"How to Terminate the GLIF by Building a Campus Big Data Freeway System"

Keynote Lecture

12th Annual Global LambdaGrid Workshop

Chicago, IL

October 11, 2012

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

The White House Announcement Has Galvanized U.S. Campus CI Innovations

News

White House launches big data R&D effort

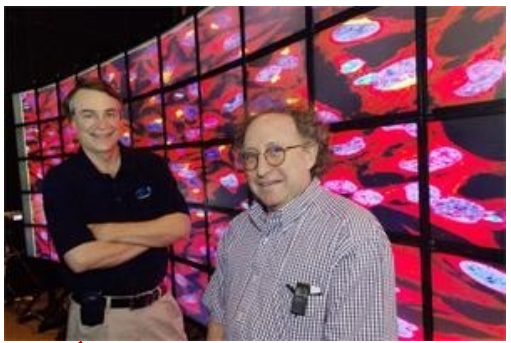
NSF and DARPA are among the agencies looking to harness the power of large volumes of data

By Grant Gross

March 29, 2012 12:34 PM ET

5 Comments + Briefcase What's this?

The OptIPuter Creates a Big Data Global Collaboratory Built on a 10Gbps "End-to-End" Lightpath Cloud



End User OptIPortal





Local or Remote Instruments



HD/4k Live Video

NSF

HPC

TeraGrid™



10G Lightpaths

Campus Optical Switch



amazon web services™



Data Repositories & Clusters



HD/4k Video Repositories

SDSC

OptIPuter

it²

Calit2 Sunlight OptIPuter Exchange
Six Years of Experience with Campus 10G Termination

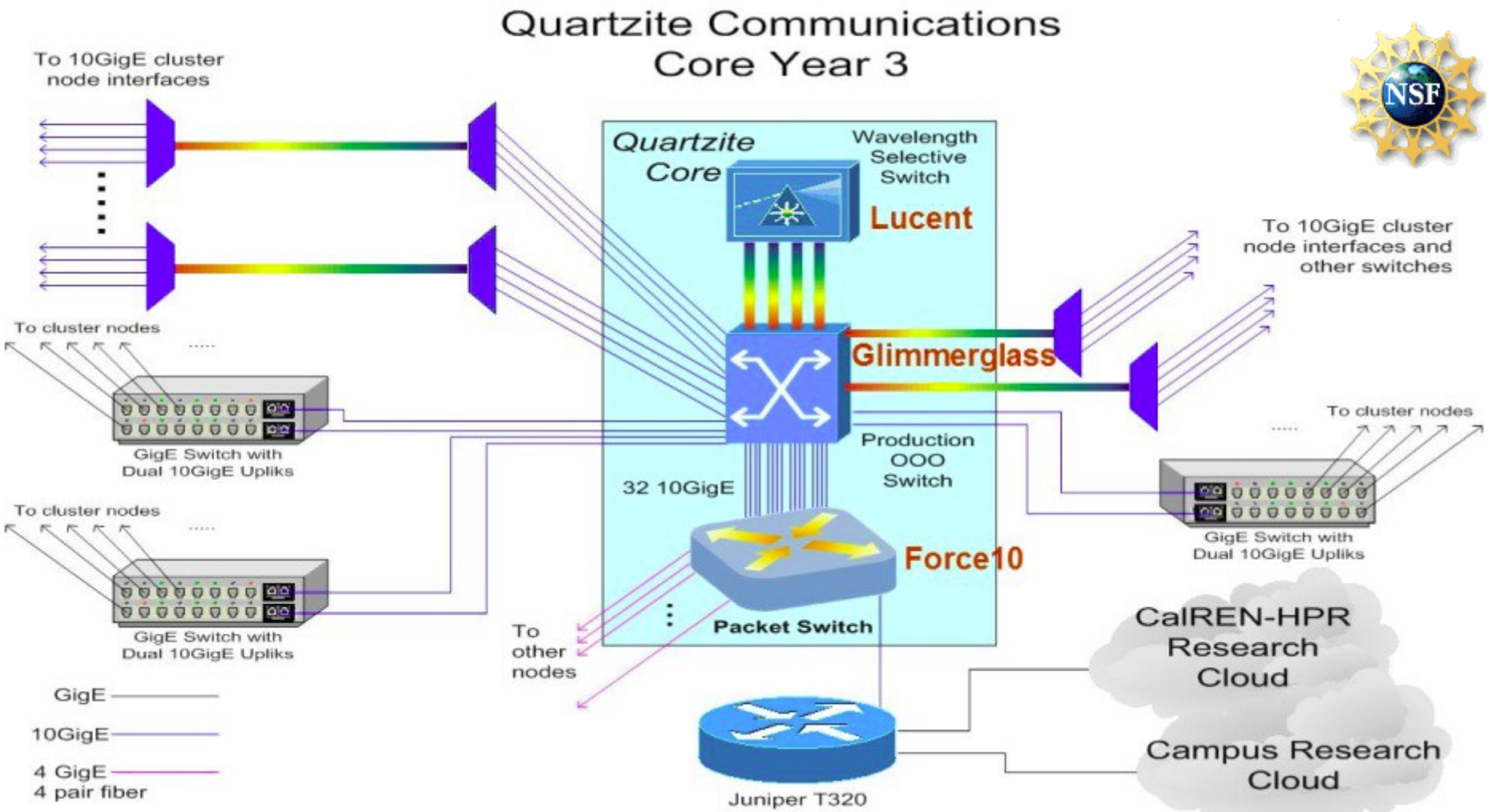


Maxine Brown, EVL, UIC OptIPuter Project Manager

SDSC

it²

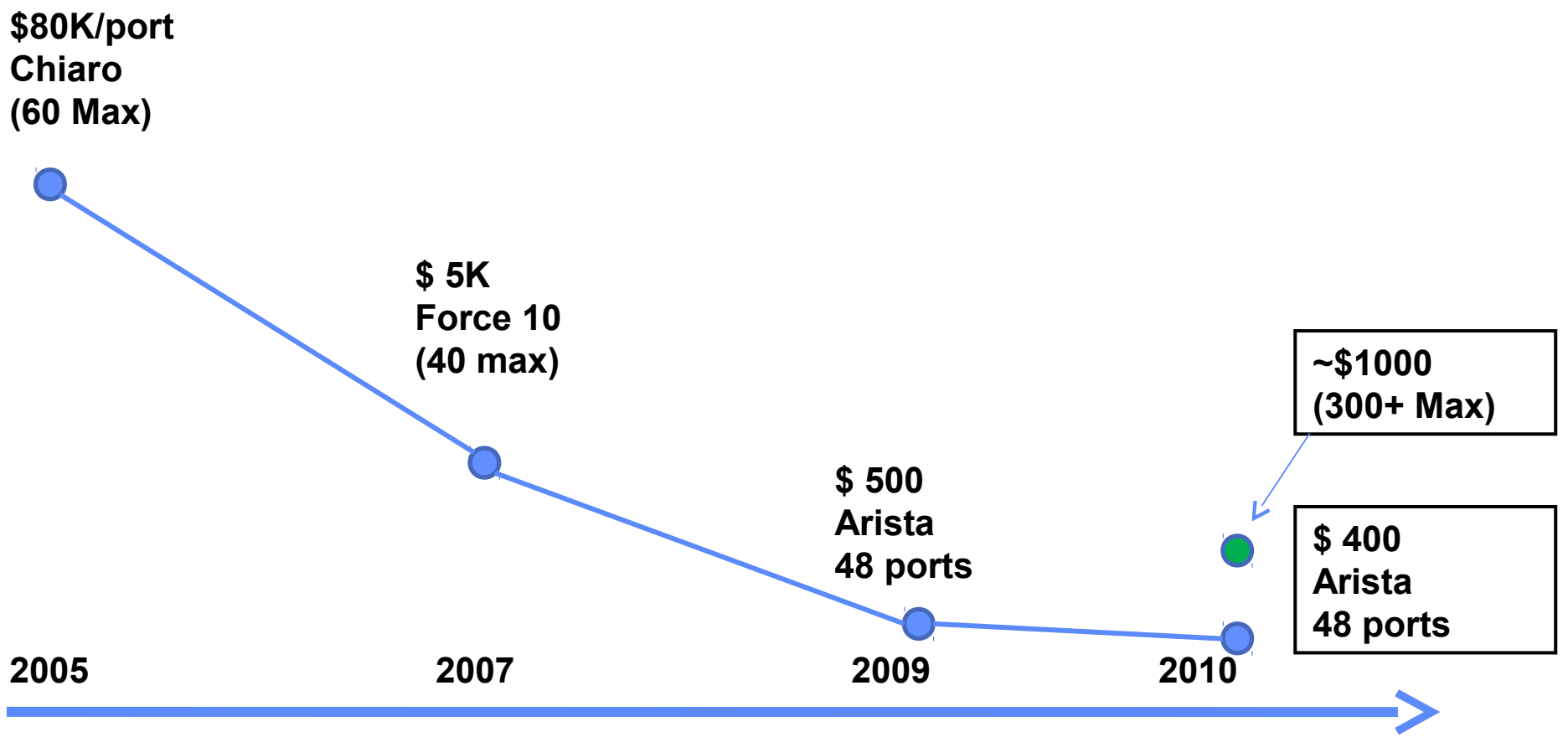
Prism@UCSD Prototype
NSF Quartzite Grant



NSF Quartzite Grant 2004-2007
Phil Papadopoulos, PI

Rapid Evolution of 10GbE Port Prices Makes Campus-Scale 10Gbps CI Affordable

- Port Pricing is Falling
- Density is Rising – Dramatically
- Cost of 10GbE Approaching Cluster HPC Interconnects



SDSC

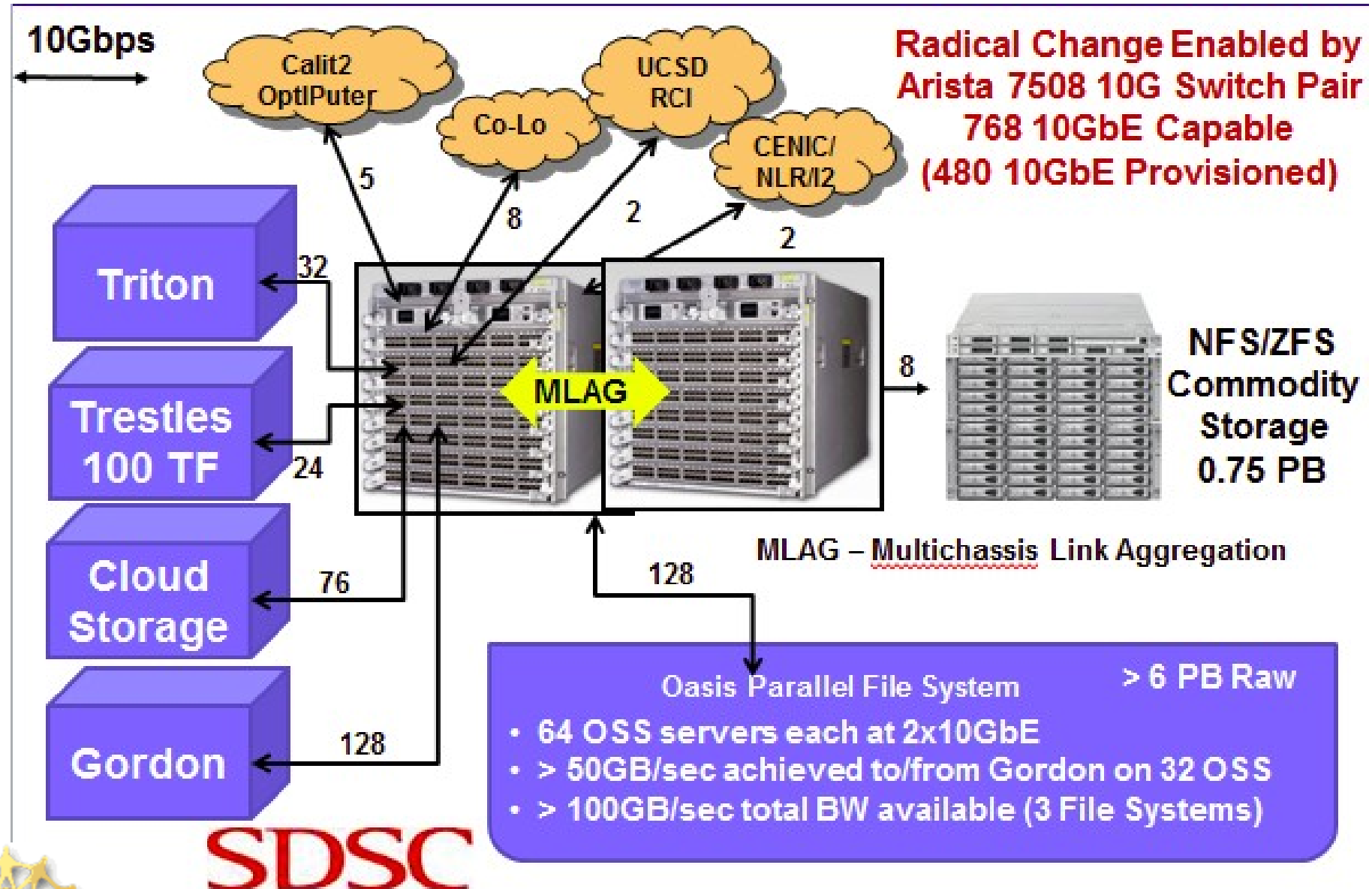
Source: Philip Papadopoulos, SDSC/Calit2

