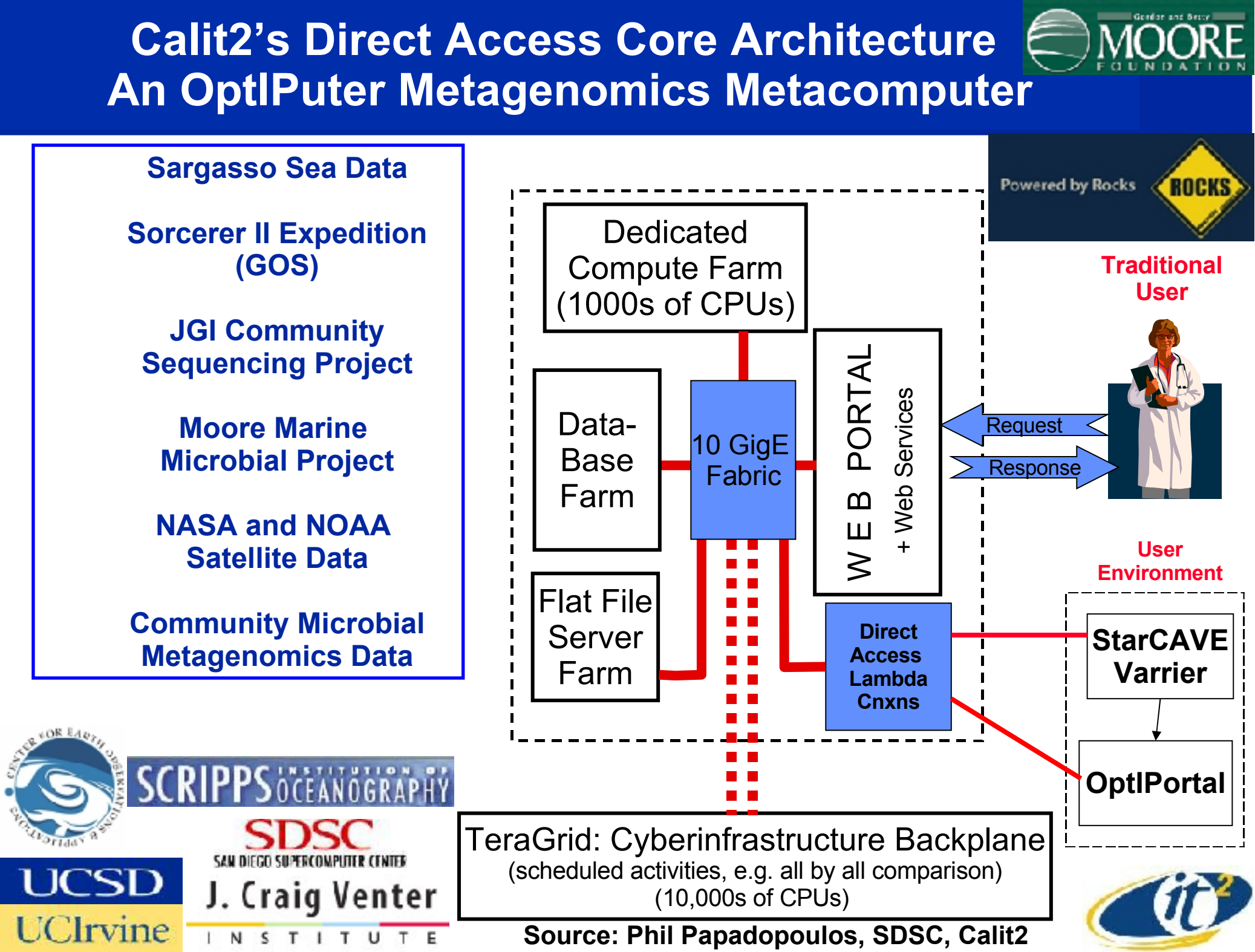
JGI Community Sequencing Project

Moore Marine Microbial Project

NASA and NOAA Satellite Data

Community Microbial Metagenomics Data

Powered by Rocks



Source: Phil Papadopoulos, SDSC, Calit2

CAMERA's Global Microbial Metagenomics CyberCommunity—Can We Employ Social Network Software?

