“The Pacific Research Platform- a High-Bandwidth Distributed Supercomputer”

Super Computing Asia (SCA21)
Singapore
March 2-4, 2021

Dr. Larry Smarr
Founding Director Emeritus, California Institute for Telecommunications and Information Technology;
Distinguished Professor Emeritus, Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD
http://lsmarr.calit2.net

PACIFIC RESEARCH PLATFORM

Abstract

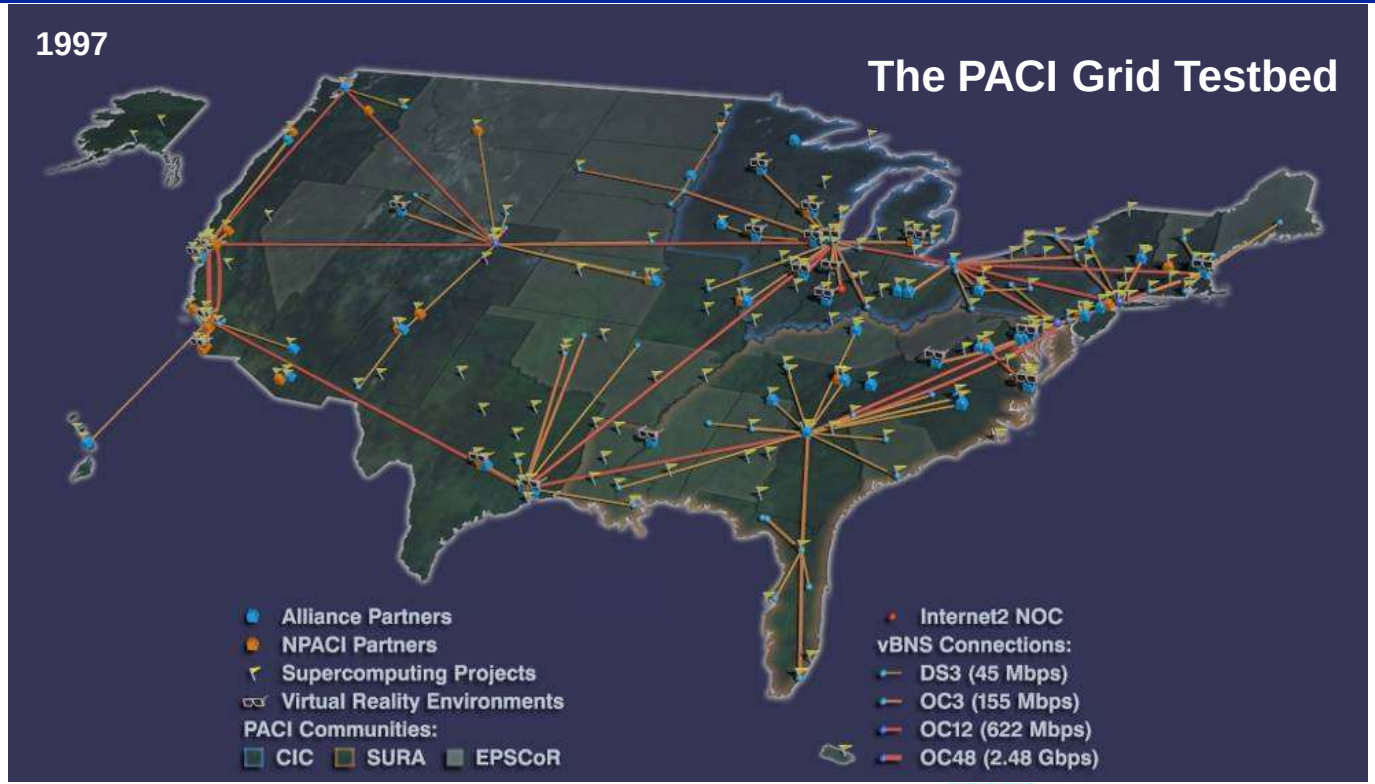
The National Science Foundation is funding three grants which create a regional, national, to global-scale distributed supercomputer, optimized for machine learning research and data analysis of large scientific datasets. The Pacific Research Platform (PRP) is integrated with the Cognitive Hardware and Software Ecosystem Community Infrastructure (CHASE-CI) and Toward a National Research Platform (TNRP). This high-performance cyberinfrastructure uses 10 to 100Gbps optical fiber networks to interconnect across 30 campuses nearly 200 Science DMZ Data Transfer Nodes (DTNs) endpoints, which are rack-mounted PCs optimized for 10-100Gbps data transfers, containing multicore CPUs, two to eight GPUs, and up to 256TB of disk each. Users' containerized software applications are orchestrated across the highly instrumented PRP by Kubernetes. Currently over 400 user namespaces are active on the PRP, supporting a wide range of applications.

PRP
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it²

1985-2000 NSF Funds Supercomputer Centers, NSFnet, vBNS, and PACI: Creating the First Prototype of a National Research Platform

vBNS led to



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National Computational Science ALLIANCE

2002-2009: The OptIPuter - Can We Make Wide-Area Bandwidth Equal to Cluster Backplane Speeds?



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

Distributed Global Cyberinfrastructure to Support Data-Intensive Scientific Research and Collaboration

