“The Pacific Research Platform: Building a Distributed Big Data Machine Learning Supercomputer”

Invited Talk
San Diego Supercomputer Center
University of California San Diego
April 4, 2019

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

PRP PACIFIC RESEARCH PLATFORM

it²

34 Years Ago,
NSF Adopted a DOE High-Performance Computing Model







NCSA Was Modeled on LLNL

SDSC Was Modeled on MFEnet

PRP PACIFIC RESEARCH PLATFORM

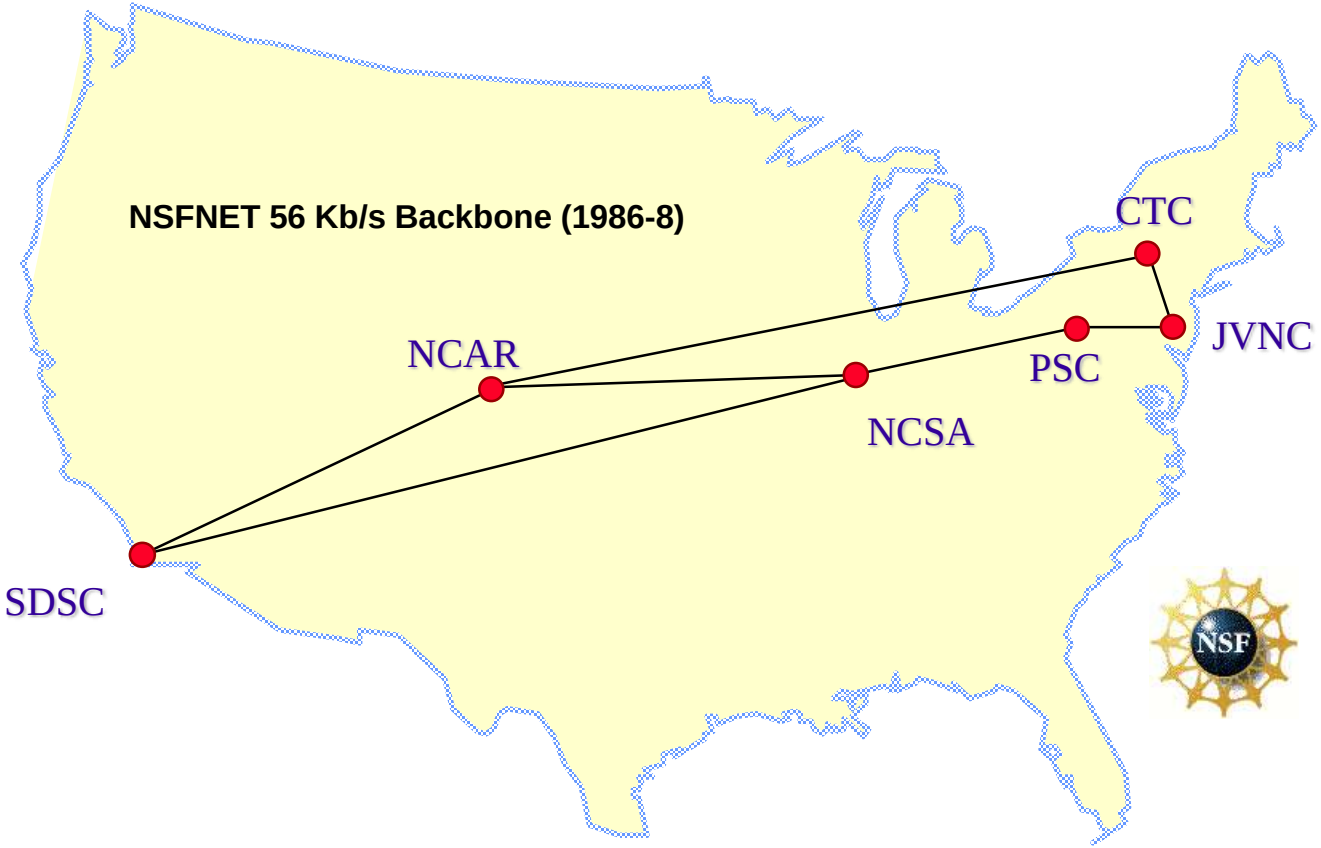
NCSA

NSF

SDSC

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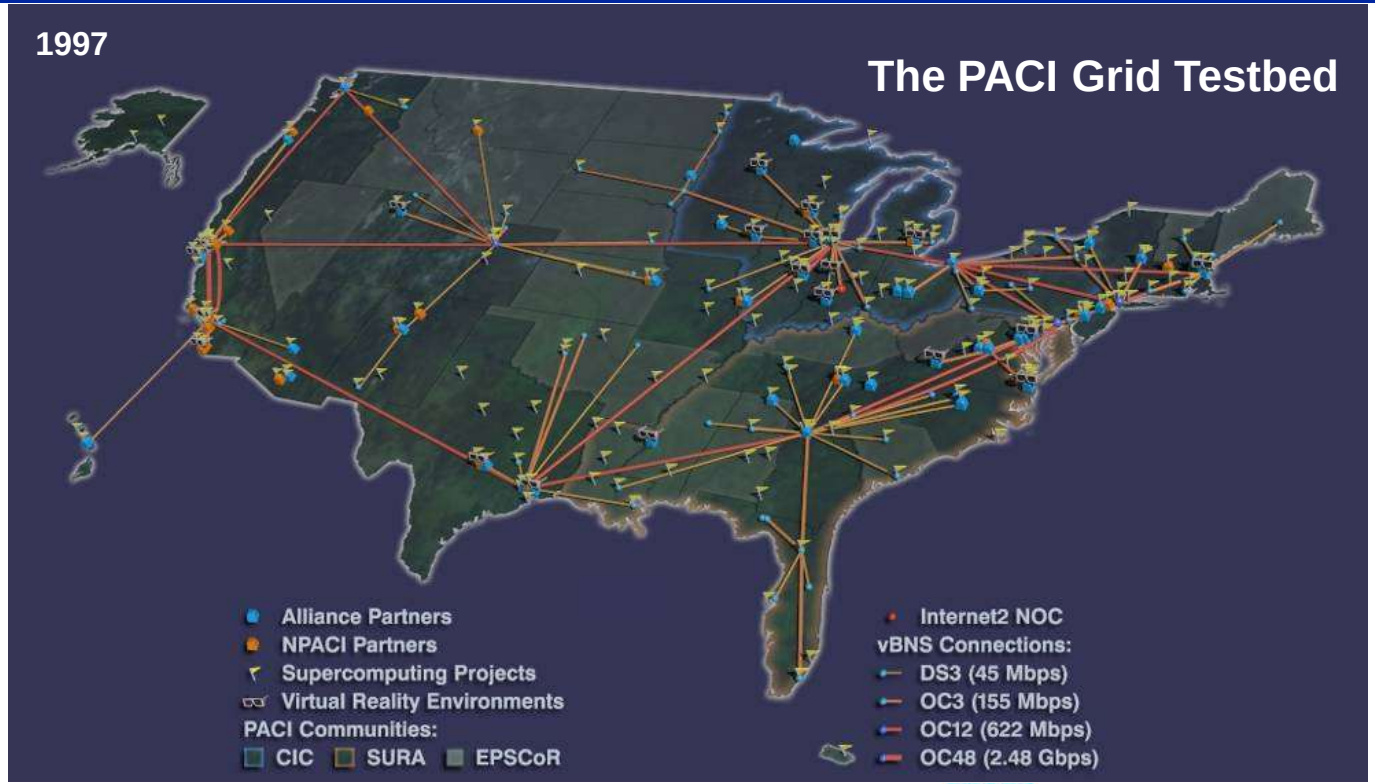
Launching the Nation's Information Infrastructure: NSFnet Supernetwork and the Six NSF Supercomputers



PRP's Backbone is One Million Times Faster!

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

vBNS led to



PACIFIC RESEARCH PLATFORM

NPACI

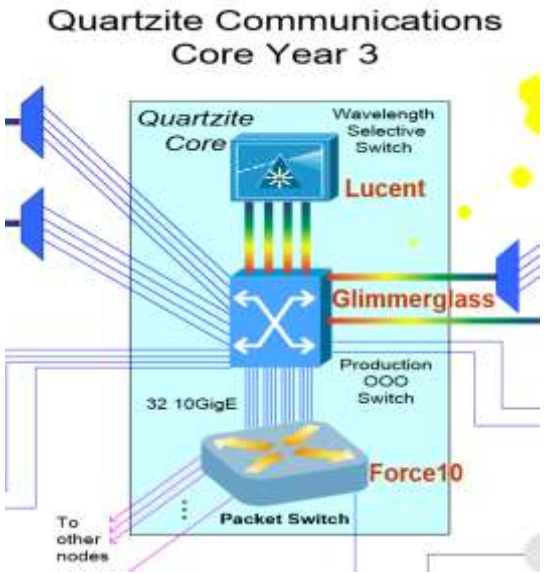
National Computational Science ALLIANCE

Calit2 & SDSC Have Been Working Toward PRP for 17 Years: OptIPuter, Quartzite, Prism



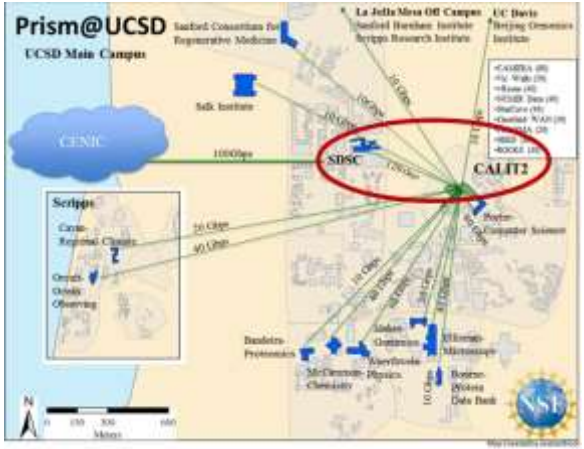
Calit2 (UCSD, UCI), SDSC, and UIC Leads—Larry Smarr PI
Univ. Partners: NCSA, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

OptIPuter
PI Smarr,
Co-PI DeFanti
Co-PI Papadopoulos, Ellisman
2002-2009



Goals by 2008:
>= 50 endpoints at 10 GigE
>= 32 Packet switched
>= 32 Switched wavelengths
>= 300 Connected endpoints

Quartzite
PI Papadopoulos,
Co-PI Smarr
2004-2007



Prism@UCSD
PI Papadopoulos,
Co-PI Smarr
2013-2015

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



End User OptIPortal



Instruments



HD/4k Telepresence



HD/4k Video Cams



10G Lightpath



HPC

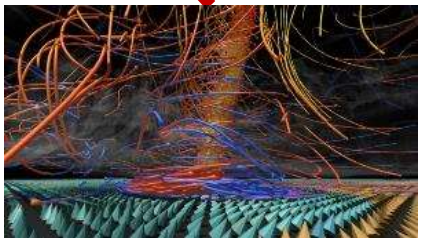
TeraGrid

LS 2009 Slide

Campus Optical Switch



Data Repositories & Clusters



HD/4k Video Images

OptIPuter

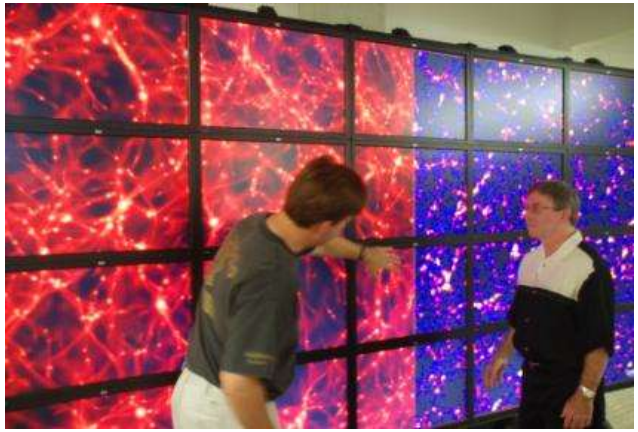
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Project StarGate Goals: Combining Supercomputers and Supernetworks