it²

Arista Switch Becomes Central Switching Point for 10Gbps Wavelengths



Arista Enables SDSC's Massive Parallel 10G Switched Data Analysis Resource



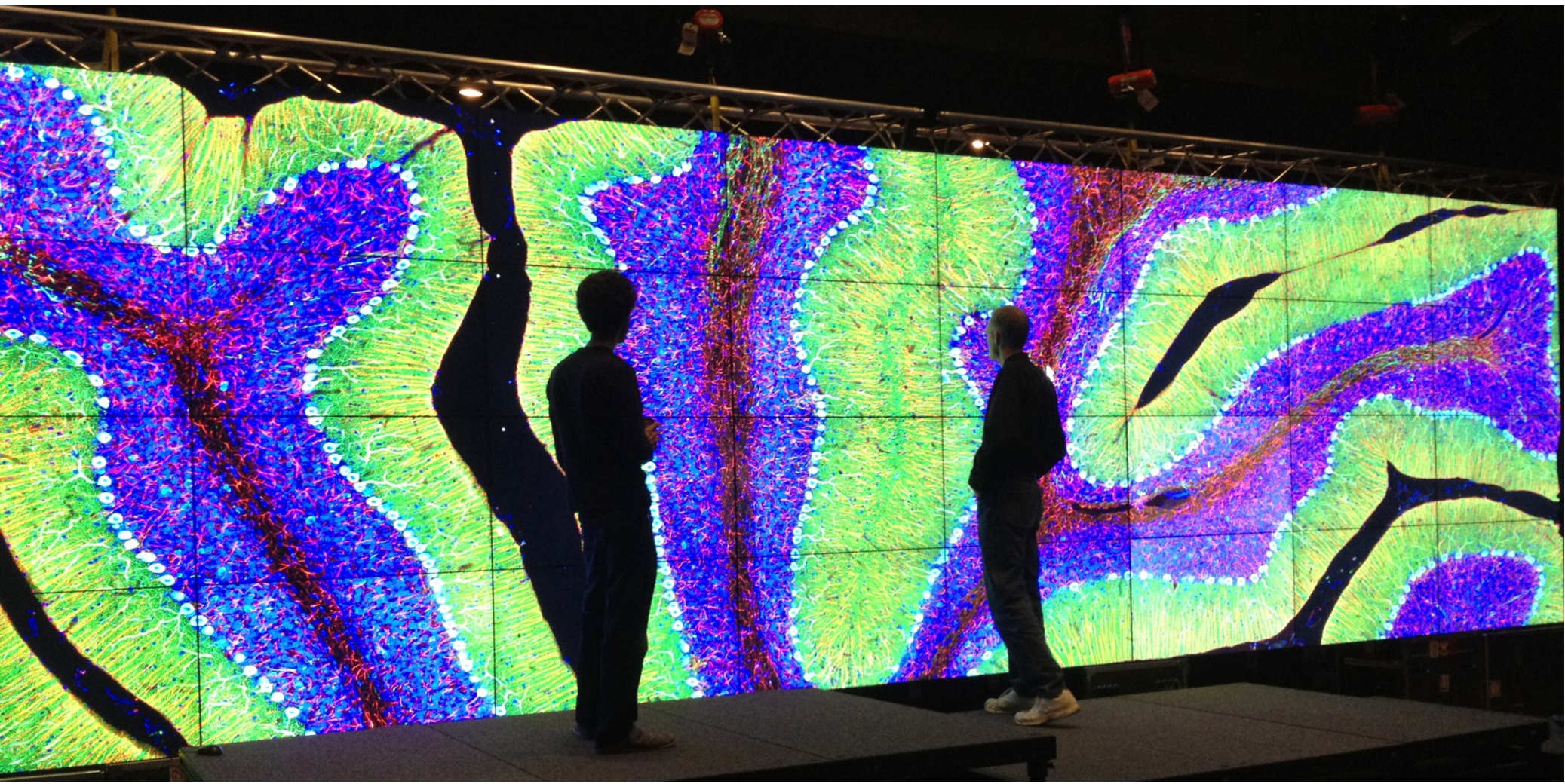
Quickly Deployable Nearly Seamless OptIPortables Provide 10G Visualization Termination Device

45 minute setup, 15 minute tear-down with two people (possible with one)



Image From the Calit2 KAUST Lab

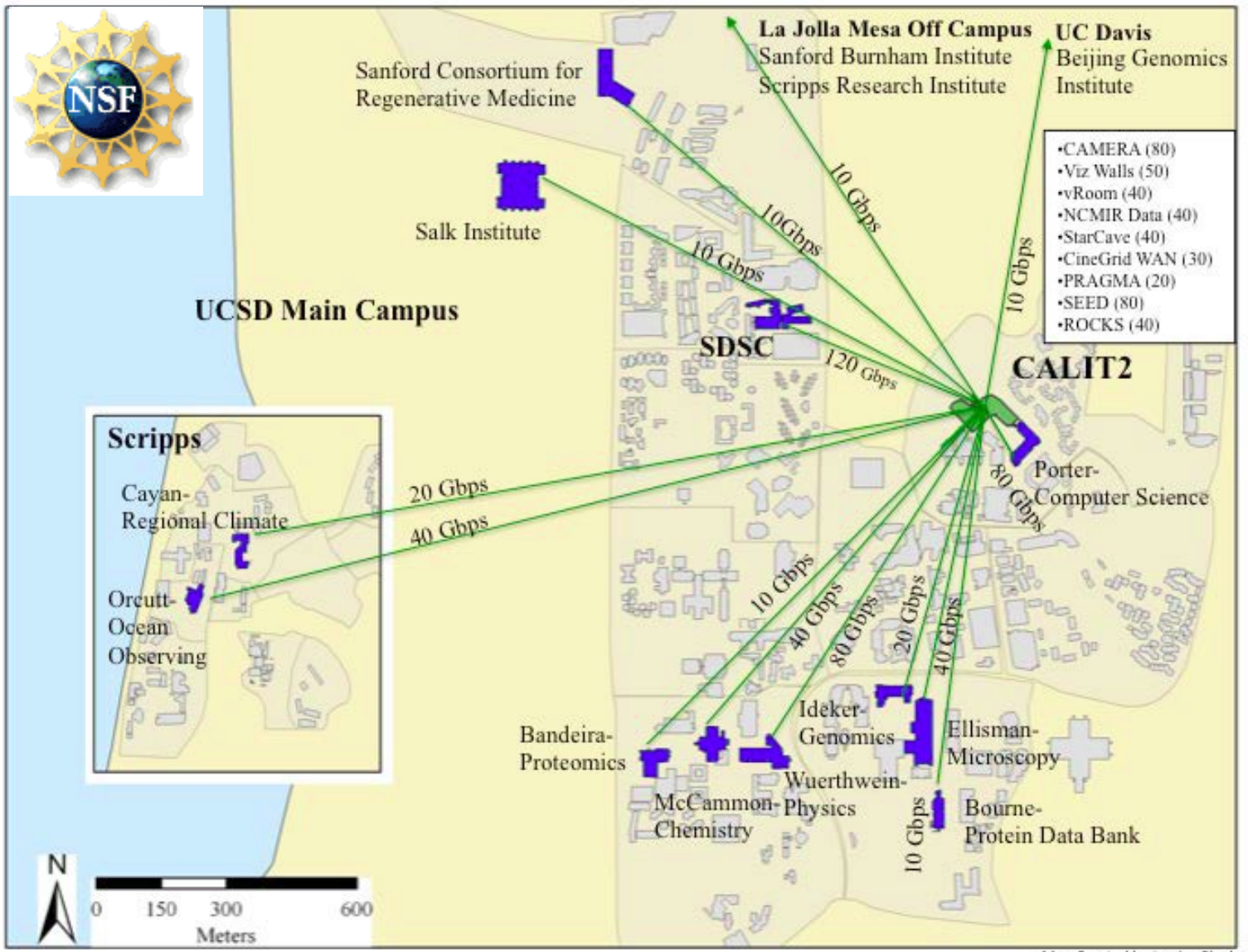
OptIPortables Can Themselves Be Scaled
4x8 OptIPortables = 64 Mpixels



End User FIONA Merges Gordon I/O Nodes and Data Oasis Storage Nodes into the OptIPortable

- **FIONA**
  - Flash Drive Space: 1.4TB
  - Ethernet: 20Gbps
  - Local Disk Space: 18TB
  - Flash-to-Net: 2GB/sec (est)
  - Disk-to-Net: 600-700MB/s
  - OptIPortable Scalable Vis
- **Gordon**
  - Flash Drive Space: 4TB
  - Ethernet: 20 Gbps
  - Local Disk Space: 0TB
  - Flash-to-Net: 3GB/sec (measured)
  - Disk-to-Net: 2GB/s (requires Oasis I/O servers)
  - No Vis

