"Creating a Science-Driven Big Data Superhighway"

**Remote Briefing to the Ad Hoc Big Data Task Force
of the NASA Advisory Council Science Committee
NASA Goddard Space Flight Center
June 28, 2016**

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Vision:
Creating a Pacific Research Platform

**Use Optical Fiber Networks to Connect
All Data Generators and Consumers,
Creating a "Big Data" Freeway System**

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

This Vision Has Been Building for 15 Years

NSF's OptIPuter Project: Demonstrating How SuperNetworks Can Meet the Needs of Data-Intensive Researchers

LS Slide 2005

**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

DOE ESnet's Science DMZ: A Scalable Network Design Model for Optimizing Science Data Transfers

- **A Science DMZ integrates 4 key concepts into a unified whole:**
  - A network architecture designed for high-performance applications, with the science network distinct from the general-purpose network

  - The use of dedicated systems as data transfer nodes (DTNs)

  - Performance measurement and network testing systems that are regularly used to characterize and troubleshoot the network

  - Security policies and enforcement mechanisms that are tailored for high performance science environments

> **The DOE ESnet Science DMZ and the NSF "Campus Bridging" Taskforce Report Formed the Basis for the NSF Campus Cyberinfrastructure Network Infrastructure and Engineering (CC-NIE) Program**
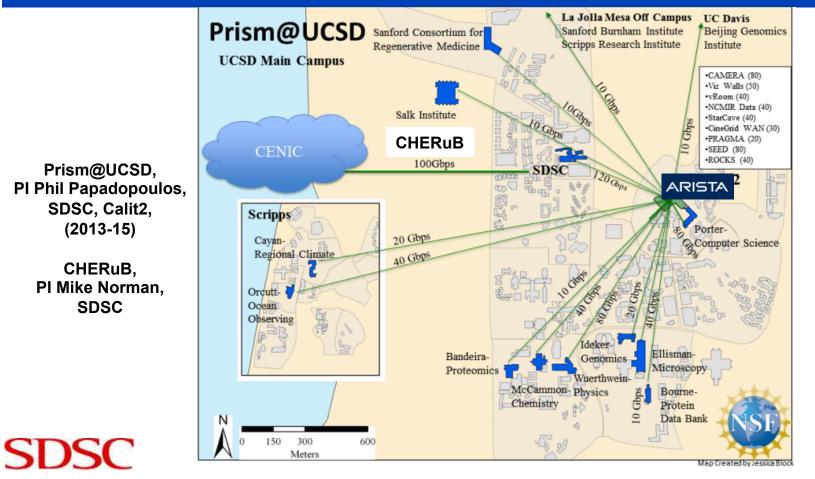
Science DMZ Coined 2010

ESnet
FASTERDATA KNOWLEDGEBASE

http://fasterdata.es.net/science-dmz/

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

Prism@UCSD, PI Phil Papadopoulos, SDSC, Calit2, (2013-15)

CHERuB, PI Mike Norman, SDSC

Map Created by Jessica Block

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

**FIONAs Are
Science DMZ Data Transfer Nodes (DTNs) &
Optical Network Termination Devices**

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

Rack-Mount Build:

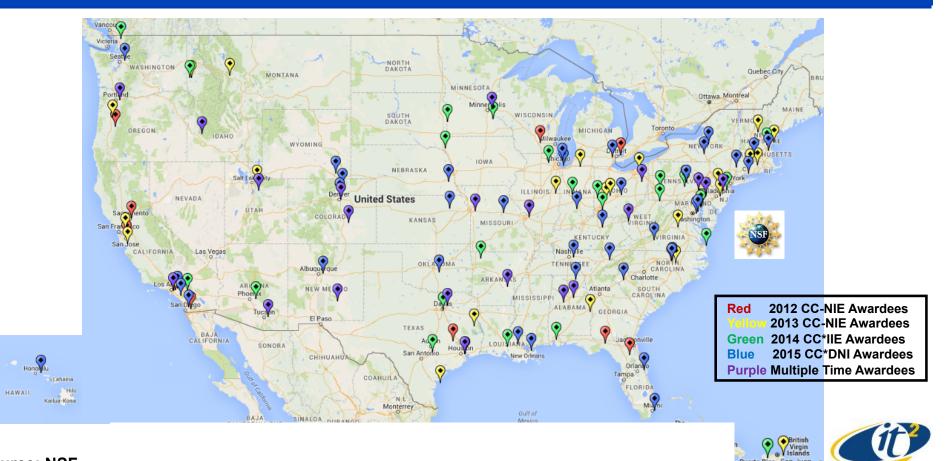|		
Cost	$8,000	$20,000
Intel Xeon Haswell	E5-1650 v3 6-Core	2x E5-2697 v3 14-Core
RAM	128 GB	256 GB
SSD	SATA 3.8 TB	SATA 3.8 TB
Network Interface	10/40GbE Mellanox	2x40GbE Chelsi+Mellanox
GPU		NVIDIA Tesla K80

