“The Pacific Research Platform: a Science-Driven Big-Data Freeway System.”

Invited Presentation

2015 Campus Cyberinfrastructure PI Workshop

Austin, TX

September 30, 2015

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

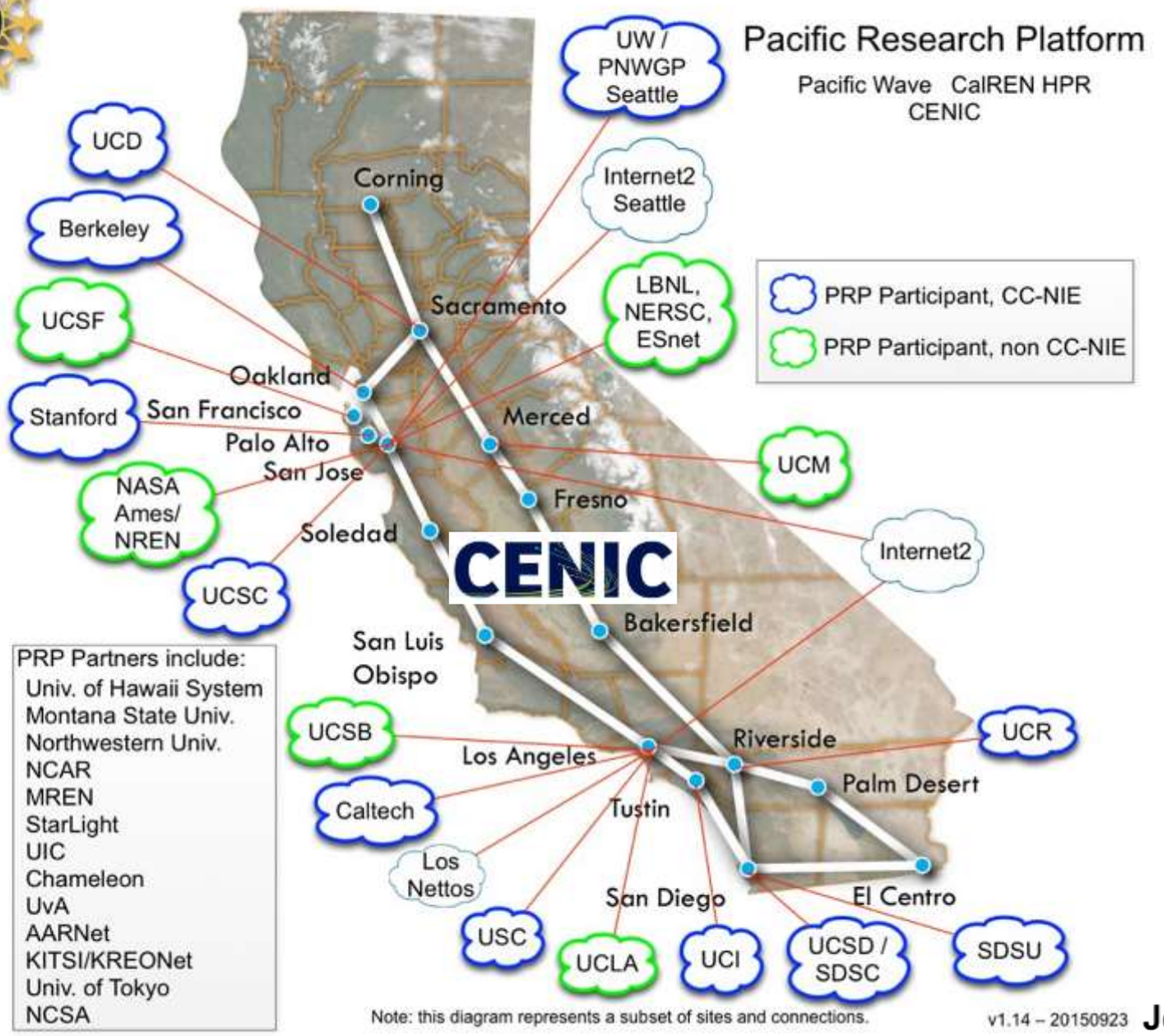
Vision: Creating a West Coast "Big Data Freeway" Connected by CENIC/Pacific Wave to Internet2 & GLIF

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

"The Bisection Bandwidth of a Cluster Interconnect, but Deployed on a 20-Campus Scale."

This Vision Has Been Building for 25 Years

The Pacific Research Platform Creates a Regional End-to-End Science-Driven "Big Data Freeway System"



NSF CC*DNI $5M 10/2015-10/2020

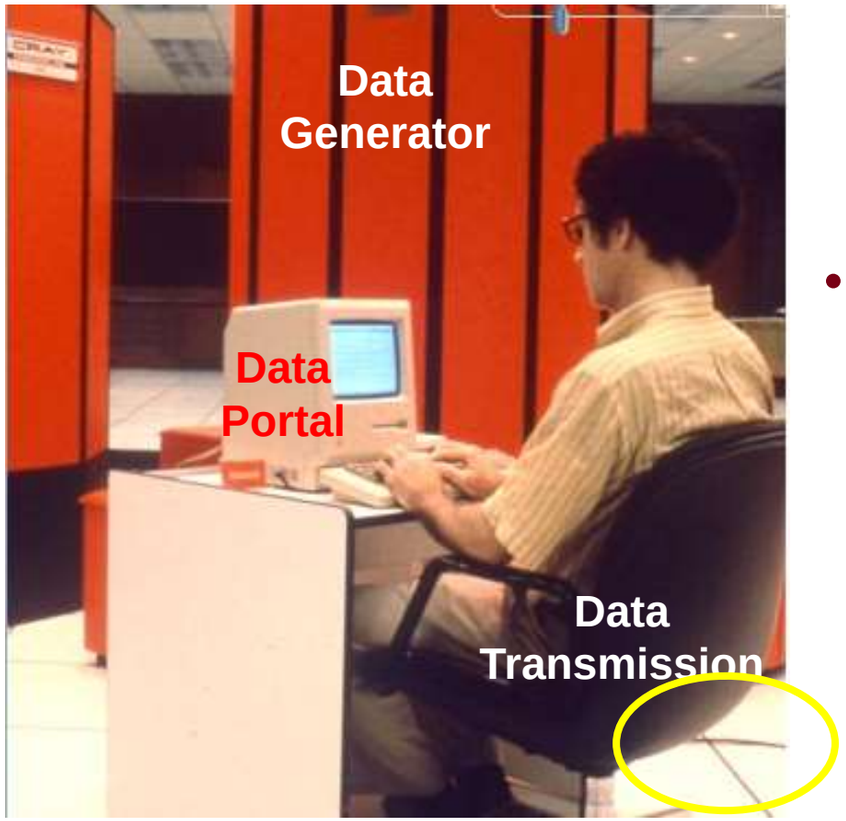
PI: Larry Smarr, UC San Diego Calit2
Co-Pis:

- **Camille Crittenden, UC Berkeley CITRIS,**
- **Tom DeFanti, UC San Diego Calit2,**
- **Philip Papadopoulos, UC San Diego SDSC,**
- **Frank Wuerthwein, UC San Diego Physics and SDSC**

NSF-Funded Workshop For PRP Members October 14-16 Calit2@UCSD

Source: John Hess, CENIC

NCSA Telnet--“Hide the Cray” Paradigm That We Still Use Today



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

Source: Larry Smarr 1985

Interactive Supercomputing End-to-End Prototype:
Using Analog Communications to Prototype the Fiber Optic 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