- **Create an "End-to-End" 10Gbps Workflow**
- **Explore Use of OptIPortals as Petascale Supercomputer "Scalable Workstations"**
- **Exploit Dynamic 10Gbps Circuits on ESnet**
- **Connect Hardware Resources at ORNL, ANL, SDSC**
- **Show that Data Need Not be Trapped by the Network "Event Horizon"**

OptIPortal@SDSC



Rick Wagner **Mike Norman**

LS 2009 Slide

Source: Michael Norman, SDSC, UCSD

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

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Using Supernetworks to Couple End User to Remote Supercomputers and Visualization Servers

Source: Mike Norman, Rick Wagner, SDSC

Demoed SC09

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

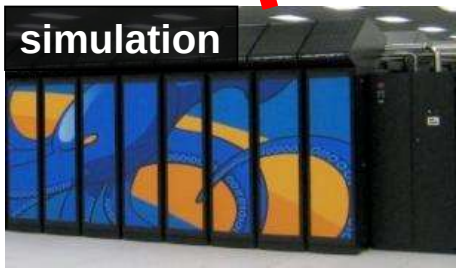
SDSC



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



LS 2009 Slide

*ANL * Calit2 * LBNL * NICS * ORNL * SDSC
www.calit2.net/newsroom/release.php?id=1624

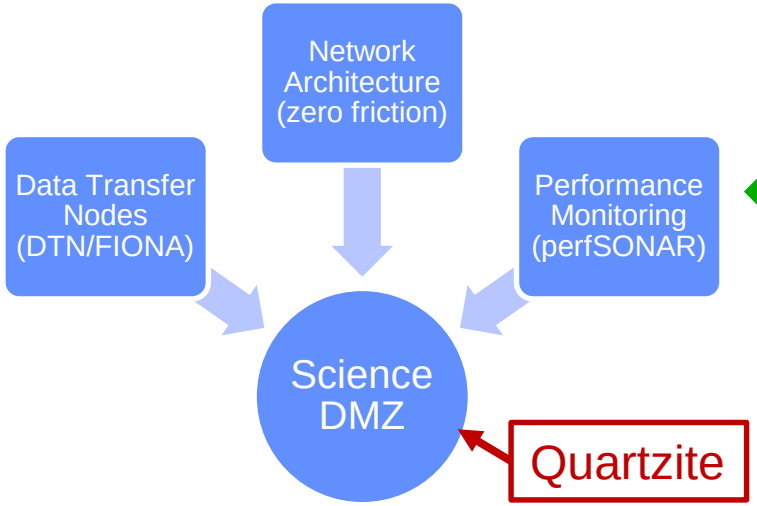
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7 Years Ago,
NSF Adopted a DOE High-Performance Networking Model

ScienceDMZ Coined in 2010 by ESnet
Basis of PRP Architecture and Design



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

DOE

NSF

NSF Campus Cyberinfrastructure Program
Has Made Over 250 Awards



Prism

2012 2013 2014 2015 2016 2017 2018

Slide Adapted From Inder Monga, ESnet

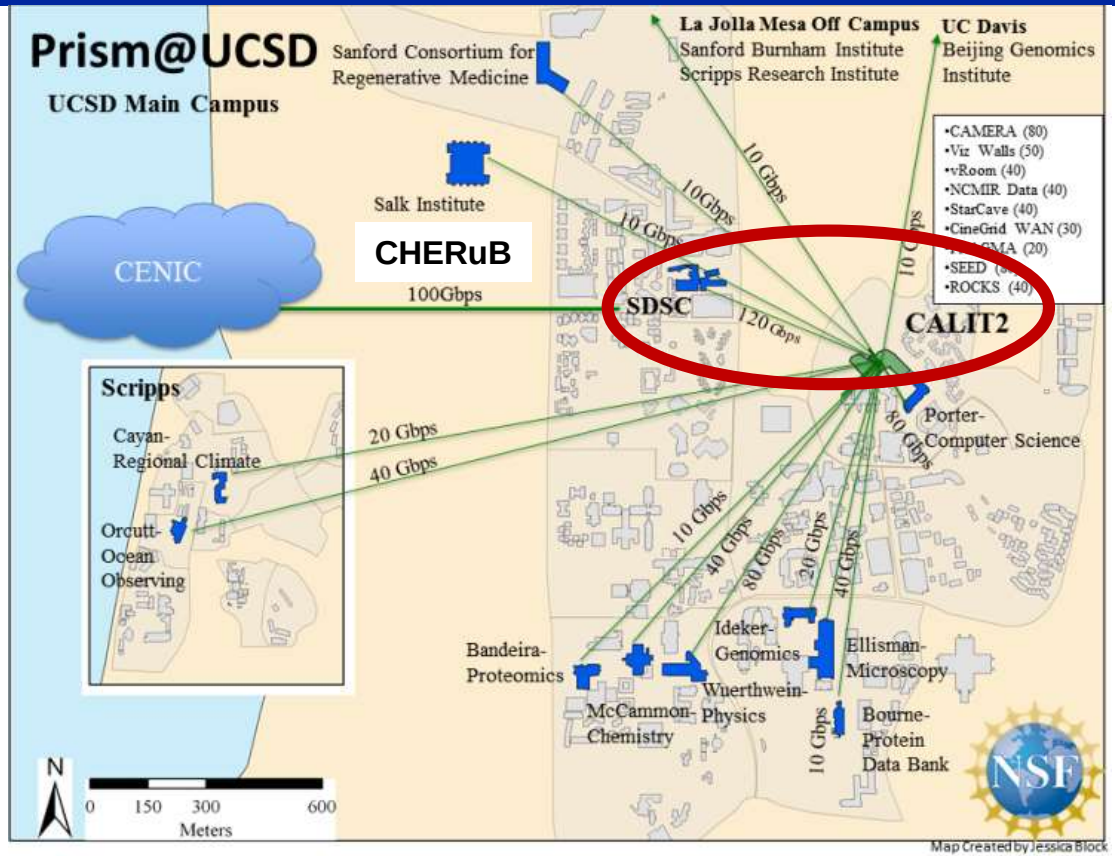
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ESnet FASTERDATA KNOWLEDGEBASE

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Creating a "Big Data" Plane on Campus: NSF CC-NIE Funded Prism@UCSD and CHERuB



Prism@UCSD, Phil Papadopoulos, SDSC, Calit2, PI; Smarr co-PI
CHERuB, Mike Norman, SDSC PI

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2015: The Pacific Research Platform Connects Campus "Big Data Freeways" to Create a Regional End-to-End Science-Driven "Big Data Superhighway" System



Source: John Hess, CENIC

NSF CC*DNI Grant
$6M 10/2015-10/2020

PI: Larry Smarr, UC San Diego Calit2

Co-PIs:

- **Camille Crittenden, UC Berkeley CITRIS,**
- **Tom DeFanti, UC San Diego Calit2/QI,**
- **Philip Papadopoulos, UCSD SDSC, UCI**
- **Frank Würthwein, UCSD Physics and SDSC**

Letters of Commitment from:

- 50 Researchers from 15 Campuses
- 32 IT/Network Organization Leaders

CENIC 2016 Innovations in Networking Award for Experimental Applications

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PRP Engineers Designed and Built Several Generations of Flash I/O Network Appliances (FIONAs)

UCSD-Designed FIONAs Solved the Disk-to-Disk Data Transfer Problem *at Near Full Speed* on Best-Effort 10G, 40G and 100G Networks



Two FIONA DTNs at UC Santa Cruz: 40G & 100G



FIONette—
1G, $250
Used for
Training 50
Engineers in
2018-2019



John Graham & Dima Mishin at SC'17
with 100G FIONA8

PRP
PACIFIC RESEARCH PLATFORM

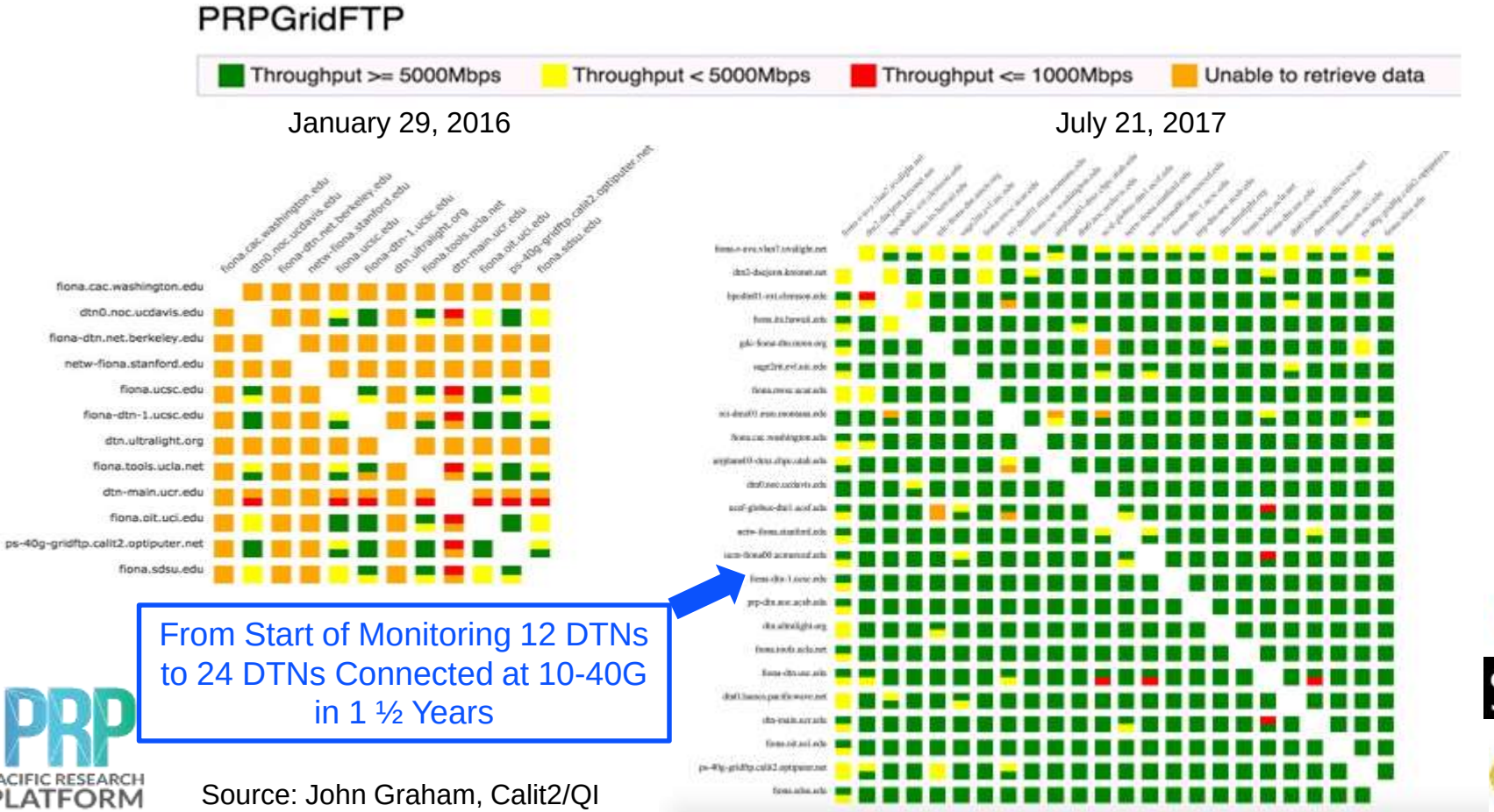
NSF

FIONAs Designed by Phil Papadopoulos, John Graham,
Joe Keefe, and Tom DeFanti

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2016-2017: PRP Measured Disk-to-Disk Throughput with 10GB File Transfer 4 Times Per Day in Both Directions for All PRP Sites until they Worked Well