OptIPuter
$13.5M
PI Smarr,
Co-PI DeFanti
Co-PI Papadopoulos, Ellisman
2002-2009

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OptIPuter

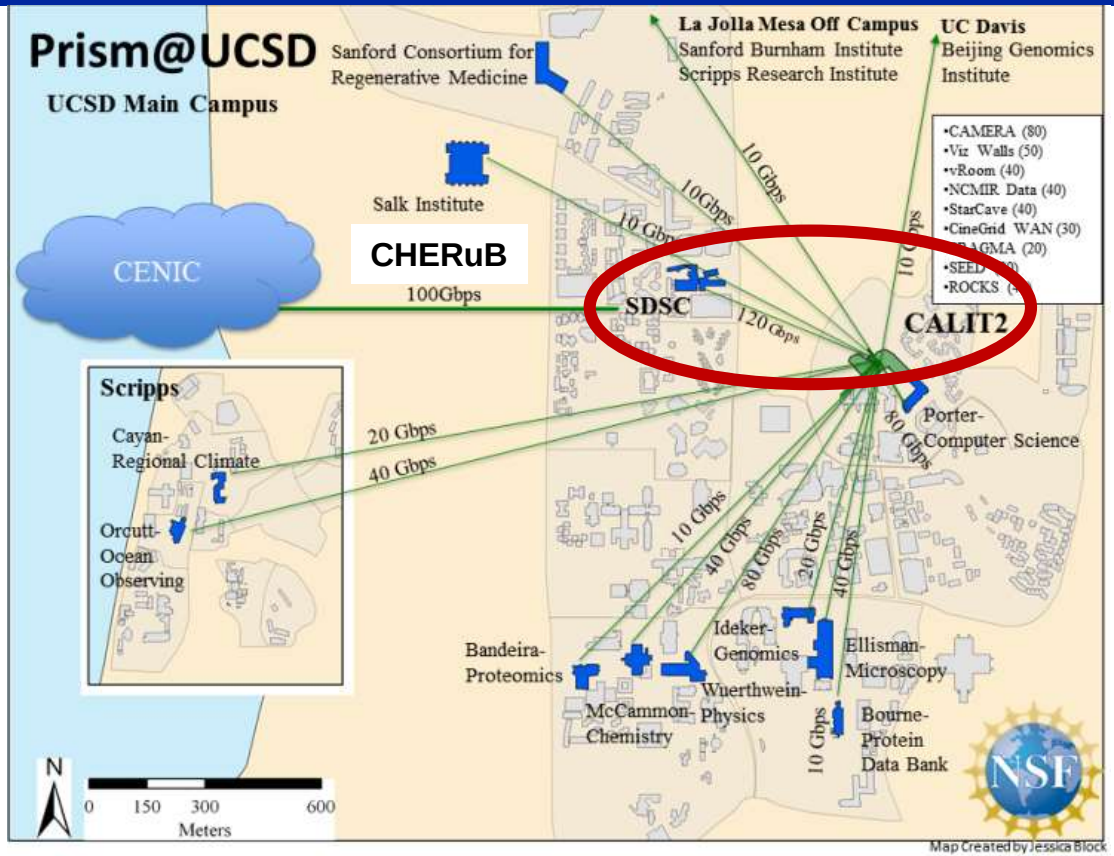
NSF

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SDSC

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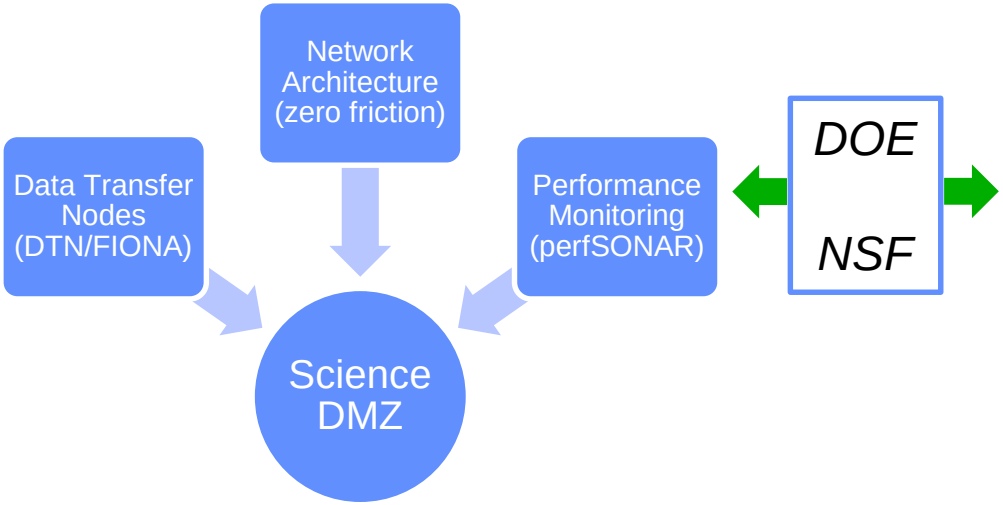
2013-2015: Creating a "Big Data" Optical Backplane on Campus: NSF Funded Prism@UCSD and CHERuB



Prism@UCSD, $500,000, Phil Papadopoulos, SDSC, Calit2, PI; Smarr co-PI
CHERuB, $500,000, Mike Norman, SDSC PI

2010-2020: DOE & NSF Partnering on Science Engagement and ScienceDMZ Technology Adoption

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



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

NSF Campus Cyberinfrastructure Program
Has Made Over 340 Awards



2012-2020:
Across 50 States and Territories

Slide Adapted From Inder Monga, ESnet

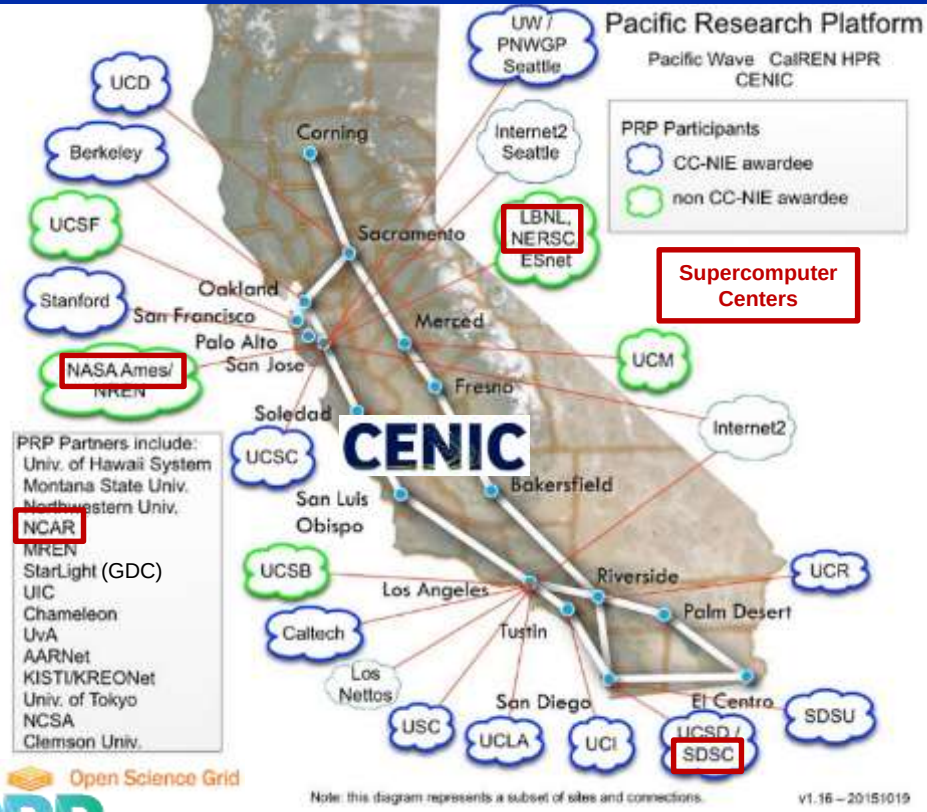
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ESnet FASTERDATA KNOWLEDGEBASE

NSF

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2015 Vision: The Pacific Research Platform Will Connect Science DMZs Creating a Regional End-to-End Science-Driven Community Cyberinfrastructure



Map Source: John Hess, CENIC

NSF CC*DNI Grant
$6.3M 10/2015-10/2020
In Year 5 Now

PI: Larry Smarr, UC San Diego Calit2

Co-PIs:

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



Letters of Commitment from:

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

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Terminating the Fiber Optics - Data Transfer Nodes (DTNs): 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
Up to 256 TB Rotating Storage