RAID Drives 0 to 112TB (add ~$100/TB)

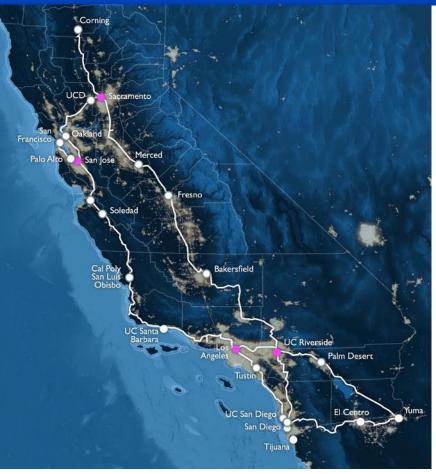# How Prism@UCSD Transforms Big Data Microbiome Science: Preparing for Knight/Smarr 1 Million Core-Hour Analysis

NIH

NCBI National Center for Biotechnology Information

INTERNET 2

CENIC

Knight 1024 Cluster In SDSC Co-Lo

Gordon

COMET SDSC

SDSC

CHERuB 100Gbps

1.3Tbps

Data Oasis 7.5PB, 200GB/s

ARISTA

120Gbps

Knight Lab

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

10Gbps

Prism@UCSD

QUALCOMM INSTITUTE

40Gbps

Emperor & Other Vis Tools

64Mpixel Data Analysis Wall

IGM Institute for Genomic Medicine

it²

NSF Has Funded Over 100 Campuses to Build Local Big Data Freeways

Red 2012 CC-NIE Awardees
Yellow 2013 CC-NIE Awardees
Green 2014 CC*IIE Awardees
Blue 2015 CC*DNI Awardees
Purple Multiple Time Awardees

Source: NSF

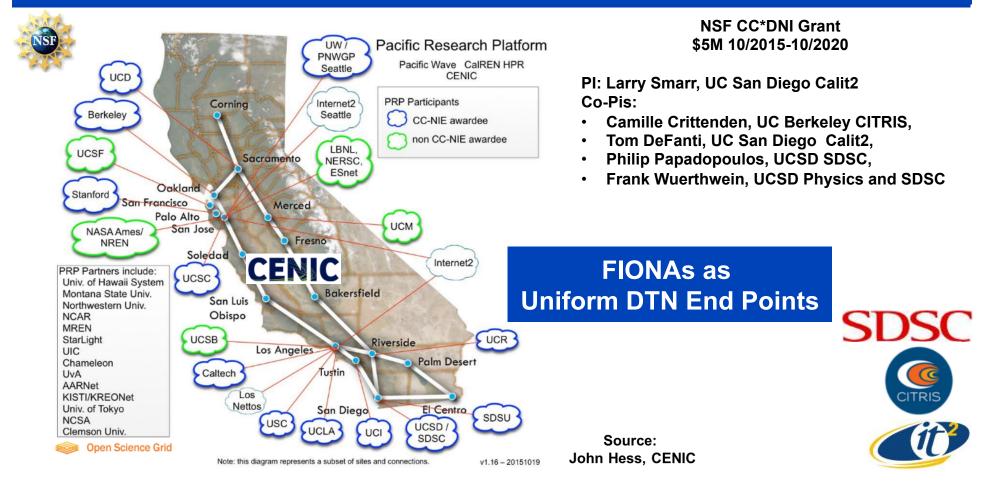# We Are Building on 15 Years of Member Investment in CENIC: California's Research & Education Network

