"A California-Wide Cyberinfrastructure for Data-Intensive Research"

Invited Presentation

CENIC Annual Retreat

Santa Rosa, CA

July 22, 2014

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

http://lsmarr.calit2.net

Vision: Creating a California-Wide Science DMZ Connected to CENIC, I2, & GLIF

Use Lightpaths to Connect
All Data Generators and Consumers,
Creating a "Big Data" Plane
Integrated With High Performance Global Networks

"The Bisection Bandwidth of a Cluster Interconnect, but Deployed on a 10-Campus Scale."

This Vision Has Been Building for Over a Decade

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

OptIPuter + CalREN-XD + TeraGrid = "OptiGrid"



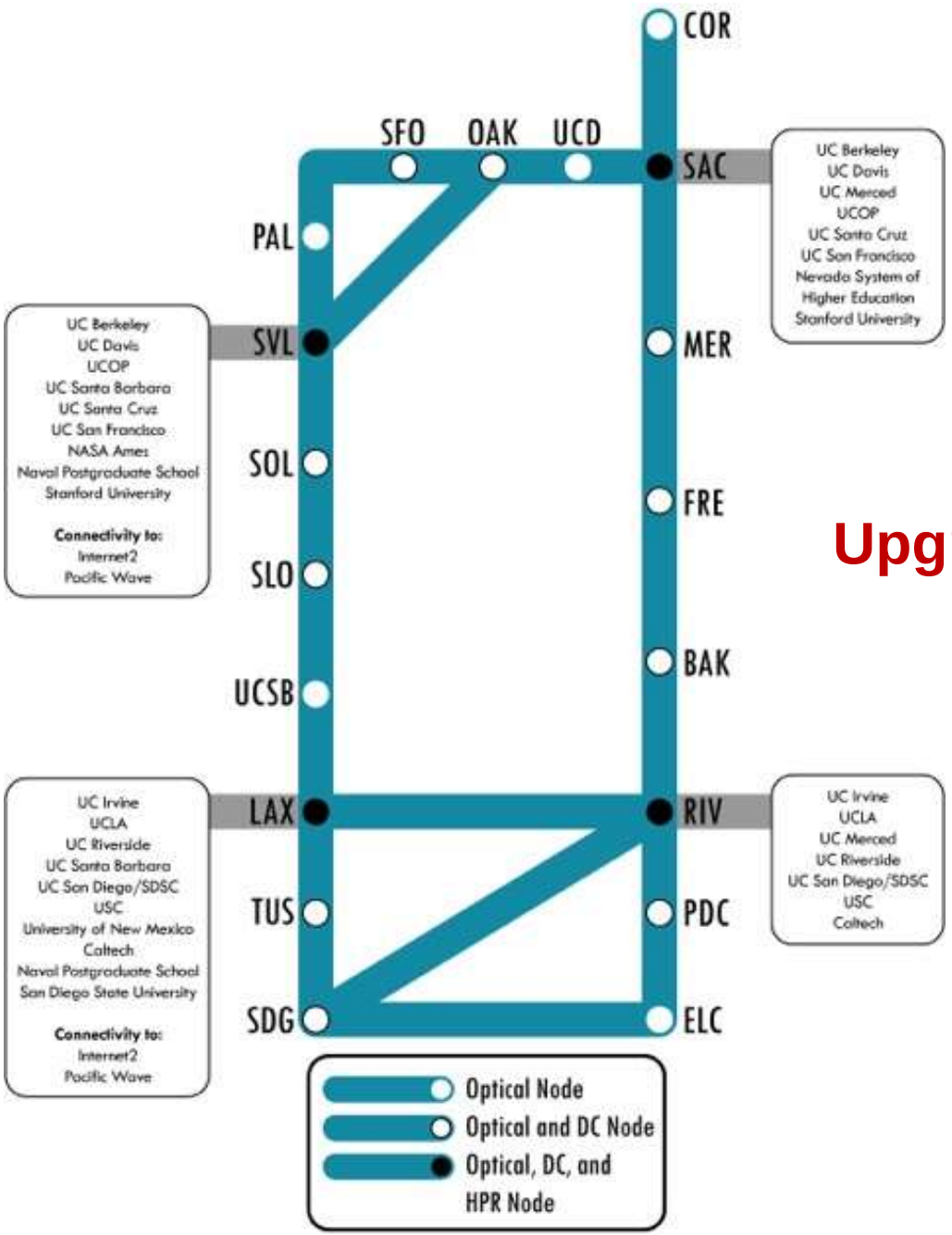


Creating a Critical Mass of End Users on a Secure LambdaGrid

LS 2005 Slide

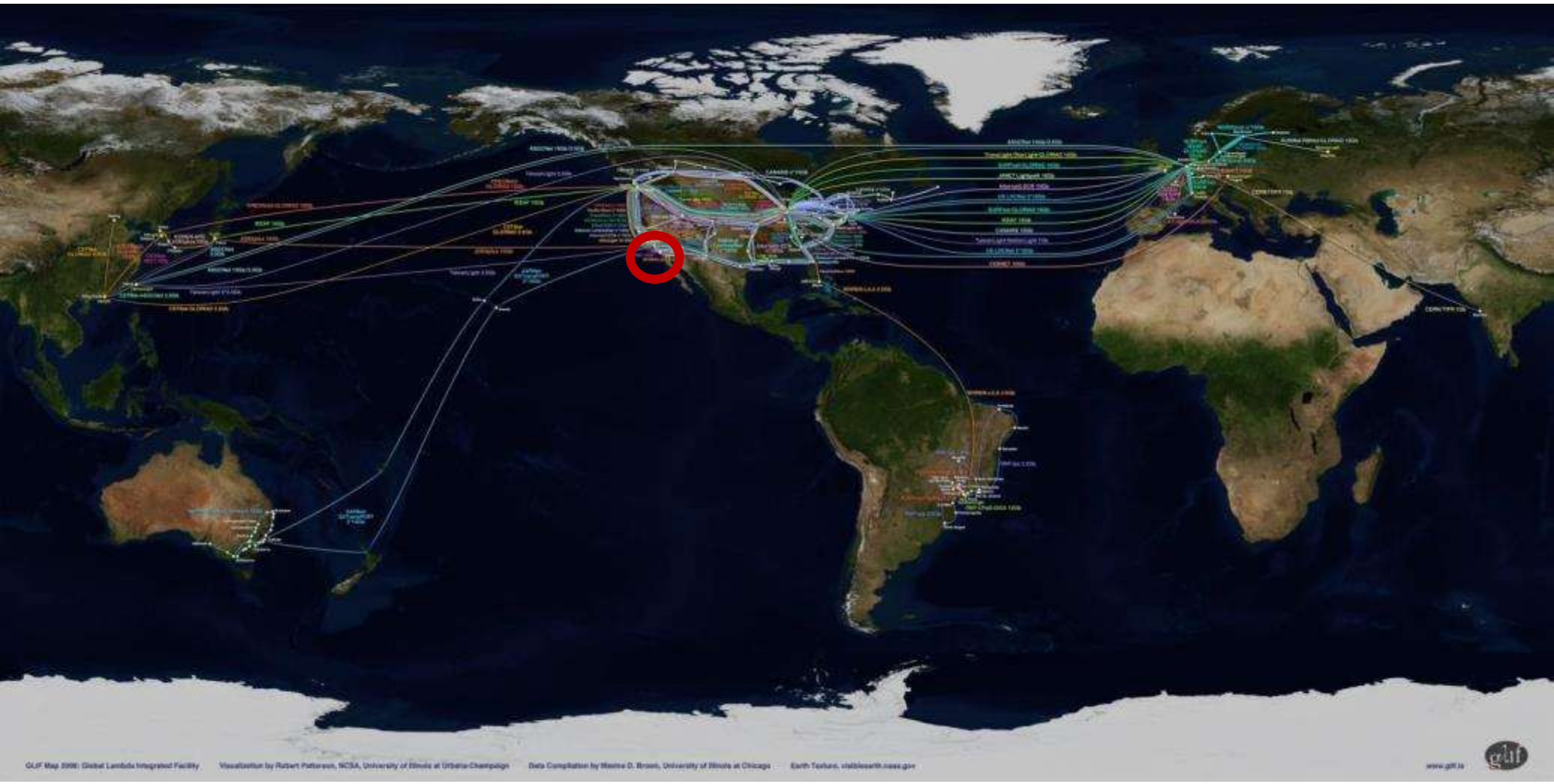
Source: Fran Berman, SDSC

CENIC Provides an Optical Backplane For the UC Campuses



Upgrading to 100G

Global Innovation Centers are Connected with 10 Gigabits/sec Clear Channel Lightpaths



Members of The Global Lambda Integrated Facility Meet Annually at Calit2's Qualcomm Institute

Source: Maxine Brown, UIC and Robert Patterson, NCSA

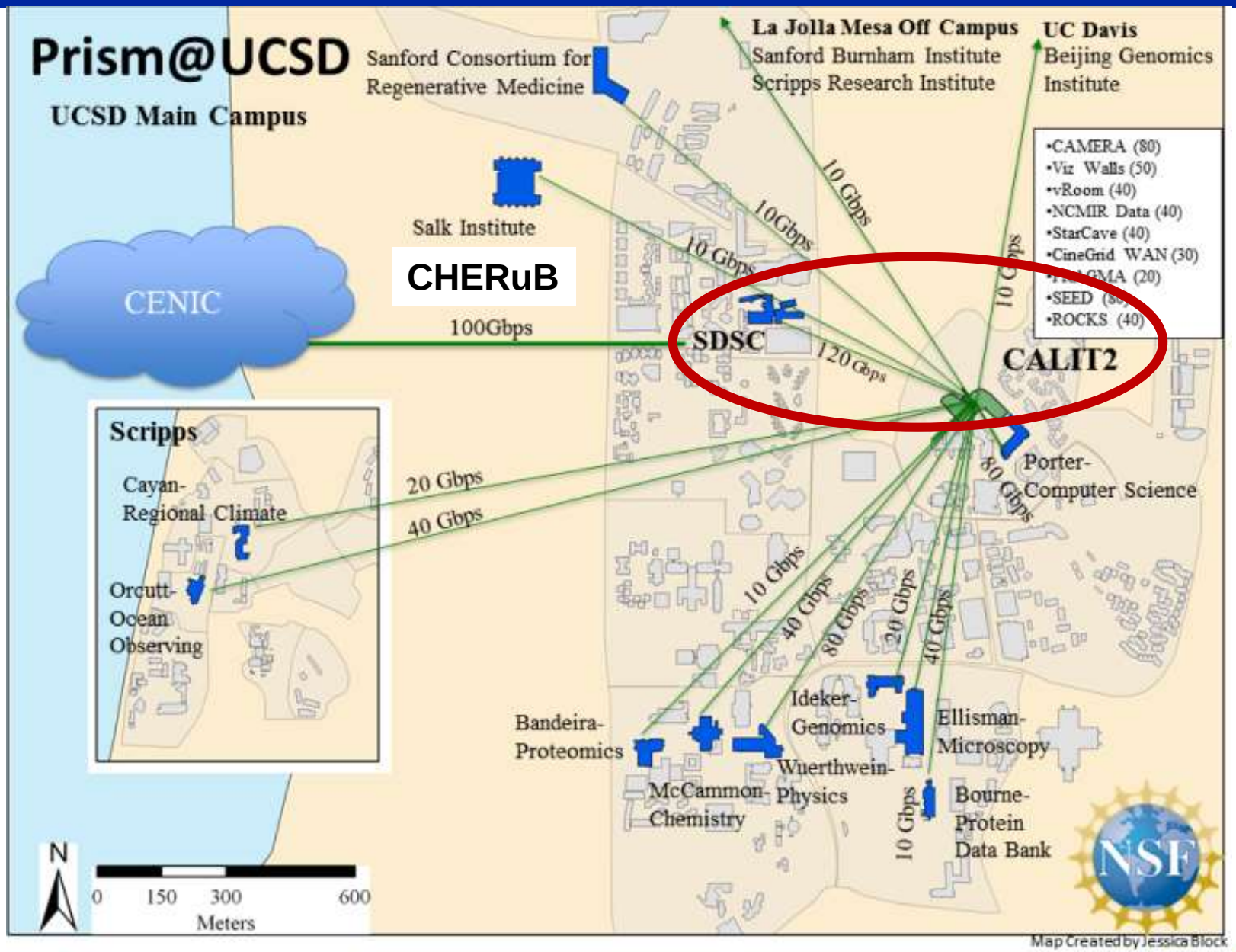
Why Now?
Federating the Dozen+ California CC-NIE Grants