Add Up to 8 Nvidia GPUs Per 2U FIONA
To Add Machine Learning Capability

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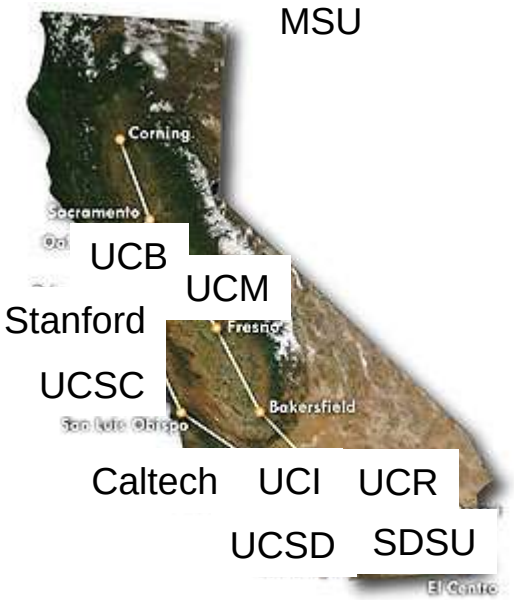
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FIONAs Designed by UCSD's Phil Papadopoulos, John Graham, Joe Keefe, and Tom DeFanti

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2017-2020: NSF CHASE-CI Grant Adds a Machine Learning Layer Built on Top of the Pacific Research Platform



NSF Grant for High Speed "Cloud" of 256 GPUs
For 30 ML Faculty & Their Students at 10 Campuses
for Training AI Algorithms on Big Data

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
Co-PIs:

- Tajana Rosing
- Ken Kreutz-Delgado
- Ilkay Altintas
- Tom DeFanti

JACOBS SCHOOL OF ENGINEERING

SDSC UC San Diego

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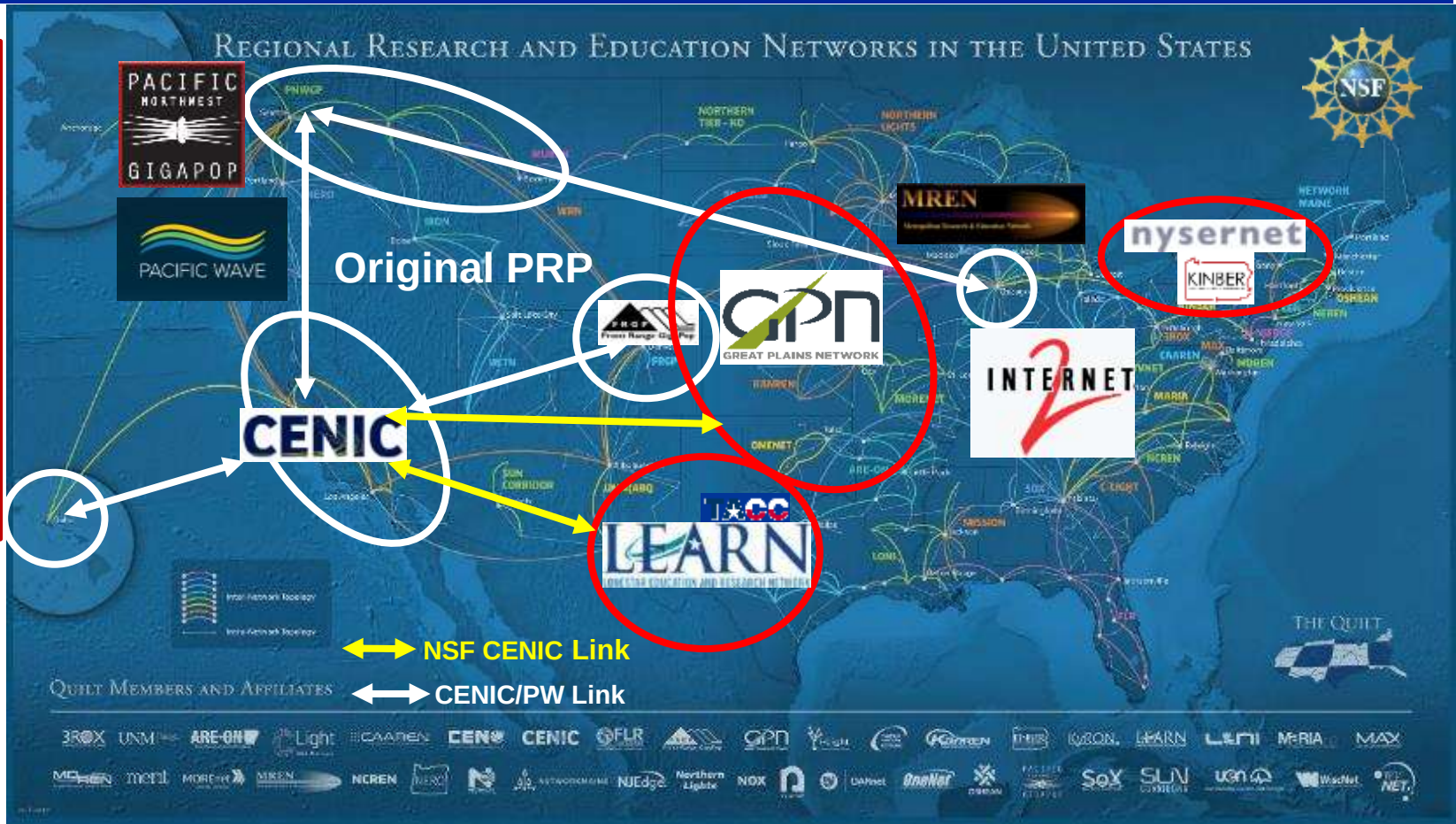
2018-2021: Toward the NRP - Using CENIC & Internet2 to Connect Quilt Regional R&E Networks

"Towards The NRP"
3-Year Grant Funded by NSF
$2.5M
October 2018

PI Smarr
Co-PIs Altintas Papadopoulos Wuerthwein Rosing DeFanti

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PRP's Nautilus Hypercluster Adopted Kubernetes to Orchestrate Software Containers and Manage Distributed Storage

Nautilus

kubernetes

Kubernetes (K8s) is an open-source system for automating deployment, scaling, and management of containerized applications.