- Members in All 58 Counties Connect via Fiber-Optics or Leased Circuits
  - 3,800+ Miles of Optical Fiber
  - Over 10,000 Sites Connect to CENIC
  - 20,000,000 Californians Use CENIC
- Funded & Governed by Segment Members
  - UC, Cal State, Stanford, Caltech, USC
  - Community Colleges, K-12, Libraries
  - Collaborate With Over 500 Private Sector Partners
  - 88 Other Peering Partners
    - (Google, Microsoft, Amazon …)

Next Step: The Pacific Research Platform Creates a Regional End-to-End Science-Driven "Big Data Superhighway" System

NSF CC*DNI Grant
$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, UCSD SDSC,**
- **Frank Wuerthwein, UCSD Physics and SDSC**

FIONAs as Uniform DTN End Points

Source:
John Hess, CENIC

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
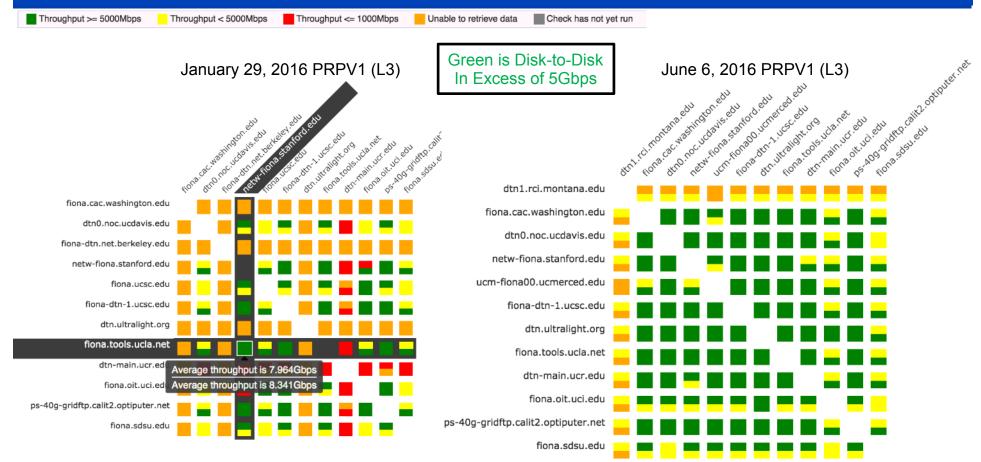between several sites for the existing experimental facility "PRPv0."

CENIC

2015 Conference
SHAKING THINGS UP   March 9-11 2015

it²

PRP Point-to-Point Bandwidth Map
GridFTP File Transfers-Note Huge Improvement in Last Six Months

■ Throughput >= 5000Mbps ■ Throughput < 5000Mbps ■ Throughput <= 1000Mbps ■ Unable to retrieve data ■ Check has not yet run

January 29, 2016 PRPV1 (L3)

Green is Disk-to-Disk
In Excess of 5Gbps

June 6, 2016 PRPV1 (L3)

Average throughput is 7.964Gbps
Average throughput is 8.341Gbps

Pacific Research Platform
Driven by Multi-Site Data-Intensive Research

Particle
Physics

CMS

Biomedical
'omics

Telescope
Surveys

Earthquake
Engineering

Visualization,
Virtual Reality,
Collaboration

PRP Timeline

- # PRPv1
  - A Routed Layer 3 Architecture
  - 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
  - Incorporating SDN/SDX, AutoGOLE / NSI
  - 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
  - Cooperating Research Groups

Invitation-Only PRP Workshop Held in Calit2's Qualcomm Institute
October 14-16, 2015

- **130 Attendees From 40 organizations**
  - **Ten UC Campuses, as well as UCOP Plus 11 Additional US Universities**
  - **Four International Organizations (from Amsterdam, Canada, Korea, and Japan)**
  - **Five Members of Industry Plus NSF**

