“National Federated Compute Platforms: The Pacific Research Platform”

NSF Virtual CC* PI Workshop

September 22, 2021

Dr. Larry Smarr

Founding Director Emeritus, California Institute for Telecommunications and Information Technology;

Distinguished Professor Emeritus, Dept. of Computer Science and Engineering

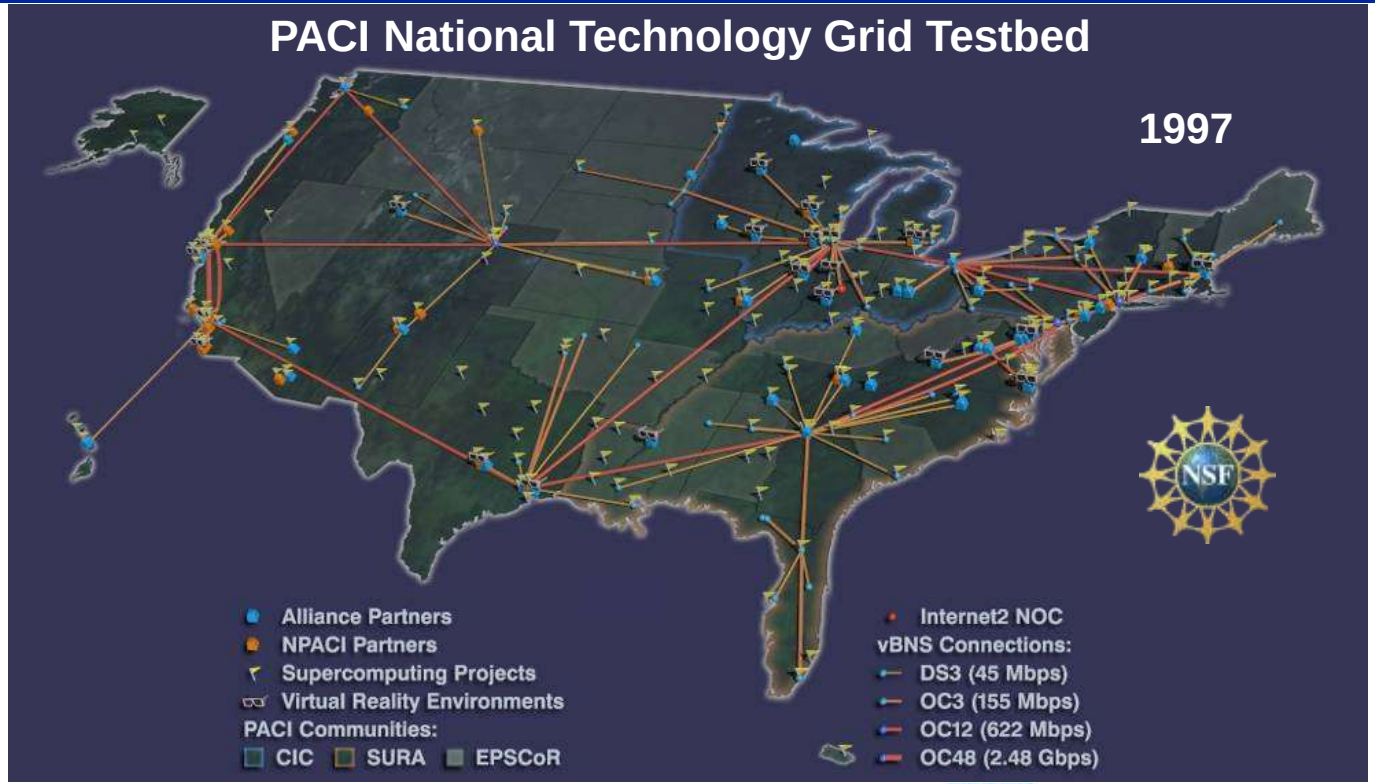
Jacobs School of Engineering, UCSD

http://lsmarr.calit2.net

PACIFIC RESEARCH PLATFORM

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

Key Role of Miron Livny & Condor



vBNS led to

INTERNET2

PRP PACIFIC RESEARCH PLATFORM