Planet Scale

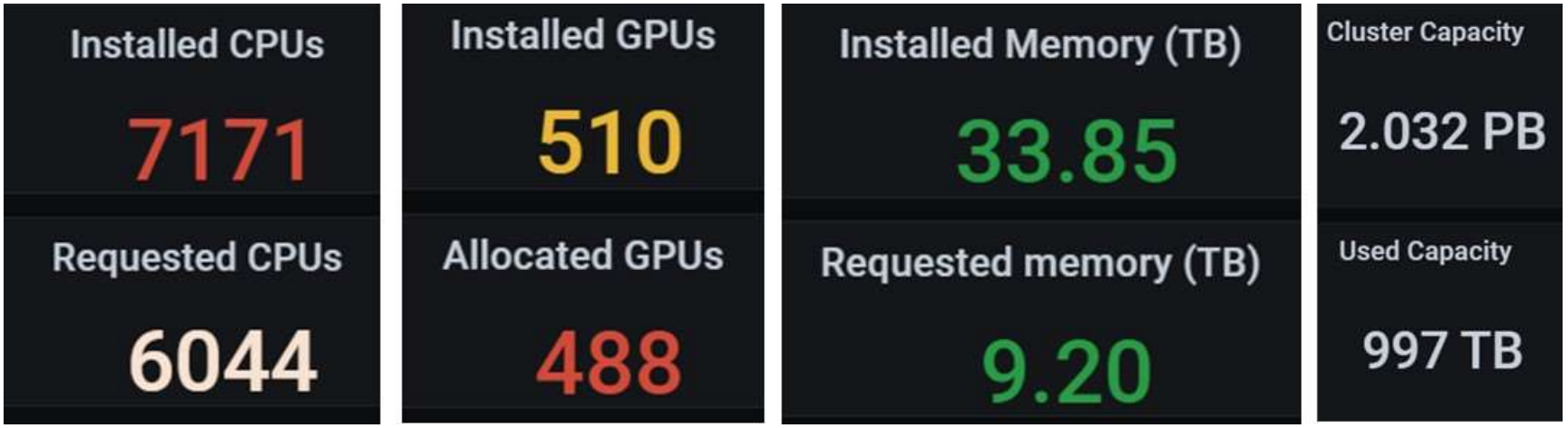
Designed on the same principles that allows Google to run billions of containers a week, Kubernetes can scale without increasing your ops team.

"Kubernetes with Rook/Ceph Allows Us to Manage Petabytes of Distributed Storage and GPUs for Data Science, While We Measure and Monitor Network Use."
--John Graham, Calit2/QI UC San Diego

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PRP's Nautilus Forms a Multi-Application Kubernetes Container-Orchestrated "Big Data" Storage and Machine-Learning Distributed Computer