From Start of Monitoring 12 DTNs to 24 DTNs Connected at 10-40G in 1 ½ Years

Source: John Graham, Calit2/QI

PRP's First 2.5 Years:
Connecting Multi-Campus Application Teams and Devices



CMS

Particle Physics

Biomedical 'omics



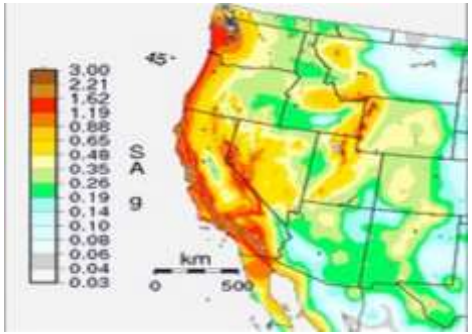
NSF



INTERMEDIATE PALOMAR TRANSIENT FACTORY

Telescope Surveys

Earth Sciences



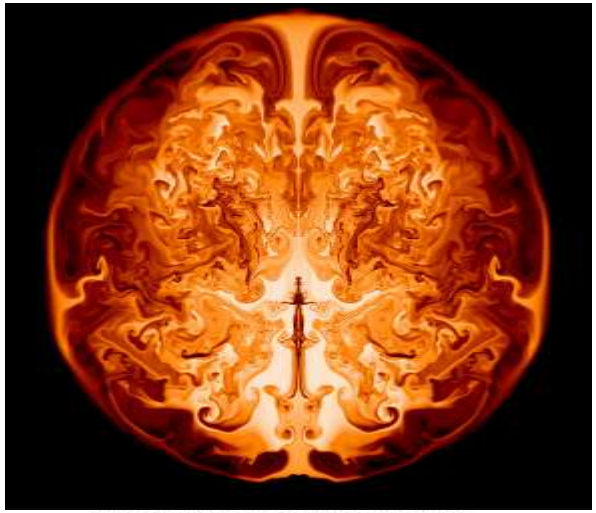
Visualization, Virtual Reality, Collaboration



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2017: Speeding Downloads Using 100 Gbps PRP Link Over CENIC Couples UC Santa Cruz Astrophysics Cluster to LBNL NERSC Supercomputer



A 2D superluminous supernova simulation generated with the CASTRO code. (Image: Ken Chen, National Astronomical Observatory of Japan)

K. Chen, S. Woolsey, T. Sukhbold, The Astrophysical Journal, 832, 1, Nov. 2016

NERSC Project PI:
S. Woolsey, UC Santa Cruz

CENIC



NSF-Funded Cyberengineer
Shaw Dong @UCSC
Receiving FIONA
Feb 7, 2017

CENIC 2018 Innovations in Networking Award for Research Applications

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BERKELEY LAB Bringing Science Solutions to the World

NERSC

ESnet

SDSC

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2018/2019: Installing Community Shared Storage and GPUs in June, December & January at UC Merced, UC Santa Cruz, UC Riverside, and Stanford





160-192TB added to 11 PRPv1 FIONAs









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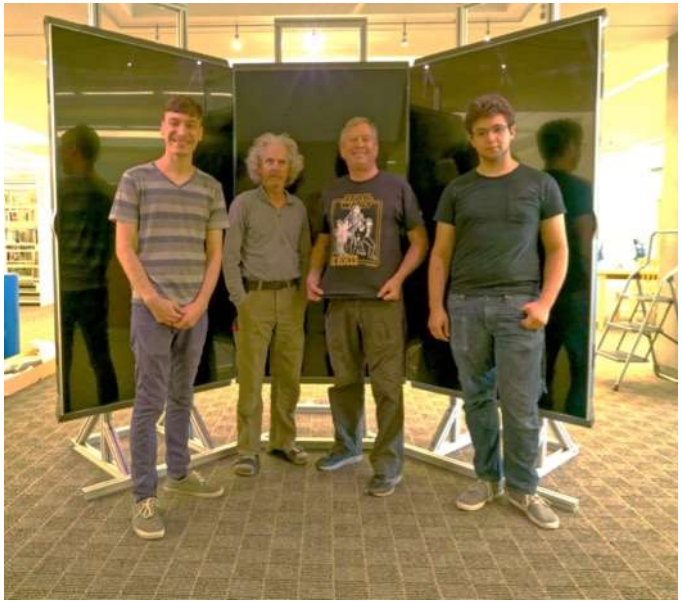
PRP Links At-Risk Cultural Heritage and Archaeology Datasets at UCB, UCLA, UCM and UCSD with CAVEkiosks-a PRP Deliverable



48 Megapixel CAVEkiosk
UCSD Library



48 Megapixel CAVEkiosk
UCB CITRIS Tech Museum



24 Megapixel CAVEkiosk
UCM Library

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UC President Napolitano's Research Catalyst Award to
UC San Diego (Tom Levy), UC Berkeley (Benjamin Porter), UC Merced (Nicola Lercari) and UCLA (Willeke Wendrich)

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2018/2019: PRP Game Changer!
Using Kubernetes to Orchestrate Containers Across the PRP

CADE METZ BUSINESS 06.10.14 01:15 PM

GOOGLE OPEN SOURCES ITS SECRET WEAPON IN CLOUD COMPUTING

WIRED

"Kubernetes is a way of stitching together a collection of machines into, basically, a big computer,"
--Craig Mcluckie, Google
and now CEO and Founder of Heptio

"Everything at Google runs in a container."
--Joe Beda,Google

How Kubernetes Conquered 2017 (and is Positioned for 2018)





Dan Meyer
December 25, 2017

sdx central

Kubernetes, an open-source software project that started at Google, has exploded in popularity and is now used by at least 54% of the Fortune 500. BUSINESS INSIDER **Rosalie Chan** Jan. 27, 2019,

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CLOUD NATIVE COMPUTING FOUNDATION

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PRP Has Adopted Rook Cloud-Native Storage Orchestrator, Which Runs 'Inside' Kubernetes



Battle-tested, production storage

Rook is based on an embedded version of Ceph, which has 10+ years of production deployments and runs some of the worlds largest clusters.

Cloud-native environment integration

Rook runs as a cloud-native service for optimal integration with applications in need of block, object, or file storage.

Source: John Graham, Calit2/QI

PRP Provides Widely-Used Kubernetes Services For Application Research, Development and Collaboration





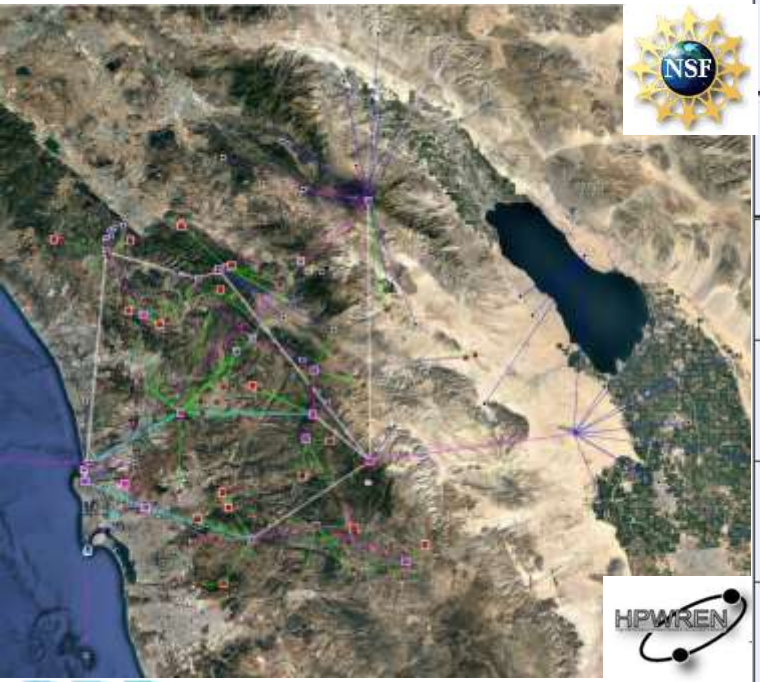
PRP
PACIFIC RESEARCH PLATFORM

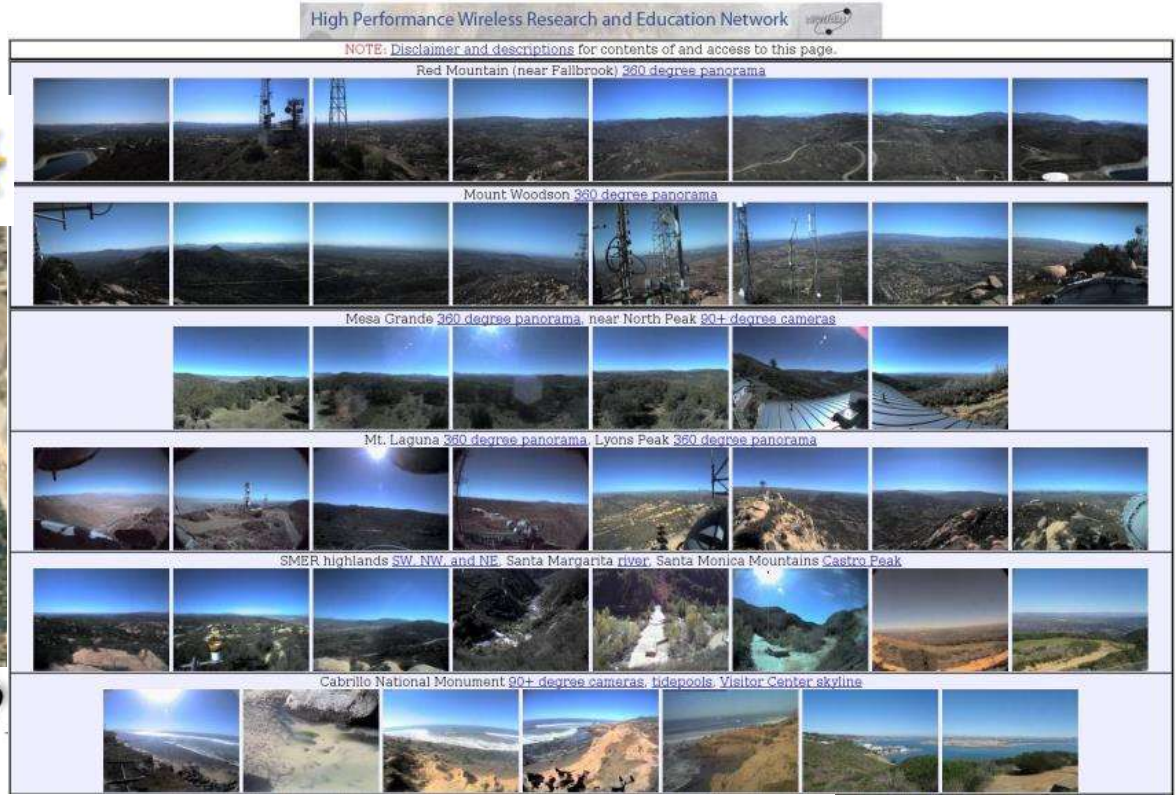
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2017-2019: HPWREN: 15 Years of NSF-Funded Real-Time Network Cameras and Meteorological Sensors on Top of San Diego Mountains for Environmental Observations