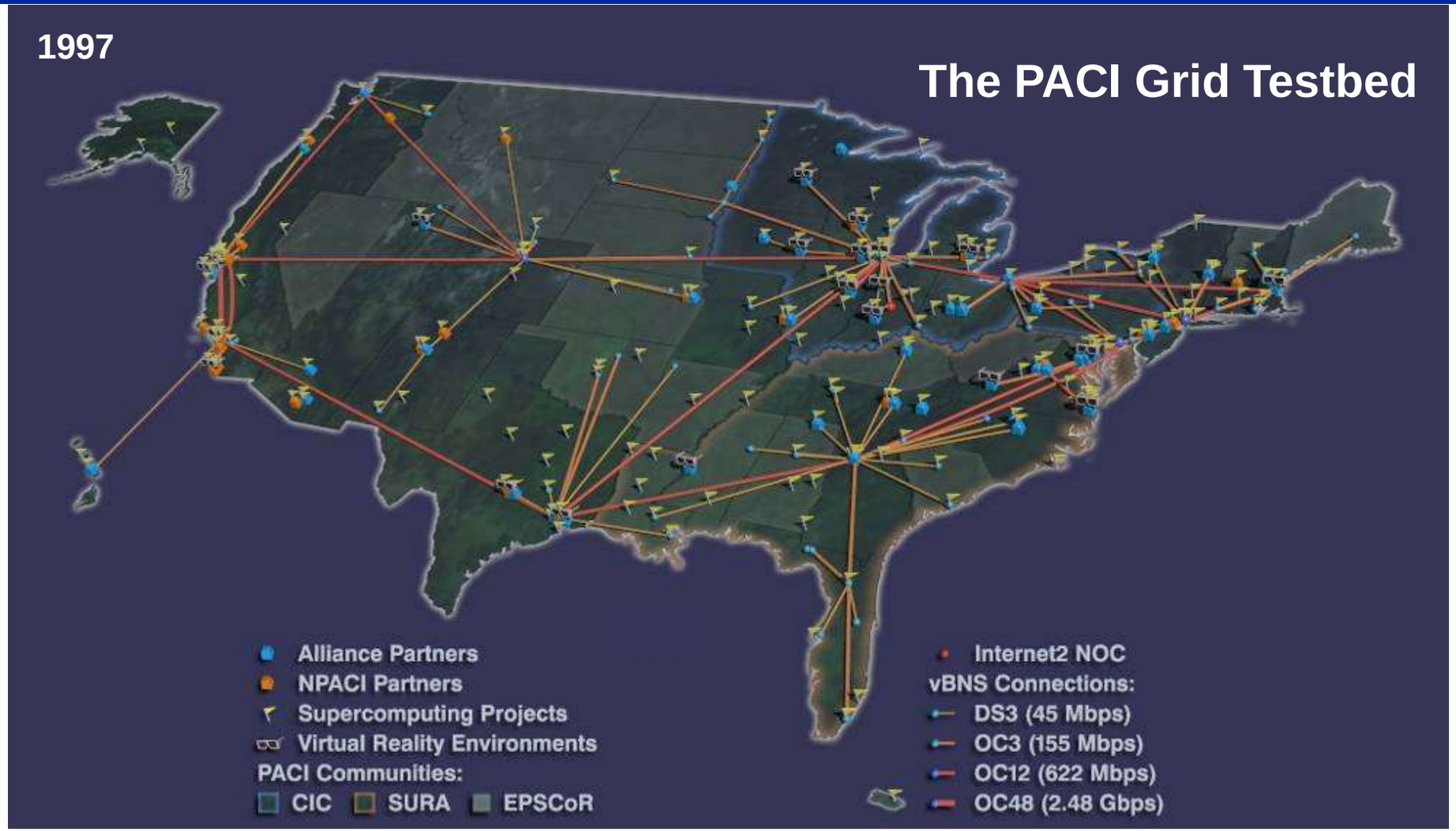
**"We're using satellite technology…
to demo what It might be like to have high-speed fiber-optic links between advanced computers
in two different geographic locations."**

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

NCSA™

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NSF's PACI Program was Built on the vBNS to Prototype America's 21st Century Information Infrastructure



Chesapeake Bay Simulation End-to-End Collaboratory: vBNS Linked CAVE, ImmersaDesk, Power Wall, and Workstation

Alliance Project: Collaborative Video Production via Tele-Immersion and Virtual Director

Alliance Application Technologies
Environmental Hydrology Team







Alliance 1997





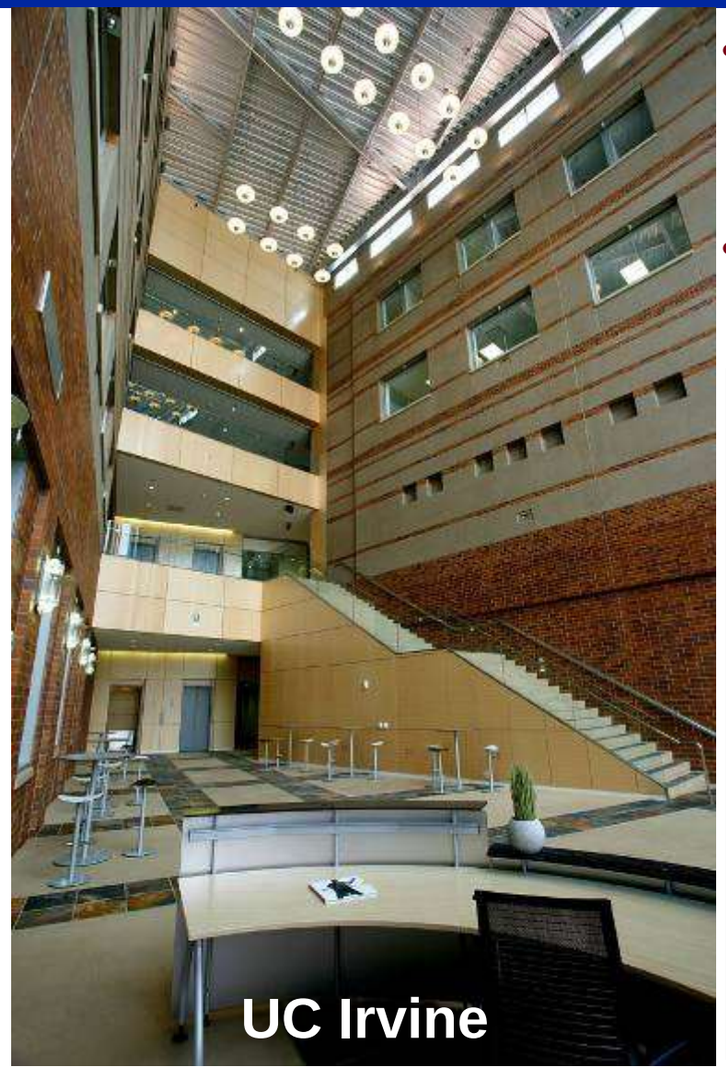
NCSA™ UIC

sgi®

ALLIANCE

Donna Cox, Robert Patterson, Stuart Levy, NCSA Virtual Director Team
Glenn Wheless, Old Dominion Univ.

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…

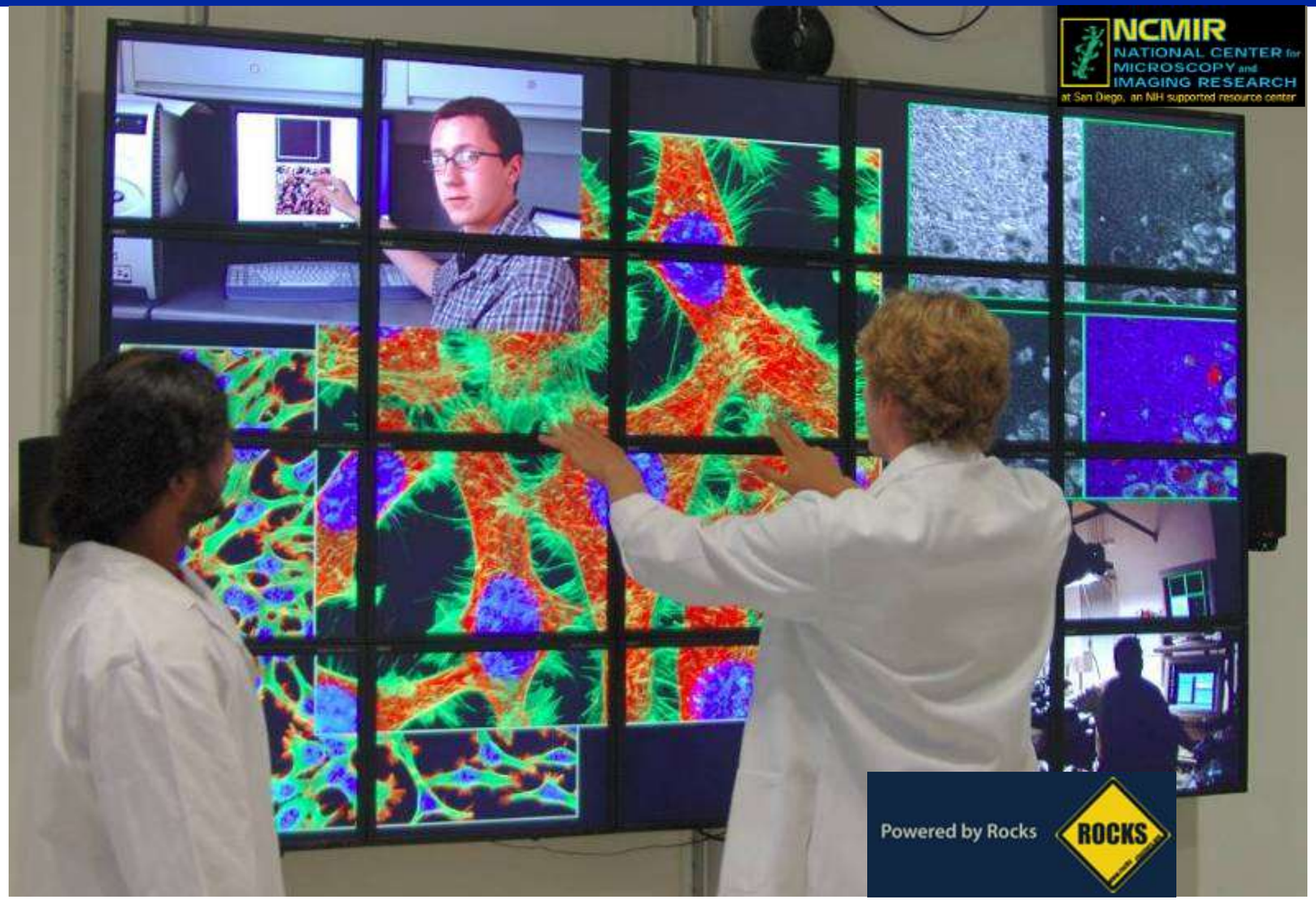
Linking the Calit2 Auditoriums at UCSD and UCI With HD Streams