PRP First Application: 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

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

jupyter

Evolved from the IPython Project

Source: John Graham, QI

PRP UC-JupyterHub Backbone
UCB   Next Step: Deploy Across PRP   UCSD

Source: John Graham, Calit2

GPU JupyterHub:

2 x 14-core CPUs
256GB RAM
1.2TB FLASH
3.8TB SSD
Nvidia K80 GPU
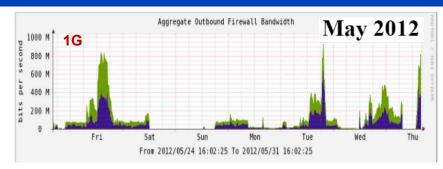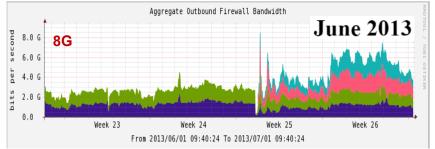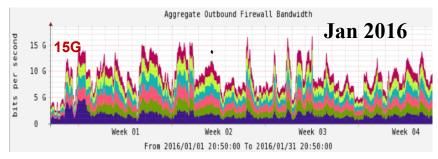Dual 40GbE NICs
And a Trusted Platform
Module

GPU JupyterHub:

1 x 18-core CPUs
128GB RAM
3.8TB SSD
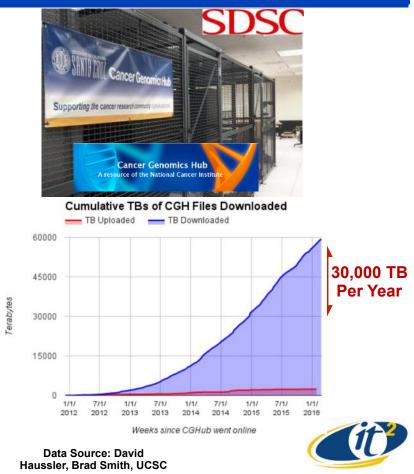Nvidia K80 GPU
Dual 40GbE NICs
And a Trusted Platform
Module

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

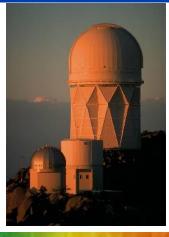**Data Source: David Haussler, Brad Smith, UCSC**

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

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
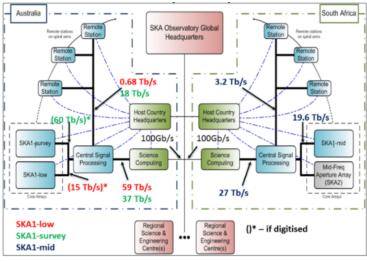at NERSC
Increased by 4x**

Global Scientific Instruments Will Produce Ultralarge Datasets Continuously Requiring Dedicated Optic Fiber and Supercomputers

Square Kilometer Array

IBM to build exascale supercomputer for the world's largest, million-antennae telescope

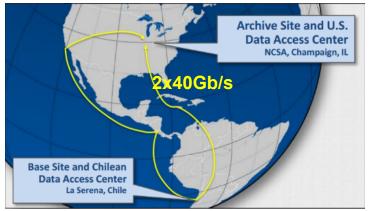By Sebastian Anthony on April 2, 2012 at 11:48 am | 8 Comments

https://tnc15.terena.org/getfile/1939

Large Synoptic Survey Telescope

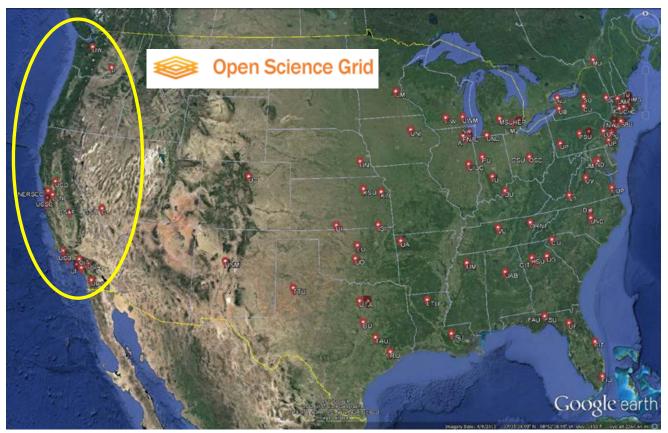**Tracks ~40B Objects, Creates 10M Alerts/Night Within 1 Minute of Observing**