Source: Hans Werner Braun, HPWREN PI





NSF

HPWREN

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UC San Diego

SDSC SAN DIEGO SUPERCOMPUTER CENTER

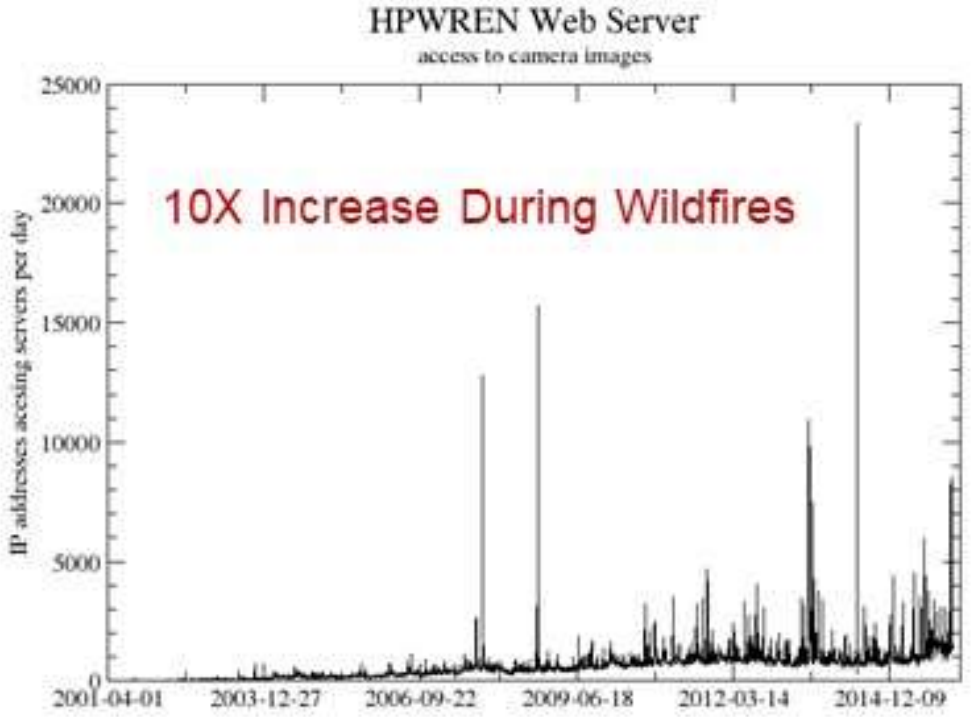
SCRIPPS INSTITUTION OF OCEANOGRAPHY

SAN DIEGO STATE UNIVERSITY

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PRP Uses CENIC 100G Optical Fiber to Link UCSD, SDSU & UCI HPWREN Data Servers

- To Maintain Public Responsiveness of HPWREN Web Server
- Data Redundancy
- Disaster Recovery
- High Availability
- Kubernetes Handles Software Containers and Data



Data From Hans-Werner Braun

PRP PACIFIC RESEARCH PLATFORM

HPWREN

UC San Diego

SDSC SAN DIEGO SUPERCOMPUTER CENTER

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Calit2

SAN DIEGO STATE UNIVERSITY

Once a Wildfire is Spotted, PRP Brings High-Resolution Weather Data to Fire Modeling Workflows in WIFIRE



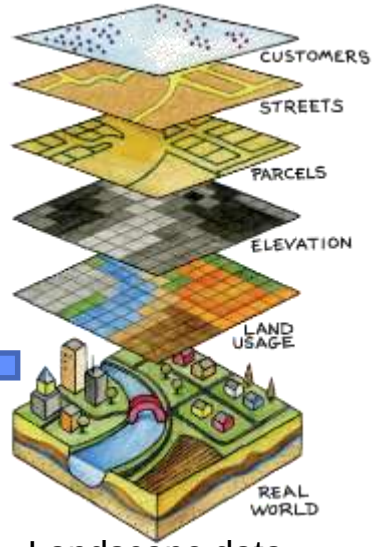
Real-Time Meteorological Sensors



Source: Ilkay Altintas, SDSC

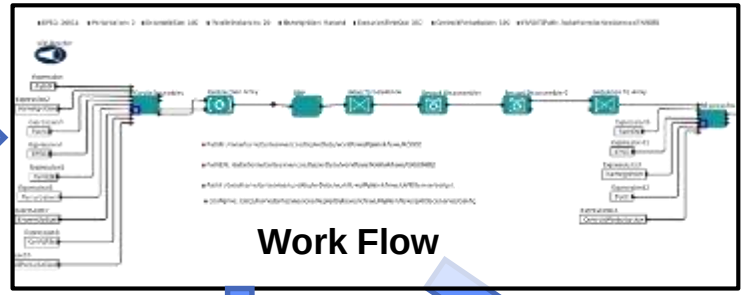


WIFIRE

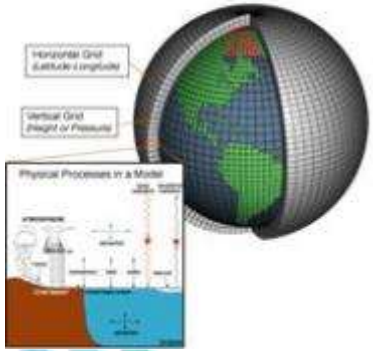


Landscape data

PRP



Weather Forecast









PRP
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PRPv1 to PRPv2:
Transition from Network Diagnosing to Application Support

- **PRPv1 first Designed, Built, and Installed ~40 Purpose-built FIONAs, DTNs Tuned to Measure and Diagnose End-to-End 1G, 10G, 40G and 100G Connections to CENIC's 100G HPR and National/International Partners**

- **But Scientists Clearly Need More than Bandwidth Tests:**
  - **They Need to Share Their Data at High Speed and Compute on It**
  - **Commercial Clouds are Not Cost-Effective for Sharing Big Data**

- **So, PRPv2 is Adding ~4 PBs Distributed Storage:**
  - **~200GB Rotating Disk on 14 PRPv1 FIONAs in Campus DMZs**
  - **2PB NSF-Funded BeeGFS Parallel File Storage at San Diego State University**

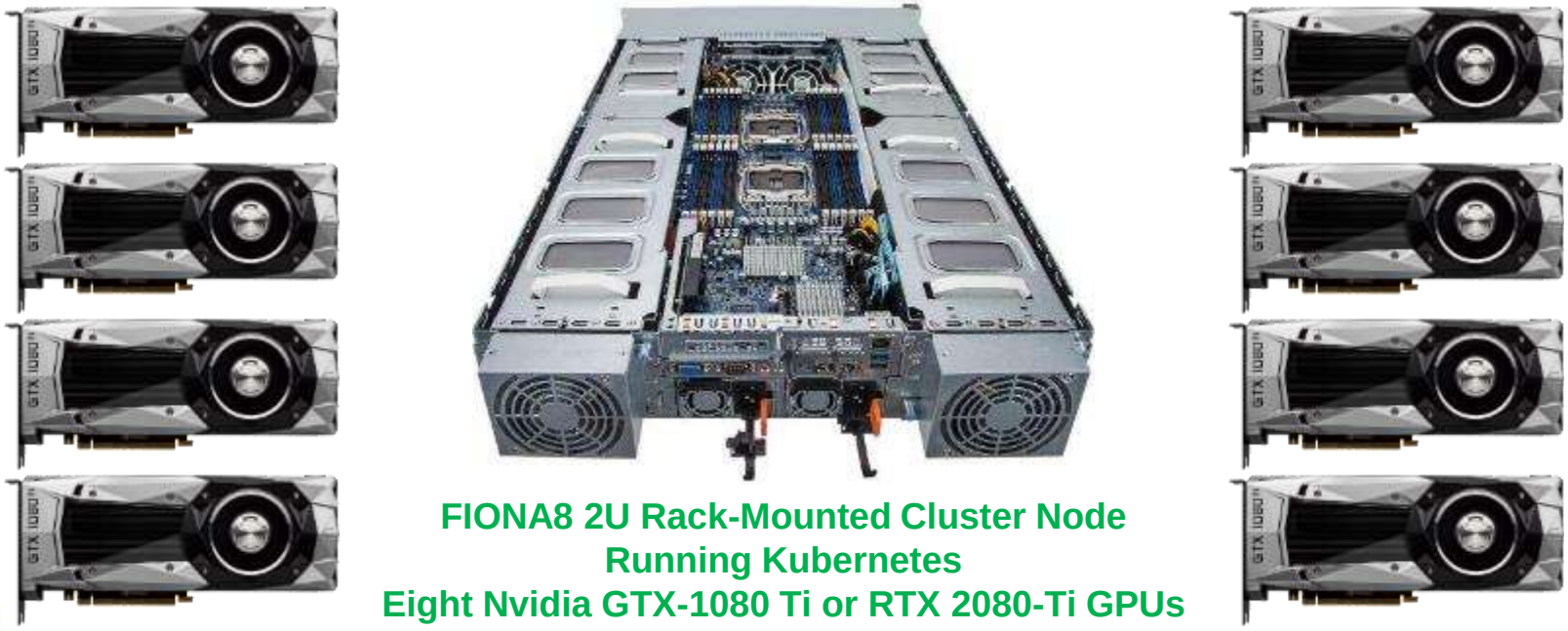
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2017: FIONA8s: PRPv2 Created FIONA8s By Adding 8 GPUs to Support PRP Big Data Applications Needing Machine Learning For Science



FIONA8 2U Rack-Mounted Cluster Node
Running Kubernetes
Eight Nvidia GTX-1080 Ti or RTX 2080-Ti GPUs

~$20,000

32 AMD cores, 256GB RAM, 1TB NVMe SSDs

Expandable to 8TB NVMe, 16TB SSD,1TB RAM, 64 cores (add $10,000)