Photo by Erik Jepsen, UC San Diego

NSF's OptIPuter Project: Using Supernetworks to Meet the Needs of Data-Intensive Researchers

OptIPortal– Termination Device for the OptIPuter Global Backplane



2003-2009
$13,500,000

In August 2003, Jason Leigh and his students used RBUDP to blast data from NCSA to SDSC over the TeraGrid DTFnet, achieving18Gbps file transfer out of the available 20Gbps

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

Integrated "OptIPlatform" Cyberinfrastructure System: A 10Gbps Lightpath Cloud



End User OptIPortal



Instruments



HD/4k Telepresence



HD/4k Video Cams



Campus Optical Switch

10G Lightpath

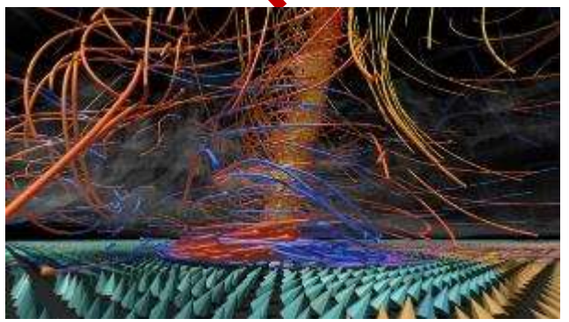


HPC

TeraGrid



Data Repositories & Clusters



HD/4k Video Images

LS 2009 Slide

OptIPuter

it²

So Why Don't We Have a National Big Data Cyberinfrastructure?

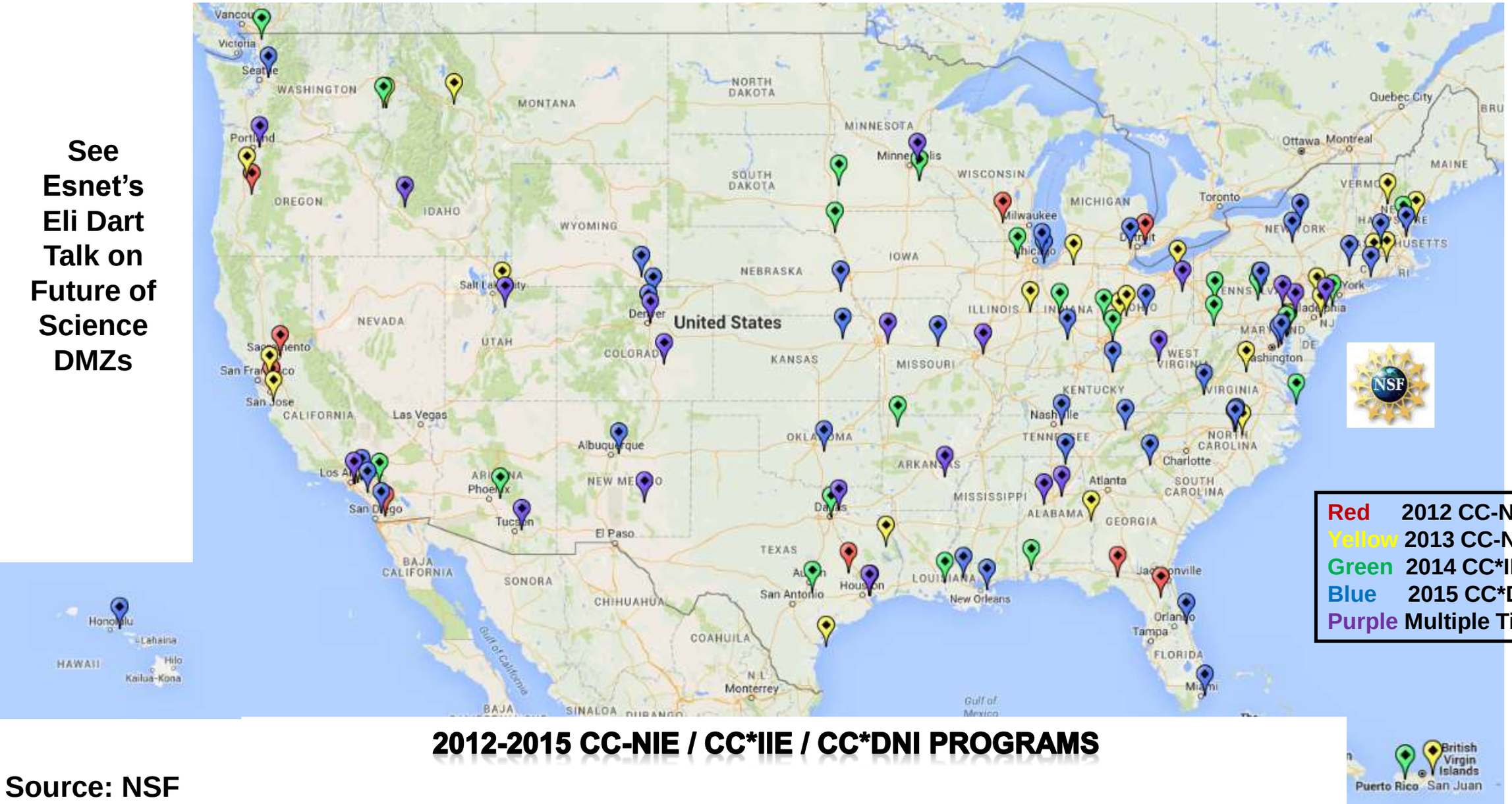
"Research is being stalled by 'information overload,' Mr. Bement said, because data from digital instruments are piling up far faster than researchers can study. In particular, he said, campus networks need to be improved. High-speed data lines crossing the nation are the equivalent of six-lane superhighways, 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 May 2005



Based on Community Input and on ESnet's Science DMZ Concept, NSF Has Funded Over 100 Campuses to Build Local Big Data Freeways