How a Campus Can Terminate the GLIF: NSF Has Awarded Prism@UCSD Optical Switch



SDSC

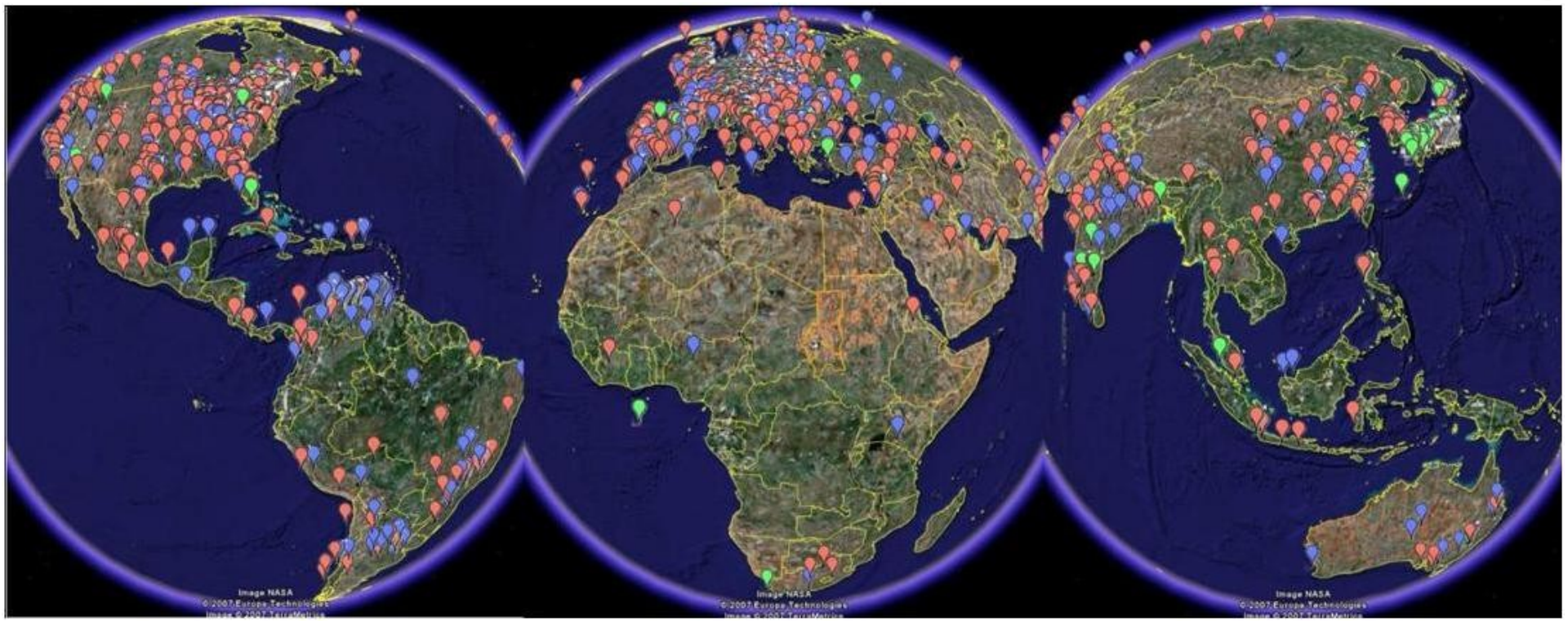
Phil Papadopoulos, SDSC, Calit2, PI

Global Access to On-Campus Resources

- **Protein Data Bank**
- **Center for Computational Mass Spectrometry**

Remote Users Need Access to Protein Data Bank: 2010 FTP Traffic

PDB Has >80,000 Structures Supported by NSF for 35 Years



RCSB PDB
159 million
entry downloads

PDBe
34 million
entry downloads

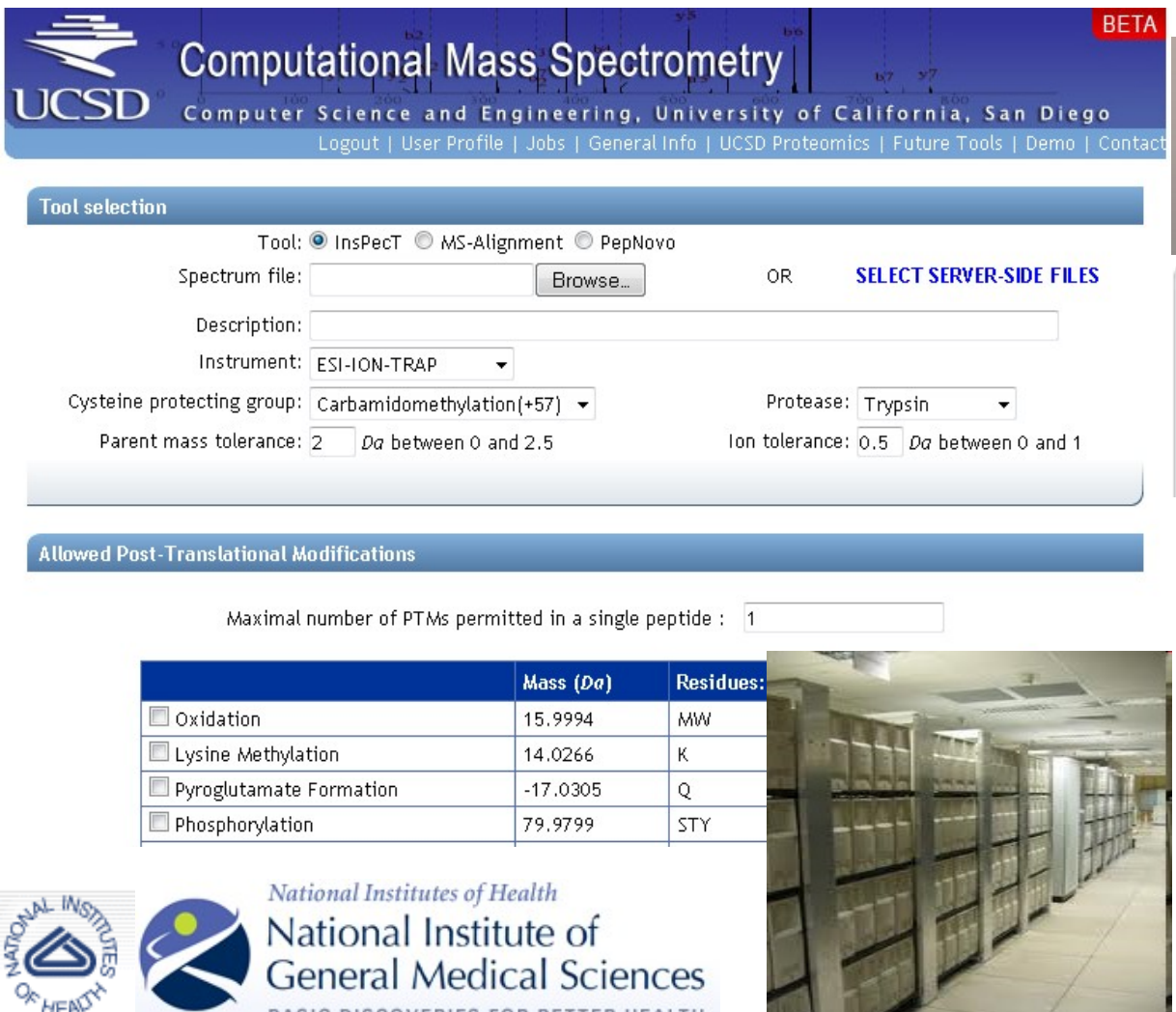
PDBj
16 million
entry downloads

Source: Phil Bourne, UCSD

UCSD Center for Computational Mass Spectrometry Becoming Global MS Repository

***ProteoSAFe*: Compute-intensive discovery MS at the click of a button**

***MassIVE*: repository and identification platform for all MS data in the world**



Source: Nuno Bandeira, UCSD

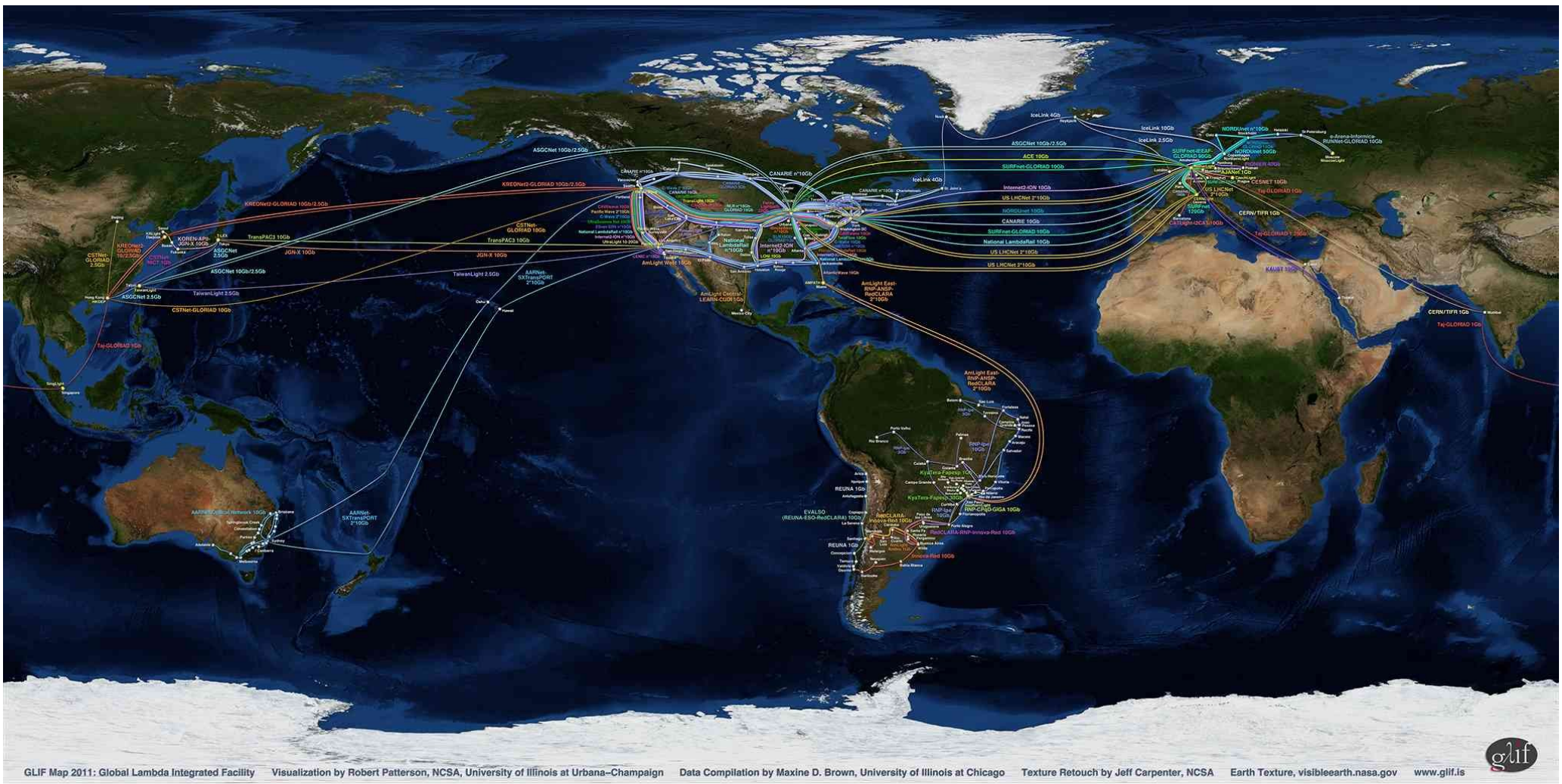
National Institutes of Health
National Institute of General Medical Sciences
BASIC DISCOVERIES FOR BETTER HEALTH

Campus User Access to Remote Resources

- GLIF
- Experimental Particle Physics
- Ocean Observatory Initiative
- Remote Supercomputing
- Creating Regional Climate Forecasts

The Global Lambda Integrated Facility--
Creating a Planetary-Scale High Bandwidth Collaboratory