Over 1850 Registered Users From Over 50 Countries



camera
Marine Microbial Ecology

J. Craig Venter INSTITUTE

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The Global Lambda Integrated Facility (GLIF) Creates MetaComputers on the Scale of Planet Earth

Maxine Brown, Tom DeFanti, Co-Chairs

iGrid 2005

THE GLOBAL LAMBDA INTEGRATED FACILITY

www.igrid2005.org

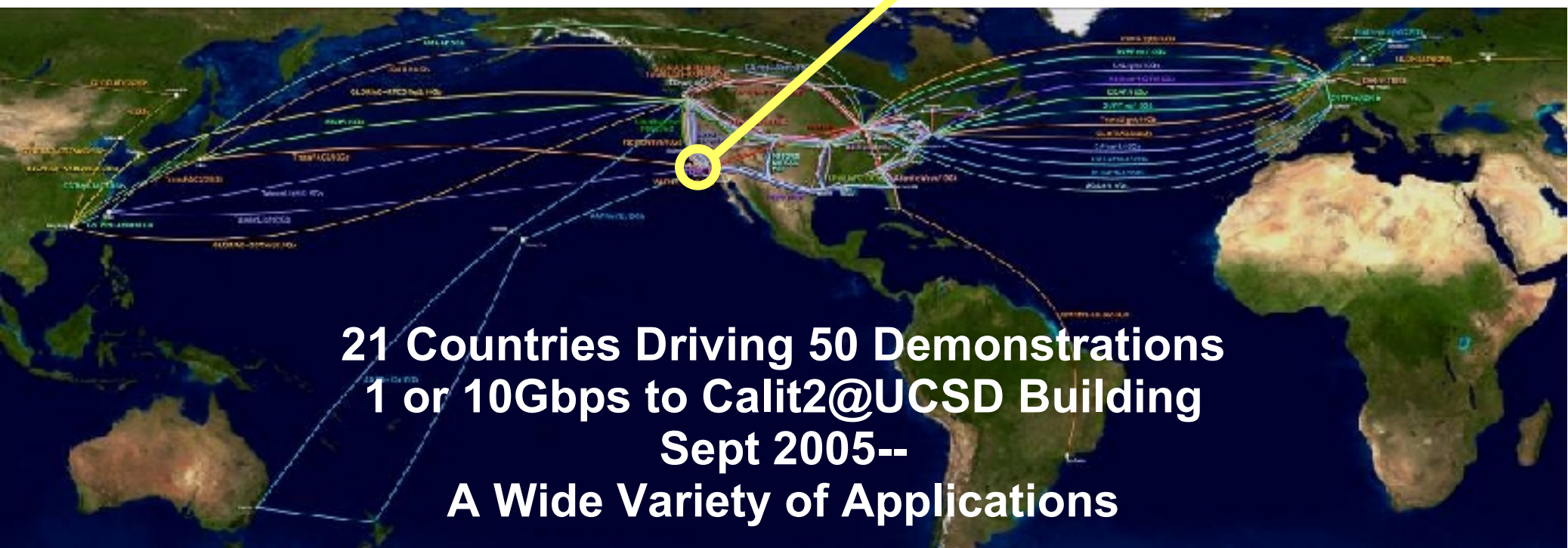


the UC Discovery Grant

September 26-30, 2005

Calit2 @ University of California, San Diego

California Institute for Telecommunications and Information Technology

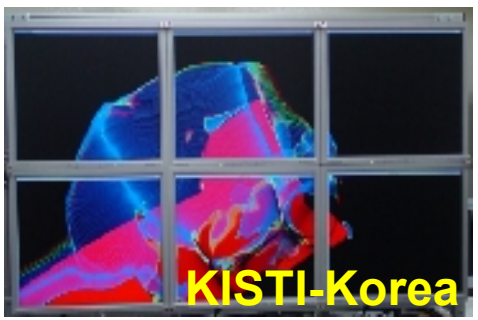


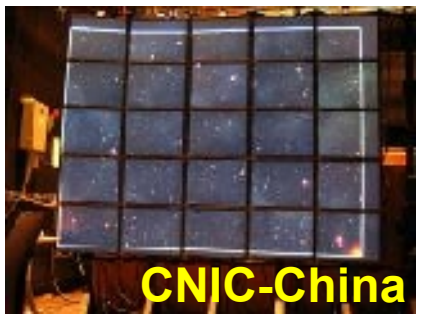
21 Countries Driving 50 Demonstrations
1 or 10Gbps to Calit2@UCSD Building
Sept 2005--
A Wide Variety of Applications