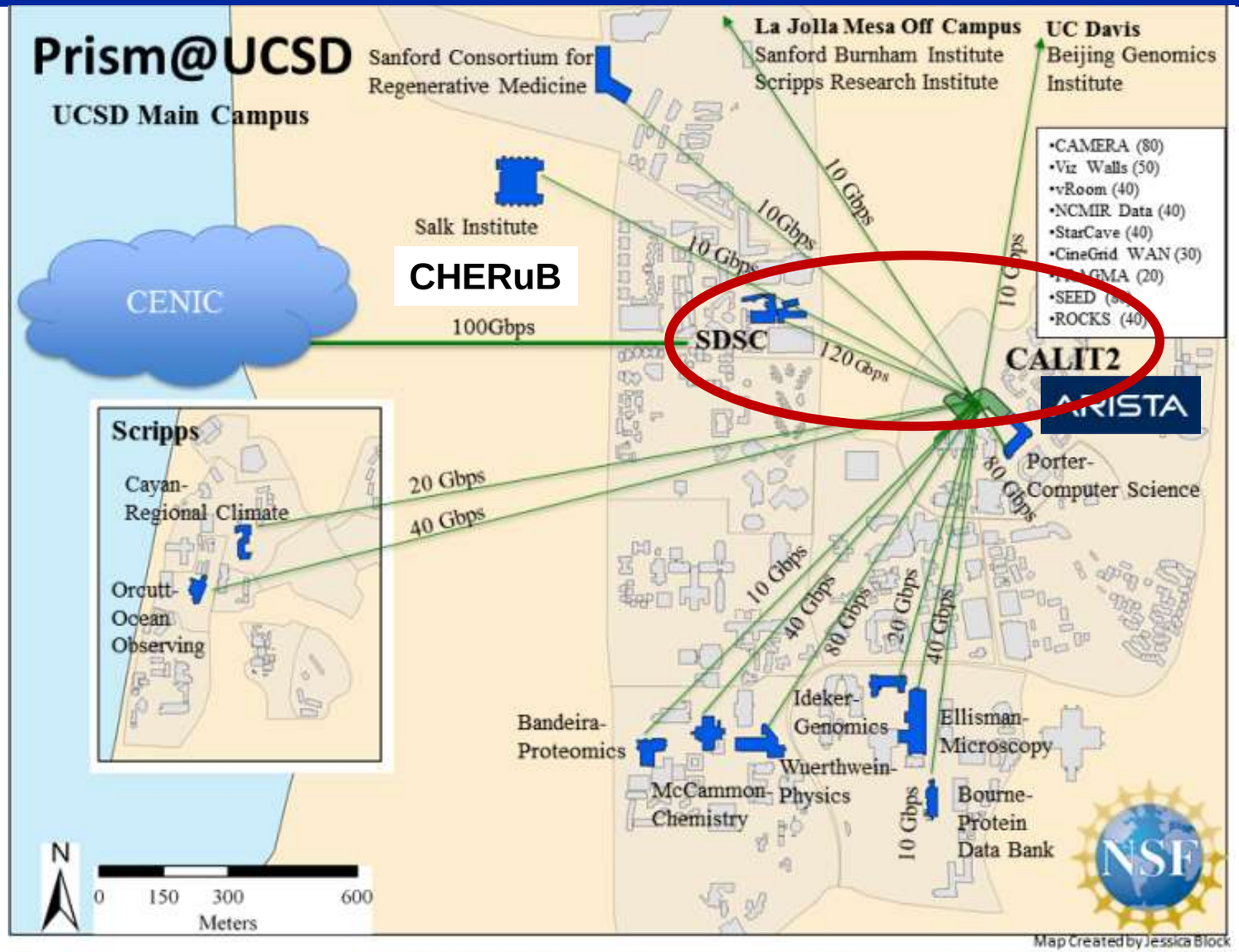
See Esnet's Eli Dart Talk on Future of Science DMZs



2012-2015 CC-NIE / CC*IIE / CC*DNI PROGRAMS

Source: NSF

Creating a "Big Data" Freeway on Campus: NSF Funded Prism@UCSD and CHeruB



Prism@UCSD, Phil Papadopoulos, SDSC, Calit2, PI
CHERuB, Mike Norman, SDSC PI

FIONA – Flash I/O Network Appliance: Linux PCs Optimized for Big Data

FIONAs Are Science DMZ Data Transfer Nodes & Optical Network Termination Devices



UCSD CC-NIE Prism Award & UCOP
Phil Papadopoulos & Tom DeFanti
Joe Keefe & John Graham

UCOP Rack-Mount Build:

Cost	$7700	$21,000
Intel Xeon Haswell Multicore	E5-1650 v3 6-Core	2x E5-2697 v3 14-Core
RAM	1 TB	16 TB
SSD	4 TB	16 TB
Network Interface	10GbE/40GbE	100GbE
GPU		NVIDIA Tesla K80 24GB
RAID Drives 0 to 112TB (add ~$100/TB)		

SDSC

QUALCOMM INSTITUTE

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Customizing Prism@UCSD to Specific Big Data Requirements for Rob Knight's Lab – PRP Does This on a Sub-National Scale

NIH

NCBI
National Center for Biotechnology Information

INTERNET2

CENIC

Knight 1024 Cluster
In SDSC Co-Lo



Gordon





SDSC

CHERuB
100Gbps

Data Oasis
7.5PB,
100GB/s

Knight Lab



FIONA
12 Cores/GPU
128 GB RAM
3.5 TB SSD
48TB Disk
10Gbps NIC

ARISTA

120Gbps

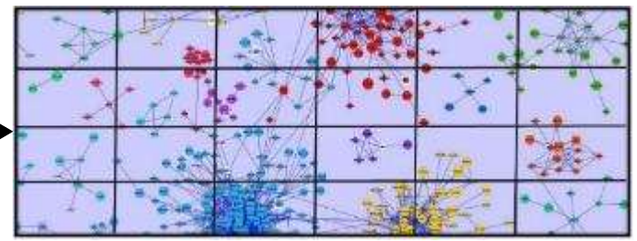
10Gbps

40Gbps



Prism@UCSD

Emperor & Other Vis Tools



64Mpixel Data Analysis Wall

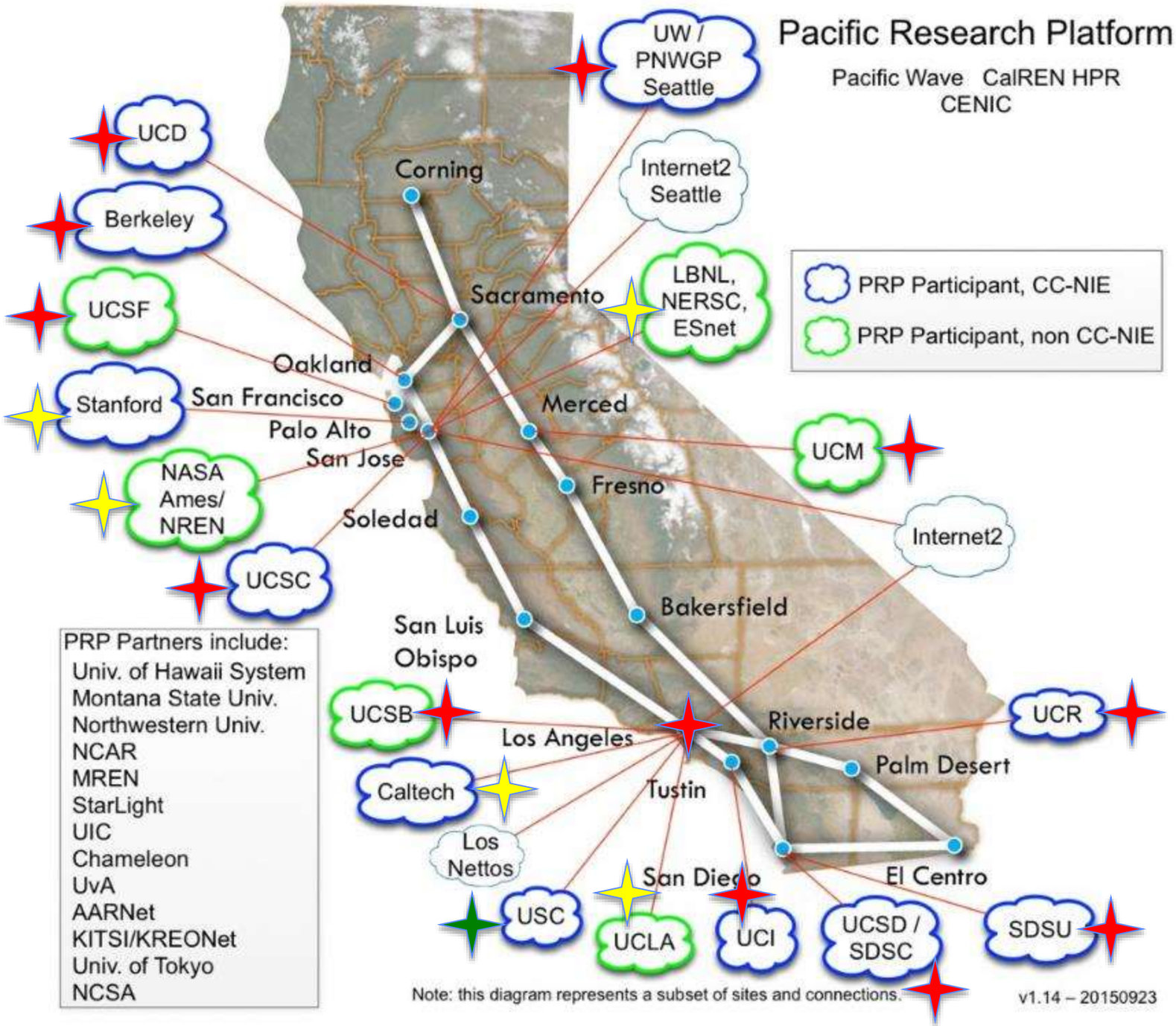


IGM
Institute for Genomic Medicine

QUALCOMM INSTITUTE

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FIONAs as Uniform DTN End Points