- **2011 ACCI Strategic Recommendation to the NSF #3:**
  - **NSF should create a new program funding high-speed (currently 10 Gbps) connections from campuses to the nearest landing point for a national network backbone. The design of these connections must include support for dynamic network provisioning services and must be engineered to support rapid movement of large scientific data sets."**
  - **- pg. 6, NSF Advisory Committee for Cyberinfrastructure Task Force on Campus Bridging, Final Report, March 2011**
    - **www.nsf.gov/od/oci/taskforces/TaskForceReport_CampusBridging.pdf**
  - **Led to Office of Cyberinfrastructure RFP March 1, 2012**
- **NSF's Campus Cyberinfrastructure – Network Infrastructure & Engineering (CC-NIE) Program**
  - **85 Grants Awarded So Far (NSF Summit in June 2014)**
    - **Roughly $500k per Campus**

California Must Move Rapidly or Lose a Ten-Year Advantage!

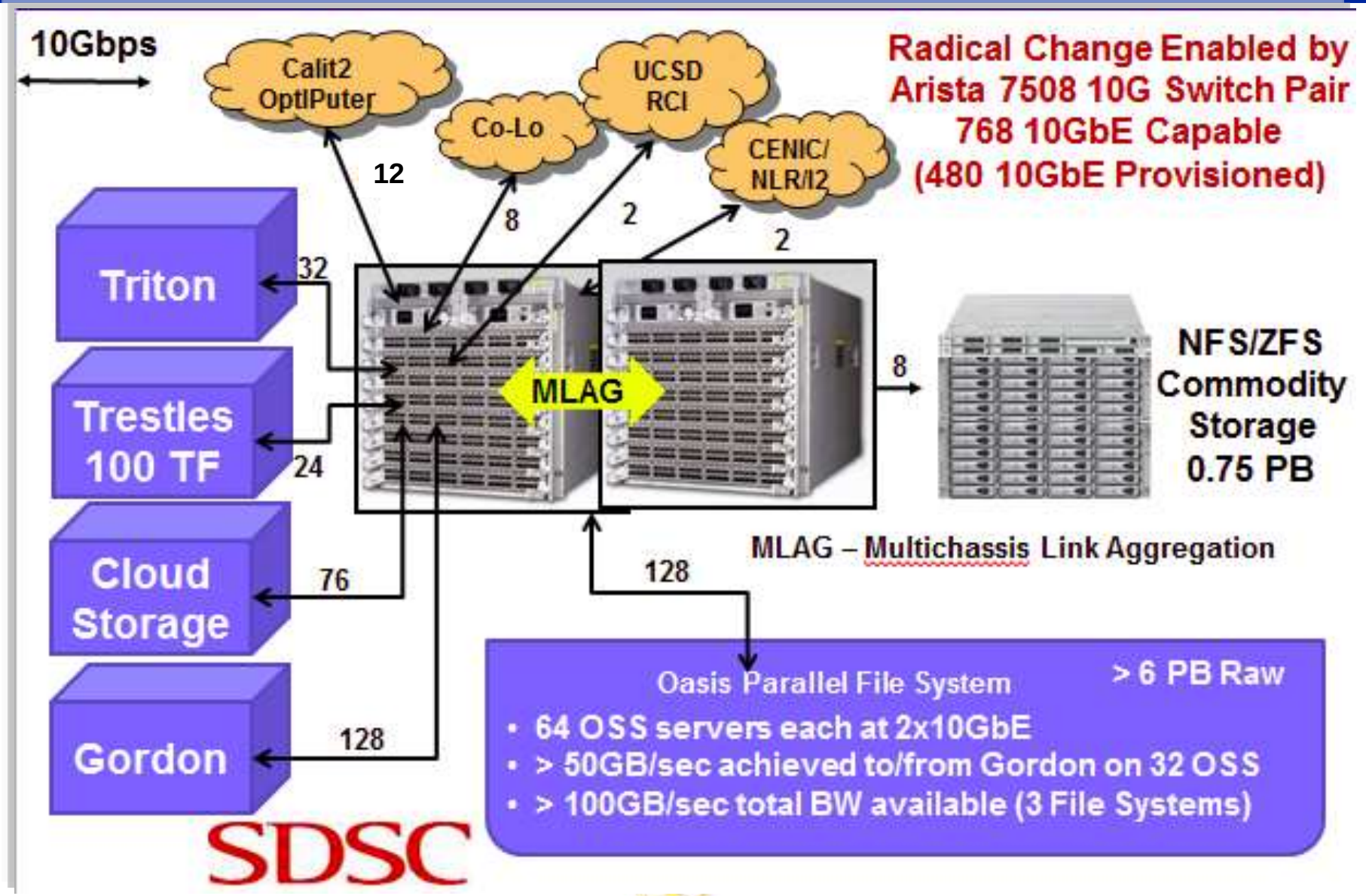


Creating a "Big Data" Plane
NSF CC-NIE Funded Prism@UCSD



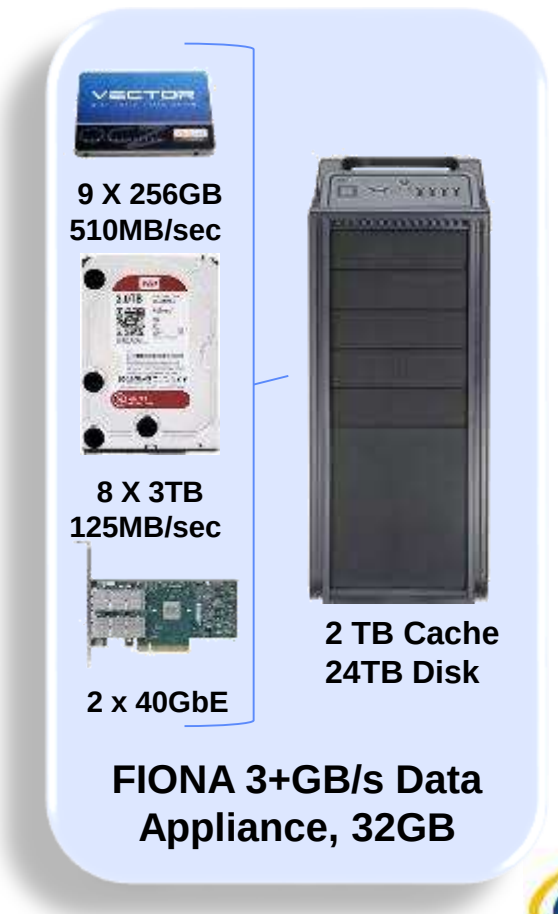
NSF CC-NIE Has Awarded Prism@UCSD Optical Switch
Phil Papadopoulos, SDSC, Calit2, PI