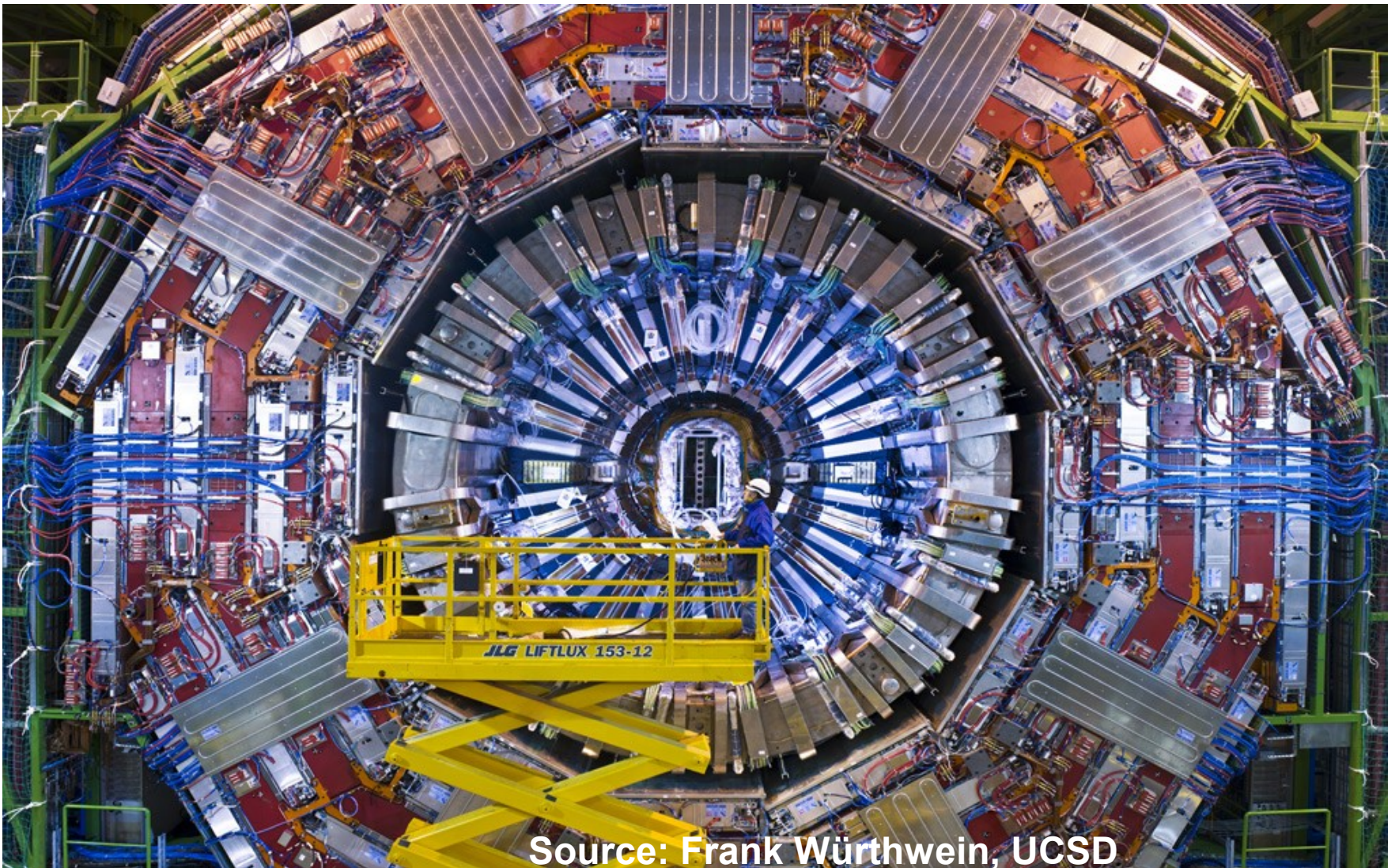
Calit2 Linked to GLIF by Campus 10G Dedicated Lambdas



www.glif.is/publications/maps/GLIF_5-11_World_2k.jpg

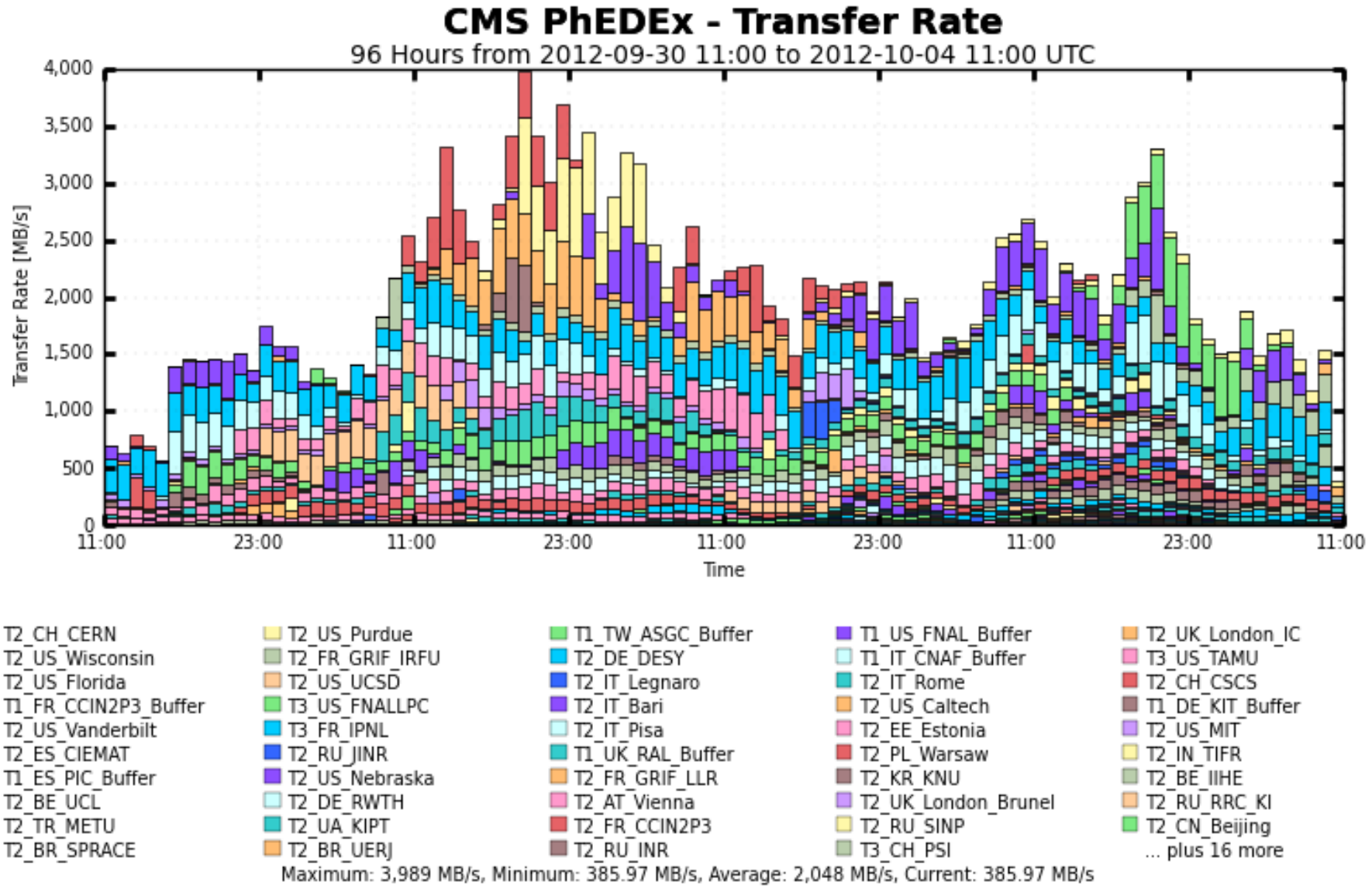
The CERN Large Hadron Collider
CMS Experiment

- 1 to 10 Petabytes of raw data per year
- 2000 Scientists (1200 Ph.D. in physics)
  - ~ 180 Institutions in ~ 40 countries



Source: Frank Würthwein, UCSD

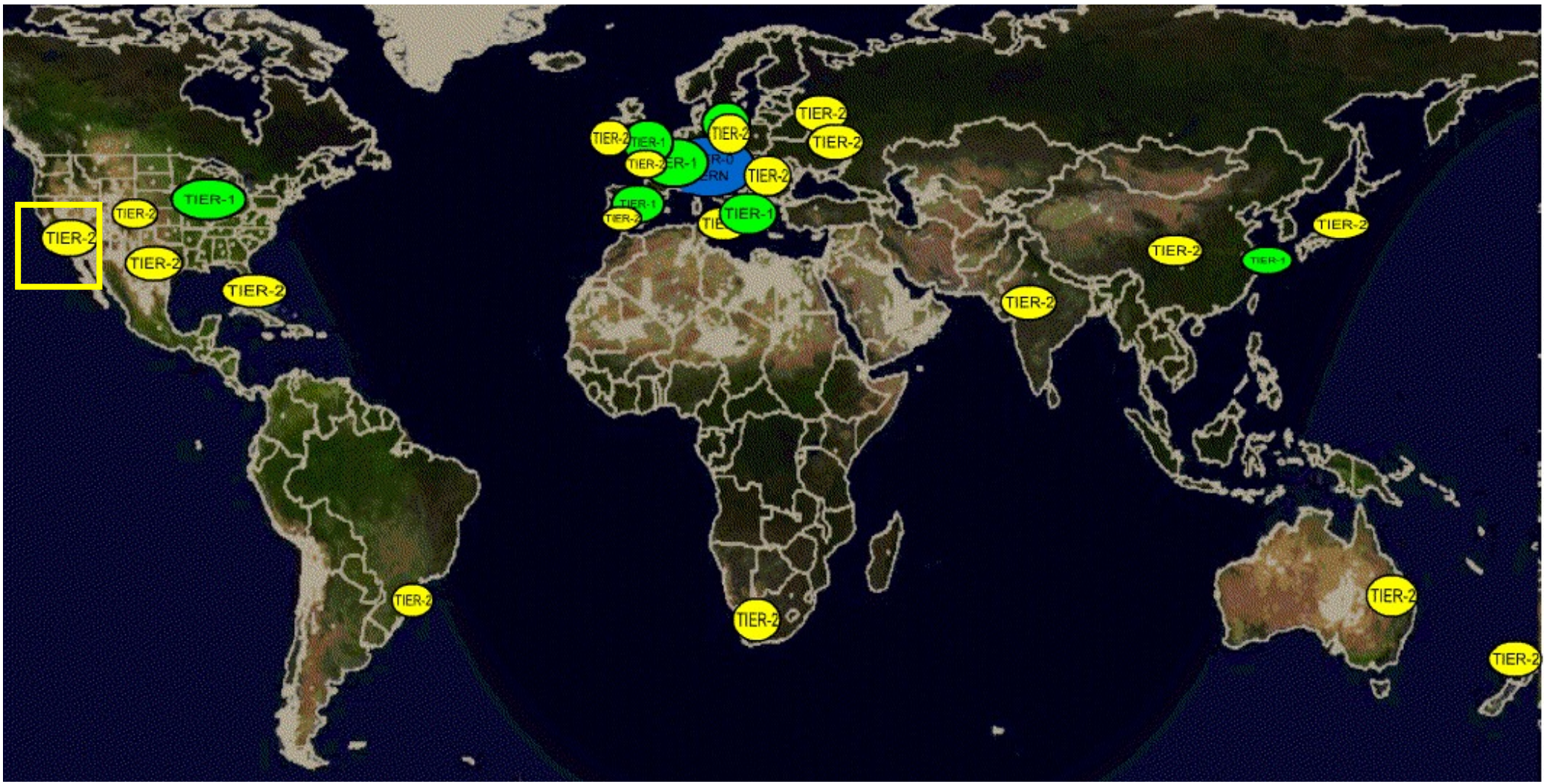
Aggregate Data Rate Leaving LHR-CMS Can Exceed 30 Gbps



Source: Frank Würthwein, UCSD

LHC Has Optical Networks Connecting Tier-1 and Tier-2 Sites with CERN

UCSD Hosts a Tier-2 Site



Source: Frank Würthwein, UCSD

The Open Science Grid

A Consortium of Universities and National Labs to share resources and technologies to advance Science



OSG delivered across 112 sites

In the last 24 Hours	
374,000	Jobs
1,717,000	CPU Hours
2,518,000	Transfers
1,193	TB Transferred