CC*DNI FIONA DTN

FIONA DTNs

Existing DTNs

As of October 2015

Ten Week Sprint to Demonstrate the West Coast Big Data Freeway System: PRPv0

FIONA DTNs Now Deployed to All UC Campuses And Most PRP Sites

As of 3/9/15, the Pacific Research Platform (PRPv0) as a facility, logs rather good performance:

From	To	Measured Bandwidth	Data Transfer Utility
San Diego State Univ.	UC Los Angeles	5Gb/s out of 10	GridFTP
UC Riverside	UC Los Angeles	9Gb/s out of 10	GridFTP
UC Berkeley	UC San Diego	9.6Gb/s out of 10	GridFTP
UC Davis	UC San Diego	9.6Gb/s out of 10	GridFTP
UC Irvine	UC Los Angeles	9.6Gb/s out of 10	GridFTP
UC Santa Cruz	UC San Diego	9.6Gb/s out of 10	FDT
Stanford	UC San Diego	12Gb/s out of 40	FDT
Univ. of Washington	UC San Diego	12Gb/s out of 40	FDT
UC Los Angeles	UC San Diego	36Gb/s out of 40	FDT
Caltech	UC San Diego	36Gb/s out of 40	FDT

Table I.2.1: Bandwidth of flash disk-to-flash disk file transfers shown between several sites for the existing experimental facility "PRPv0."

Presented at CENIC 2015
March 9, 2015



Digital Research Platform: Distributed IPython/Jupyter Notebooks:
Cross-Platform, Browser-Based Application Interleaves Code, Text, & Images

IJulia
IHaskell
IFSharp
IRuby
IGo
IScala
IMathics
Ialdor
LuaJIT/Torch
Lua Kernel
IRKernel (for the R language)
IErlang
IOCaml
IForth
IPerl
IPerl6
Ioctave
Calico Project

- kernels implemented in Mono, including Java, IronPython, Boo, Logo, BASIC, and many others



Evolved from the IPython Project

IScilab
IMatlab
ICSharp
Bash
Clojure Kernel
Hy Kernel
Redis Kernel
jove, a kernel for io.js
IJavascript
Calysto Scheme
Calysto Processing
idl_kernel
Mochi Kernel
Lua (used in Splash)
Spark Kernel
Skulpt Python Kernel
MetaKernel Bash
MetaKernel Python
Brython Kernel
IVisual VPython Kernel

Source: John Graham, QI

PRP Has Deployed Powerful FIONA Servers at UCSD and UC Berkeley to Create a UC-Jupyter Hub Backplane

Berkeley News

RESEARCH, TECHNOLOGY & ENGINEERING

Project Jupyter gets $6M to expand collaborative data-science software

By Sarah Yang | JULY 7, 2015



Fernando Perez and Brian Granger discuss the architecture of Project Jupyter, as its scope expands to reach data science applications in more than 40 programming languages. (Photo by Adriana Restrepo)

FIONAs Have GPUs and Can Spawn Jobs to SDSC's Comet Using inCommon CILogon Authenticator Module for Jupyter. Deep Learning Libraries Have Been Installed

Source: John Graham, QI

PRP Timeline

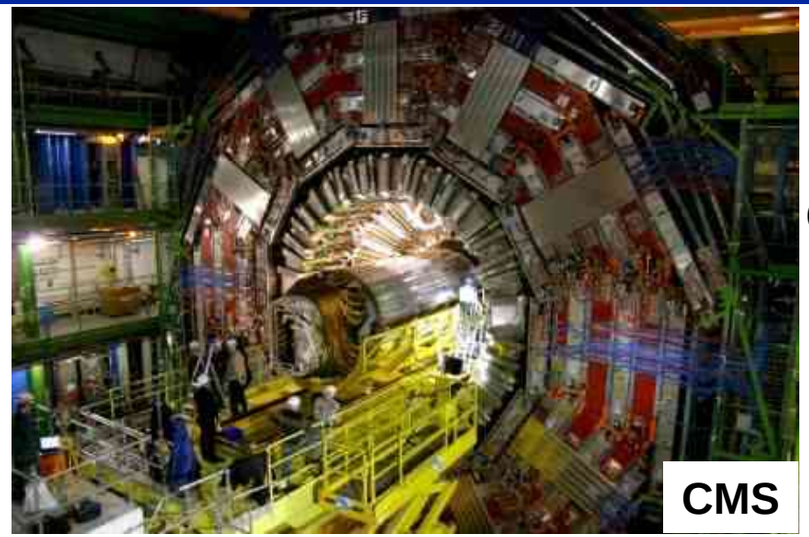
- **PRPv1**
  - A Layer 2 and Layer 3 System
  - Completed In 2 Years
  - Tested, Measured, Optimized, With Multi-domain Science Data
  - Bring Many Of Our Science Teams Up
  - Each Community Thus Will Have Its Own Certificate-Based Access To its Specific Federated Data Infrastructure.

- **PRPv2**
  - Advanced Ipv6-Only Version with Robust Security Features
    - e.g**. Trusted Platform Module Hardware and SDN/SDX Software**
  - Support Rates up to 100Gb/s in Bursts And Streams
  - Develop Means to Operate a Shared Federation of Caches

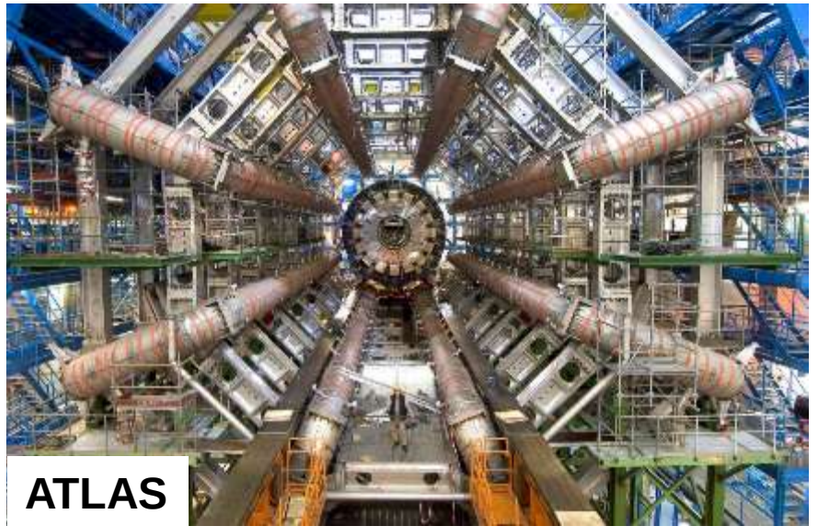
Pacific Research Platform
Multi-Campus Science Driver Teams

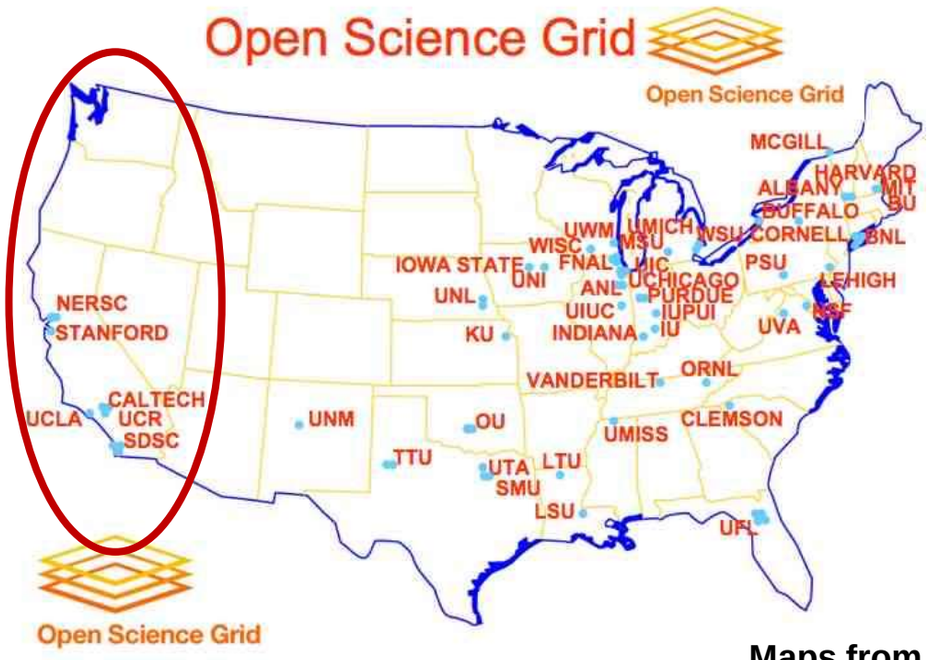
- **Particle Physics**
- **Astronomy and Astrophysics**
  - **Telescope Surveys**
  - **Galaxy Evolution**
  - **Gravitational Wave Astronomy**
- **Biomedical**
  - **Cancer Genomics Hub/Browser**
  - **Microbiome and Integrative ‘Omics**
  - **Integrative Structural Biology**
- **Earth Sciences**
  - **Data Analysis and Simulation for Earthquakes and Natural Disasters**
  - **Climate Modeling: NCAR/UCAR**
  - **California/Nevada Regional Climate Data Analysis**
  - **CO2 Subsurface Modeling**
- **Scalable Visualization, Virtual Reality, and Ultra-Resolution Video**