UC-Wide "Big Data Plane"
Puts High Performance Data Resources Into Your Lab

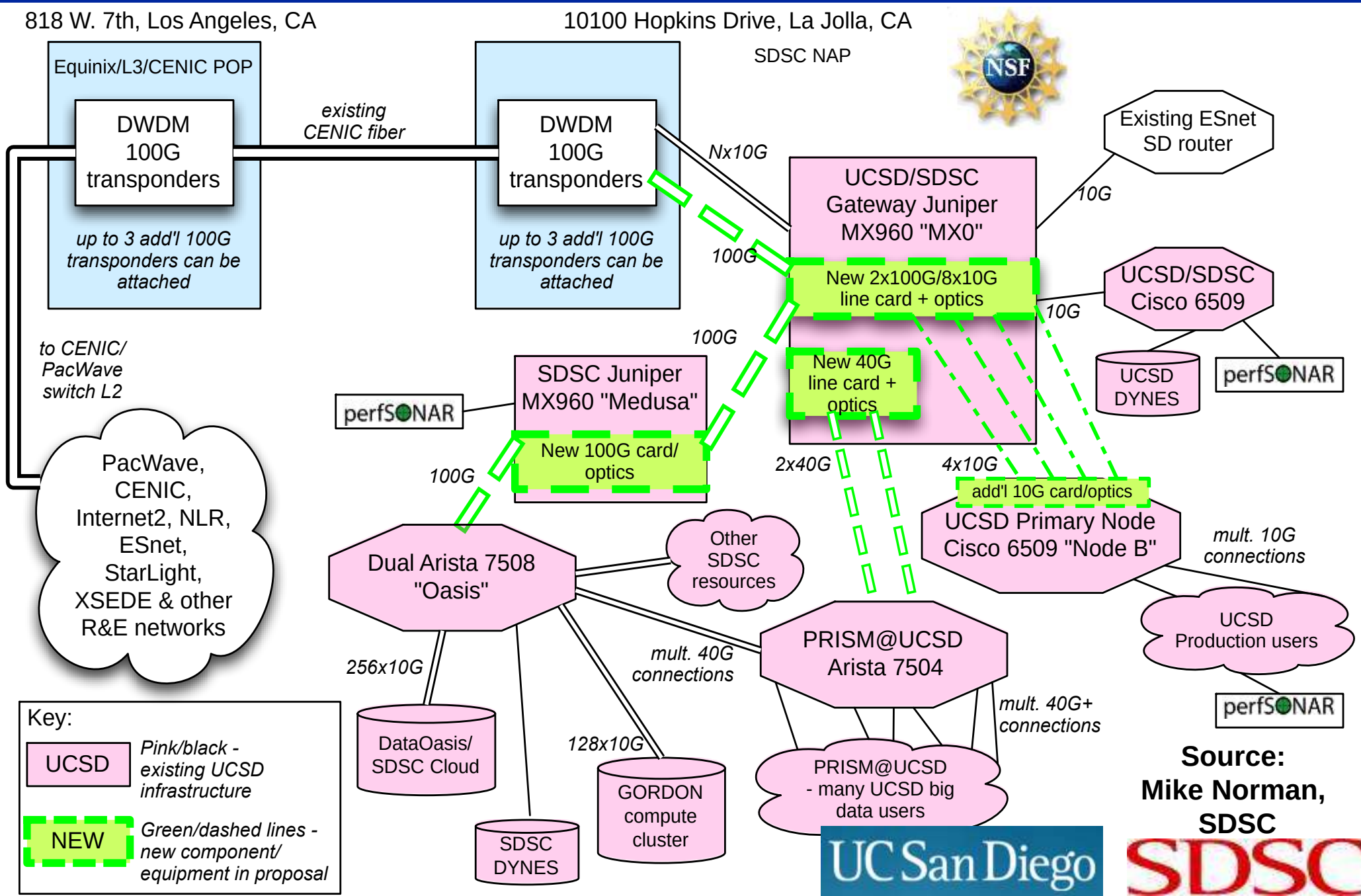


How to Terminate 10Gbps in Your Lab
FIONA – Inspired by Gordon

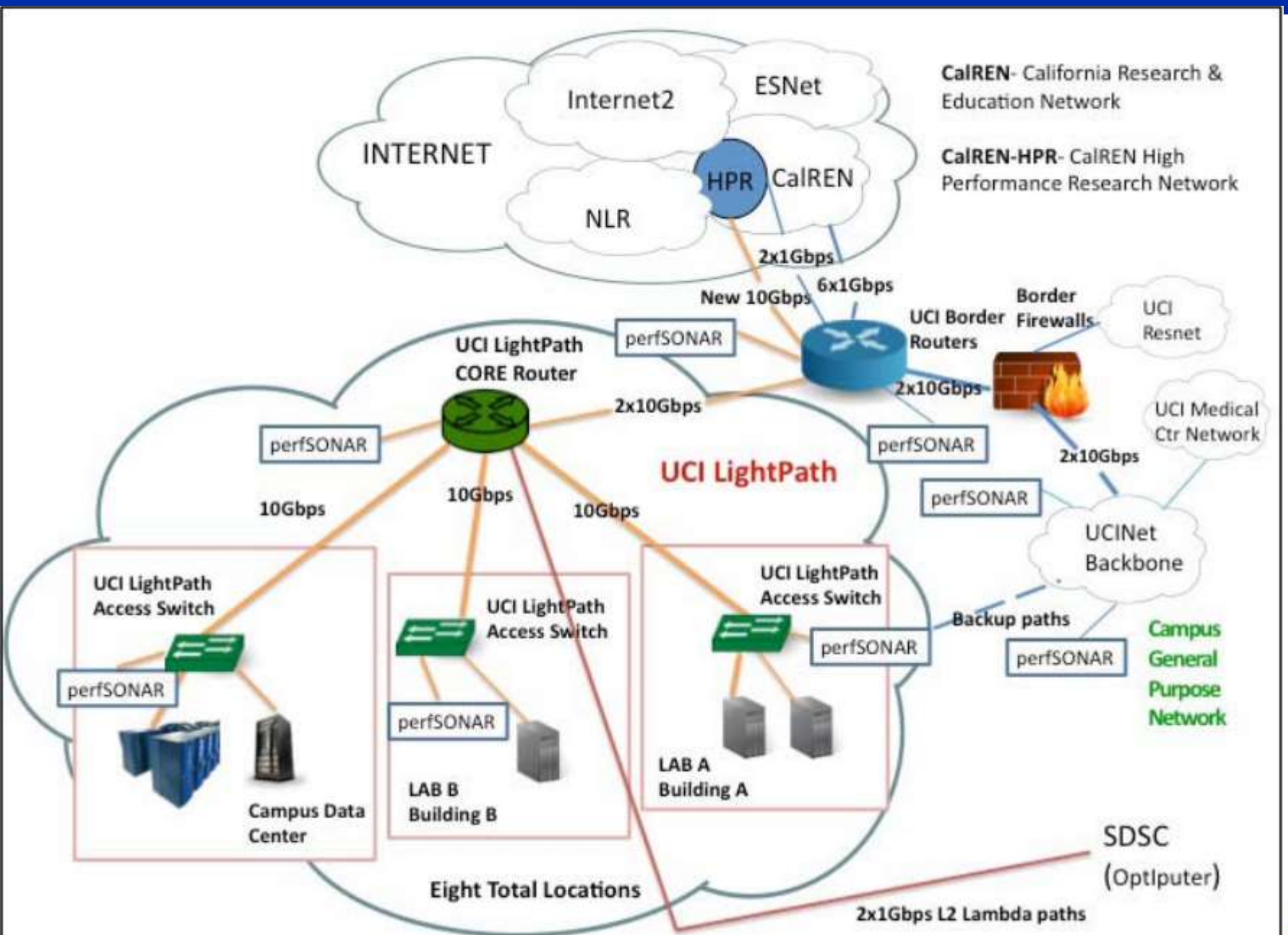
- **FIONA – Flash I/O Node Appliance**
  - Combination of Desktop and Server Building Blocks
  - US$5K - US$7K
  - Desktop Flash up to 16TB
  - RAID Drives up to 48TB
  - Drive HD 2D & 3D Displays
  - 10GbE/40GbE Adapter
  - Tested speed 30Gbs
  - Developed by UCSD's
    - Phil Papadopoulos
    - Tom DeFanti
    - Joe Keefe



100G CENIC to UCSD—NSF CC-NIE Configurable, High-speed, Extensible Research Bandwidth (CHERuB)

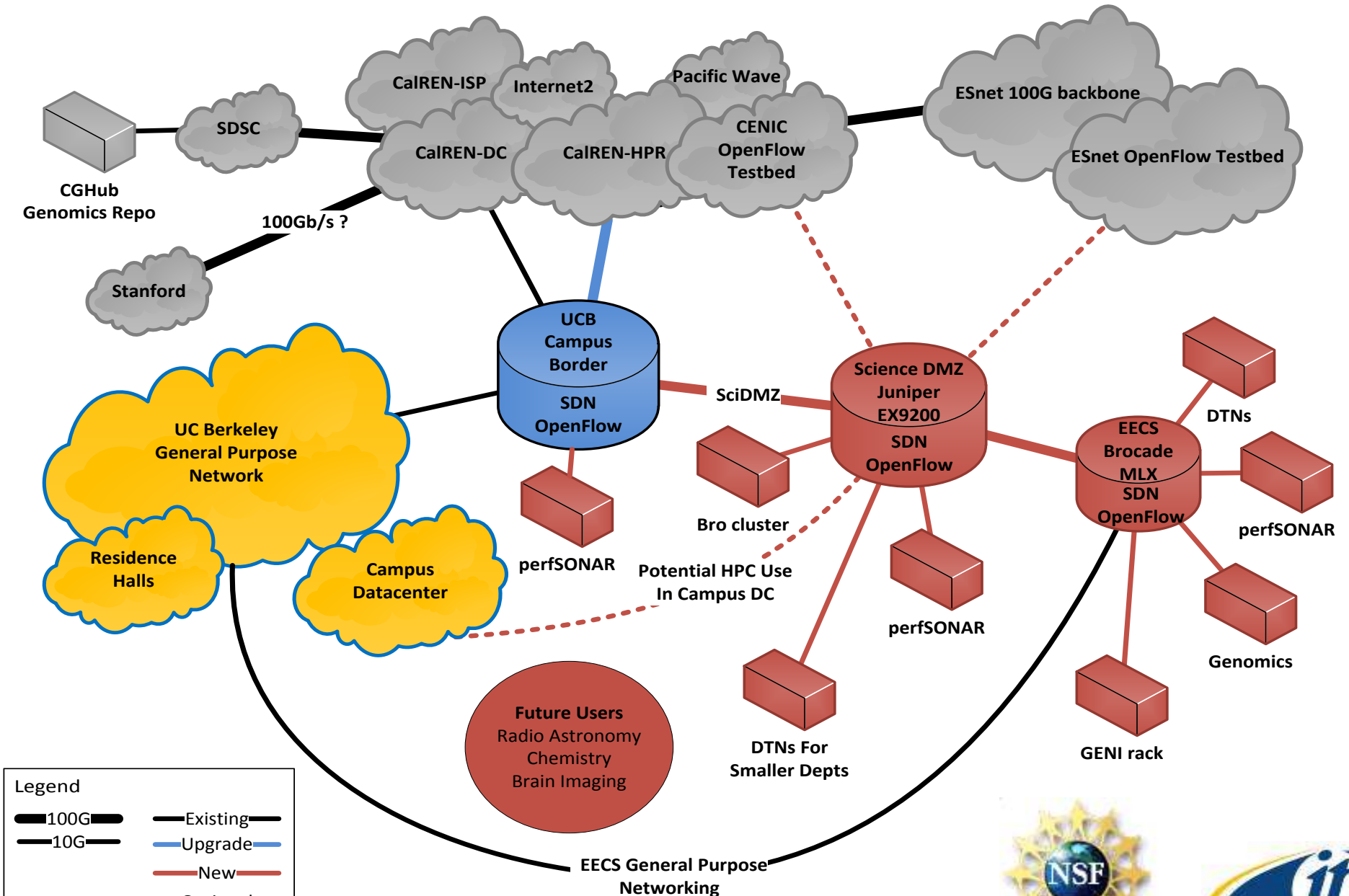


NSF CC-NIE Funded UCI LightPath: A Dedicated Campus Science DMZ Network for Big Data Transfer