Dual 10G ports

Design: John Graham, Calit2

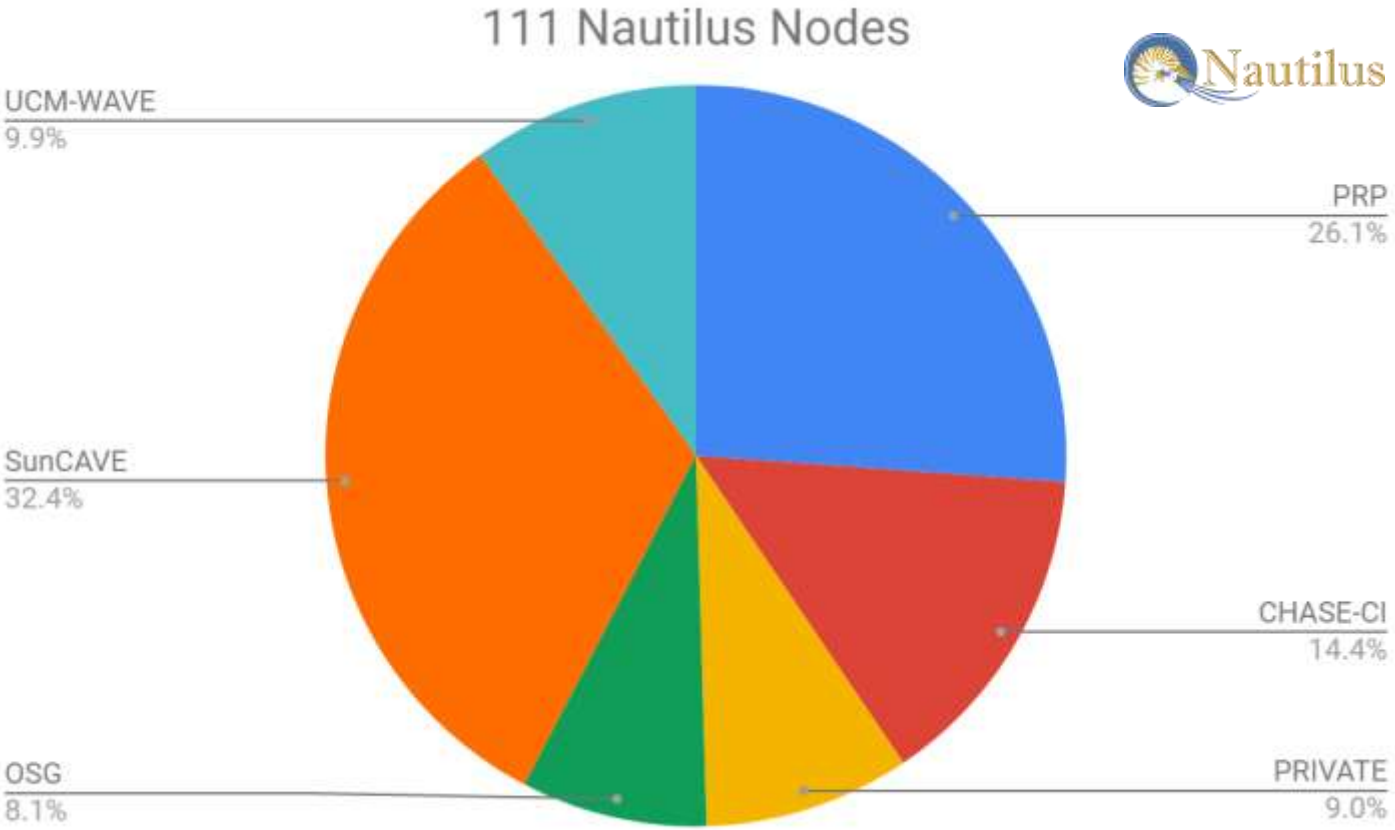
NSF

PRP
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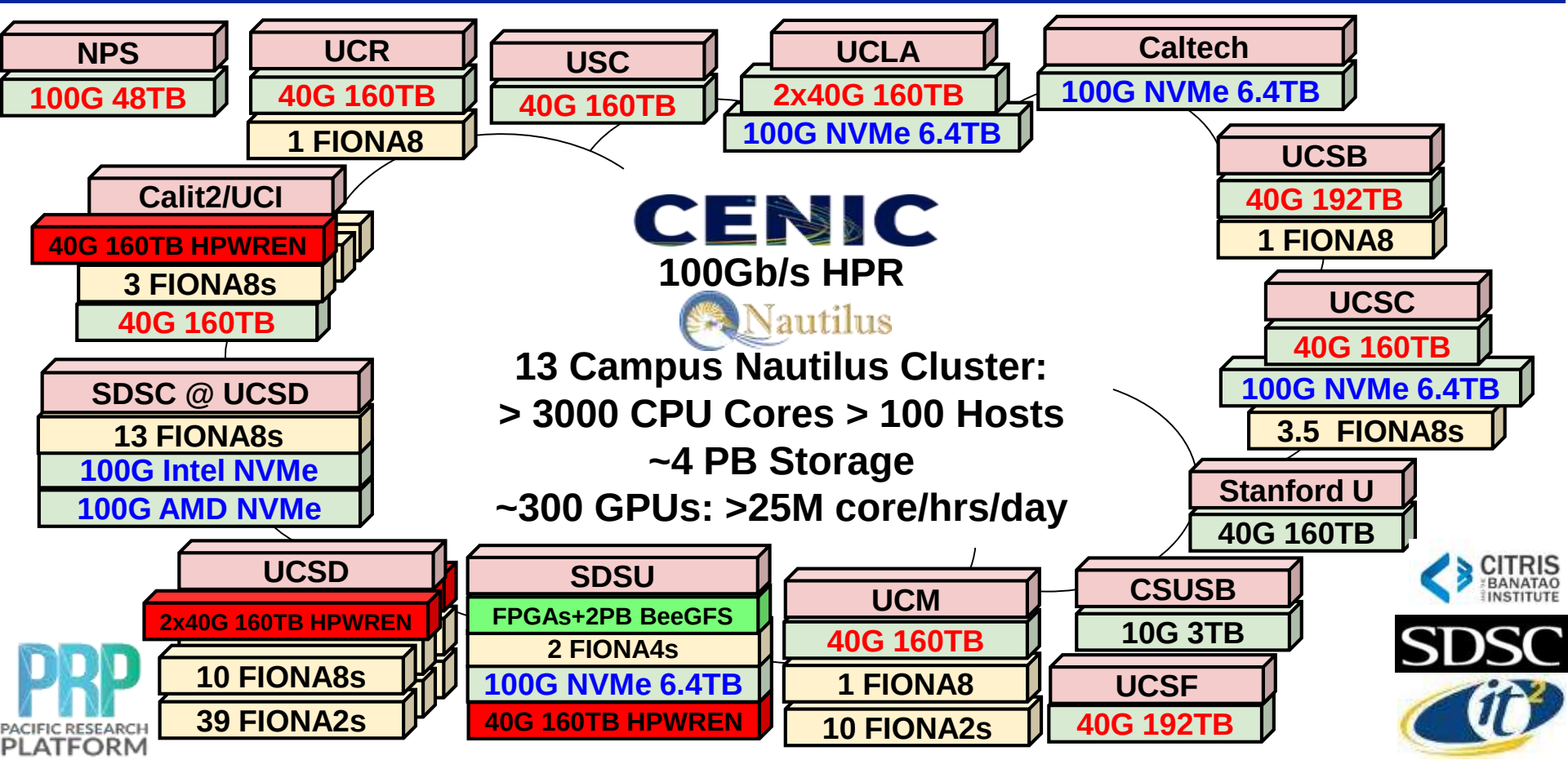
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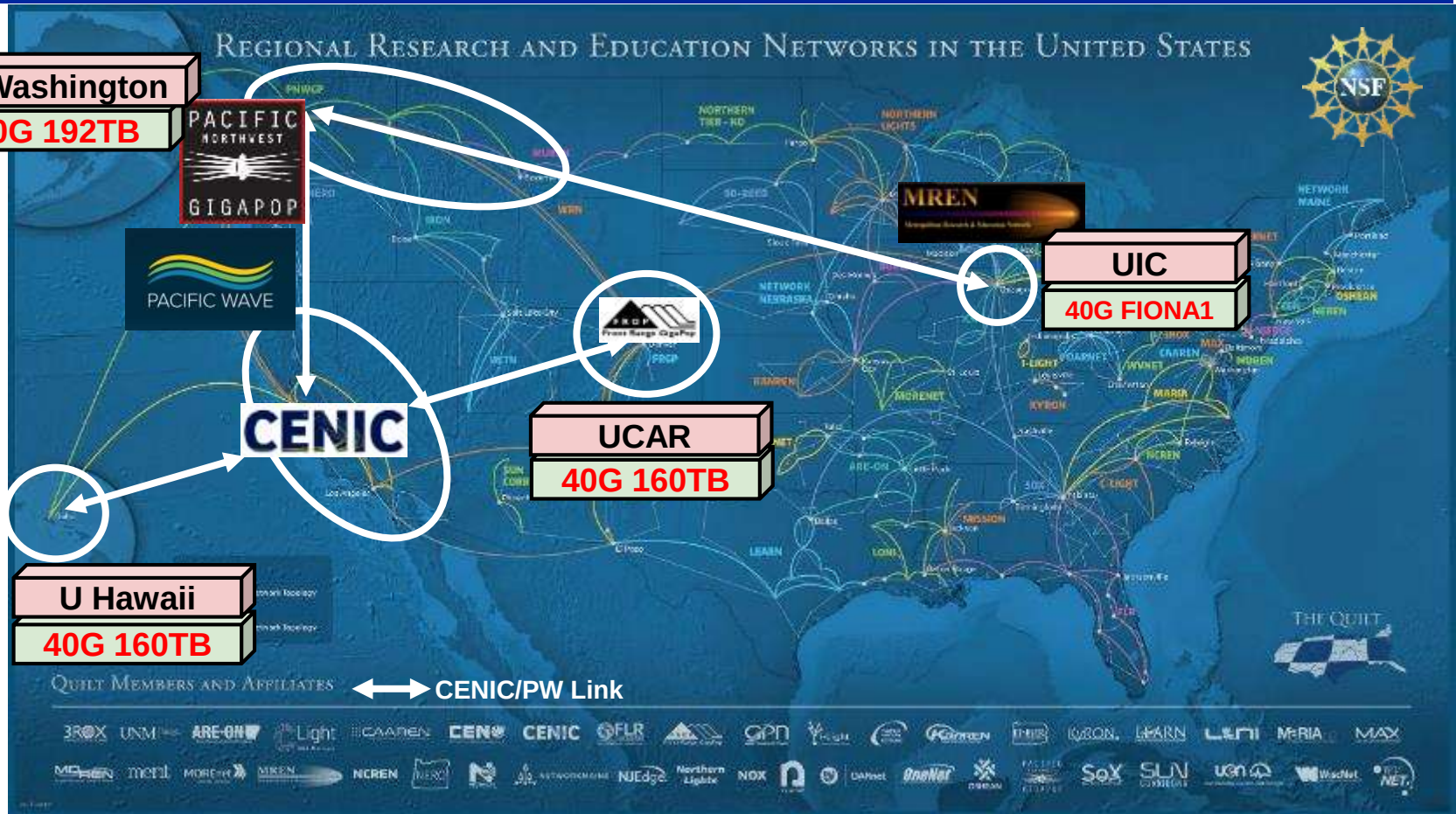
Collaboration Enables PRP To Supply Only One Quarter of Total Nautilus Nodes



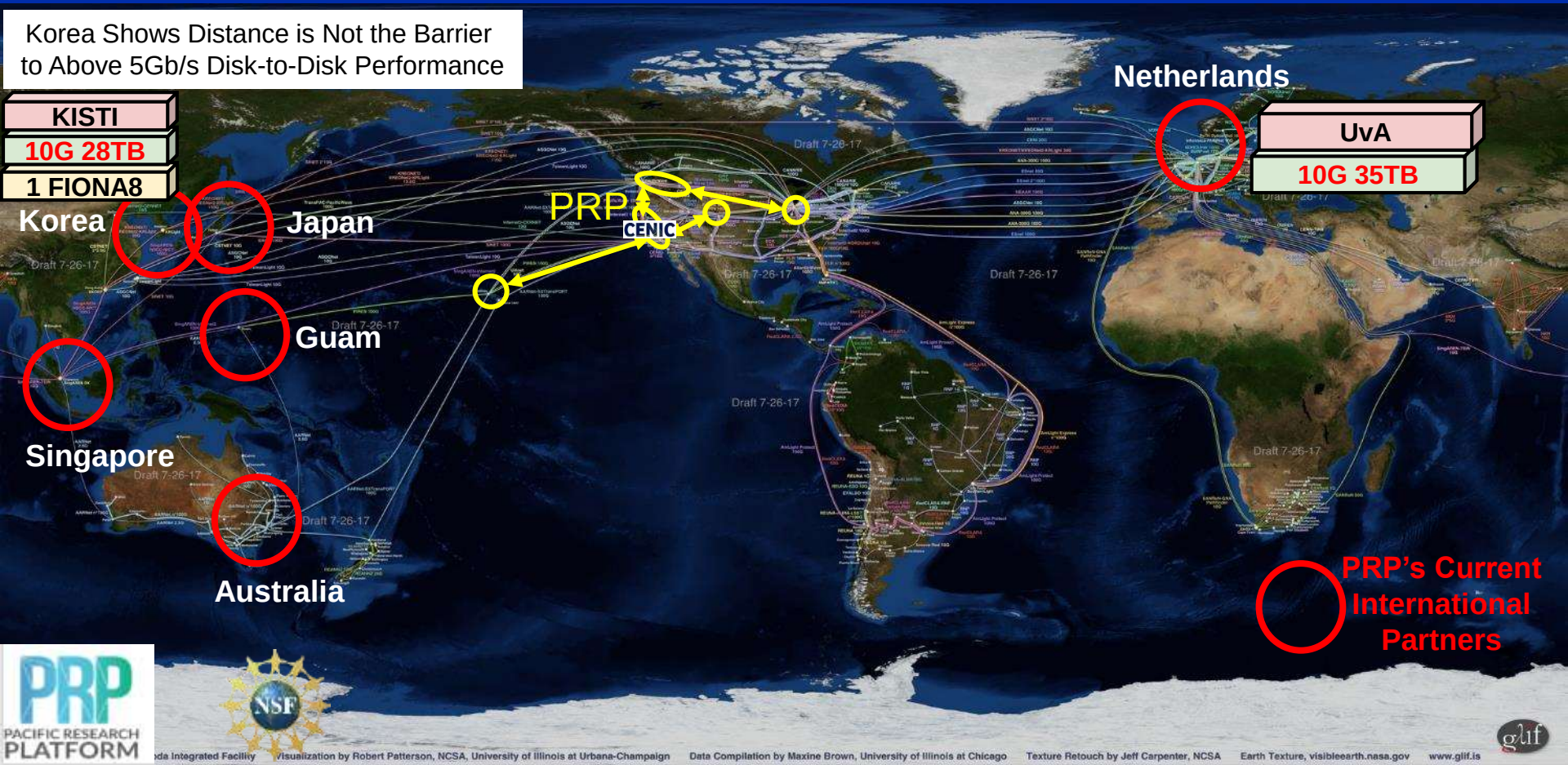
CENIC California-Connected PRP Nautilus Cluster
March 2019