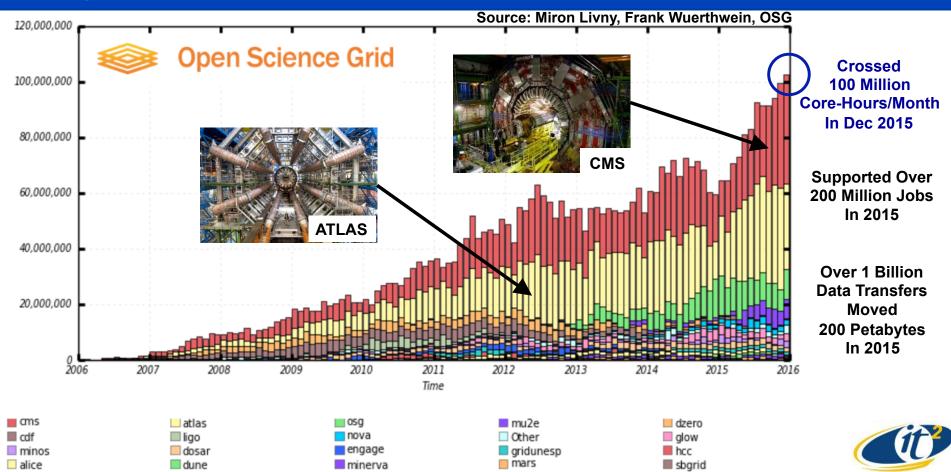www.lsst.org/sites/default/files/documents/DM%20Introduction%20-%20Kantor.pdf

OSG Federates Clusters in 40/50 States: Creating a Scientific Compute and Storage "Cloud"
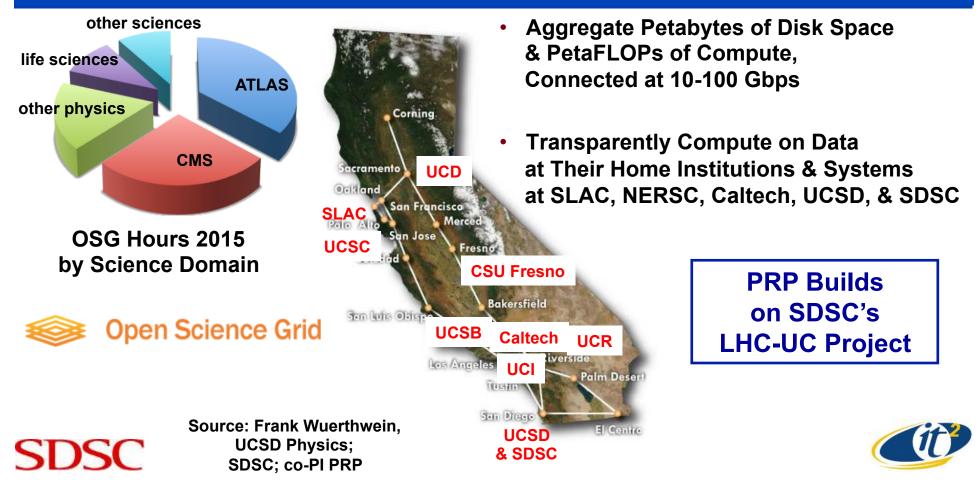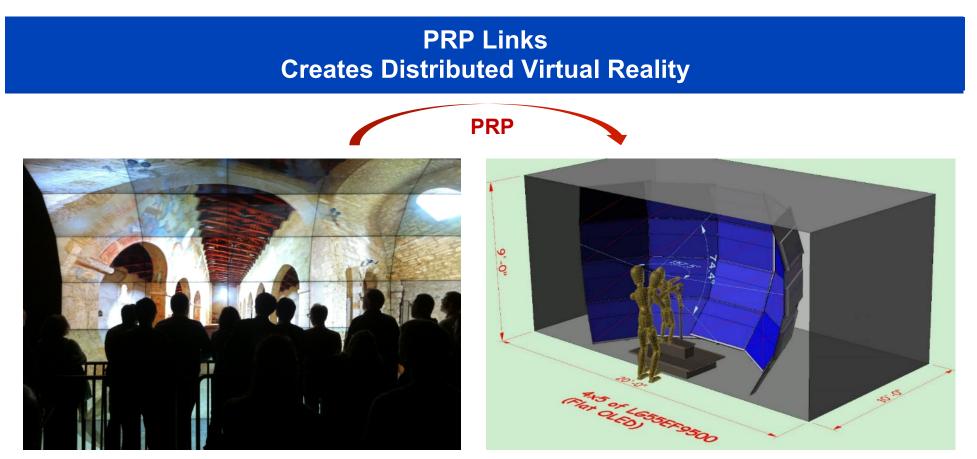