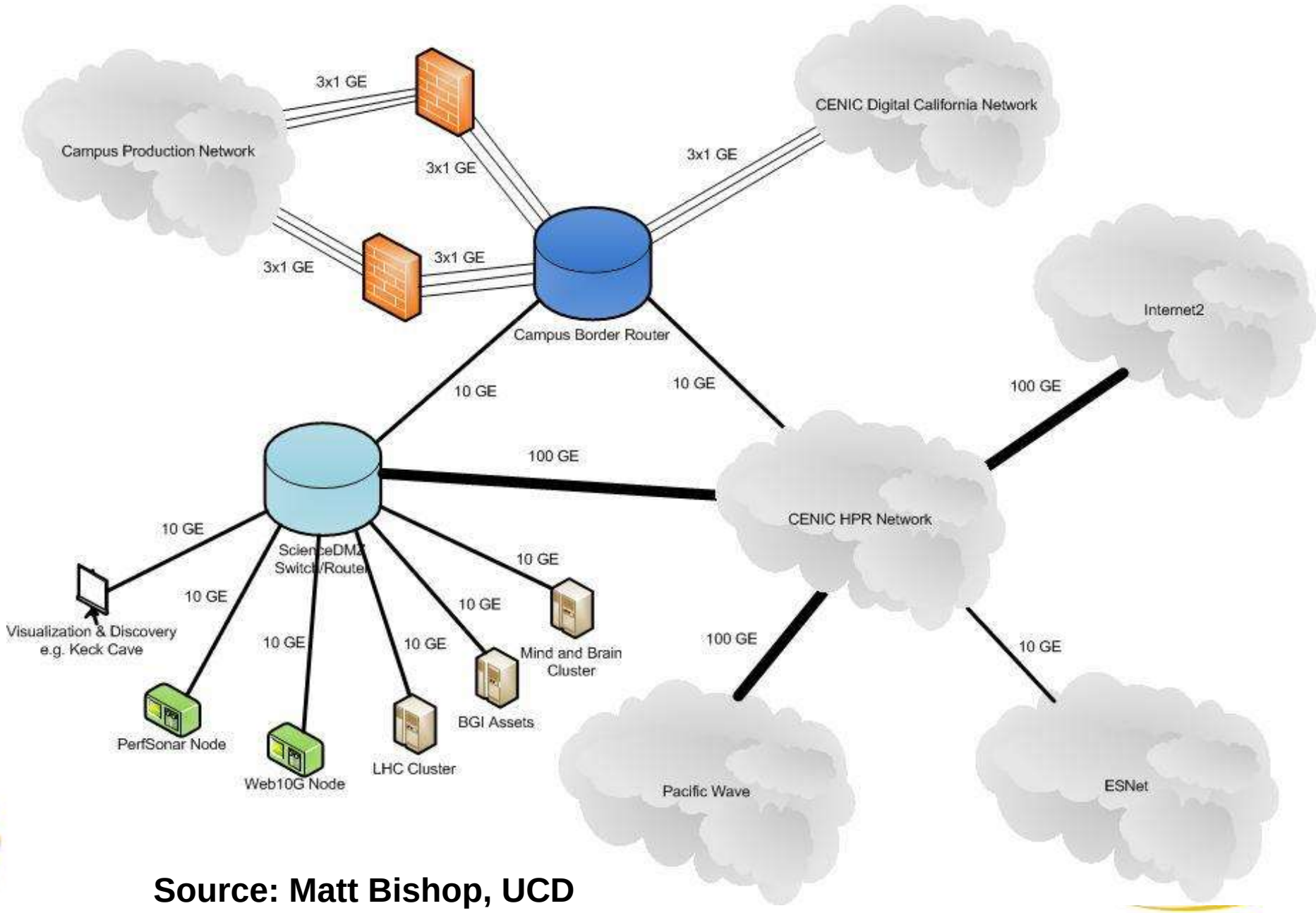
Source: Dana Roode, UCI

NSF CC-NIE Funded UC Berkeley ExCEEDS - Extensible Data Science Networking



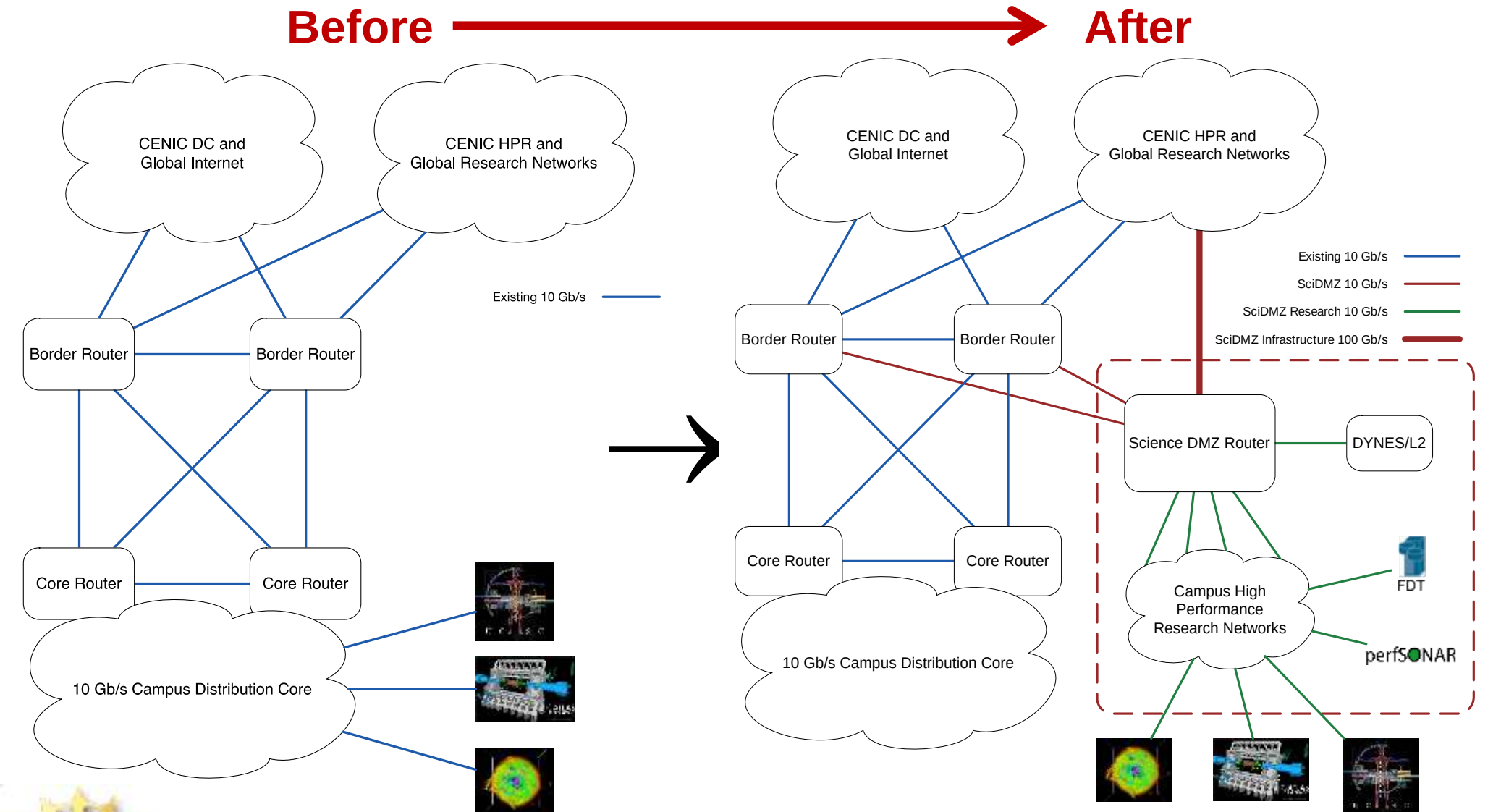
Source: Jon Kuroda, UCB

NSF CC-NIE Funded UC Davis Science DMZ Architecture



Source: Matt Bishop, UCD

NSF CC-NIE Funded Adding a Science DMZ to Existing Shared Internet at UC Santa Cruz



Source: Brad Smith, UCSC

Coupling to California CC-NIE Winning Proposals From Non-UC Campuses

- **Caltech**
  - Caltech High-Performance OPtical Integrated Network (CHOPIN)
  - CHOPIN Deploys Software-Defined Networking (SDN) Capable Switches
  - Creates 100Gbps Link Between Caltech and CENIC and Connection to:
    - California OpenFlow Testbed Network (COTN)
    - Internet2 Advanced Layer 2 Services (AL2S) network
  - Driven by Big Data High Energy Physics, astronomy (LIGO, LSST), Seismology, Geodetic Earth Satellite Observations
- **Stanford University**
  - Develop SDN-Based Private Cloud
  - Connect to Internet2 100G Innovation Platform
  - Campus-Wide Sliceable/VIrtualized SDN Backbone (10-15 switches)
    - SDN control and management
- **San Diego State University**
  - Implementing a ESnet Architecture Science DMZ
  - Balancing Performance and Security Needs
  - Promote Remote Usage of Computing Resources at SDSU

Also USC

cenic

NSF

Source: Louis Fox, CENIC CEO

High Performance Computing and Storage Become Plug Ins to the "Big Data" Plane

NERSC

SDSC



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NERSC and ESnet
Offer High Performance Computing and Networking

EDISON ELECTRIFIES SCIENTIFIC COMPUTING

NERSC Flips Switch on New Flagship Supercomputer



Cray XC30 2.4 Petaflops
Dedicated Feb. 5, 2014

SDSC's Comet is a ~2 PetaFLOPs System Architected for the "Long Tail of Science"



UCSD

NSF

SDSC

UCSD/SDSC Provides CoLo Facilities Over Multi-Gigabit/s Optical Networks

	Capacity	Utilized	Headroom
Racks	480 (=80%)	340	140
Power (MW) (fall 2014)	6.3 (13 to bldg)	2.5	3.8
Cooling capacity (MW)	4.25	2.5	1.75
UPS (total) (MW)	3.1	1.5	1.6
UPS/Generator MW	1.1	0.5	0.6

Network Connectivity (Fall '14)

- **100Gbps** (*CHERuB* - layer 2 only): via CENIC to PacWave, Internet2 AL2S & ESnet
- **20Gbps** (each): CENIC HPR (Internet2), CENIC DC (K-20+ISPs)
- **10Gbps** (each): CENIC HPR-L2, ESnet L3, Pacwave L2, XSEDENet, FutureGrid (IU)

Current Usage Profile (racks)

- UCSD: 248
- Other UC campuses: 52
- Non-UC nonprofit/industry: 26

Protected-Data Equipment or Services (PHI, HIPAA)

- UCD, UCI, UCOP, UCR, UCSC, UCSD, UCSF, Rady Children's Hospital

UC San Diego
Research Cyberinfrastructure

SDSC
it²

Triton Shared Computing Cluster
"Hotel" & "Condo" Models

- **Participation Model:**
  - Hotel:
    - Pre-Purchase Computing Time as Needed / Run on Subset of Cluster
    - For Small/Medium & Short-Term Needs
  - Condo:
    - Purchase Nodes with Equipment Funds and Have "Run Of The Cluster"
    - For Longer Term Needs / Larger Runs
  - Annual Operations Fee Is Subsidized (~75%) for UCSD

- **System Capabilities:**
  - Heterogeneous System for Range of User Needs
    - Intel Xeon, NVIDIA GPU, Mixed Infiniband / Ethernet Interconnect
  - 180 Total Nodes, ~ 80-90TF Performance
  - 40+ Hotel Nodes
  - 700TB High Performance Data Oasis Parallel File System
  - Persistent Storage via Recharge
- **User Profile:**
  - 16 Condo Groups (All UCSD)
  - ~600 User Accounts
  - Hotel Partition
    - Users From 8 UC Campuses
    - UC Santa Barbara & Merced Most Active After UCSD
  - ~70 Users from Outside Research Institutes and Industry