OptIPortals
Are Being Adopted Globally


AIST-Japan


Osaka U-Japan


KISTI-Korea


CNIC-China


NCHC-Taiwan


UZurich

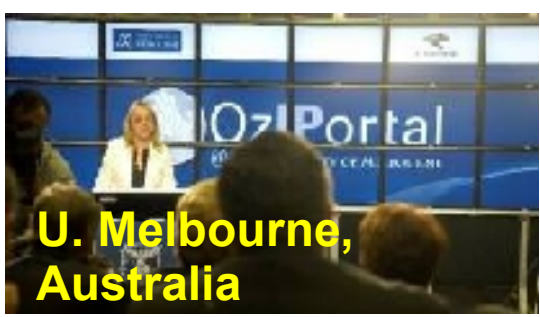

SARA- Netherlands


Brno-Czech Republic


EVL@UIC


Calit2@UCSD


Calit2@UCI



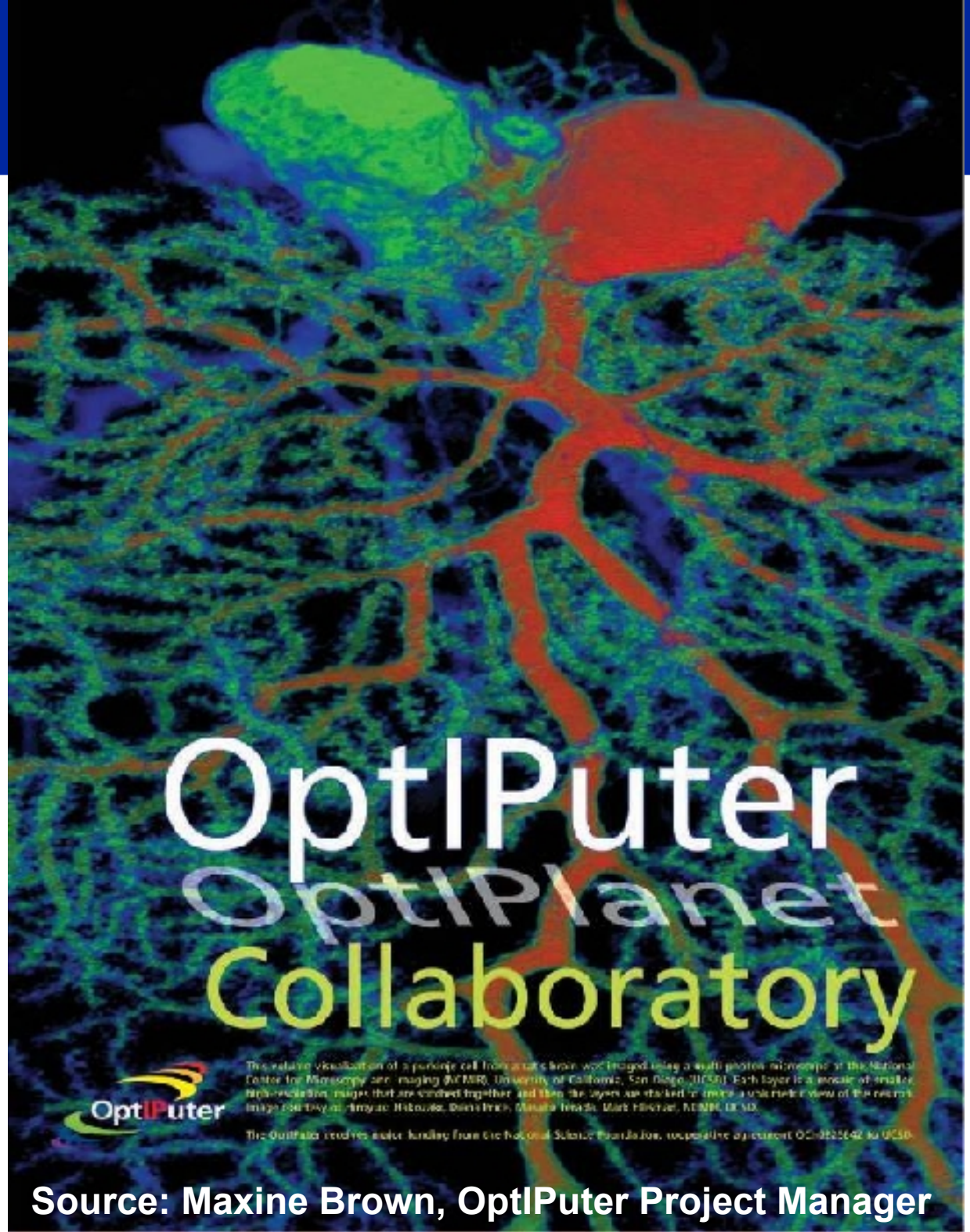
U. Melbourne, Australia