Particle Physics: Creating a 10-100 Gbps LambdaGrid to Support LHC Researchers



LHC Data Generated by CMS & ATLAS Detectors Analyzed on OSG

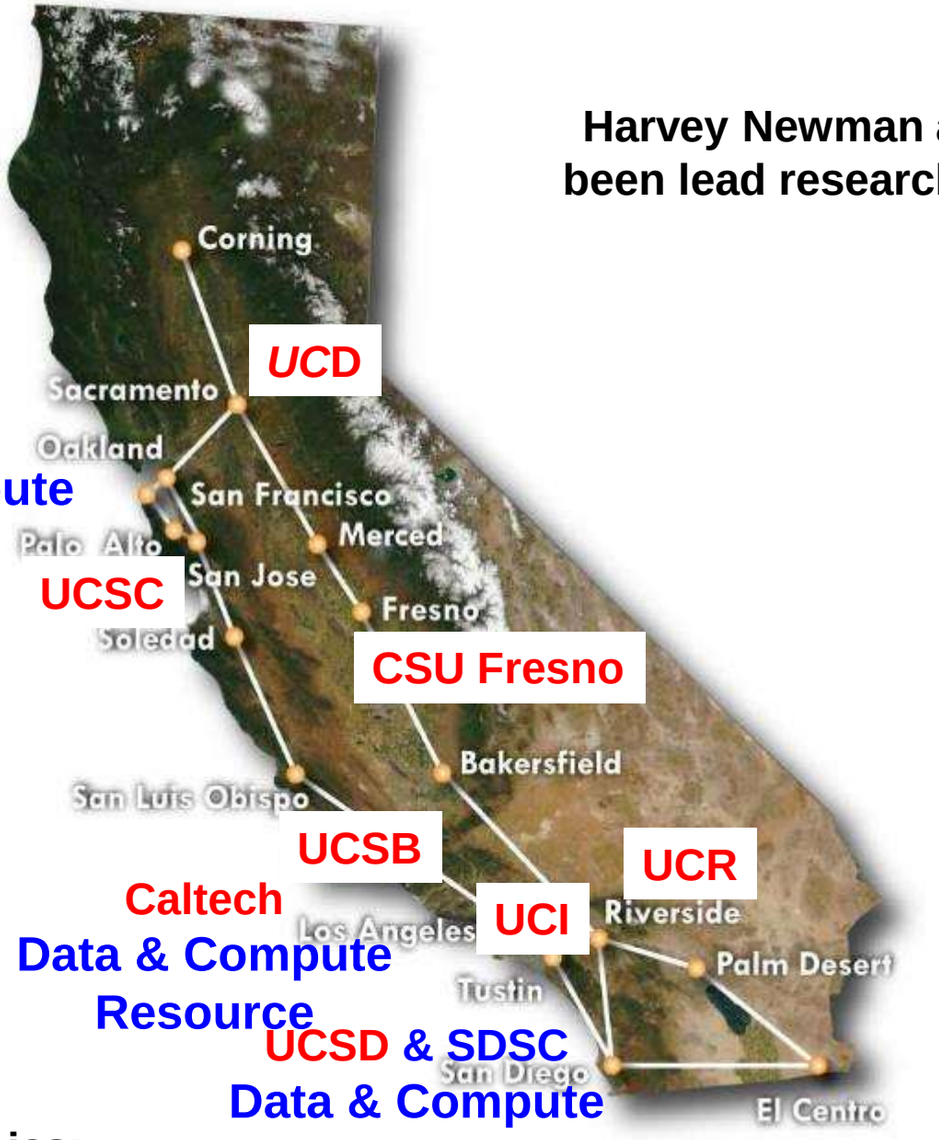






Maps from www.uslhc.us

LHC Scientists Across Eight CA Universities Benefit From Petascale Data & Compute Resources across PRP



Harvey Newman and Azher Mughal of Caltech have been lead researchers in 40Gbps and 100Gbps DTNs

Source: Frank Wuerthwein, UCSD Physics; SDSC; co-PI PRP

Goal: Allow LHC Community to Use Five Major Data & Compute Resources in CA: SLAC, NERSC, Caltech, UCSD, SDSC

- **Aggregate Petabytes of Disk Space & Petaflops of Compute**
- **Transparently Compute on Data at Their Home Institutions & These 5 Major Centers**
  - **Uniform Execution Environment**
  - **XrootD Data Federations for ATLAS & CMS**
    - **Serving Local Disks Outbound to Remotely Running Jobs**
    - **Caching Remote Data Inbound for Locally Running Jobs**
  - **HTCondor "Overflow" of Jobs from Local Cluster to Major Centers**
    - **Satisfy Peak Needs to Accelerate Path from Idea to Publication**
- **Collaboration of PRP, SDSC, and Open Science Grid**
  - **PRP Builds on SDSC LHC-UC Project**



Open Science Grid

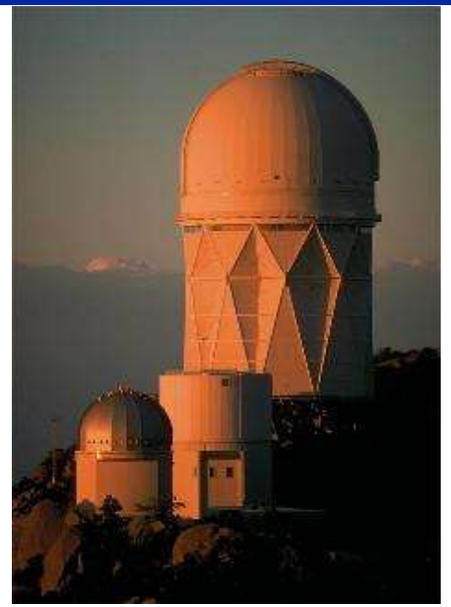
Source: Frank Wuerthwein, UCSD Physics; SDSC; co-PI PRP

Two Automated Telescope Surveys Creating Huge Datasets Will Drive PRP



Precursors to LSST and NCSA

PRP Allows Researchers to Bring Datasets from NERSC to Their Local Clusters for In-Depth Science Analysis- see UCSC's Brad Smith Talk