NPACI

National Computational Science ALLIANCE

The 25 Years From the National Techology Grid To the National Research Platform

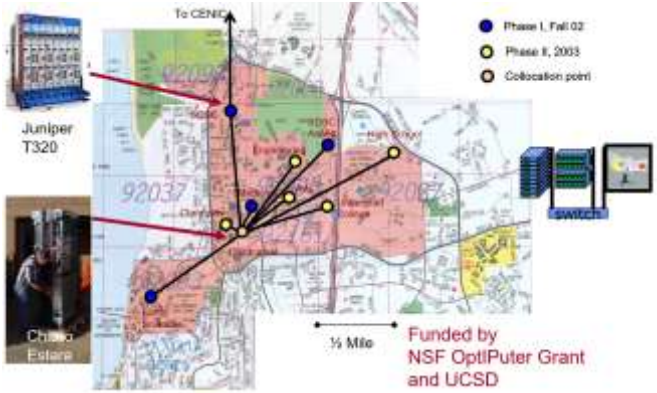
The goal is a powerful, persistent, distributed U.S. national resource as usable in the future as the NSF Supercomputer Center standalone machines were in the 1980s and 1990s.

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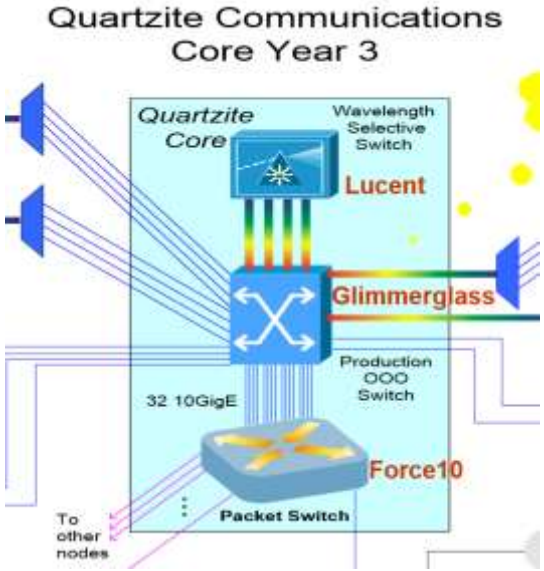
From ***I-WAY to the National Technology Grid***, CACM, 40, 51 (1997)
Rick Stevens, Paul Woodward, Tom DeFanti, and Charlie Catlett