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Powered by Rocks ROCKS

evl electronic visualization laboratory

it2



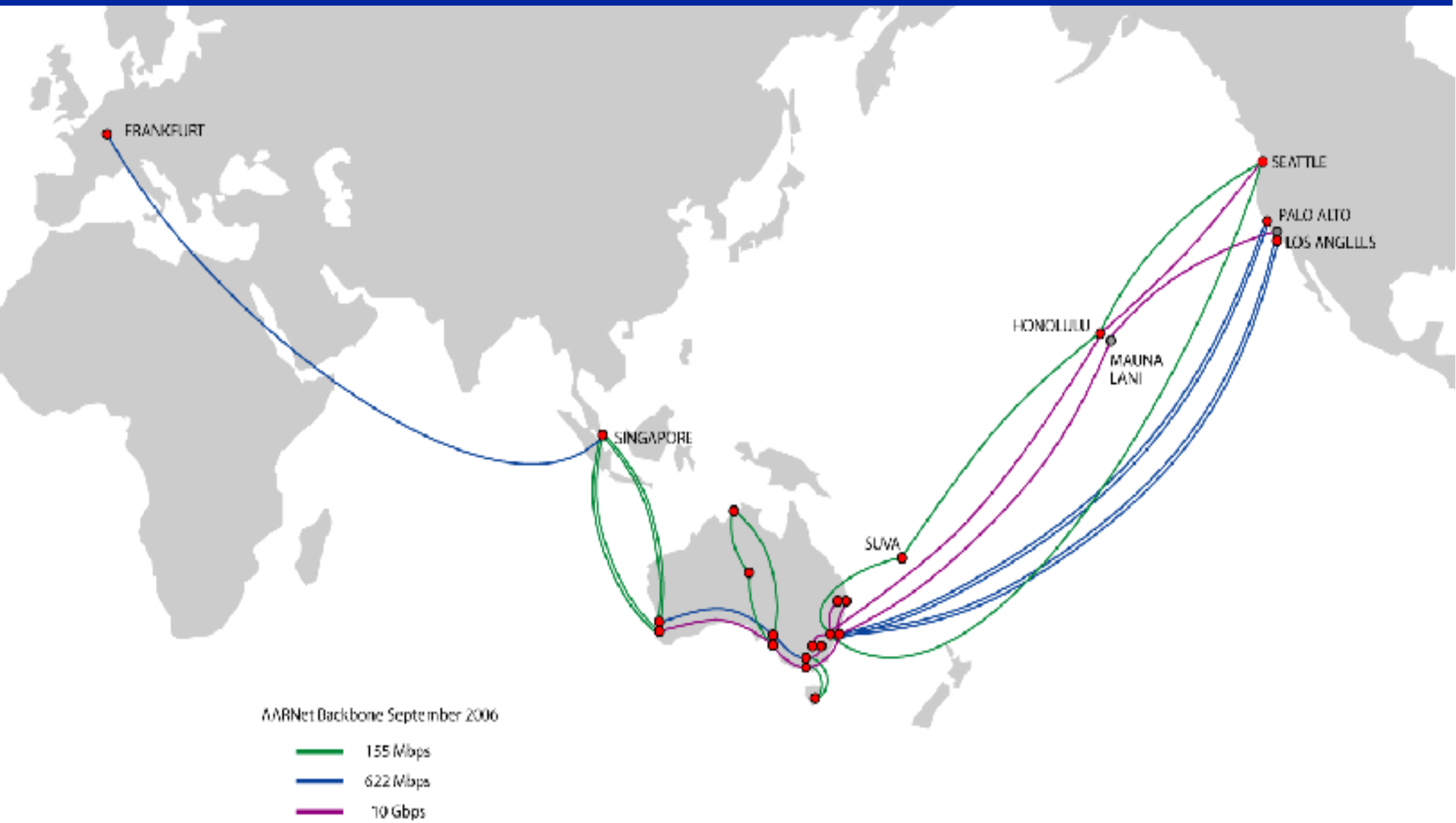
Source: Maxine Brown, OptIPuter Project Manager

Green Initiative:

Can Optical Fiber Replace Airline Travel for Continuing Collaborations ?