United States PRP Nautilus Hypercluster Connects Three Regionals and UHawaii

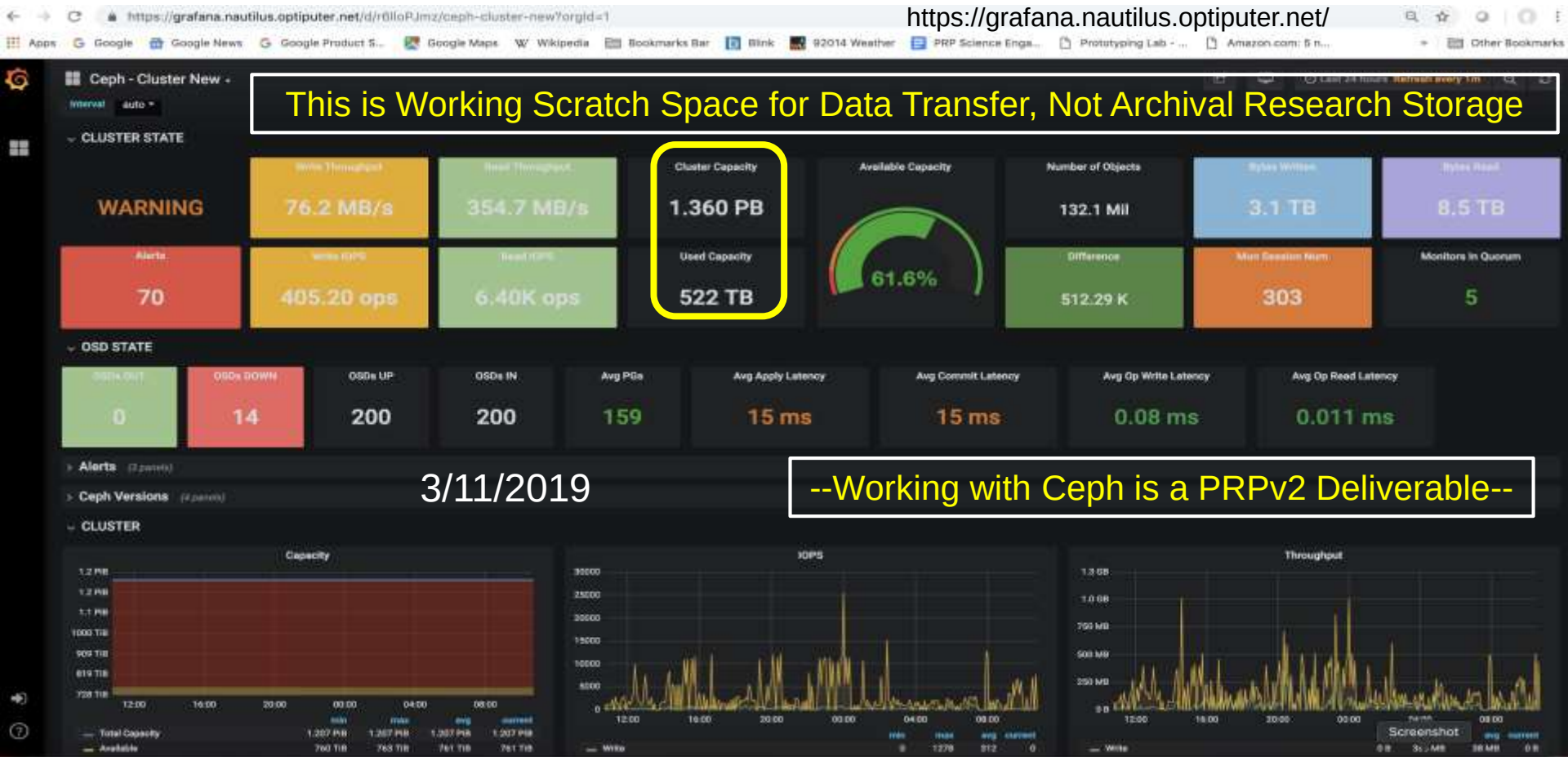


Global PRP Nautilus Hypercluster
Is Rapidly Increasing Partners Beyond Our Original Partner in Amsterdam



Open Source Grafana Allows Detailed Real-Time Monitoring of PRP Nautilus: UCD, UCSD, UCI, UCSB, UCLA, UCR, Stanford, UCAR, UCM, UCSC, UHM Ceph

https://grafana.nautilus.optiputer.net/



3/11/2019

--Working with Ceph is a PRPv2 Deliverable--

Thermal-Hydrological-Mechanical-Chemical (THMC) Modeling for Geologic CO_2 and Wastewater Injection:
Coupled System Solved in Parallel with MPI Using Domain Decomposition Across PRP Kubernetes Cluster

Darcy's Law (fluid flux [g/(cm² s)])

$$v_{\text{res}} = -\frac{K}{\mu}\rho_0\left(\nabla p_{\text{res}} - \rho g \nabla z\right)$$

Fluid Conservation (continuity equation)

$$\partial_t(\rho_0\phi) + \nabla \cdot v_{\text{res}} = q_{\text{res}}$$

Strain: the Symmetric Gradient of Displacement

$$\grave{o}(u) = \frac{1}{2}\left(\nabla u + \nabla u^T\right)$$

Rock Stress

$$\sigma(u) = \lambda\left(\nabla \cdot u\right)I + 2G\grave{o}(u)$$

Poroelastic Stress

$$\sigma_{por}(u,p) = \sigma(u) - \alpha pI$$

Reservoir Displacement

$$-\nabla \cdot \sigma_{por}(u) = f$$

Elemental Conservation of Mass / Unit Volume

$$\frac{\partial e_\beta}{\partial t} = \sum_{\alpha=1}^{N_\alpha}\left[\phi D_\alpha \nabla^2 c_\alpha - \phi\nabla\cdot(c_\alpha u)\right] - \sum_{\gamma=1}^{M}\nu_{\beta\gamma}A_\gamma G_\gamma$$

Conservation of Energy

$$\frac{\partial\left(\rho c_p T\right)}{\partial t} + \nabla\cdot\left(\rho c_p T u\right) = \nabla\cdot\left(k\nabla T\right) + S_T \qquad S_T = \sum_{j=1}^{n}\frac{dc_j}{dt}h_{j(aq)}$$

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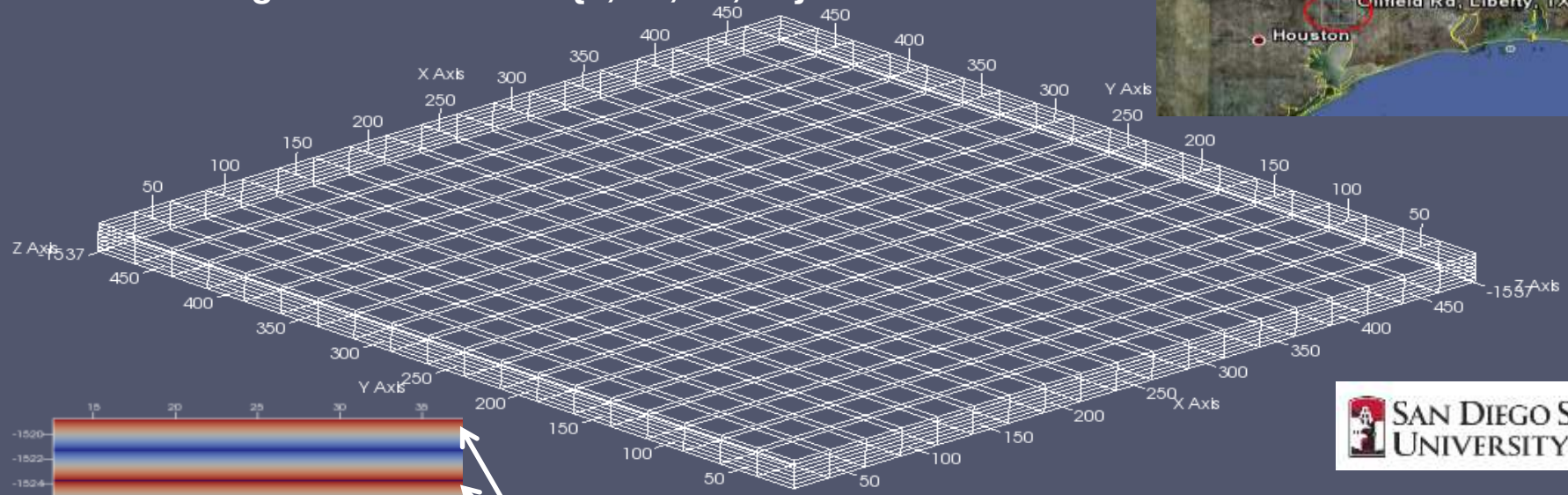
SDSC

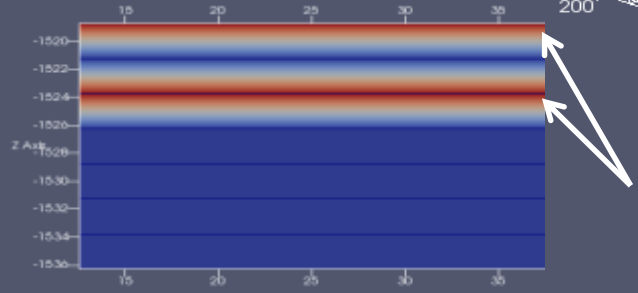
it²

Modeled Reservoir (Frio Formation)

- 0.5 km x 0.5 km x 17.5 m Volume
- Three Sandstone Layers Separated by Two Shale Layers
- 4 Grid Configurations: 20x20x{8, 16, 32, 64}







- Frio location is 30 miles northeast of Houston, in the South Liberty oilfield.
- Injection Zone is a brine-sandstone system with a top seal of 200 feet of Anahuac shale.