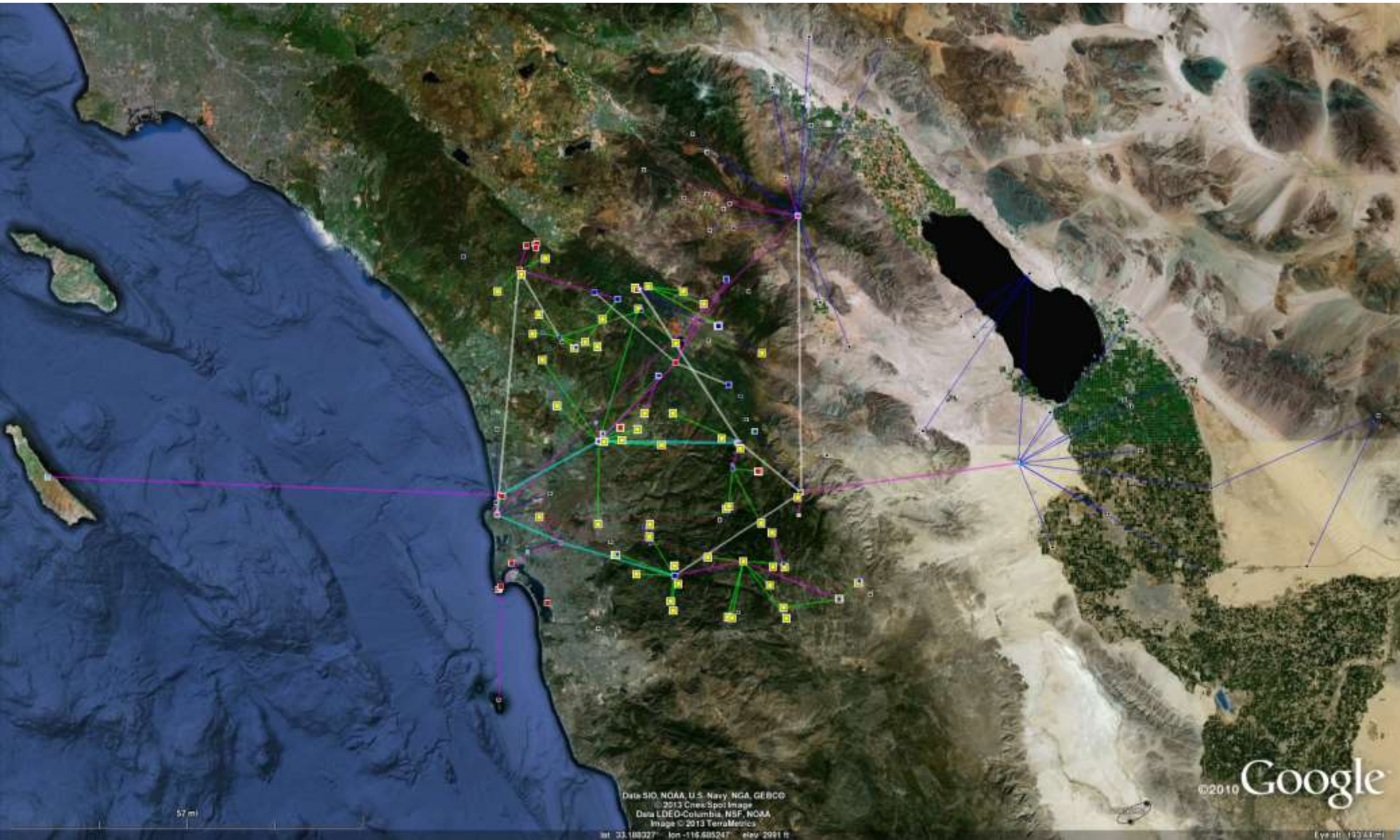
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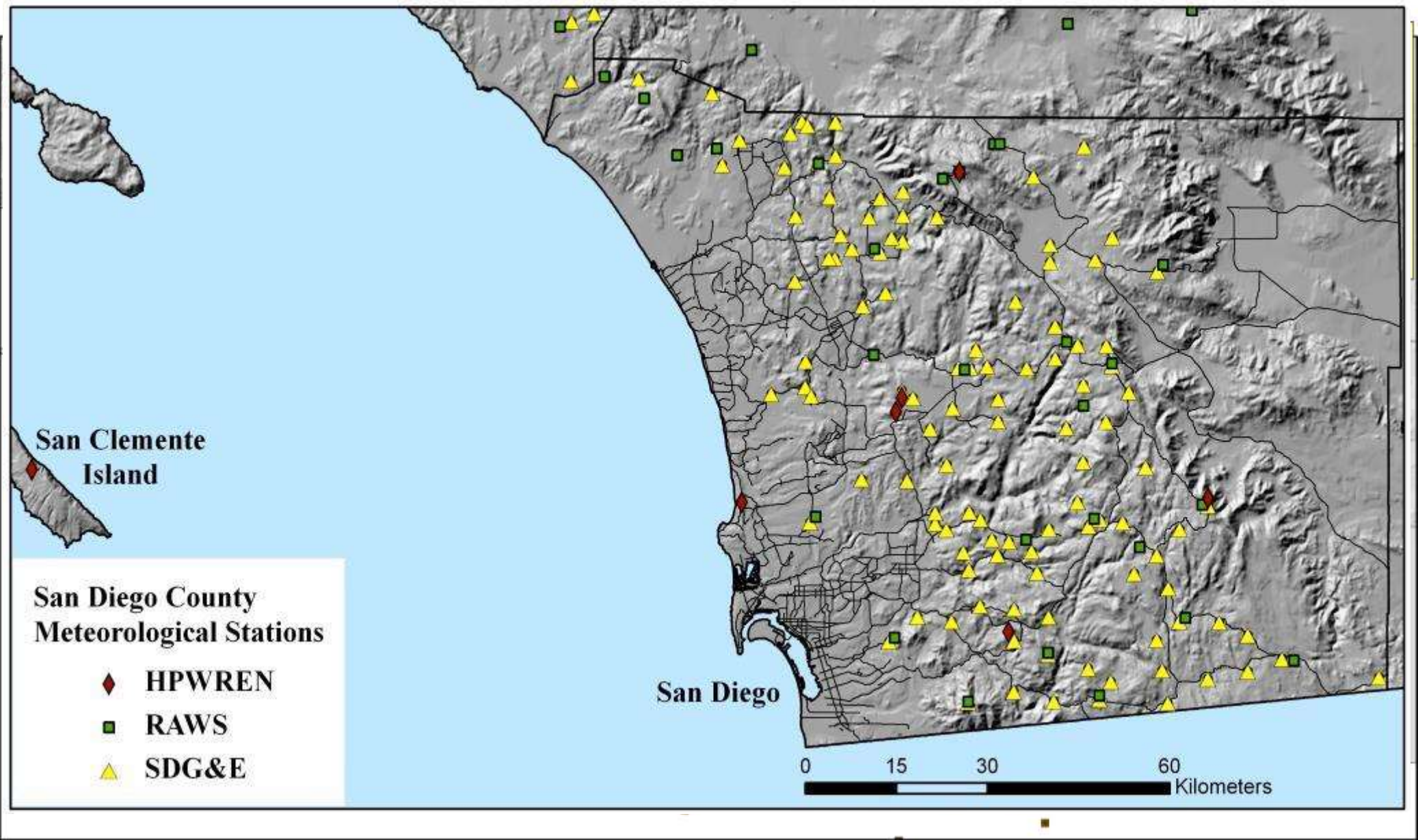
HPWREN Topology

Covers San Diego, Imperial, and Part of Riverside Counties



SoCal Weather Stations:
Note the High Density in San Diego County

Source: Jessica Block, Calit2



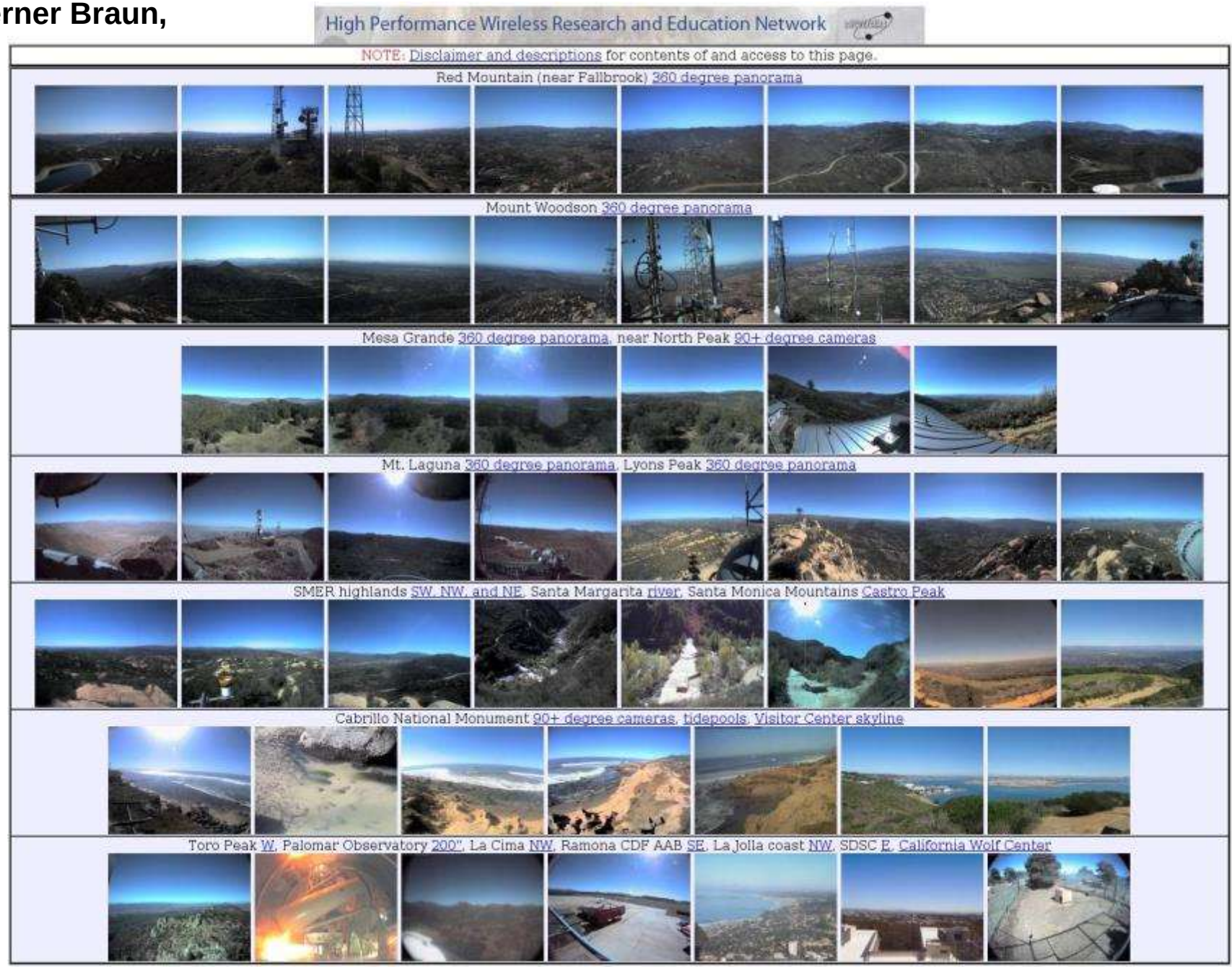
Interactive Virtual Reality of San Diego County Includes Live Feeds From 150 Met Stations