Source: Miron Livny, Frank Wuerthwein, OSG

We are Experimenting with the PRP for Large Hadron Collider Data Analysis Using The West Coast Open Science Grid on 10-100Gbps Optical Networks

Crossed 100 Million Core-Hours/Month In Dec 2015

Supported Over 200 Million Jobs In 2015

Over 1 Billion Data Transfers Moved 200 Petabytes In 2015

PRP Prototype of Aggregation of OSG Software & Services Across California Universities in a Regional DMZ

other sciences

life sciences

other physics

ATLAS

CMS

OSG Hours 2015 by Science Domain

Open Science Grid

- Aggregate Petabytes of Disk Space & PetaFLOPs of Compute, Connected at 10-100 Gbps

- Transparently Compute on Data at Their Home Institutions & Systems at SLAC, NERSC, Caltech, UCSD, & SDSC

Corning

Sacramento UCD

Oakland

San Francisco

SLAC

Palo Alto San Jose Merced

UCSC Fresno

CSU Fresno

Bakersfield

San Luis Obispo

UCSB Caltech UCR

Los Angeles Riverside

UCI Palm Desert

Tustin

San Diego El Centro

UCSD & SDSC

PRP Builds on SDSC's LHC-UC Project

SDSC

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

PRP Links
Creates Distributed Virtual Reality

PRP

WAVE@UC San Diego

CAVE@UC Merced

Planning for climate change in California

substantial shifts on top of already high climate variability

UCSD Campus Climate Researchers Need to Download Results from NCAR Remote Supercomputer Simulations to Make Regional Climate Change Forecasts
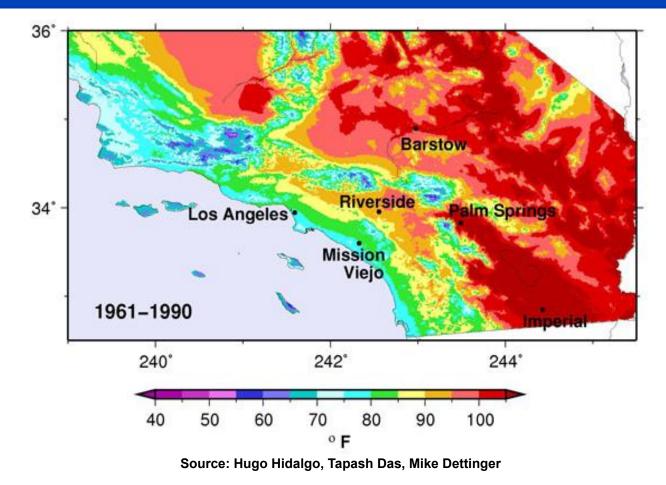
Dan Cayan

USGS Water Resources Discipline

Scripps Institution of Oceanography, UC San Diego

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

NCAR Upgrading to 10Gbps Link Over Westnet
from Wyoming and Boulder to CENIC/PRP

Sponsors:

California Energy Commission
NOAA RISA program
California DWR, DOE, NSF

Source: Hugo Hidalgo, Tapash Das, Mike Dettinger

Next Step: Global Research Platform
Building on CENIC/Pacific Wave and GLIF

Current International GRP Partners