INTERMEDIATE PALOMAR TRANSIENT FACTORY

300 images per night.
100MB per raw image

30GB per night

120GB per night

Dark Energy Spectroscopic Instrument

250 images per night.
530MB per raw image

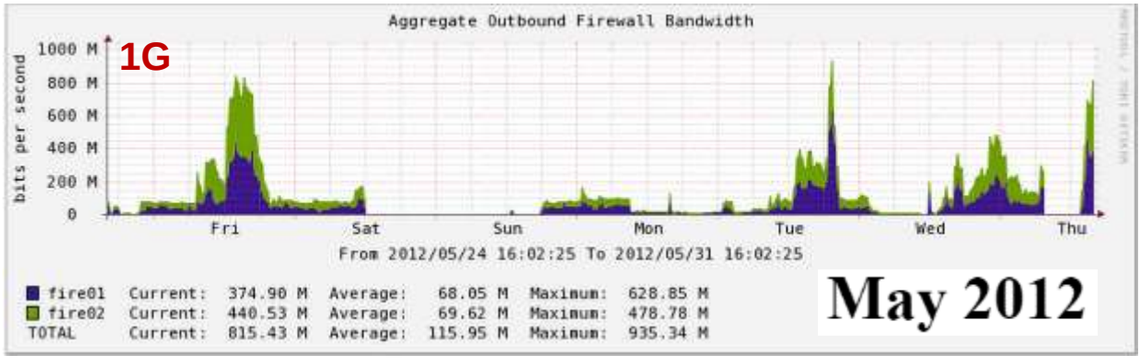
150 GB per night

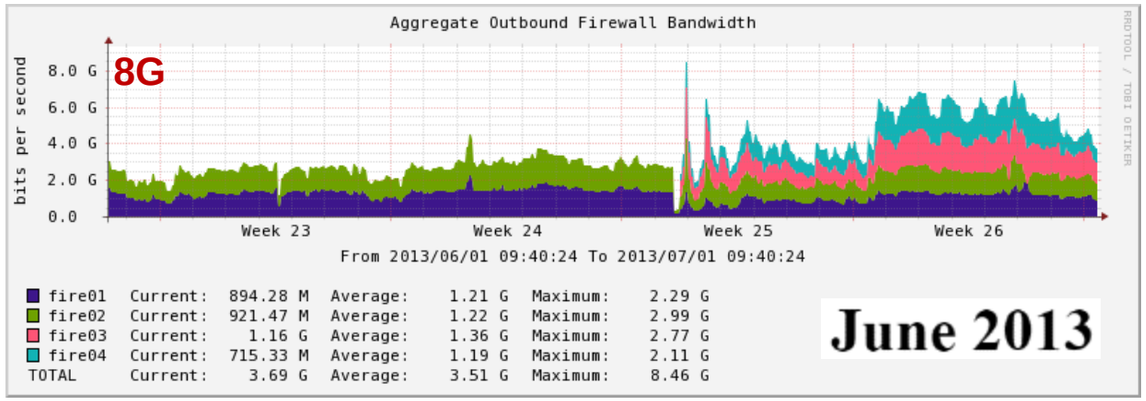
800GB per night

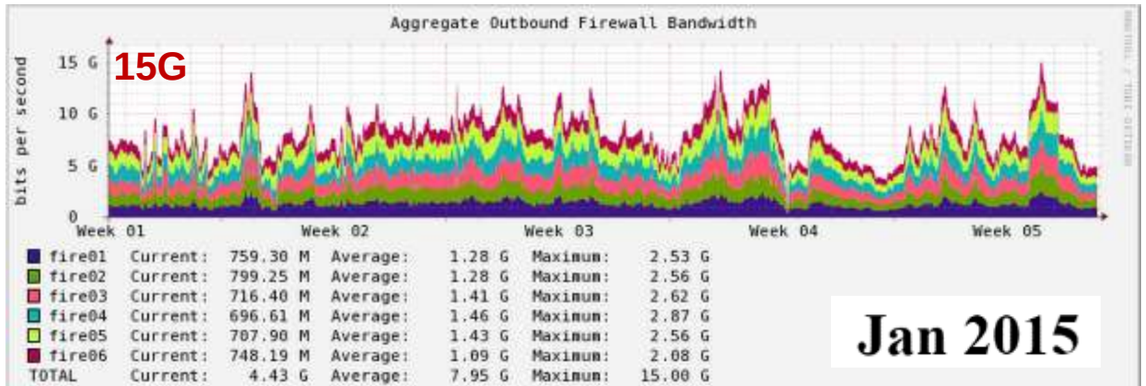
When processed at NERSC Increased by 4x

Source: Peter Nugent, Division Deputy for Scientific Engagement, LBL
Professor of Astronomy, UC Berkeley

Cancer Genomics Hub (UCSC) is Housed in SDSC CoLo: Large Data Flows to End Users at UCSC, UCB, UCSF, …

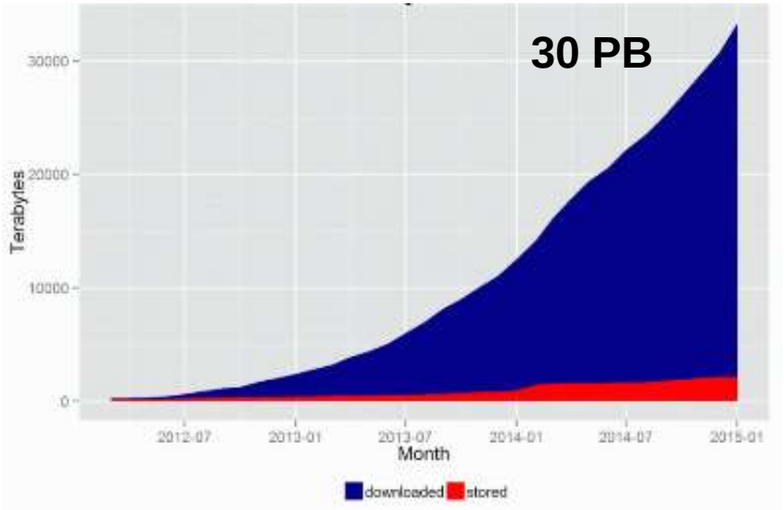








Cumulative TBs of CGH Files Downloaded



Data Source: David Haussler, Brad Smith, UCSC

Planning for climate change in California

substantial shifts on top of already high climate variability

SIO Campus Climate Researchers Need to Download Results from NCAR 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