TourCAVE at Calit2's Qualcomm Institute

Real-Time Network Cameras on Mountains for Environmental Observations

Source: Hans Werner Braun, HPWREN PI



Many Disciplines Require Dedicated High Bandwidth on Campus

Big Data Flows Add to Commodity Internet to Fully Utilize CENIC's 100G Campus Connection

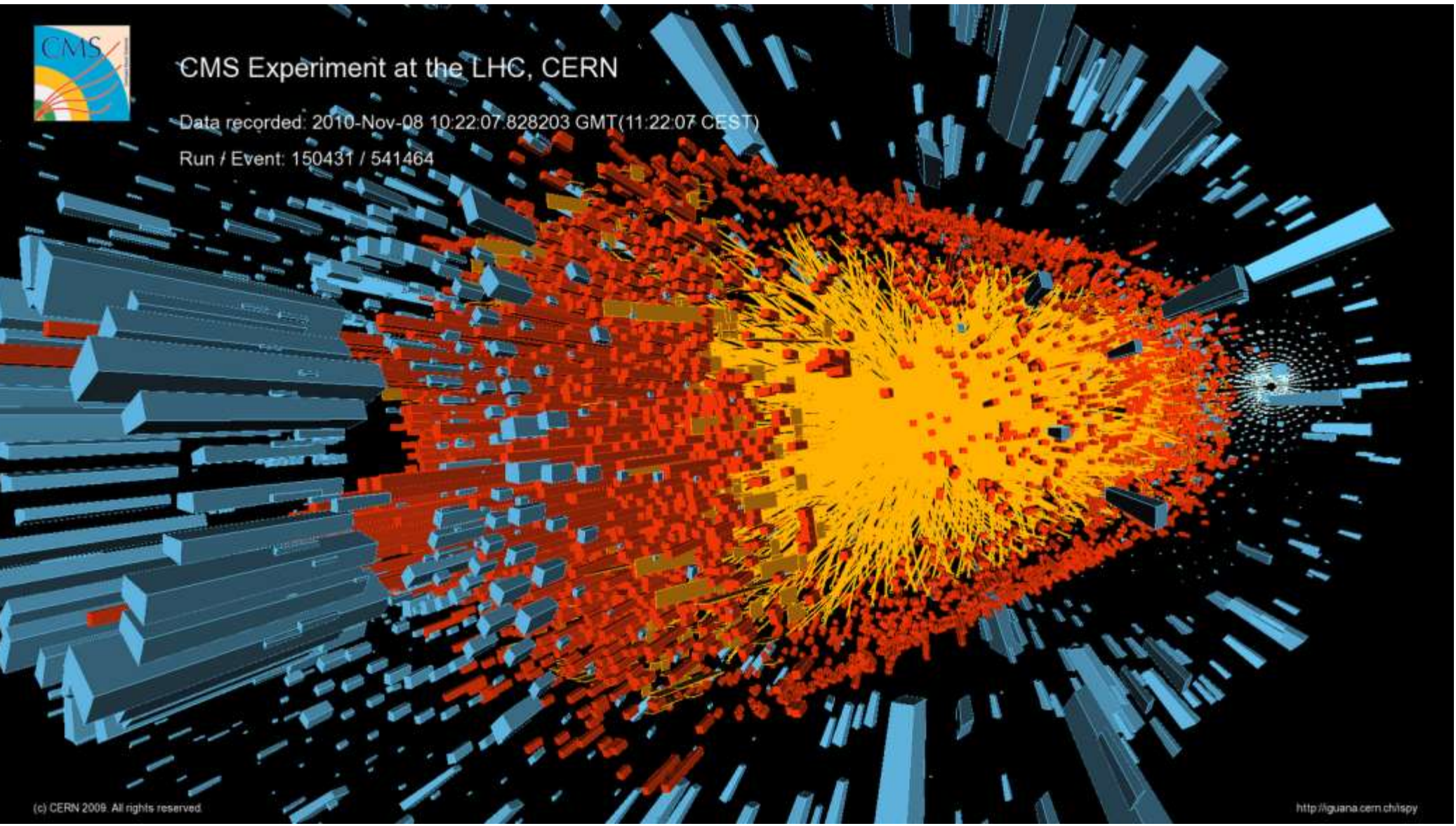
- **Remote Analysis of Large Data Sets**
  - **Particle Physics, Regional Climate Change**
- **Connection to Remote Campus Compute & Storage Clusters**
  - **Microscopy and Next Gen Sequencers**
- **Providing Remote Access to Campus Data Repositories**
  - **Protein Data Bank, Mass Spectrometry, Genomics**
- **Enabling Remote Collaborations**
  - **National and International**
- **Extending Data-Intensive Research to Surrounding Counties**
  - **HPWREN**

UC San Diego SDSC it²

California Integrated Digital Infrastructure: Next Steps

- **White Paper for UCSD Delivered to Chancellor**
  - Creating a Campus Research Data Library
  - Deploying Advanced Cloud, Networking, Storage, Compute, and Visualization Services
  - Organizing a User-Driven IDI Specialists Team
  - Riding the Learning Curve from Leading-Edge Capabilities to Community Data Services
- **White Paper for UC-Wide IDI Under Development**
  - Begin Work on Integrating CC-NIEs Across Campuses
  - Extending the HPWREN from UC Campuses
- **Calit2 (UCSD, UCI) and CITRIS (UCB, UCSC, UCD)**
  - Organizing UCOP MRPI Planning Grant
  - NSF Coordinated CC-NIE Supplements
- **Add in Other UCs, Privates, CSU, …**

PRISM is Connecting CERN's CMS Experiment To UCSD Physics Department at 80 Gbps



All UC LHC Researchers Could Share Data/Compute Across CENIC/Esnet at 10-100 Gbps

Planning for climate change in California

substantial shifts on top of already high climate variability

SIO Campus Climate Researchers Need to Download Results from Remote Supercomputer Simulations to Make Regional Climate Change Forecasts

Dan Cayan

USGS Water Resources Discipline

Scripps Institution of Oceanography, UC San Diego

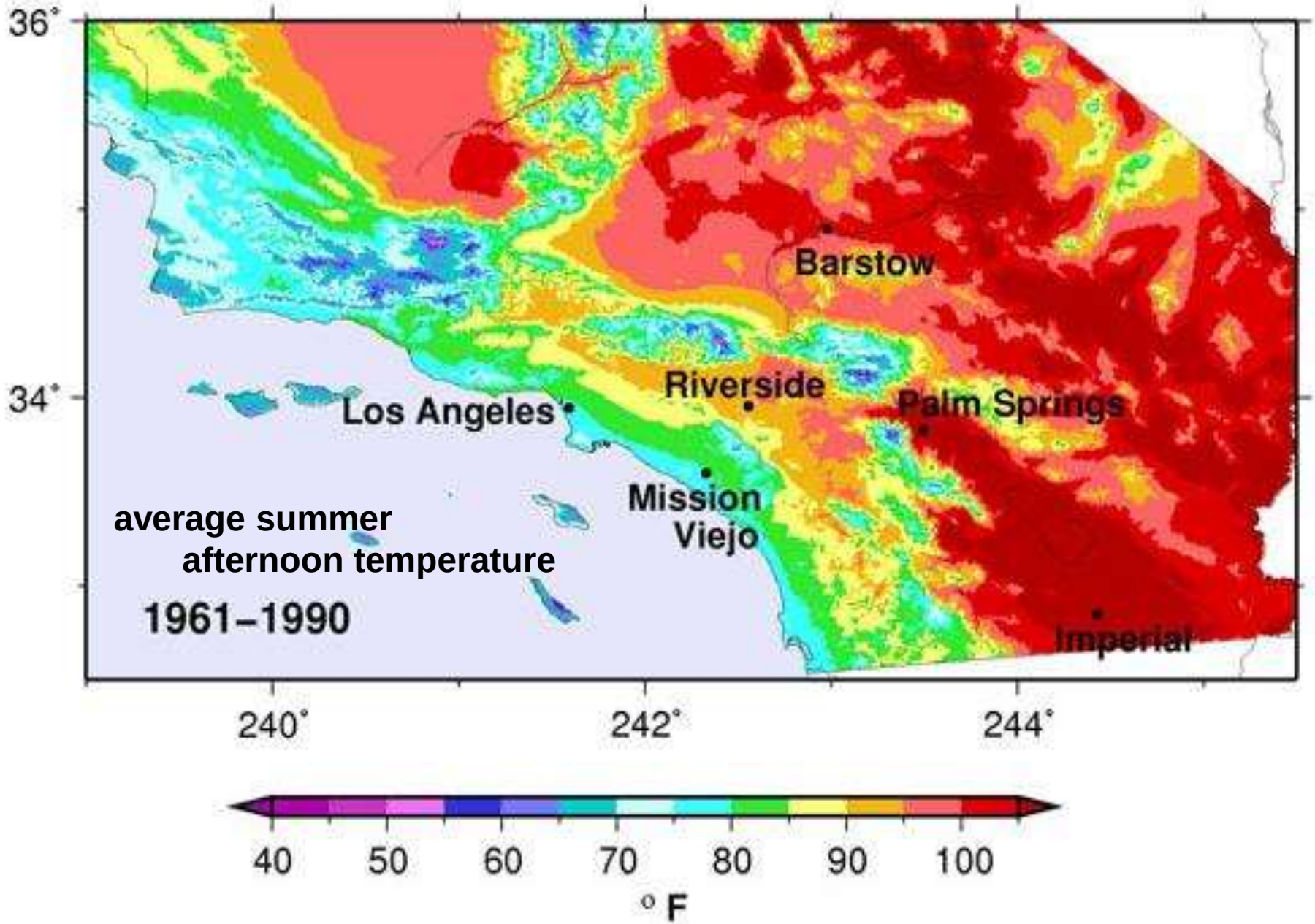
much support from Mary Tyree, Mike Dettinger, Guido Franco and other colleagues

Sponsors:

California Energy Commission

NOAA RISA program

California DWR, DOE, NSF



GFDL A2 1km downscaled to 1km
Source: Hugo Hidalgo, Tapash Das, Mike Dettinger

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

NCMIR



Shared Infrastructure

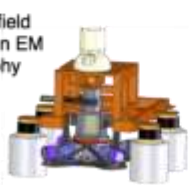


Scientific Instruments













Local SOM Infrastructure













End User FIONA Workstation

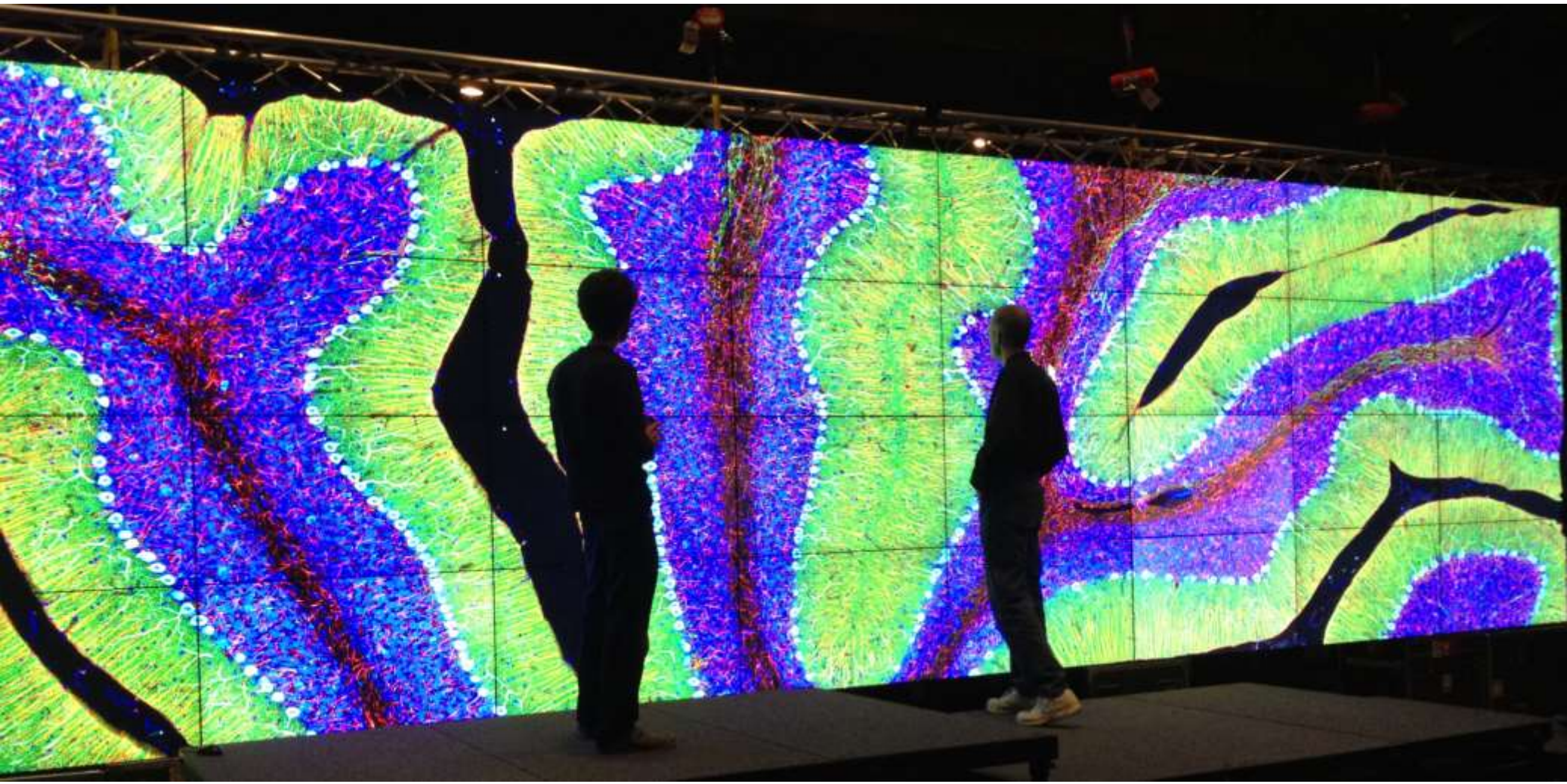




SDSC

Source: Steve Peltier, Mark Ellisman, NCMIR

PRISM Links Calit2's VROOM to NCMIR to Explore Confocal Light Microscope Images of Rat Brains



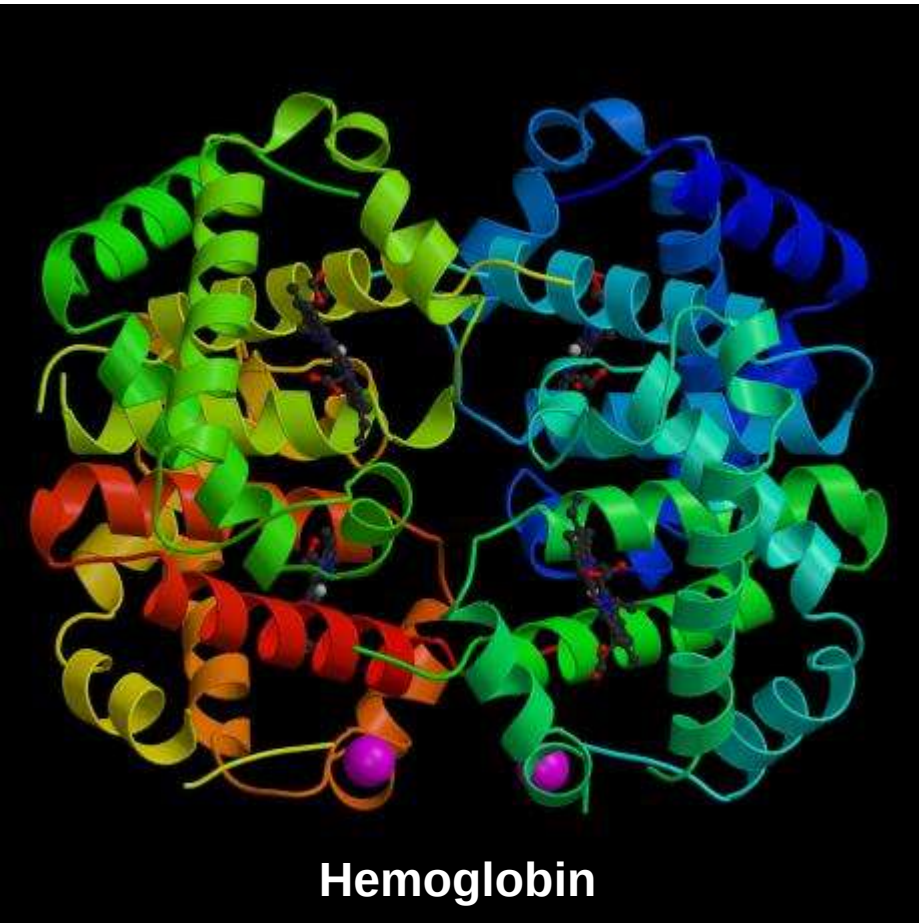


NCMIR National Center for Microscopy and Imaging Research

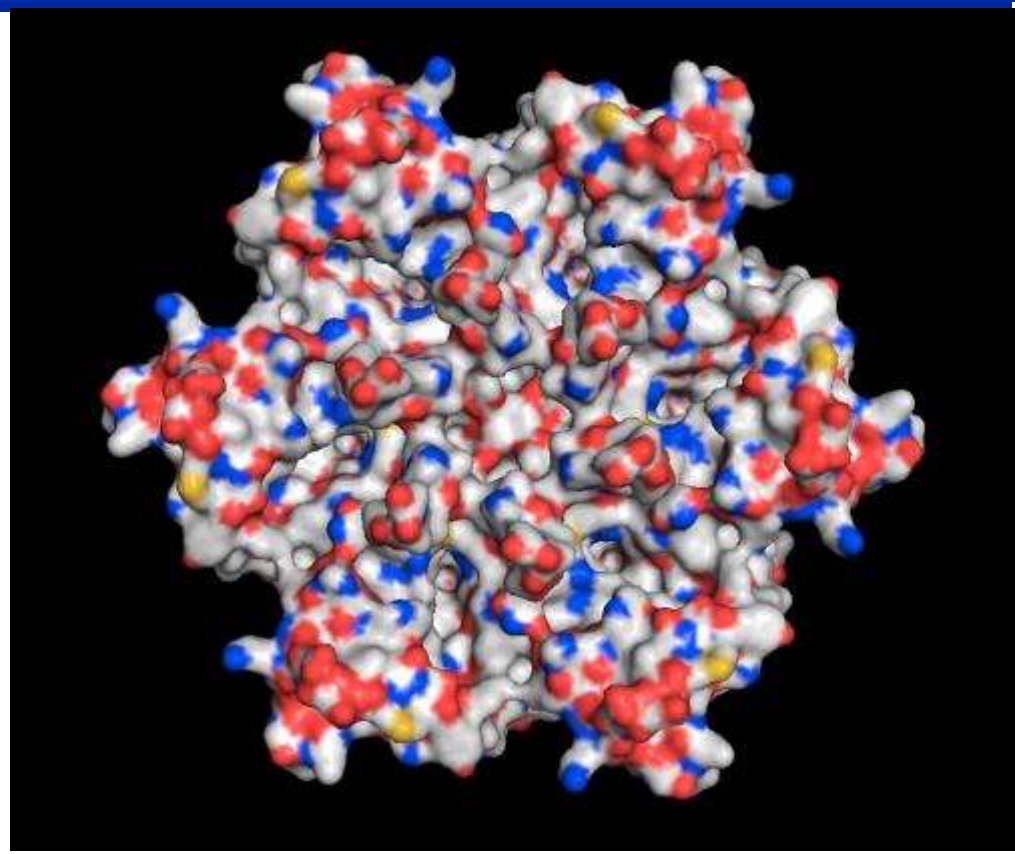
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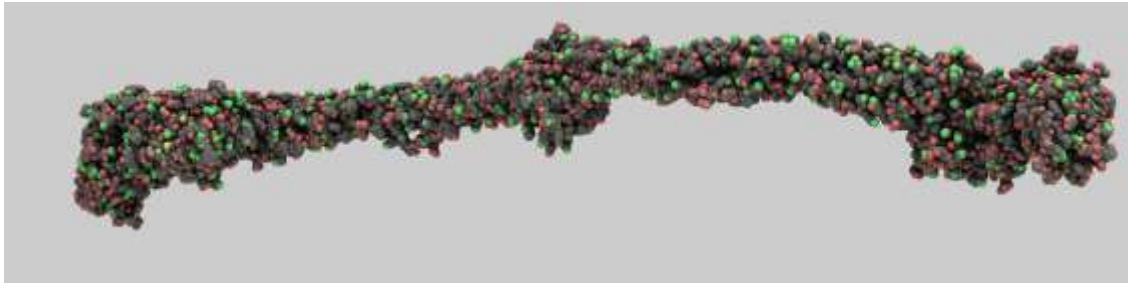
Protein Data Bank (PDB) Needs Bandwidth to Connect Resources and Users