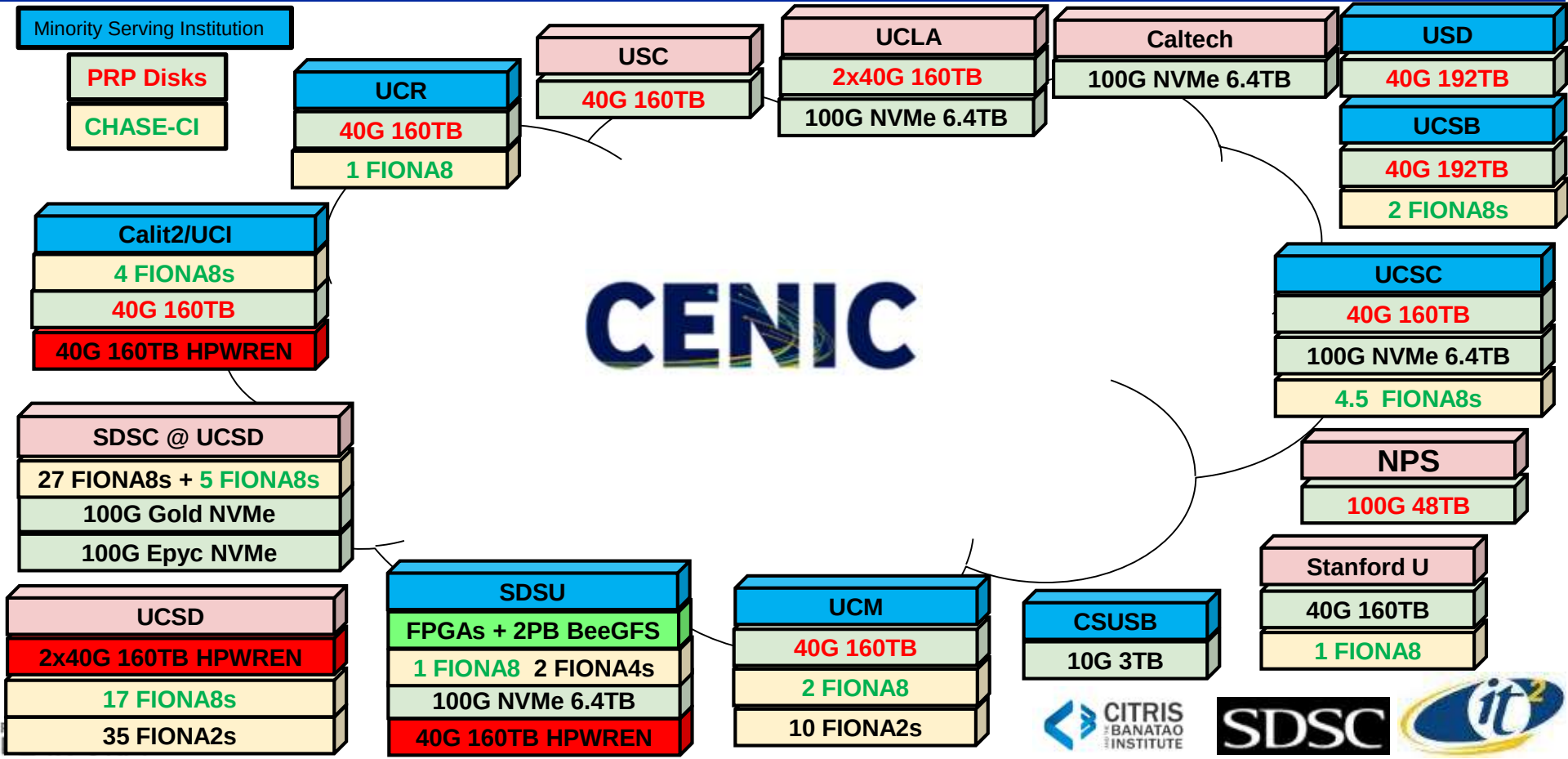
Nautilus

PRP PACIFIC RESEARCH PLATFORM

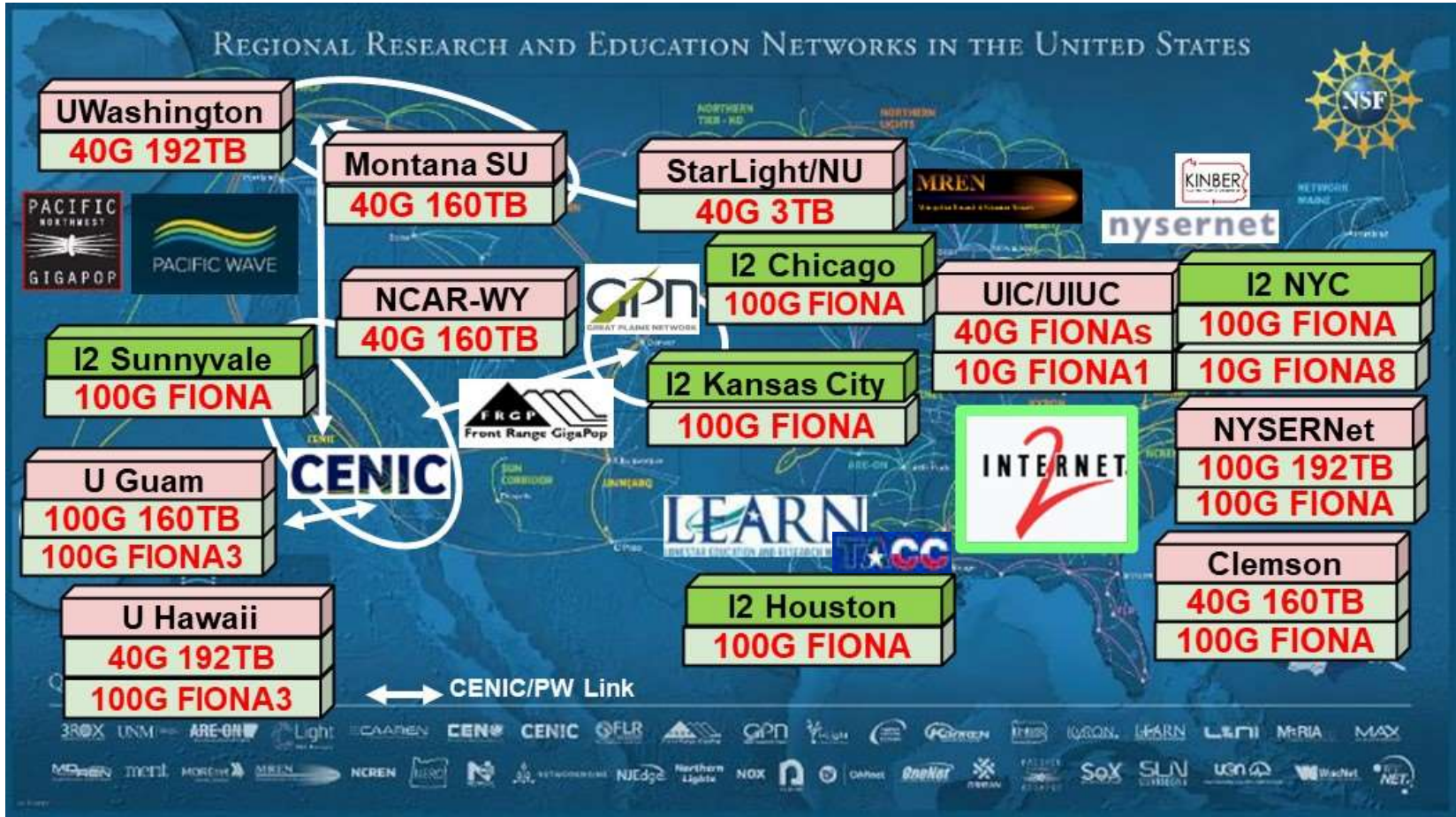
Source: grafana.nautilus.optiputer.net on 11/3/2020

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PRP's California Nautilus Hypercluster Connected by Use of CENIC's 100G Network



PRP/TNRP's United States (Outside California) Nautilus Hypercluster Now Connects 4 More Regionals and 5 Internet2 Sites



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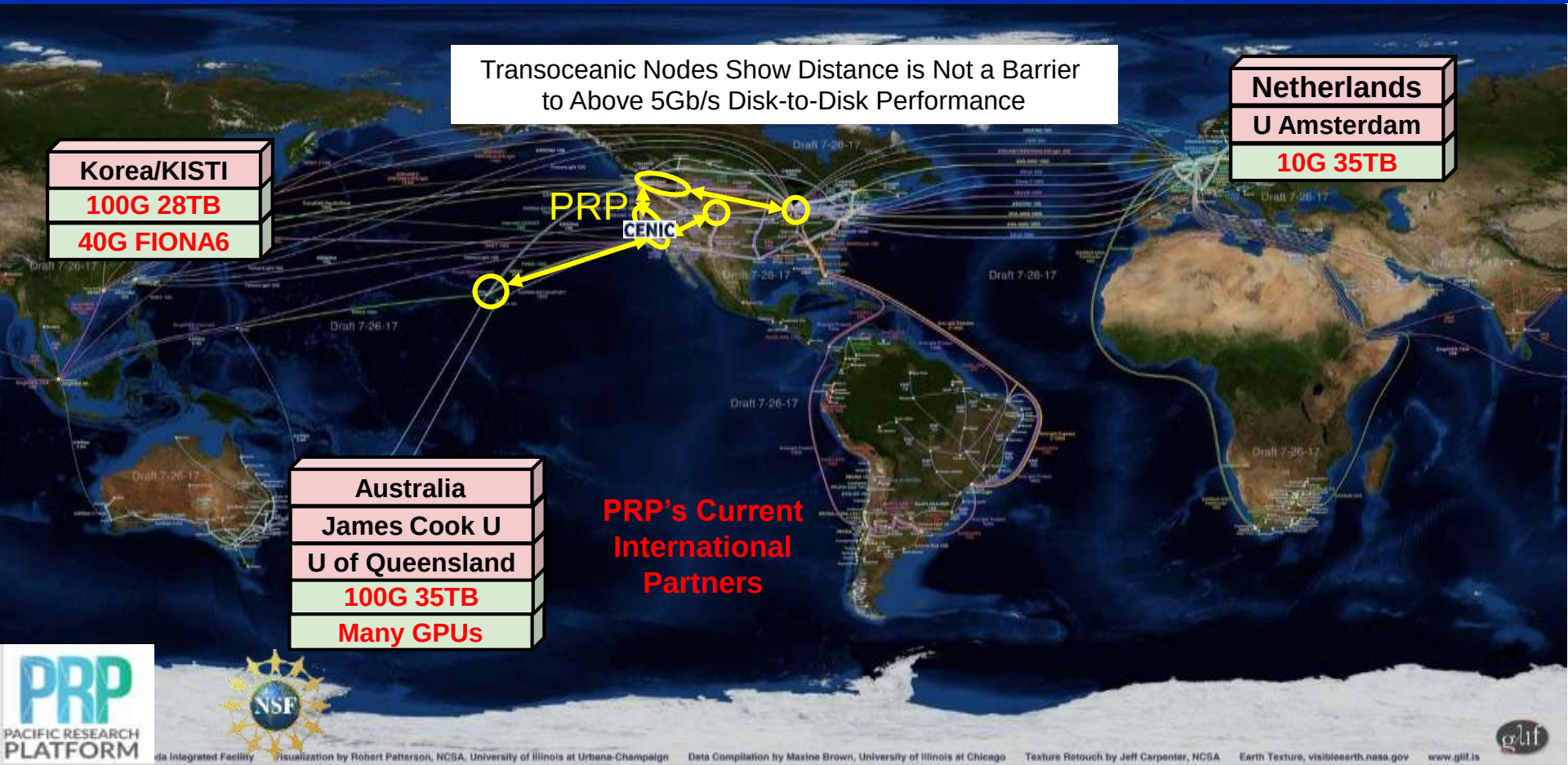
ESnet