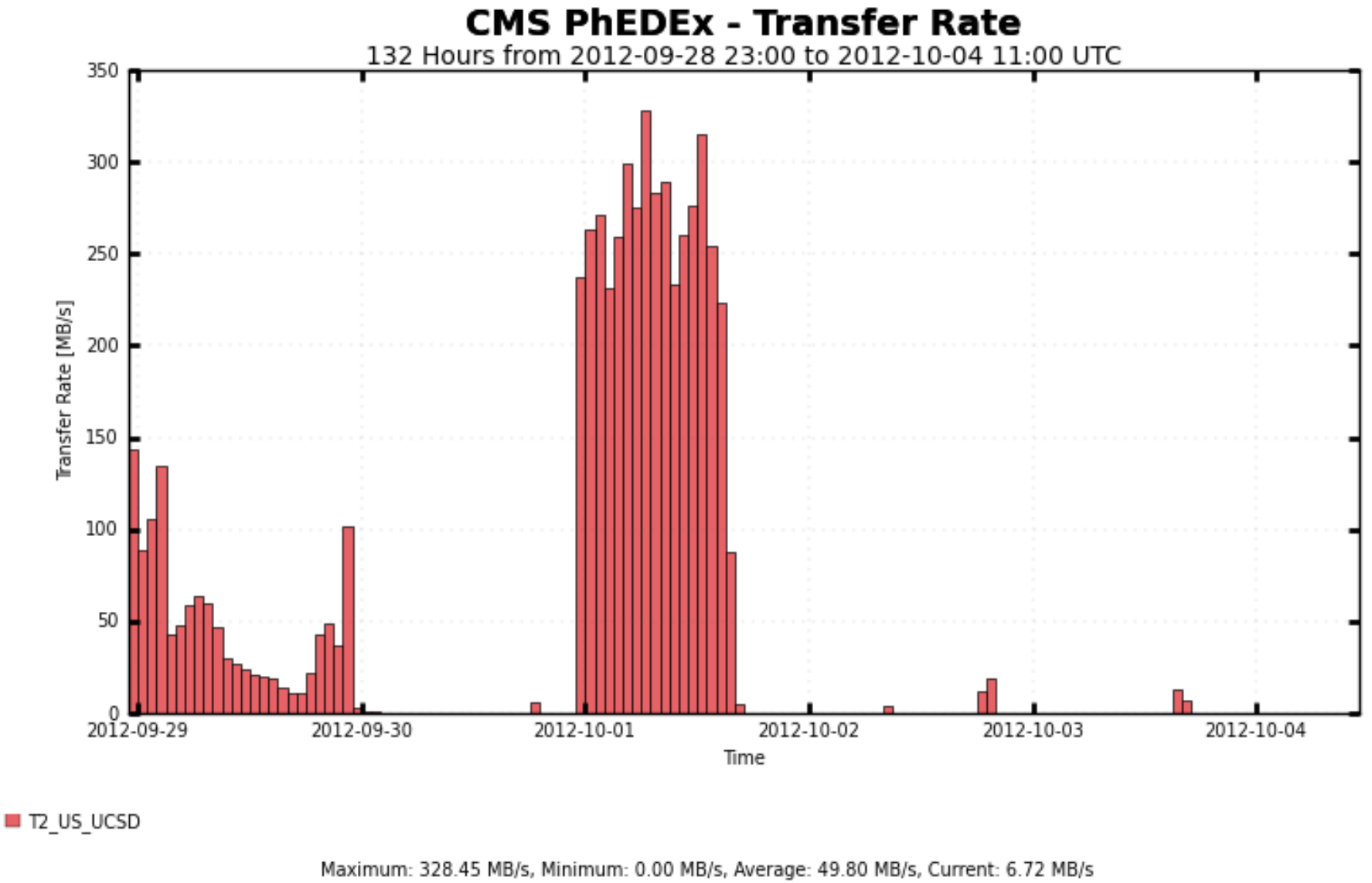
In the last 30 Days	
12,353,000	Jobs
53,652,000	CPU Hours
71,512,000	Transfers
30,747	TB Transferred

In the last Year	
205,746,000	Jobs
713,742,000	CPU Hours
623,045,000	Transfers
311,498	TB Transferred

Open for all of science, including biology, chemistry, computer science, engineering, mathematics, medicine, and physics

Source: Frank Würthwein, UCSD

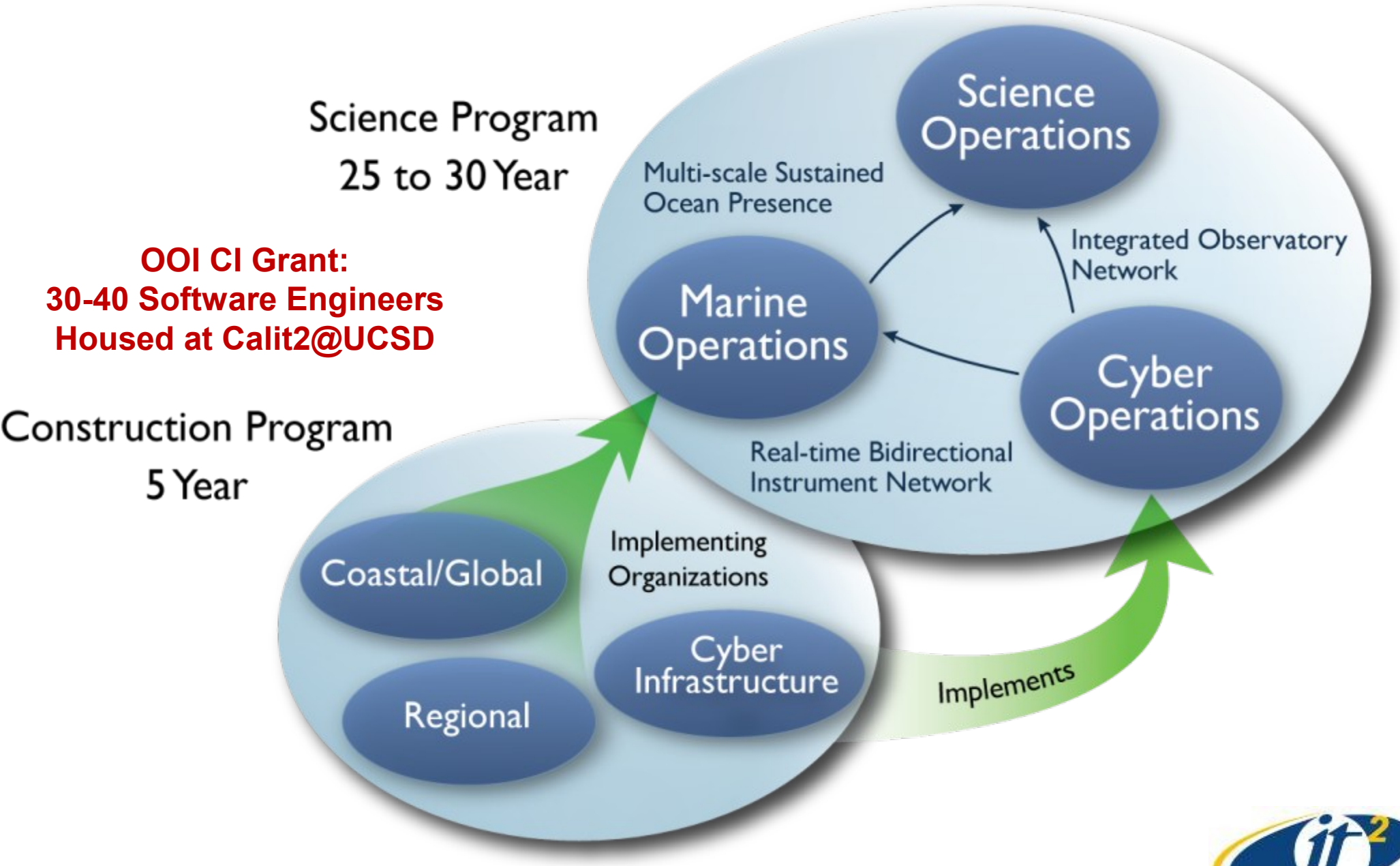
Current UCSD CMS Tier 2 Data Rate Already Peaks at 2.5 Gbps