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AARNet International Network



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



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www.calit2.net/newsroom/release.php?id=1219

Victoria Premier and Australian Deputy Prime Minister Asking Questions



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www.calit2.net/newsroom/release.php?id=1219

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University of Melbourne Vice Chancellor Glyn Davis in Calit2 Replies to Question from Australia



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OptIPlanet Collaboratory Persistent Infrastructure Between Calit2 and U Washington



OptIPuter

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

ROCKS







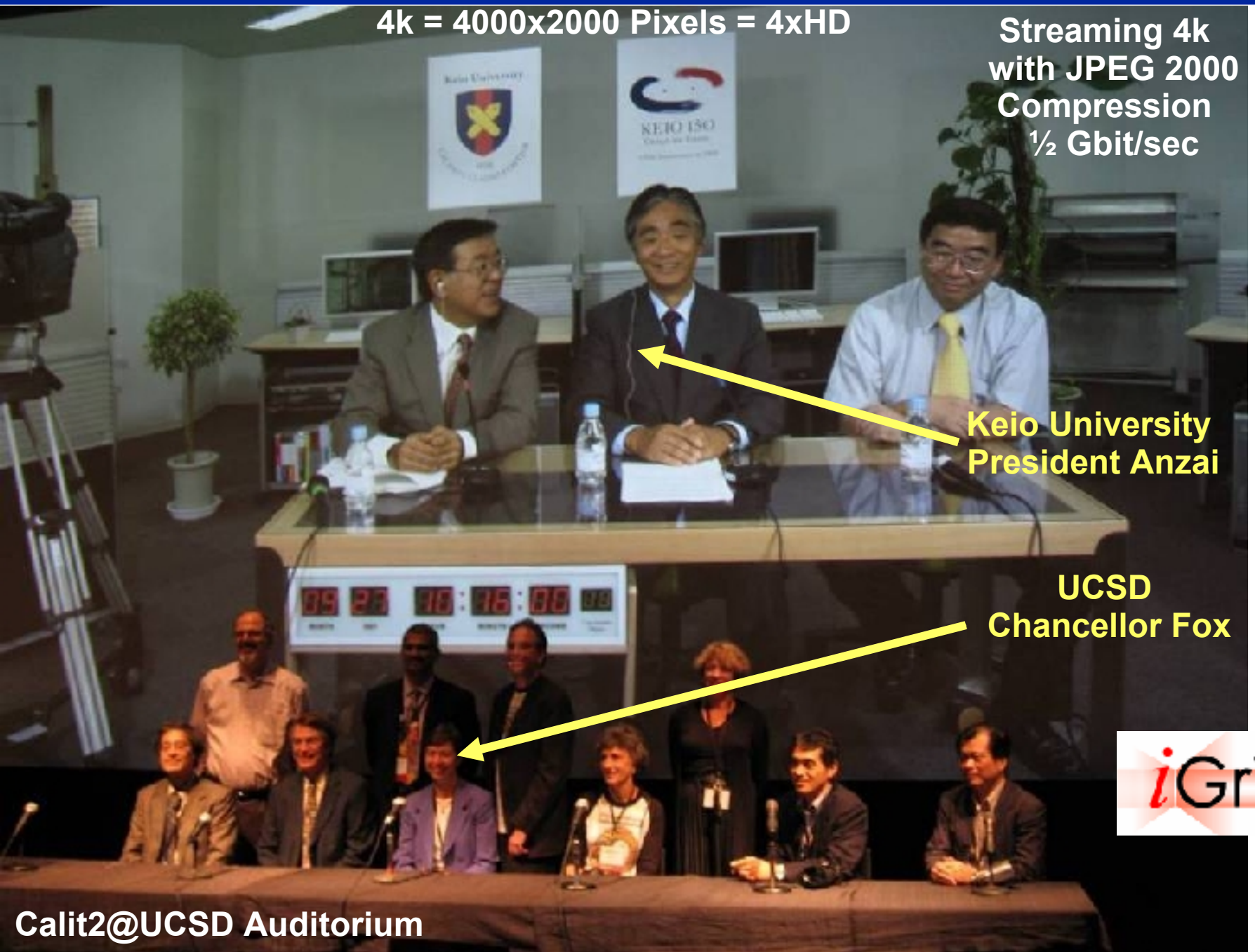
UW's Research Channel
Michael Wellings

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SAGE Global Visualcasting to Europe September 2007