CENIC

SDSC

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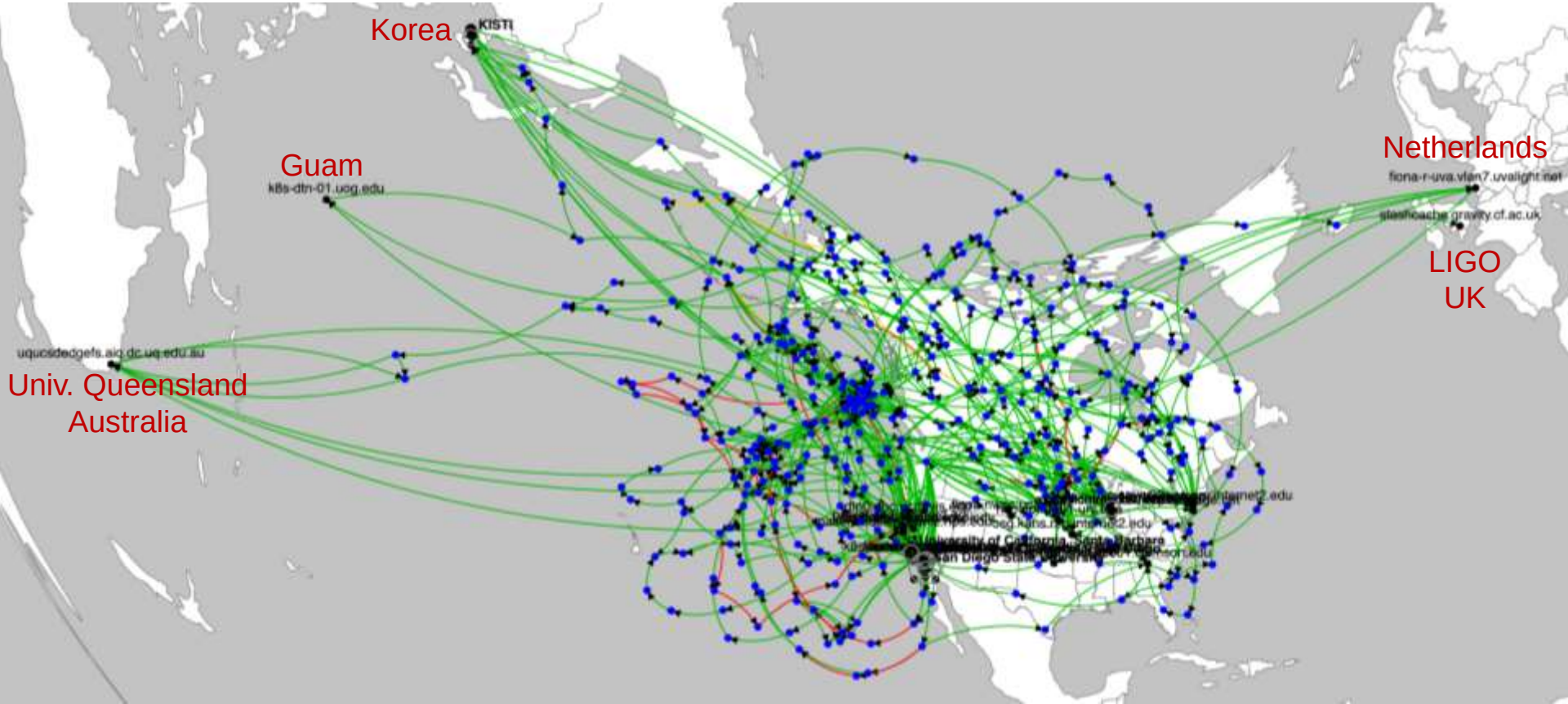
PRP's International Nautilus Hypercluster Is Adding International Partners Beyond Our Original Partner in Amsterdam



Operational Metrics: Containerized Trace Route Tool Allows Realtime Visualization of Status of PRP Network Links on a National and Global Scale

9/16/2019

Source: Dima Mishin, SDSC



Global Research Platform Workshops:
Designing for Global Collaborations of Data-Intensive Science



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2nd Global Research Platform Workshop
September 20-21, 2021, Innsbruck, Austria

PRP is Science-Driven:
Connecting Multi-Campus Application Teams and Devices



CMS

Particle Physics

Biomedical ‘omics

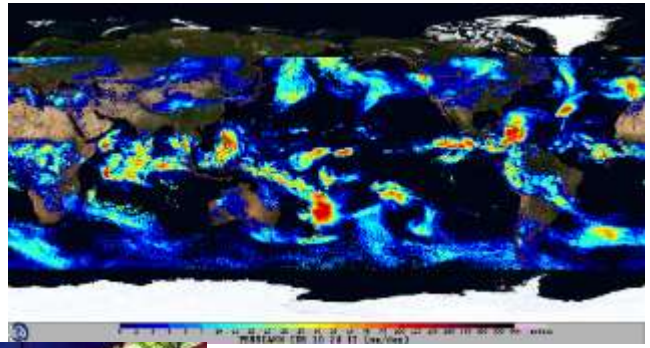


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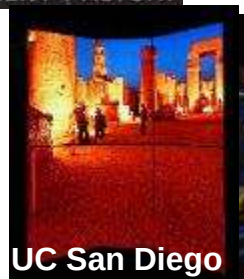


Telescope Surveys

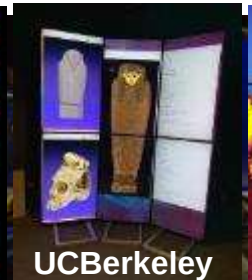
Earth Sciences



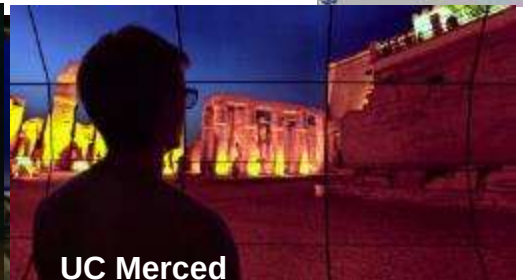
Visualization, Virtual Reality, Collaboration