Source: Frank Würthwein, UCSD

NSF's Ocean Observatory Initiative Has the Largest Funded NSF CI Grant

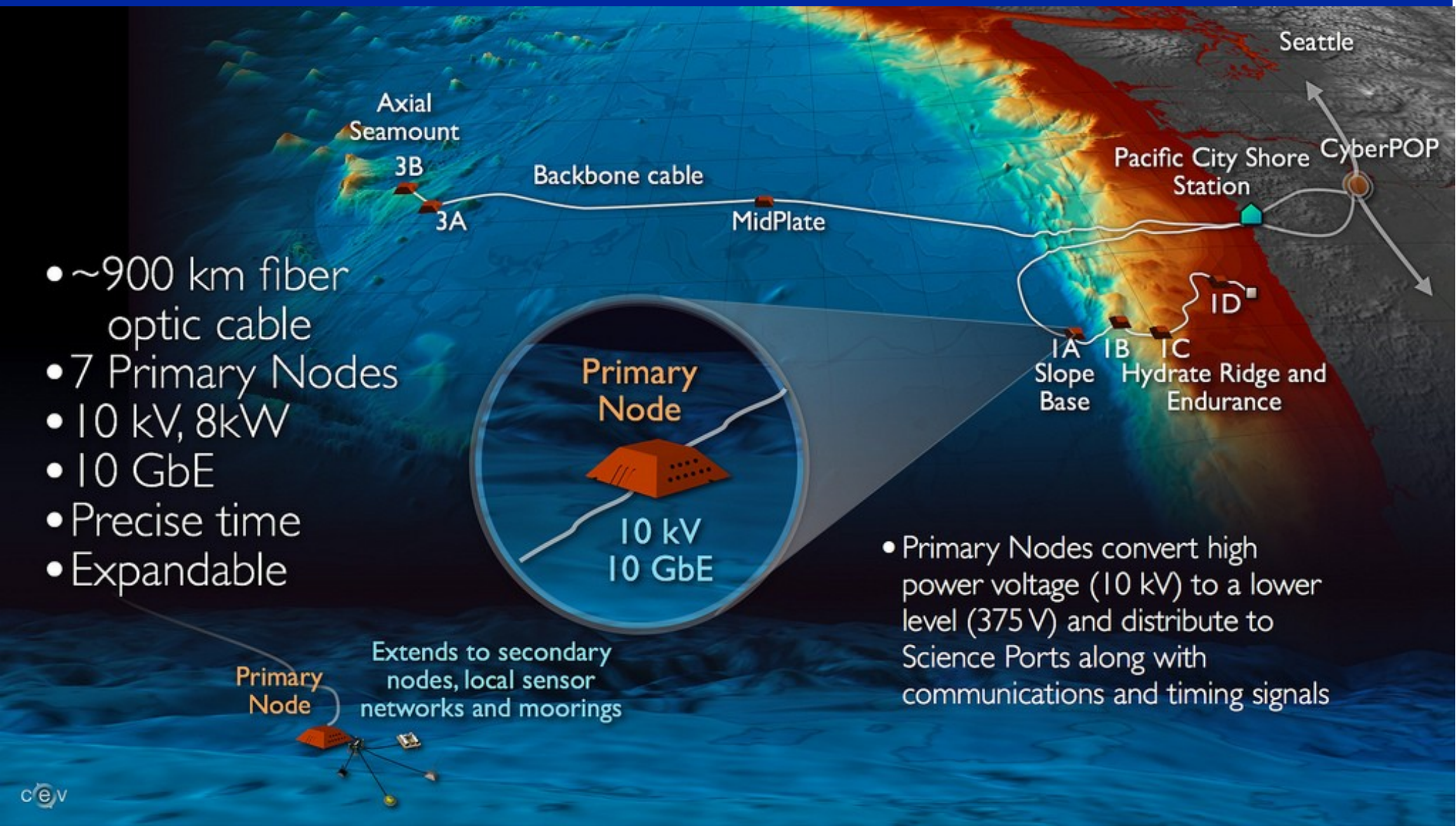
OCEAN OBSERVATORIES INITIATIVE



OOI CI Grant:
30-40 Software Engineers
Housed at Calit2@UCSD

Source: Matthew Arrott, Calit2 Program Manager for OOI CI

NSF's Ocean Observatory Initiative is Creating 10G Sensornets

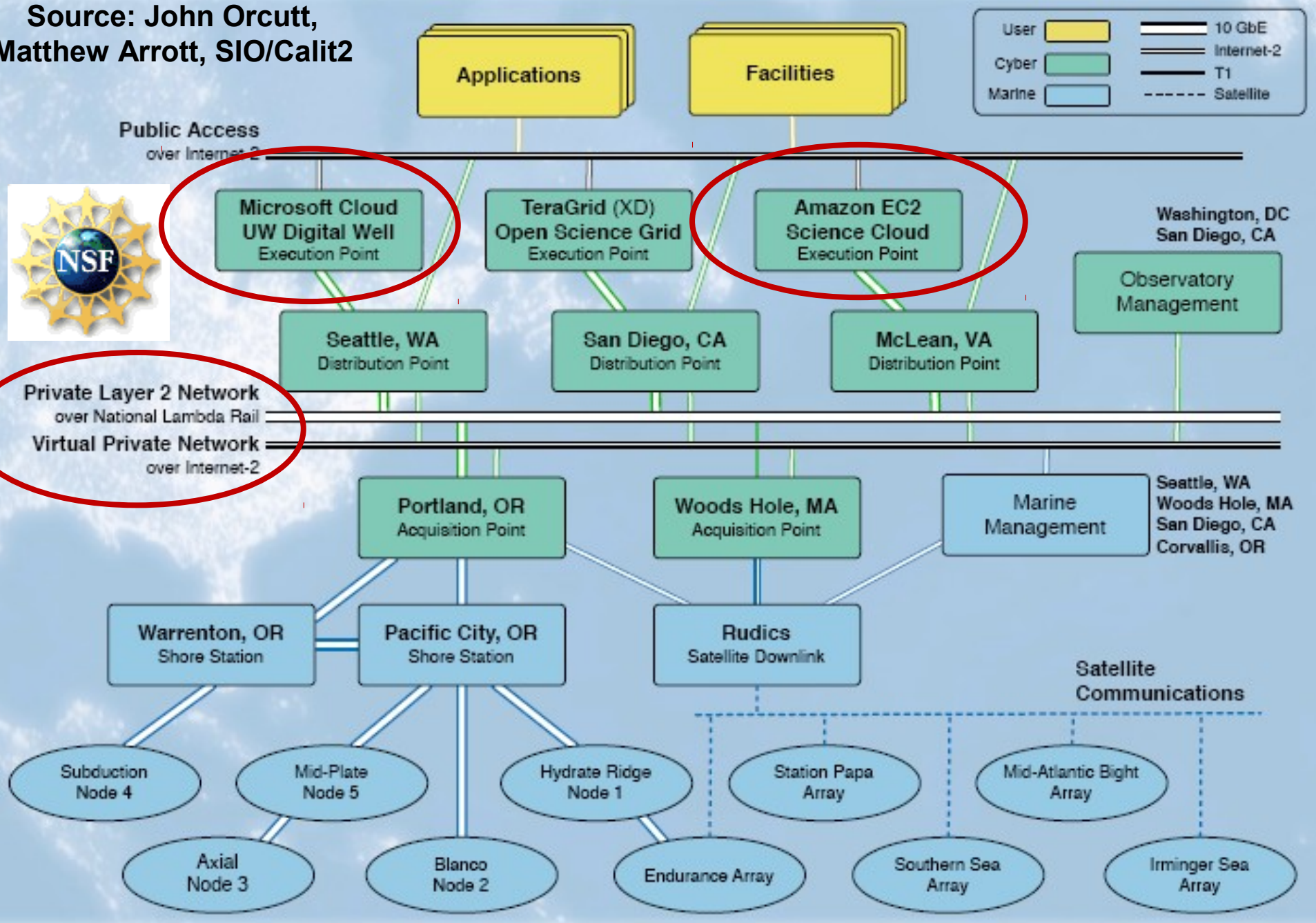


OOI NSF OSU RUTGERS UCSD UNIVERSITY of WASHINGTON it2

OOI CI is Built on Dedicated Optical Infrastructure Using Clouds

OCEAN OBSERVATORIES INITIATIVE

Source: John Orcutt, Matthew Arrott, SIO/Calit2

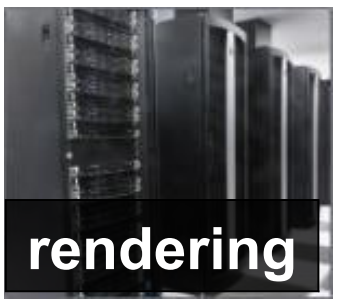


Using Supernetworks to Couple End User's OptIPortal to Remote Supercomputers and Visualization Servers

Source: Mike Norman, Rick Wagner, SDSC

Argonne NL

DOE Eureka
100 Dual Quad Core Xeon Servers
200 NVIDIA Quadro FX GPUs in 50 Quadro Plex S4 1U enclosures
3.2 TB RAM



Real-Time Interactive Volume Rendering Streamed from ANL to SDSC

ESnet
10 Gb/s fiber optic network

SDSC



Calit2/SDSC OptIPortal1
20 30" (2560 x 1600 pixel) LCD panels
10 NVIDIA Quadro FX 4600 graphics cards > 80 megapixels
10 Gb/s network throughout

NICS ORNL

NSF TeraGrid Kraken
Cray XT5
8,256 Compute Nodes
99,072 Compute Cores
129 TB RAM

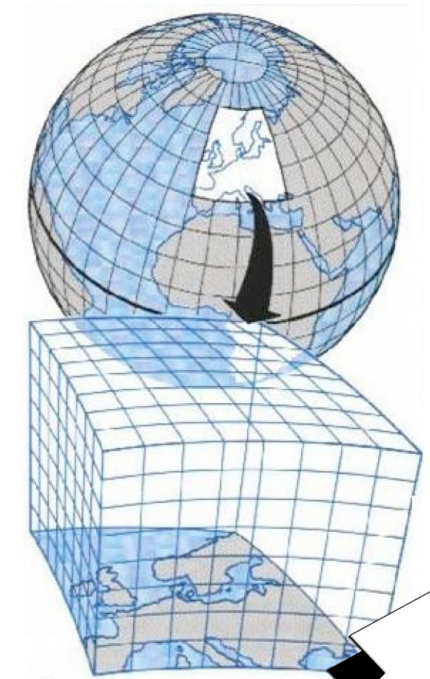


SDSC

*ANL * Calit2 * LBNL * NICS * ORNL * SDSC

Regional Climate Change Simulations: Downloading Supercomputer Simulation Data to SIO

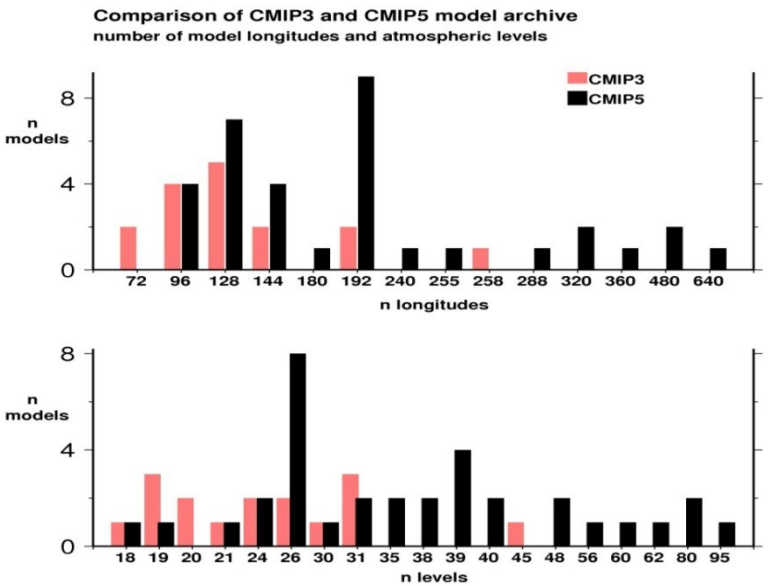
Global Climate Model



GCMs ~150km downscaled to Regional models ~ 12km

Regional Climate Model

Figure 1: insert stuff here



The number of GCM's has grown to more than 20 (from international Centers)

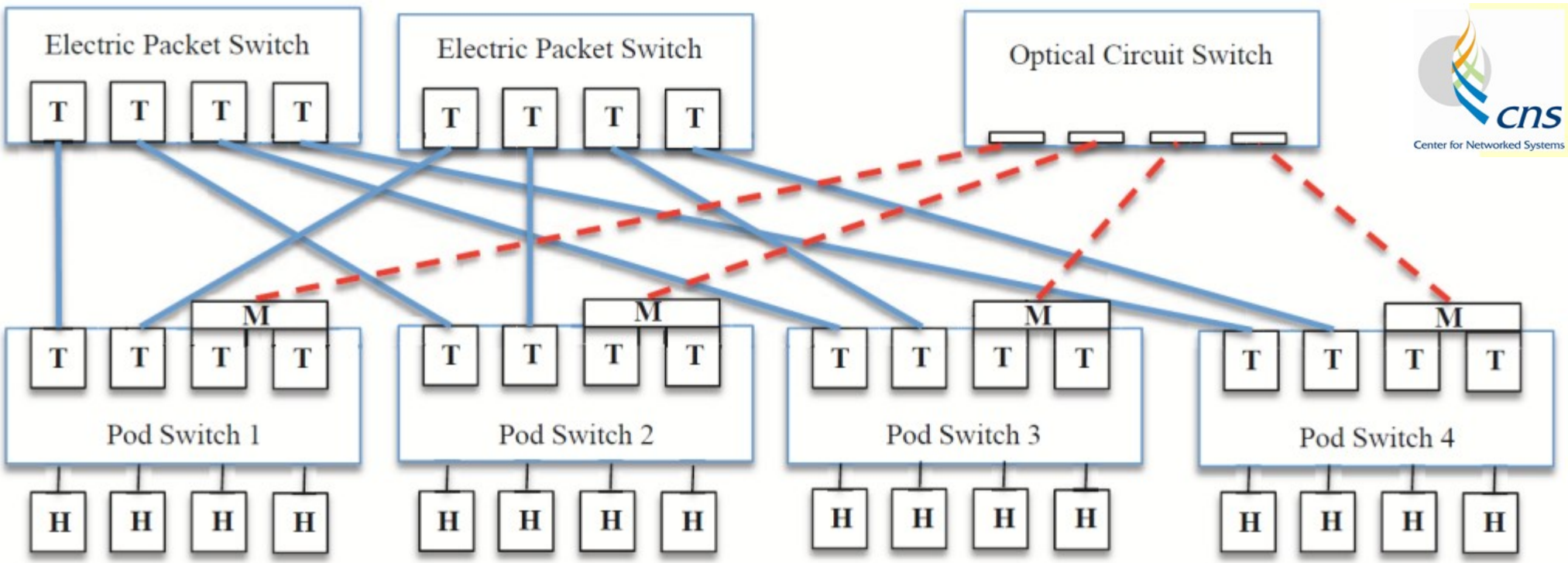
note increased resolution CMIP5 vs CMIP3 GCMs

Dan Cayan, Suraj Polade, Alexander Gershunov, Mike Dettinger, David Pierce
Scripps Institution of Oceanography, UC San Diego, USGS Water Resources Discipline