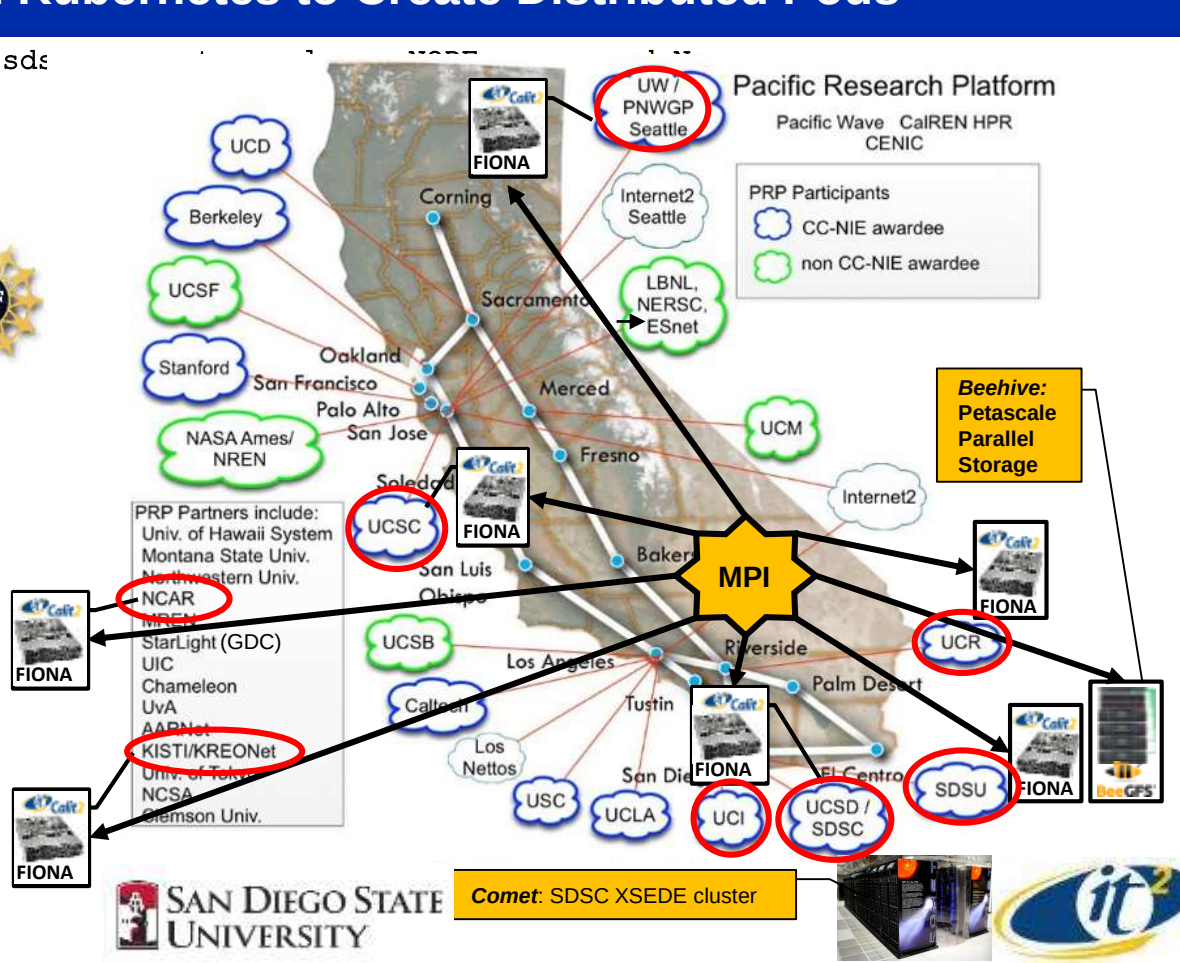
SAN DIEGO STATE UNIVERSITY

PRP Distributed-Parallel Computation: Using OpenMPI on Kubernetes to Create Distributed Pods

```
[paolini@fiona k8s]$ kubectl get pod -n sds
NODE [Creating Kubernetes Distributed Pods]
k8s-nvme-01.sdsc.optiputer.net
fiona.cac.washington.edu
dtn-main.ucr.edu
siderea.ucsc.edu
dtn2-daejeon.kreonet.net
fiona-dtn-1.ucsc.edu
fiona.nwsc.ucar.edu
k8s-epyc-01.sdsc.optiputer.net
```

With 100Gbps Intercampus Connectivity, the PRP Network Can be Utilized as an Inter-Process Communication Bus to Perform Parallel Computation

Next Generation PRP and Ethernet Alliance Roadmap: 400 Gbps, 1.6 Tbps



PRP PACIFIC RESEARCH PLATFORM

NEXT ETHERNET ERA ethernet alliance

2017: PRP Delivered the Connection of UCSD SunCAVE and UCM WAVE
2018-2019: Added Their 90 GPUs to PRP for Machine Learning Computations



UC Merced WAVE (20 Screens, 20 GPUs)



UCSD SunCAVE (70 Screens, 70 GPUs)

Worked Example of SunCAVE/WAVE GPU Usage
by NSF IceCube Neutrino Observatory

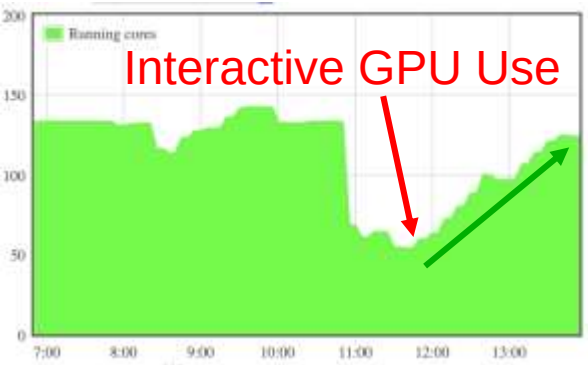
PRP
PACIFIC RESEARCH PLATFORM

Leveraging UCM Campus Funds and NSF CNS-1456638 & CNS-1730158 at UCSD

SDSC

it²

The IceCube Science Program
Spans Fundamental Physics to Observational Astronomy



IceCube GPU Needs Exceed Availability by 10x

=> Backfilling GPUs for Interactive Use on PRP with Batched IceCube Simulations

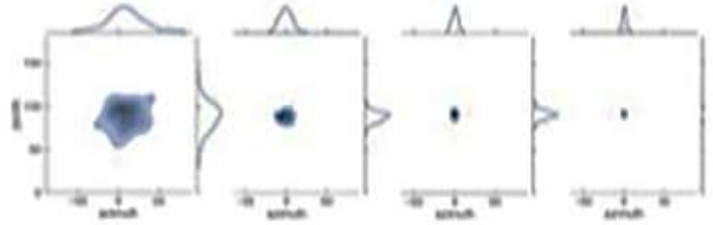


Figure 4. Possible improvements to angular resolution with better understanding of ice model

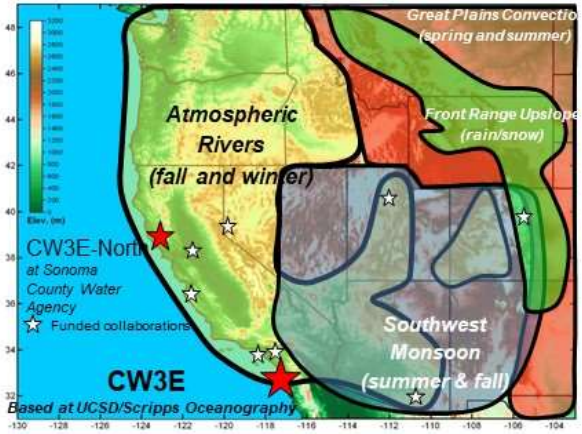
GPU Simulations Needed *to Improve Ice Model*.
=> Results in Significant Improvement in Pointing Resolution for Multi-Messenger Astrophysics



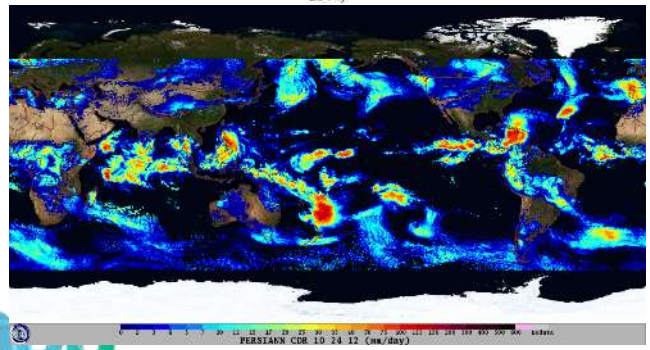
OSG Ice Cube Usage on PRP (Purple Segment) 3/9/19: Using 126 GPUs (44%) + 142 CPUs (5%) + 49 GB Ram (.3%)



Collaboration on Atmospheric Water in the West Between UC San Diego and UC Irvine



Key Phenomena Causing Extreme Precipitation in the Western U.S. (Ralph et al. 2014)



Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

Director: F. Martin Ralph Website: cw3e.ucsd.edu

Big Data Collaboration with:

Center for Hydrometeorology & Remote Sensing
University of California, Irvine

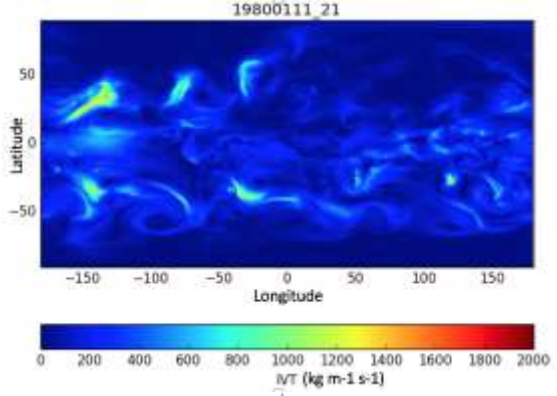
Director, Soroosh Sorooshian, UCSD Website http://chrs.web.uci.edu

PACIFIC RESEARCH PLATFORM

Source: Scott Sellers, CW3E

Scott Sellars Rapid 4D Object Segmentation of NASA Water Vapor Data - “Stitching” in Time and Space

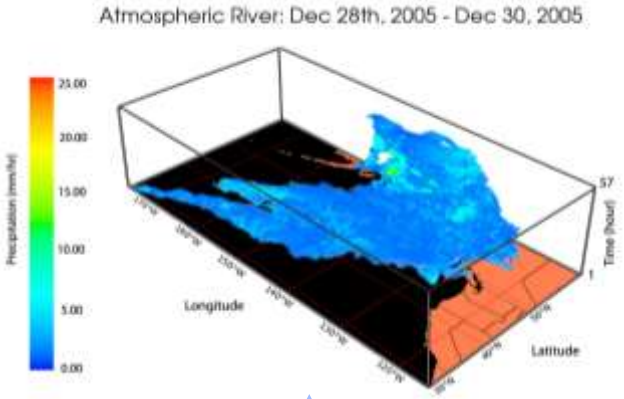
NASA *MERRA v2 – Water Vapor Data Across the Globe



Object Detection, Segmentation and Tracking



4D Object Constructed (Lat, Lon, Value, Time)



Scott L. Sellars[1], John Graham[1], Dima Mishin[1], Kyle Marcus[2] , Ilkay Altintas[2], Tom DeFanti[1], Larry Smarr[1], Joulien Tatar[3], Phu Nguyen[4], Eric Shearer[4], and Soroosh Sorooshian[4]

[1]Calit2@UCSD; [2]SDSC; *[3]Office of Information Technology, UCI; [4]Center for Hydrometeorology and Remote Sensing, UCI*

PRP Shortened Scott's Workflow From 19.2 Days to 52 Minutes - 532 Times Faster!

Pacific Research Platform (10-100 Gb/s)

Complete workflow time: 19.2 days→52 Minutes!