Telepresence Meeting
Using Digital Cinema 4k Streams



CineGrid

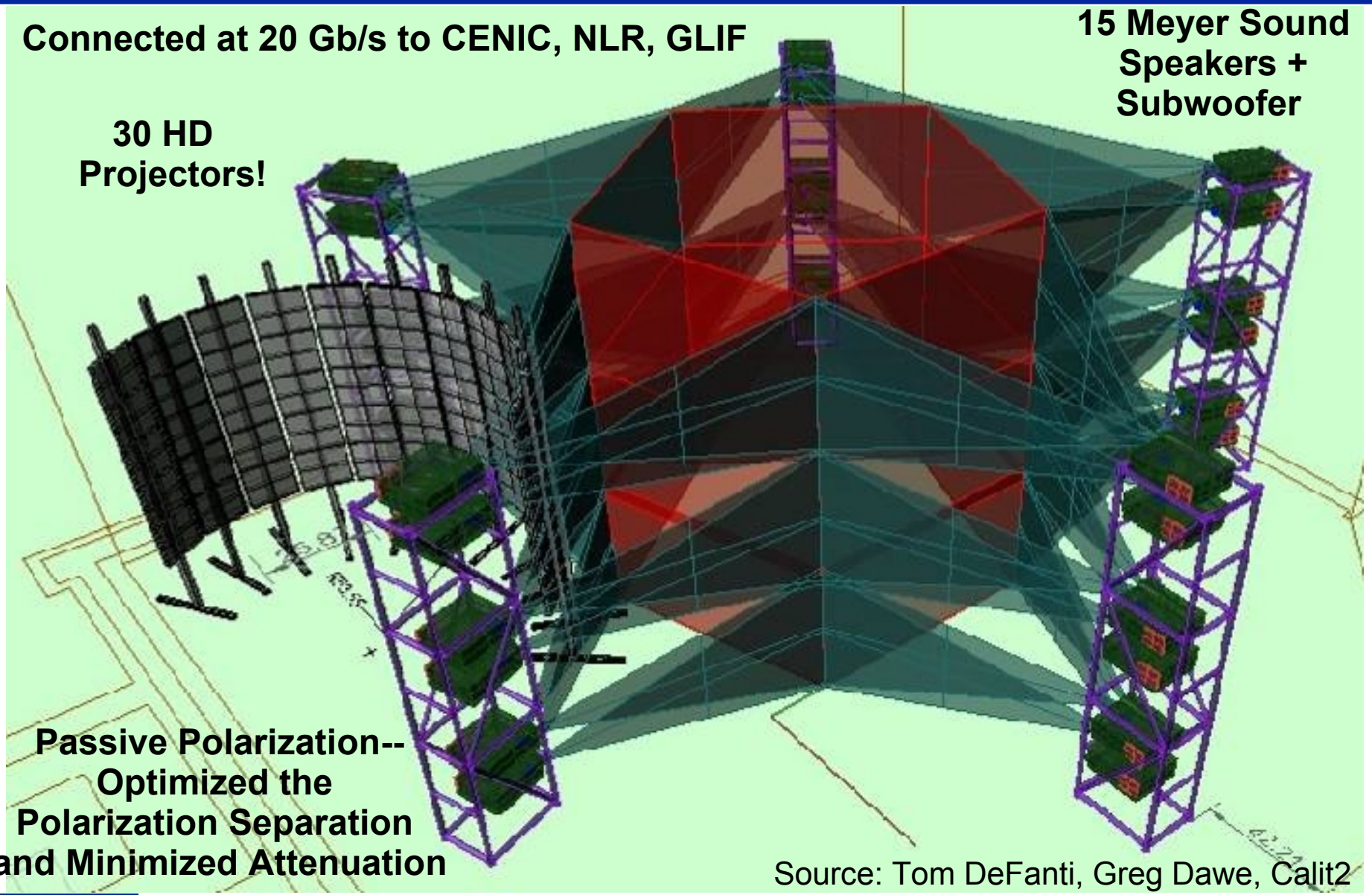
Lays Technical Basis for Global Digital Cinema

Sony
NTT
SGI

iGrid 2005

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3D OptIPortals: Calit2 StarCAVE and Varrier: Enables Exploration of Virtual Worlds



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Cluster with 30 Nvidia 5600 cards-60 GB Texture Memory

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