High Performance Connection Among On-Campus Resources

- Optically Connected Clusters
- Connecting to Cross-Campus Clusters
- Connecting Clusters to Supercomputers and Clouds
- Connecting Scientific Instruments to Data Centers and Vis

UCSD Scalable Energy Efficient Datacenter (SEED): Energy-Efficient Hybrid Electrical-Optical Networking

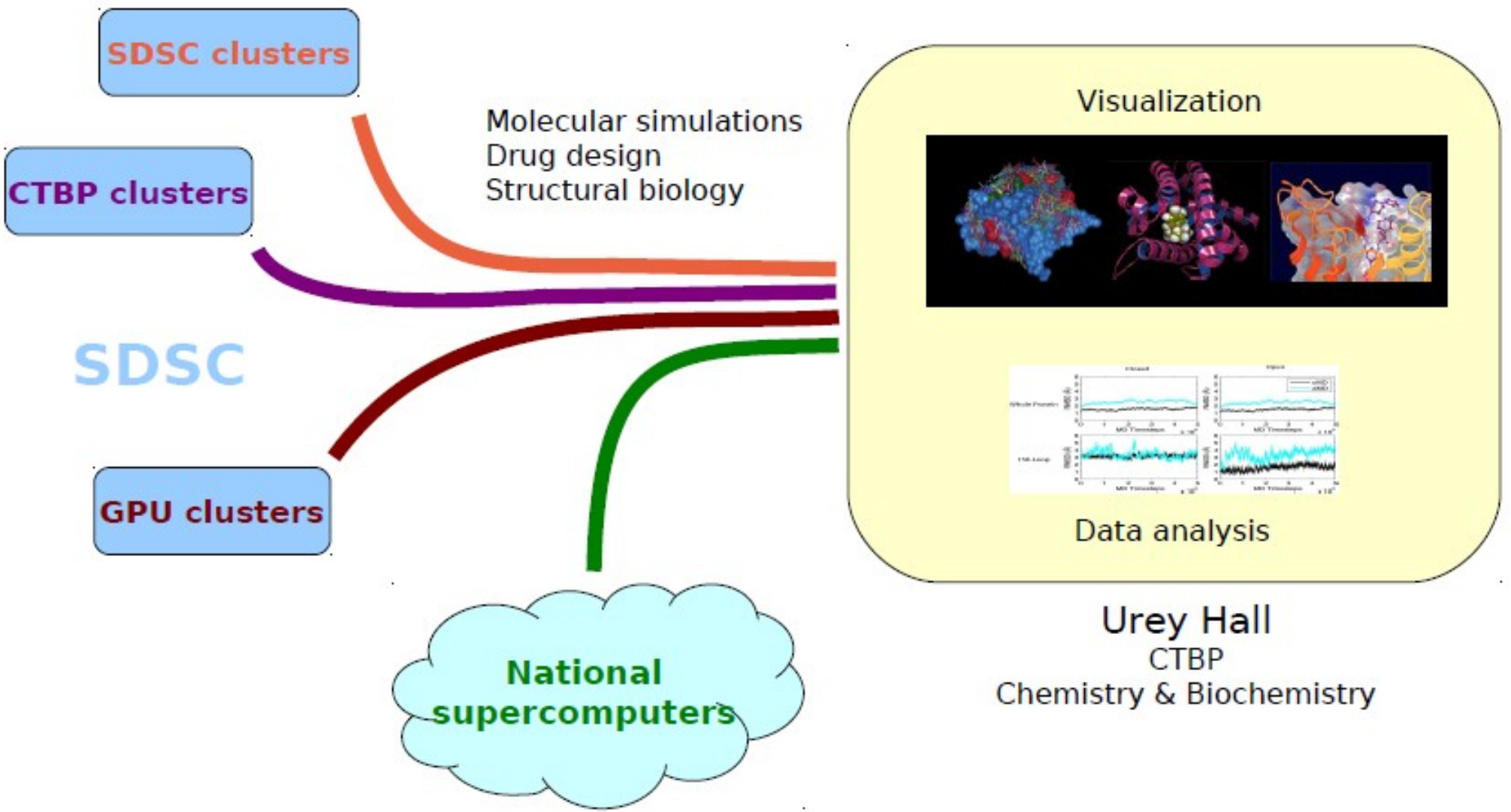


- **Build a Balanced System to Reduce Energy Consumption**
  - **Dynamic Energy Management**
  - **Use Optics for 90% of Total Data Which is Carried in 10% of the Flows**
- **SEED Testbed in Calit2 Machine Room and Sunlight Optical Switch**
  - **Hybrid Approach Can Realize 3x Cost Reduction; 6x Reduction in Cabling; and 9x Reduction in Power**

PRISM Principle inside of a Data Center

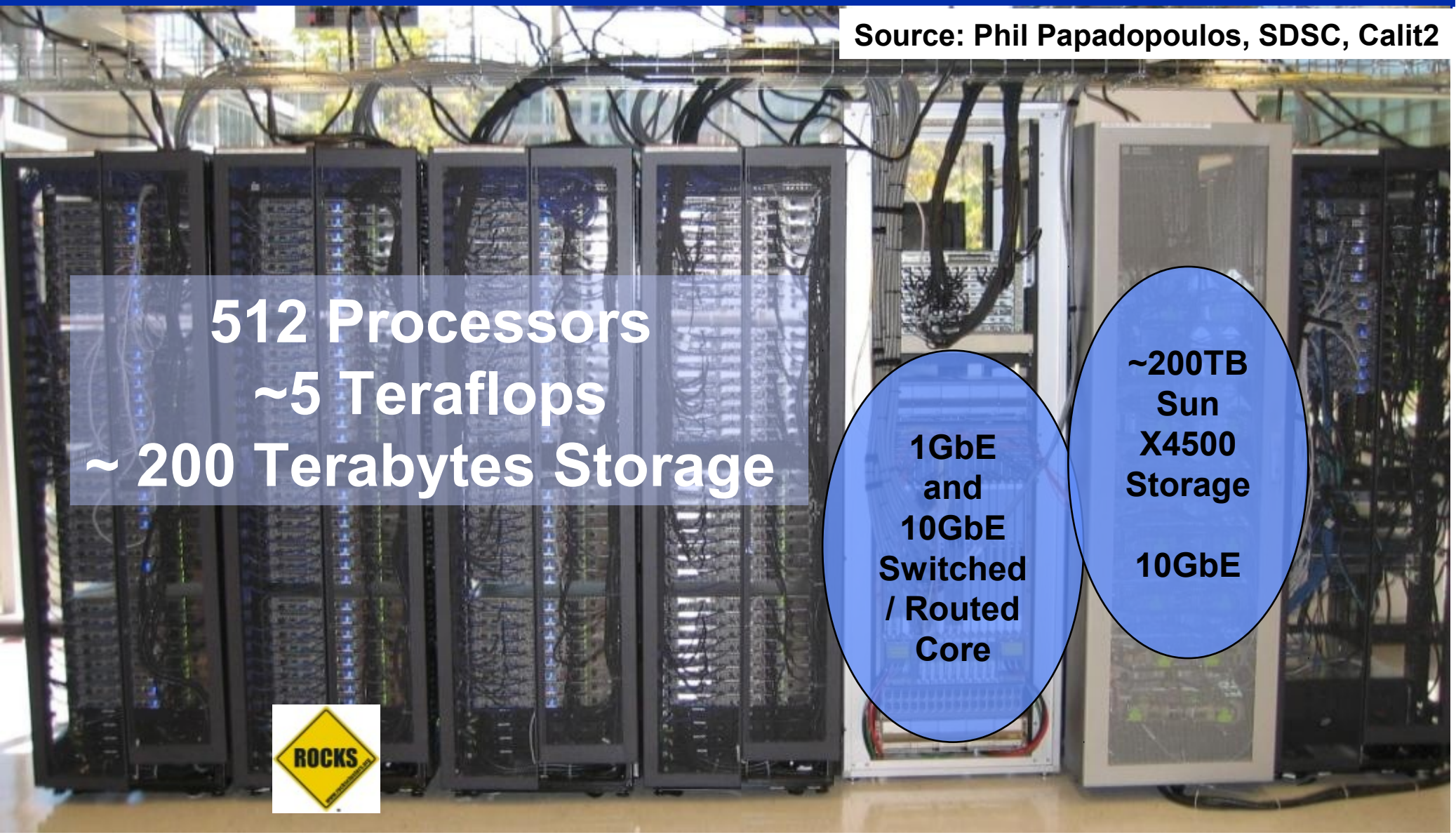
PIs of NSF MRI: George Papen, Shaya Fainman, Amin Vahdat; UCSD

UCSD Remote Cluster High Speed Connection Example



UCSD Center for Theoretical Biological Physics
Computational Biology / McCammon group

Calit2 Community Cyberinfrastructure for Advanced Microbial Ecology Research and Analysis (CAMERA)



5000 Users
90 Countries

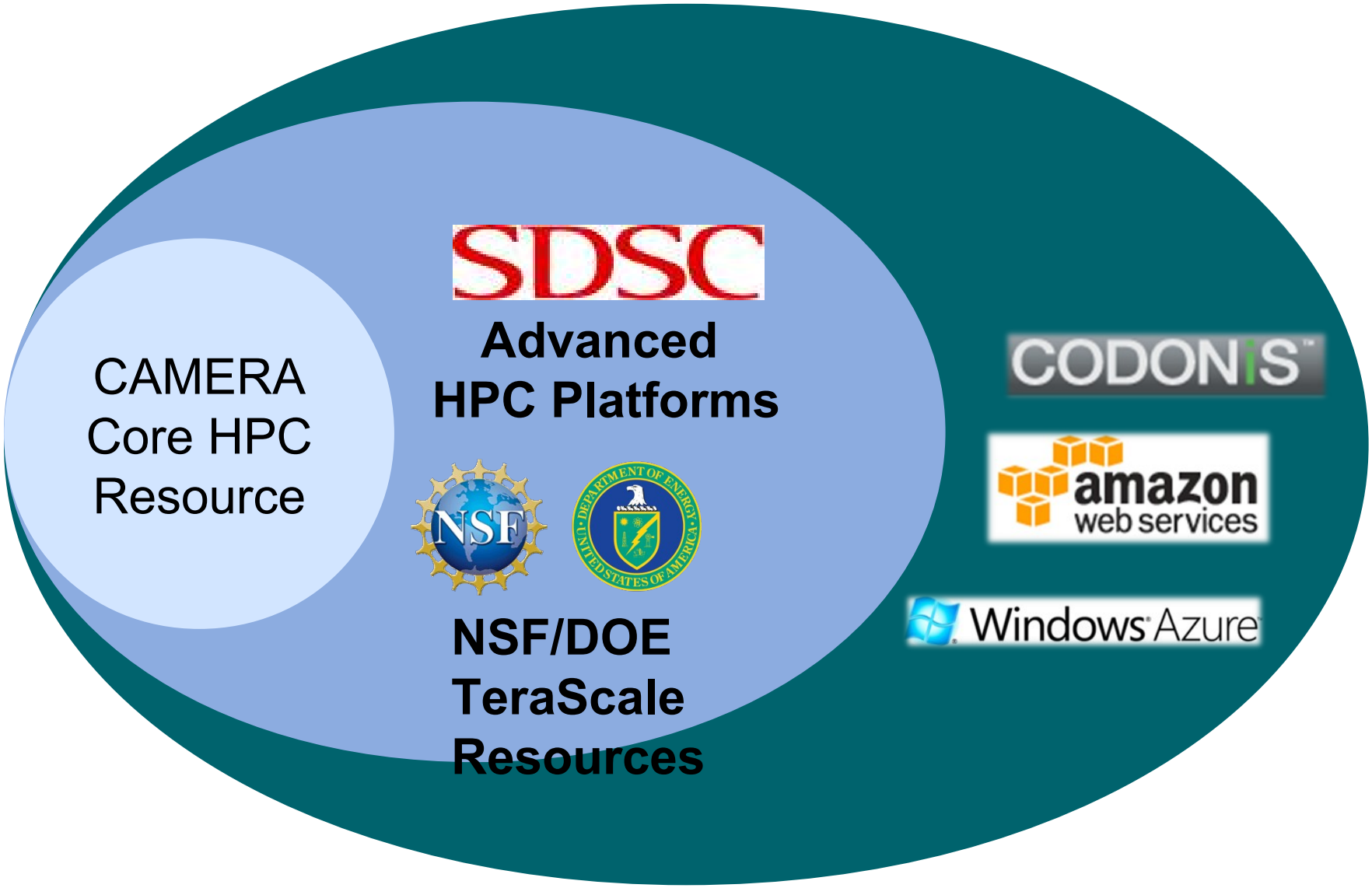
Gordon and Betty MOORE FOUNDATION

SDSC

J. Craig Venter INSTITUTE

it²

Access to Computing Resources Tailored by User's Requirements and Resources



Source: Jeff Grethe, CAMERA

NIH National Center for Microscopy & Imaging Research
Integrated Infrastructure of Shared Resources