UC San Diego



UCBerkeley



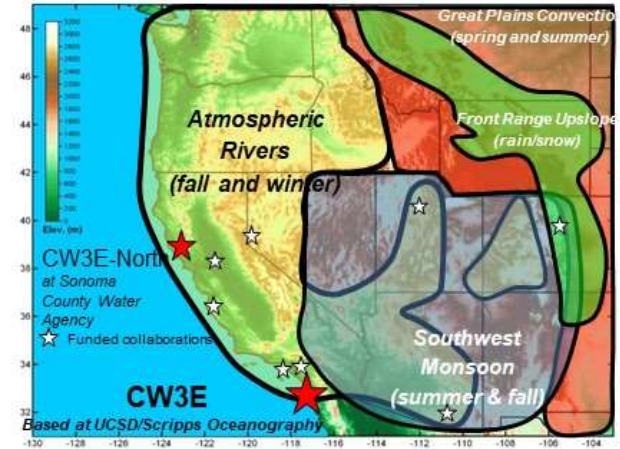
UC Merced

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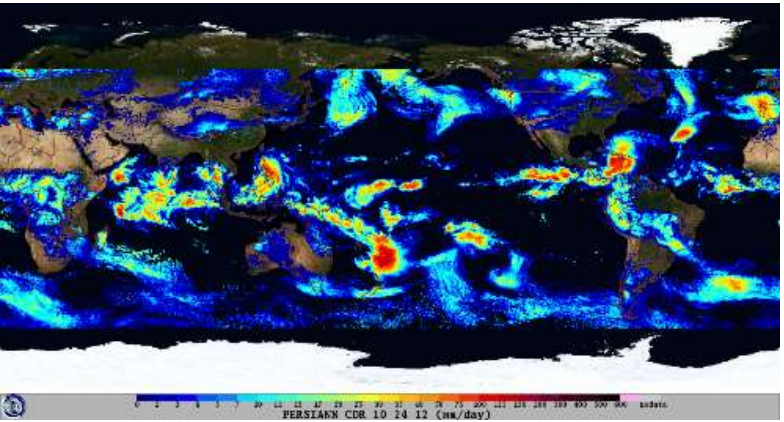
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PRP Accelerates Collaboration on *Atmospheric Water in the West* Between UC San Diego and UC Irvine



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

Big Data Collaboration with:

Center for Hydrometeorology & Remote Sensing
University of California, Irvine

Director, Soroosh Sorooshian, UCSD

Source: Scott Sellers, PhD CHRS; Postdoc CW3E

PRP Enabled Scott's Workflow to Run 532 Times Faster!

See Sellars, eScience 2019
https://ieeexplore.ieee.org/document/9041726

Pacific Research Platform (10-100 Gb/s)

Complete workflow time: 19.2 days→52 Minutes!

UC, Irvine

GPUs



Calit2's FIONA

SDSC's COMET



Source: Scott Sellers, CW3E

UC, San Diego

GPUs



Calit2's FIONA

The Open Science Grid (OSG) Has Been Integrated With the PRP

Source: Frank Würthwein,
OSG Exec Director; PRP co-PI; UCSD/SDSC

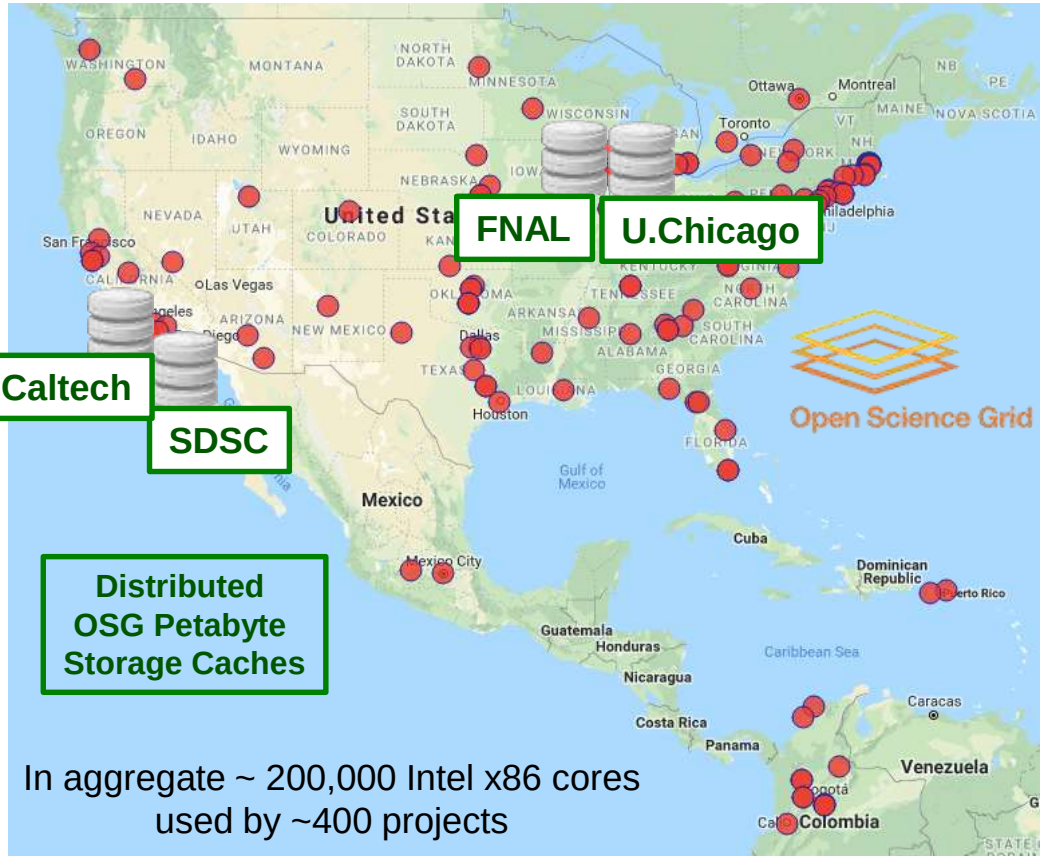
All OSG User Communities
Use HTCondor for Resource Orchestration

HTCondor
High Throughput Computing

NSF

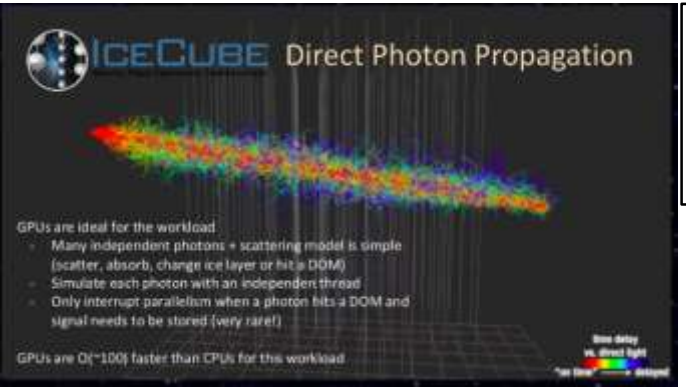
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OSG Federates ~100 Clusters Worldwide



NSF Large-Scale Observatories Are Using PRP and OSG as a Cohesive, Federated, National-Scale Research Data Infrastructure





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

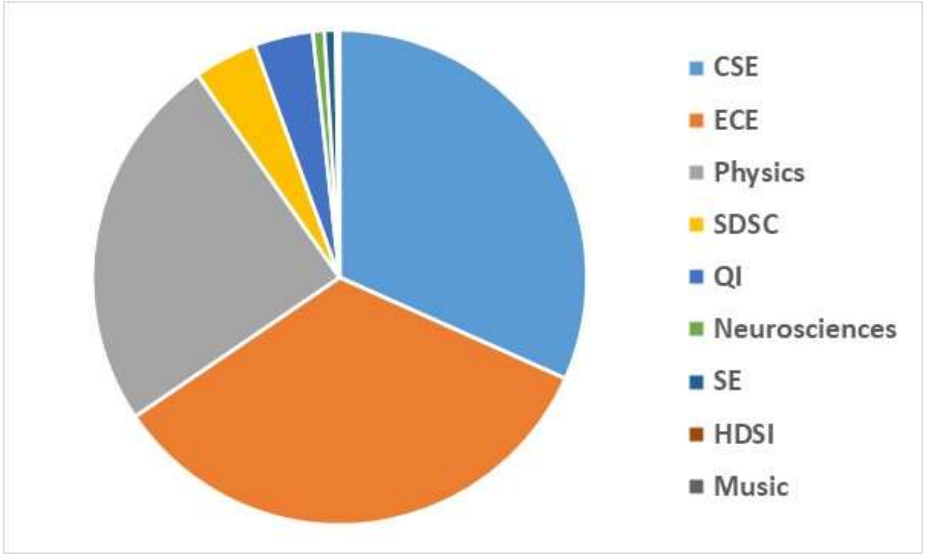


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NSF's IceCube & LIGO Both See Nautilus
as Just Another OSG Resource