UC, Irvine

GPUs



Calit2's FIONA

SDSC's COMET



UC, San Diego

GPUs

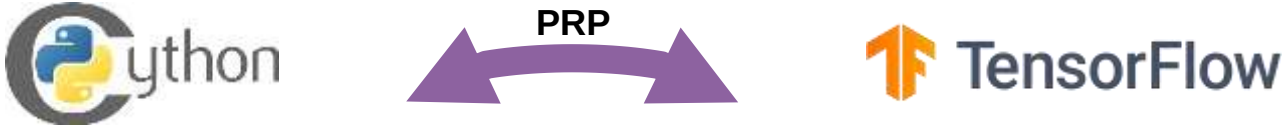


Calit2's FIONA

Source: Scott Sellers, CW3E

Next Steps
Coupling SDSC's COMET and FIONA8s Over PRP

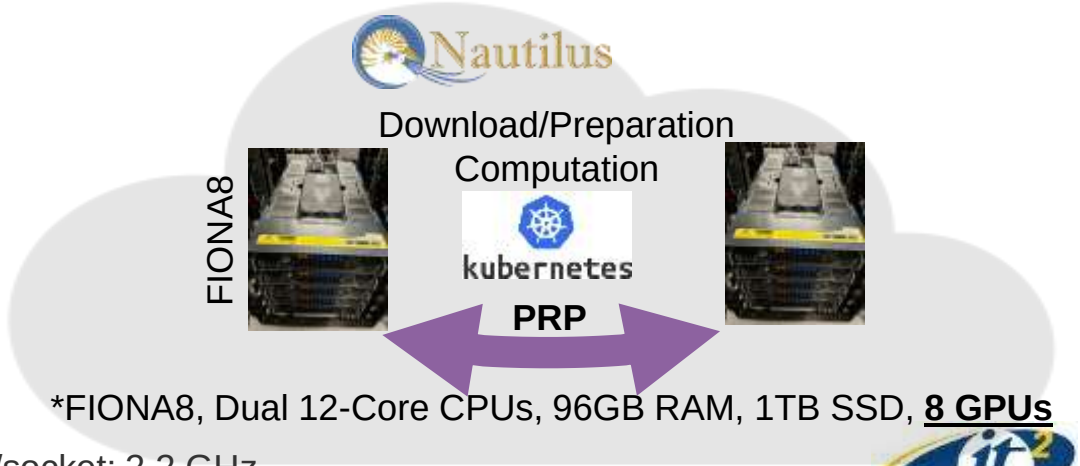
- **Divide and conquer**
  - **Harness Cython and COMET's Large Memory Nodes for Rapid Object Segmentation of Entire Data Archives**
  - **Use TensorFlow for Large Scale Machine Learning on Objects**





Large-memory Node

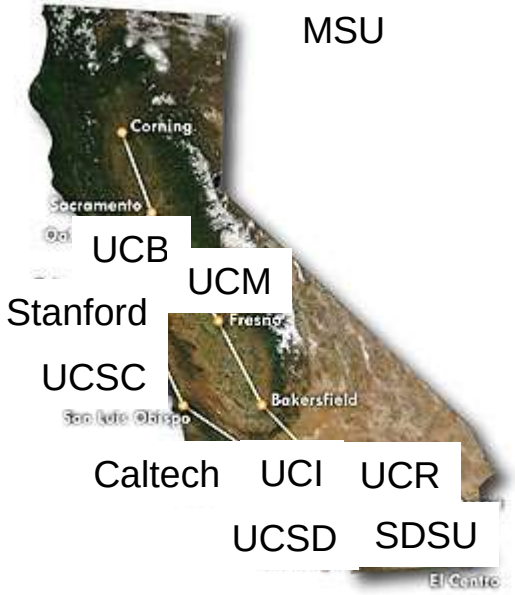
1.5 TB total memory; 4 sockets, 16 cores/socket; 2.2 GHz



*FIONA8, Dual 12-Core CPUs, 96GB RAM, 1TB SSD, **8 GPUs**

PACIFIC RESEARCH PLATFORM

2017-2020: As a PRP Science Application, NSF-Funded CHASE-CI is Building a Machine Learning Data Science Community Cyberinfrastructure



CI-New: Cognitive Hardware and Software Ecosystem Community Infrastructure (CHASE-CI)

For the Period September 1, 2017 – August 31, 2020

SUBMITTED – January 18, 2017

PI: Larry Smarr, Professor of Computer Science and Engineering, Director Calit2, UCSD
Co-PI: Tajana Rosing, Professor of Computer Science and Engineering, UCSD
Co-PI: Ken Kreutz-Delgado, Professor of Electrical and Computer Engineering, UCSD
Co-PI: Ilkay Altintas, Chief Data Science Officer, San Diego Supercomputer Center, UCSD
Co-PI: Tom DeFanti, Research Scientist, Calit2, UCSD

NSF Grant for 256 High Speed "Cloud" GPUs
For 32 ML Faculty & Their Students at 10 Campuses
To Train AI Algorithms on Big Data

94 GPUs Purchased So Far by CHASE-CI funds
240 More GPUs Added to Nautilus So Far From Other Grants/Sources

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SDSC UC San Diego it²

UCSD Adding >350 Game GPUs to Data Sciences Cyberinfrastructure - Devoted to Data Analytics and Machine Learning

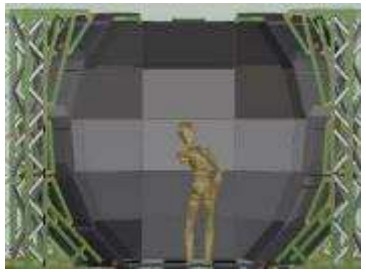
UC San Diego

IT SERVICES

95 GPUs
for Students

Open Science Grid

48 GPUs for
OSG Applications



SunCAVE 70 GPUs
WAVE + Vroom 48 GPUs

UCSD Cognitive Science

JACOBS SCHOOL OF ENGINEERING

SDSC it²



Plus 288 64-bit GPUs
On SDSC's Comet

QUALCOMM INSTITUTE



FIONA with
8-Game GPUs

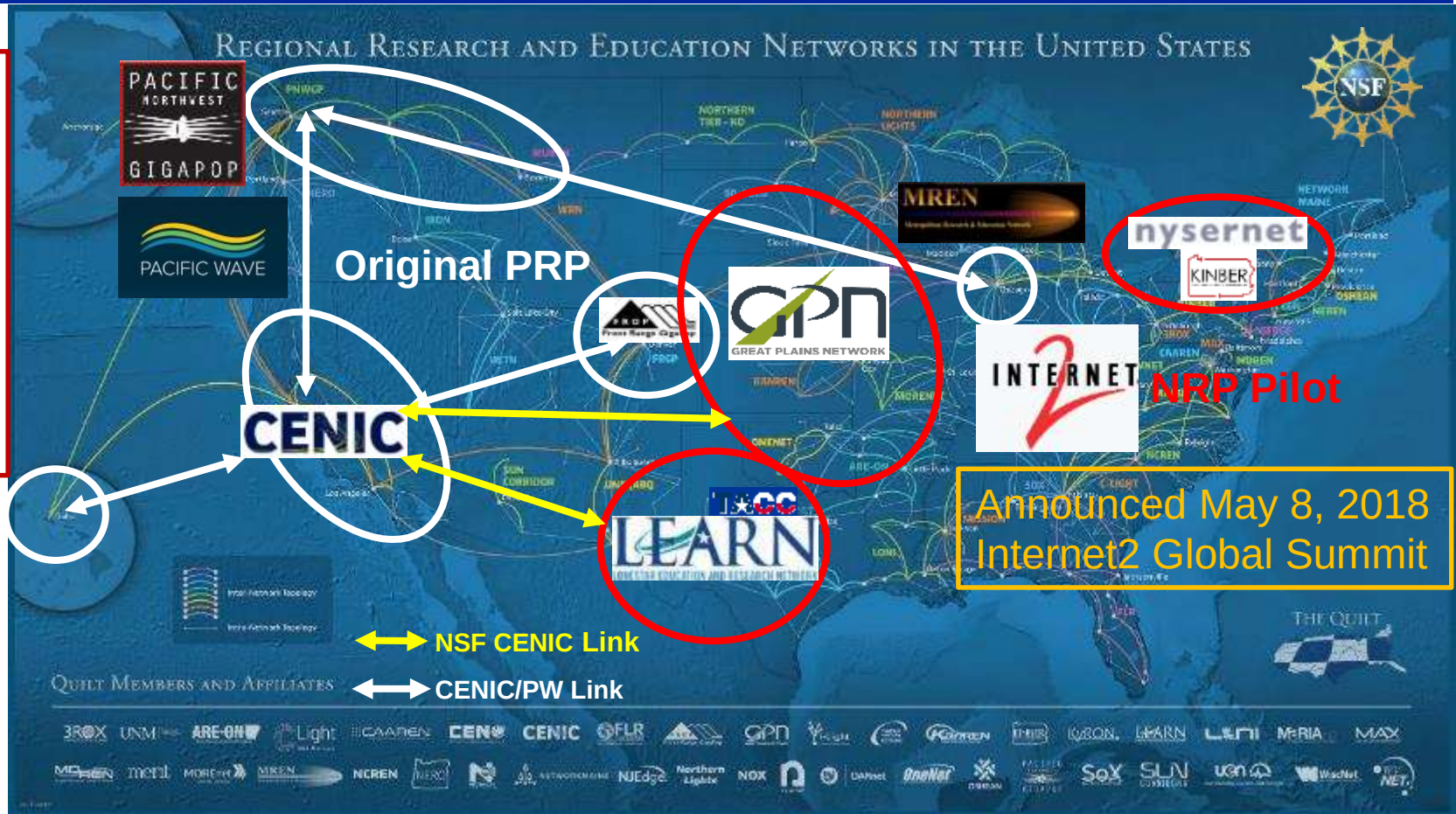
CHASE-CI Grant Provides
96 GPUs at UCSD
for Training AI Algorithms on Big Data

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2018-2019 PRP Deliverable: NRP Pilot: 18-Month National-Scale Experiment: Using CENIC & Internet2 to Connect Quilt Regional R&E Networks

"Towards The NRP"
3-Year Grant Funded by NSF
$2.5M
OAC-1826967
PI Smarr
Co-Pis Altintas Papadopoulos Wuerthwein Rosing



SDSC

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Engaging More Scientists:
Newly Designed and Updated PRP Website

http://pacificresearchplatform.org



PRP Web Site is Built on Top of Ruby - Can Easily Be Updated in a Git Environment

http://pacificresearchplatform.org is Public Facing url

- **PRP Workshops**
  - Media (http://ucsd-prp.gitlab.io/media/)
  - Reports (http://ucsd-prp.gitlab.io/reports/)
- **PRP Nautilus Cluster** (http://ucsd-prp.gitlab.io/nautilus/)
  - Documentation
  - Use Cases (http://ucsd-prp.gitlab.io/nautilus/namespaces/)
- **PRP/TNRP Pilot Engagement Team** (http://ucsd-prp.gitlab.io/TNRP/)
  - Meeting Schedules & Agendas
  - Meeting Notes

PRP PACIFIC RESEARCH PLATFORM

Design and Development: Calit2's Charles Erwin and CENIC's Lee-Ann Weber

it²

Thanks To:

- **US National Science Foundation (NSF) Awards:**
  - **CNS-1456638, CNS-1730158, ACI-1540112, ACI-1541349, & OAC-1826967**
- **University of California Office of the President CIO**
- **Calit2 and Calit2's Qualcomm Institute**
- **San Diego Supercomputer Center and UCSD's Research IT and Instructional IT**
- **Partner Campuses: UCB, UCSC, UCI, UCR, UCLA, USC, UCD, UCSB, SDSU, Caltech, NU, UWash UChicago, UIC, UHM, CSUSB, HPWREN, UMo, MSU, NYU, UNeb, UNC,UIUC, UTA/Texas Advanced Computing Center, FIU, KISTI, UVA, AIST**
- **CENIC, Pacific Wave/PNWGP, StarLight/MREN, The Quilt, Kinber, Great Plains Network, NYSERNet, LEARN, Open Science Grid**
- **Internet2, DOE ESnet, NCAR/UCAR and Wyoming Supercomputing Center**

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