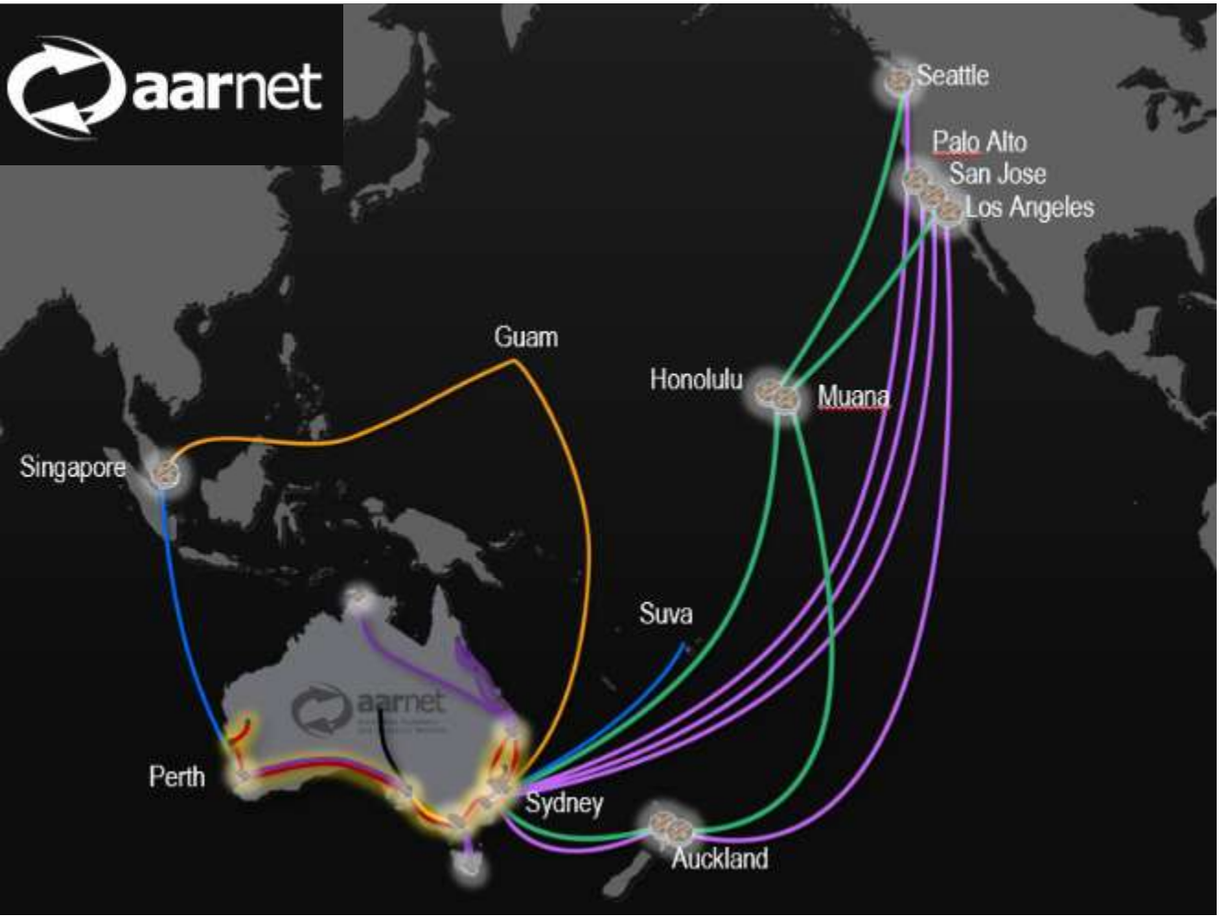
California DWR, DOE, NSF

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



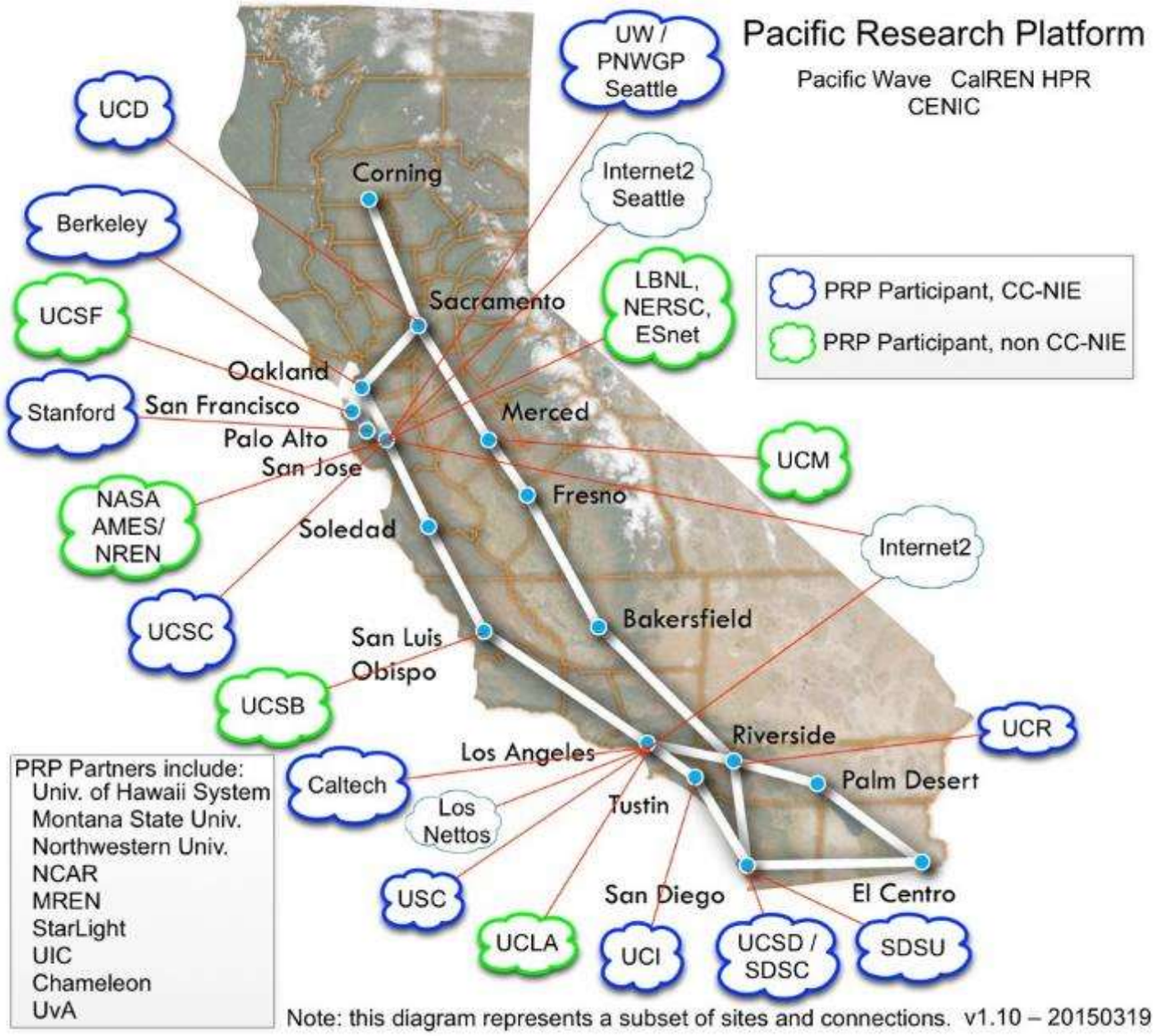
Source: NTT Sponsored ON*VECTOR Workshop at Calit2 March 6, 2013

Optical Fibers Link Australian and US Big Data Researchers



Australia forges US partnership to accelerate scientific discovery and innovation

August 5, 2015



Next Step: Use AARnet/PRP to Set Up Planetary-Scale Shared Virtual Worlds



Digital Arena, UTS Sydney

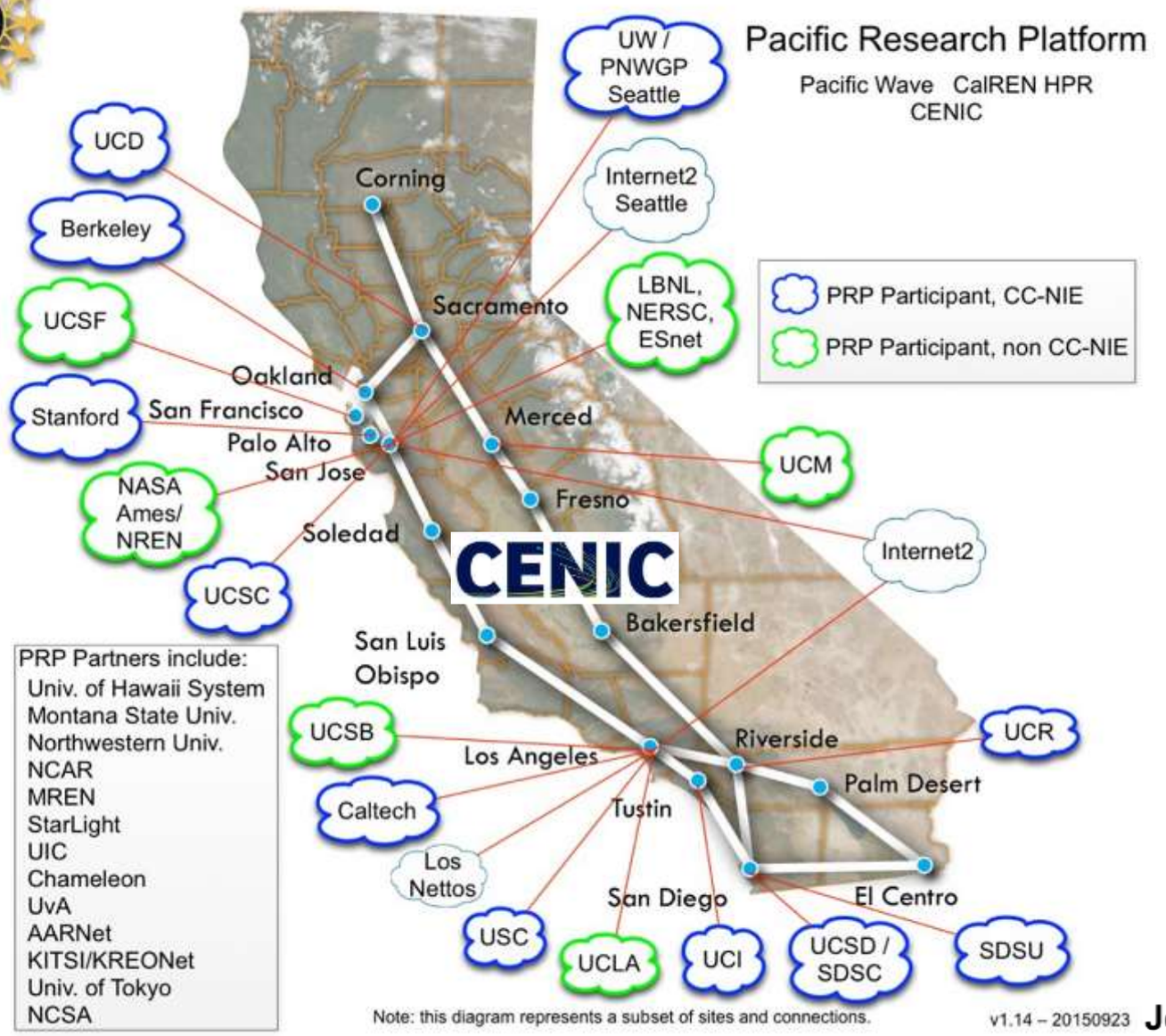


CAVE2, EVL, Chicago



CAVE2, Monash U, Melbourne

The Pacific Research Platform Creates a Regional End-to-End Science-Driven "Big Data Freeway System"



Opportunities for Collaboration with Other Regional Systems

Source:
John Hess, CENIC