- Archive of experimentally determined 3D structures of proteins, nucleic acids, complex assemblies
- One of the largest scientific resources in life sciences



Hemoglobin

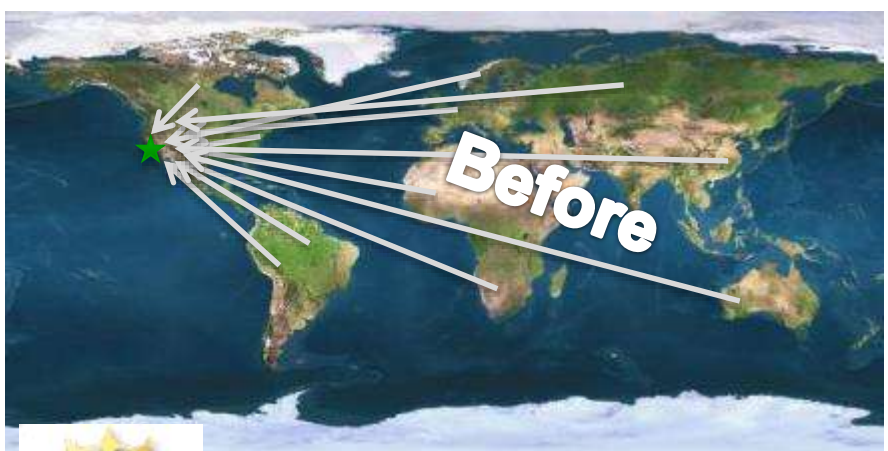




Source: Phil Bourne and Andreas Prlić, PDB

PDB Plans to Establish Global Load Balancing

- **Why is it Important?**
  - **Enables PDB to Better Serve Its Users by Providing Increased Reliability and Quicker Results**
- **Need High Bandwidth Between Rutgers & UCSD Facilities**
  - **More than 300,000 Unique Visitors per Month**
  - **Up to 300 Concurrent Users**
  - **~10 Structures are Downloaded per Second 7/24/365**





Source: Phil Bourne and Andreas Prlić, PDB

Cancer Genomics Hub (UCSC) is Housed in SDSC CoLo: Storage CoLo Attracts Compute CoLo

- CGHub is a Large-Scale Data Repository/Portal for the National Cancer Institute's Cancer Genome Research Programs
- Current Capacity is 5 Petabytes , Scalable to 20 Petabytes; Cancer Genome Atlas Alone Could Produce 10 PB in the Next Four Years



- *(David Haussler, PI)* ***"SDSC [colocation service] has exceeded our expectations of what a data center can offer. We are glad to have the CGHub database located at SDSC."***
- *Researchers can already install their own computers at SDSC, where the CGHub data is physically housed, so that they can run their own analyses. (http://blogs.nature.com/news/2012/05/us-cancer-genome-repository-hopes-to-speed-research.html)*
- *Berkeley is connecting at 100Gbps to CGHub*

SDSC

Source: Richard Moore, et al. SDSC

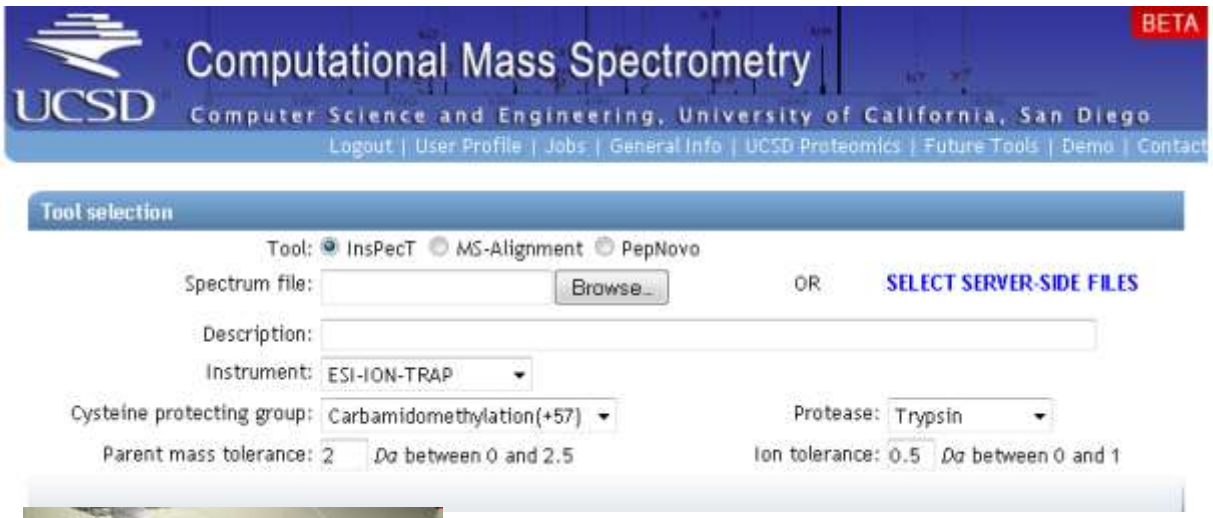
it²

PRISM Will Link Computational Mass Spectrometry and Genome Sequencing Cores to the Big Data Freeway

Source: proteomics.ucsd.edu

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

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



Molecular & Cellular Proteomics

Journal of proteome research

Statistics

Members	1544
Groups & Projects	355
Data Size (uncompressed)	23.3 TB
Data Files	13,264,659



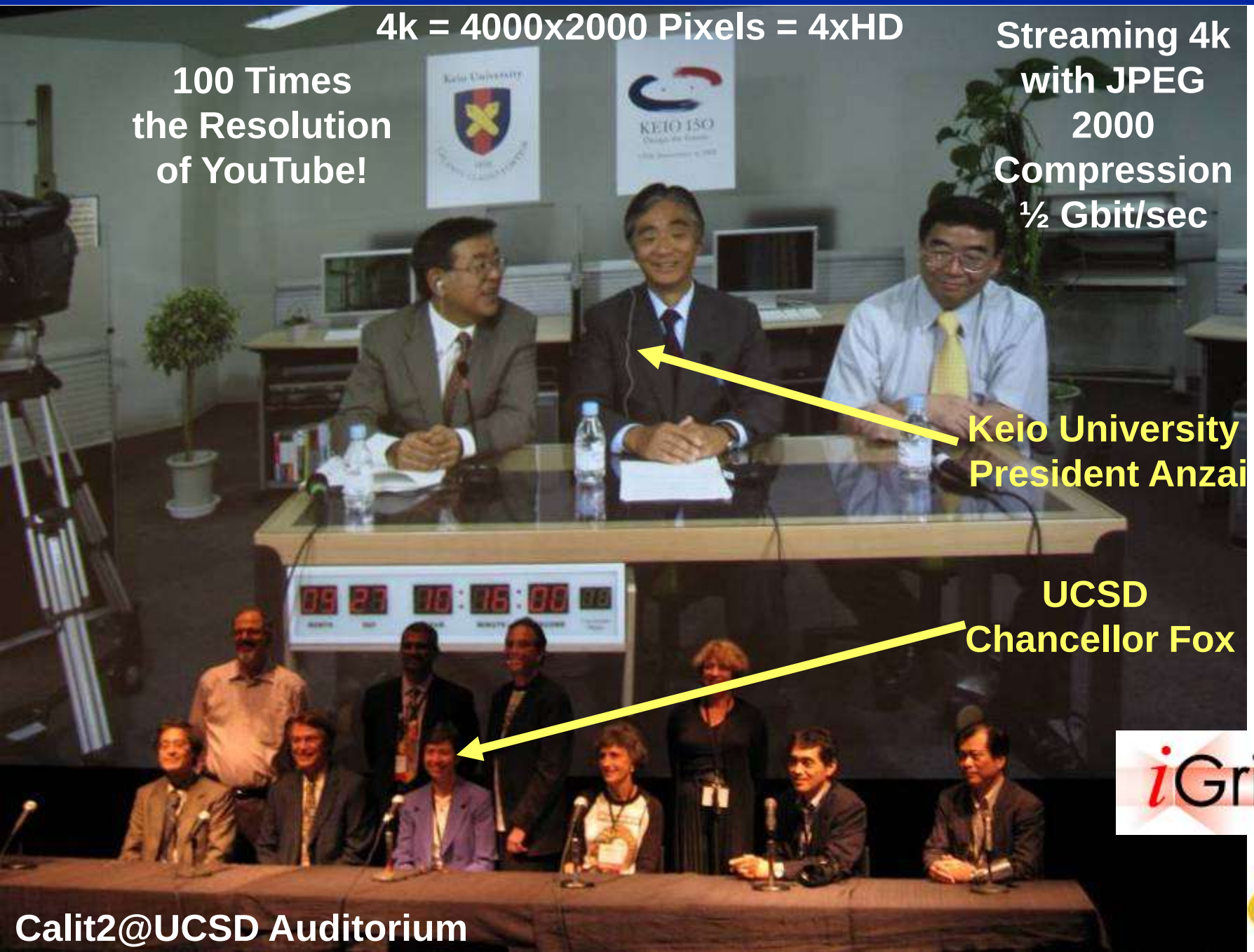


IGM Institute for Genomic Medicine

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

it²

Telepresence Meeting
Using Digital Cinema 4k Streams



CineGrid

Lays Technical Basis for Global Digital Cinema

Sony
NTT
SGI

iGrid 2005

it²

Tele-Collaboration for Audio Post-Production
Realtime Picture & Sound Editing Synchronized Over IP





Skywalker Sound@Marin **Calit2@San Diego**

Collaboration Between EVL's CAVE2 and Calit2's VROOM Over 10Gb Wavelength



Source: NTT Sponsored ON*VECTOR Workshop at Calit2 March 6, 2013



High Performance Wireless Research and Education Network

http://hpwren.ucsd.edu/

National Science Foundation awards 0087344, 0426879 and 0944131

HPWREN UCSD SDSC SAN DIEGO SUPERCOMPUTER CENTER it² SAN DIEGO STATE UNIVERSITY NATIONAL SCIENCE FOUNDATION

A Scalable Data-Driven Monitoring, Dynamic Prediction and Resilience Cyberinfrastructure for Wildfires (WiFire)

NSF Has Just Awarded the WiFire Grant – Ilkay Altintas SDSC PI

Development of end-to-end "cyberinfrastructure" for "analysis of large dimensional heterogeneous real-time sensor data"



System integration of

- real-time sensor networks,
- satellite imagery,
- near-real time data management tools,
- wildfire simulation tools
- connectivity to emergency command centers before during and after a firestorm.

The Department of FIRE PROTECTION ENGINEERING

UCSD Jacobs MECHANICAL and AEROSPACE ENGINEERING

Using Calit2's Qualcomm Institute NexCAVE for CAL FIRE Research and Planning





Source: Jessica Block, Calit2