NCMIR

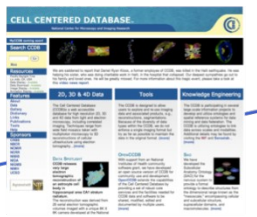


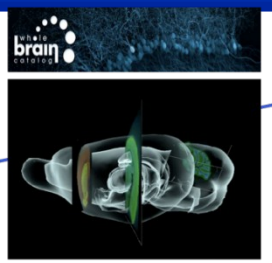
Telemicroscopy Resources:
Osaka Univ., Oxford Univ.,
The Jackson Labs





Neuroinformatics Resources





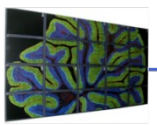


Shared Infrastructure

Development Systems

Storage Resources

OptIPortal Tiled Display







UCSD

NBCR

SDSC

CRBS

California Institute of Telecommunications and Information Technology

Storage Resources

Production Systems

Triton Petascale Resource







San Diego Supercomputer Center

Scientific Instruments

Ultra-wide Field Intra-vital LM Instruments



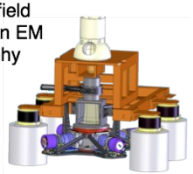
Super-resolution PALM





Serial Blockface Scanning EM

Ultra-wide field Serial Section EM Tomography





Multi-color EM, EFTEM

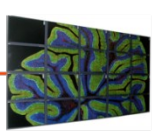
Wide-field STEM/TEM







Graphics Workstations



OptIPortal Tiled Display

End User Workstations



NCMIR Data Storage Servers



Critical Servers (Mail, Web, DB)



Large Memory Servers



NBCR Compute Clusters



GreenLight Project

GPU Compute Clusters

Local SOM Infrastructure

SDSC

Source: Steve Peltier, Mark Ellisman, NCMIR

UCSD Next Generation Sequencer Example: Professor Trey Idekar

Leichtag/Sequencer



Storage



Skaggs/Users













Next Gen Sequencers Generate ~1TB/Run



Calit2/Storage



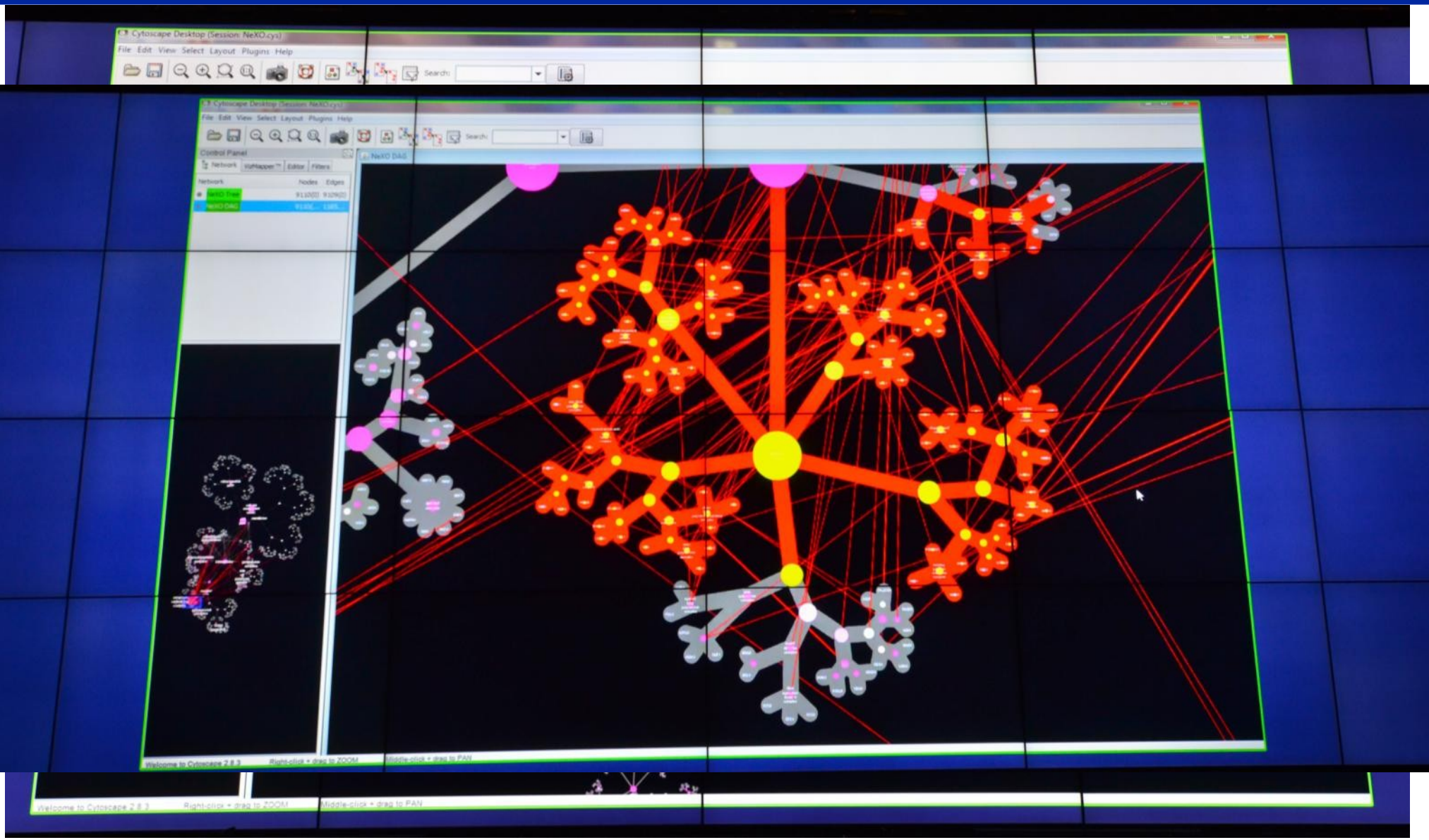
SDSC/Triton

SDSC

Source: Chris Misleh, Calit2/SOM

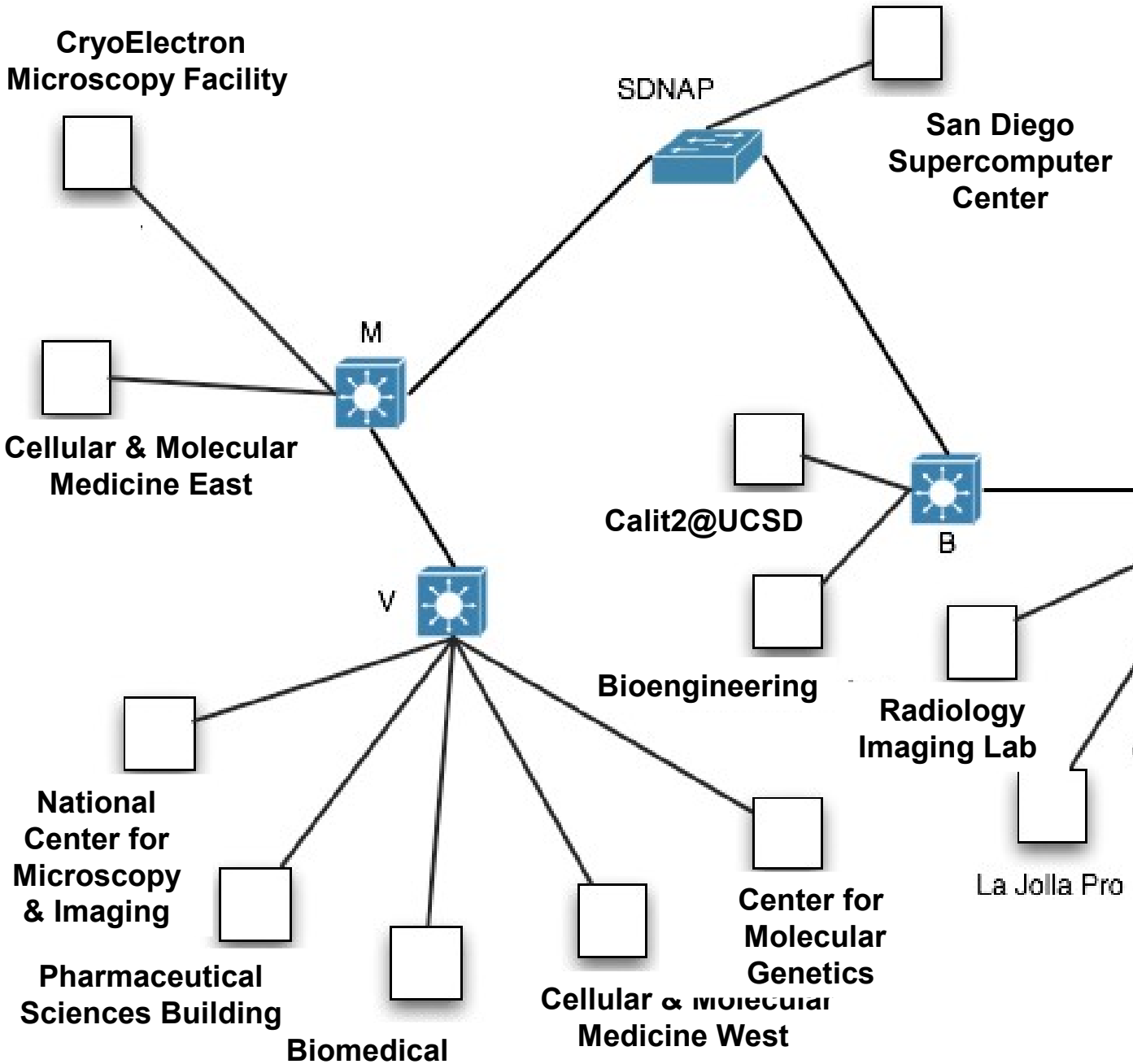
it²

Cytoscape Genetic Networks
On Vroom-64MPixels Connected at 50Gbps



Calit2 Collaboration with Trey Idekar Group

Potential UCSD Optical Networked Biomedical Researchers and Instruments



- **Connects at 10 Gbps :**
  - **Microarrays**
  - **Genome Sequencers**
  - **Mass Spectrometry**
  - **Light and Electron Microscopes**
  - **Whole Body Imagers**
  - **Computing**
  - **Storage**

Creating Detailed Plan

PRAGMA
A Calit2 Partner for Future GLIF Experiments



NSF Has Renewed PRAGMA for 5 More Years in a New Grant Through Calit2@UCSD

PIs: Peter Arzberger, Phil Papadopoulos