PRP's Nautilus GPUs
Supports a Broad Set of Science and Machine Learning Applications

3,110,765 GPU-Hours



Total Usage is Equivalent to Running 355 GPUs 24/7 for 12 Months

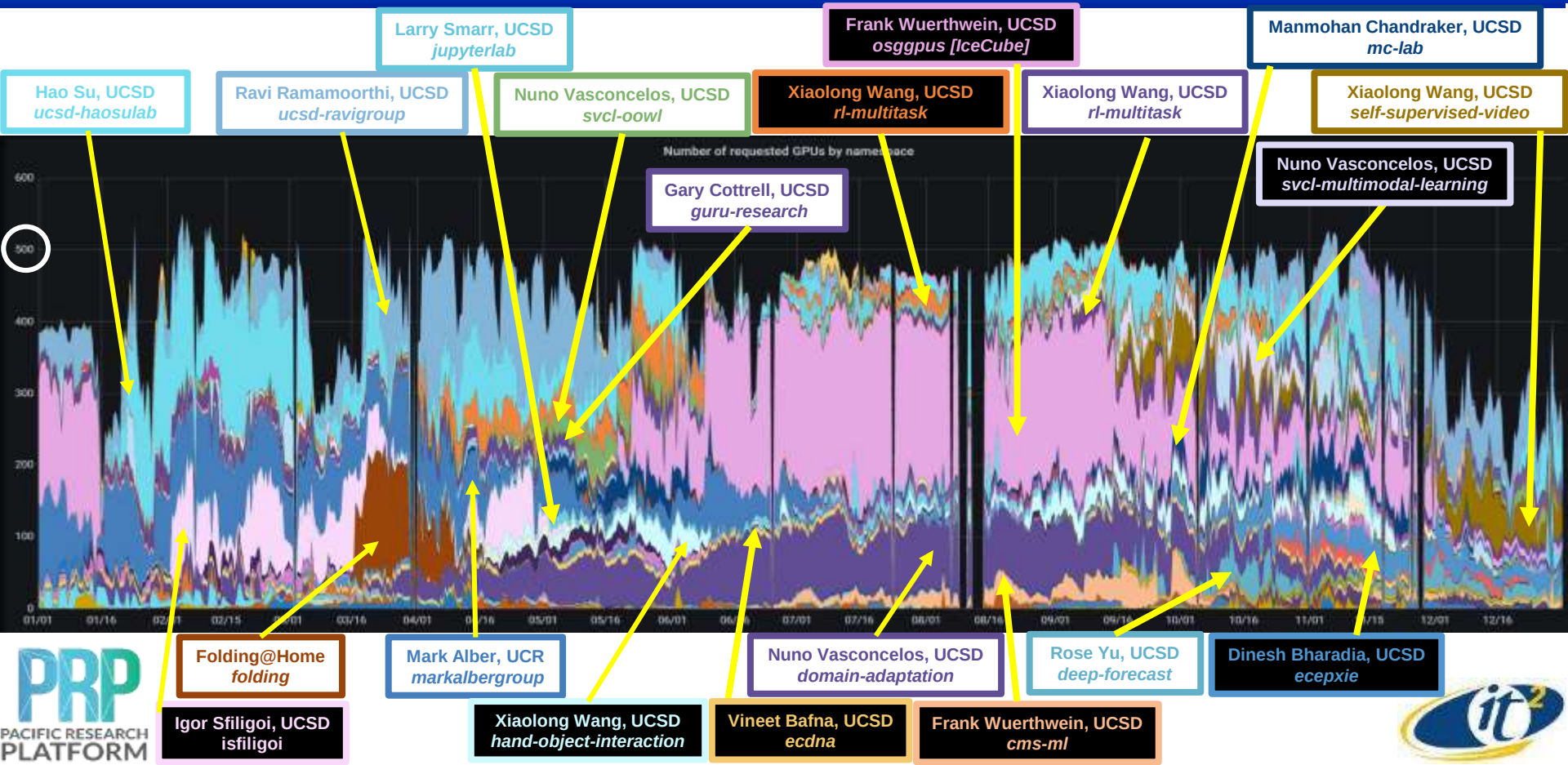
UC San Diego by Department in 2020

- Physics Usage is *Community* Data Analysis of NSF Major Facilities:
  - Large Hadron Collider
  - IceCube South Pole Neutrino Detector
  - LIGO Gravitational Wave Observatory
- SDSC and Qualcomm Institute Usage is *Community* Software Support
- CSE, ECE, SE, Neurosciences, & Music Department Usage - Individual Machine Learning Faculty Research Projects

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Top 20 Nautilus GPU Namespace Applications Used Nearly 500 GPUs in 2020



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2020-2025 NRP Future: SDSC's EXPANSE
Uses CHASE-CI Developed Composable Systems

EXPANSE

COMPUTING WITHOUT BOUNDARIES

5 PETAFLOP/S HPC and DATA RESOURCE

SDSC

XSEDE

NSF

HPC RESOURCE

13 Scalable Compute Units

728 Standard Compute Nodes

52 GPU Nodes: 208 GPUs

4 Large Memory Nodes

DATA CENTRIC ARCHITECTURE

12PB Perf. Storage: 140GB/s, 200k IOPS

Fast I/O Node-Local NVMe Storage

7PB Ceph Object Storage

High-Performance R&E Networking



~$20M over 5 Years
PI Mike Norman, SDSC

REMOTE CI INTEGRATION

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CLOUD

Open Science Grid

Heterogeneous Resources

LONG-TAIL SCIENCE

Multi-Messenger Astronomy

Genomics

Earth Science

Social Science

INNOVATIVE OPERATIONS

Composable Systems

High-Throughput Computing

Science Gateways

Interactive Computing

Containerized Computing

Cloud Bursting

PRP/TNRP/CHASE-CI Support and Community:

- US National Science Foundation (NSF) awards to UCSD, NU, and SDSC
  - CNS-1456638, CNS-1730158, ACI-1540112, ACI-1541349, & OAC-1826967
  - OAC 1450871 (NU) and OAC-1659169 (SDSU)
- UC Office of the President, Calit2 and Calit2's UCSD 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 & Wyoming Supercomputing Center, AWS, Google, Microsoft, Cisco

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