PRP Was Built on 15 Years of NSF Awards: OptIPuter, Quartzite, & Prism

Precursors to DOE Defining DMZ in 2010



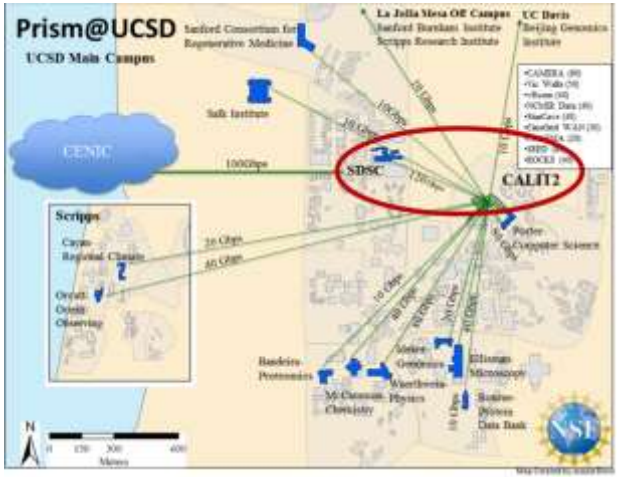
PI Smarr, 2002-2009



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

PI Papadopoulos, 2004-2007

Led to NSF CC* Award in 2013



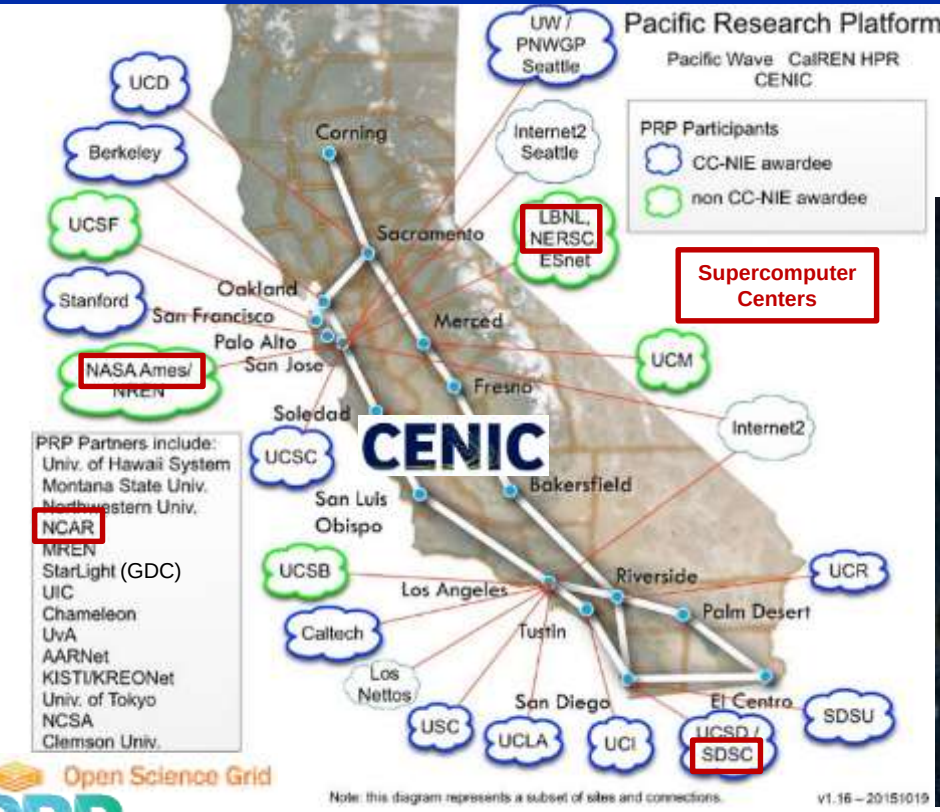
PI Papadopoulos, 2013-2015

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SDSC

20 YEARS QUALCOMM INSTITUTE

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



NSF CC*DNI Grant
$6.3M 10/2015-10/2020
In Year 6 Now, Year 7 is Funded



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CITRIS BANATAO INSTITUTE

SDSC

it²

Source: John Hess, CENIC

2015-2021: UCSD Designs PRP Data Transfer Nodes (DTNs) -- Flash I/O Network Appliances (FIONAs)

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

FIONA

(Flash Input/Output Network Appliance) FIONAs are rack-mounted PCs designed by our PRP team. They are Science DMZ Data Transfer Nodes (DTNs), optimized for 10-100Gbps data transfers and large data storage, and are also capable of holding up to eight GPUs or FPGA add-in boards or up to 256TB of disk each.

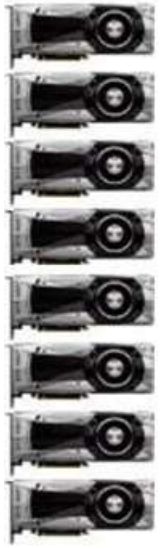
Software Specifications

Installation Instructions

Hardware Specifications

2021 – 2020 – 2019 – 2018 – 2017 – 2016 – 2015

www.pacificresearchplatform.org





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

Up to 192 TB Rotating Storage

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

PRP's Nautilus is a Multi-Institution Hypercluster Connected by Optical Networks

Nautilus

180 FIONAs on 25 Partner Campuses Networked Together at 10-100Gbps

Installed CPUs	Installed GPUs	Rotating Storage
7478	516	4000 TB

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CENIC

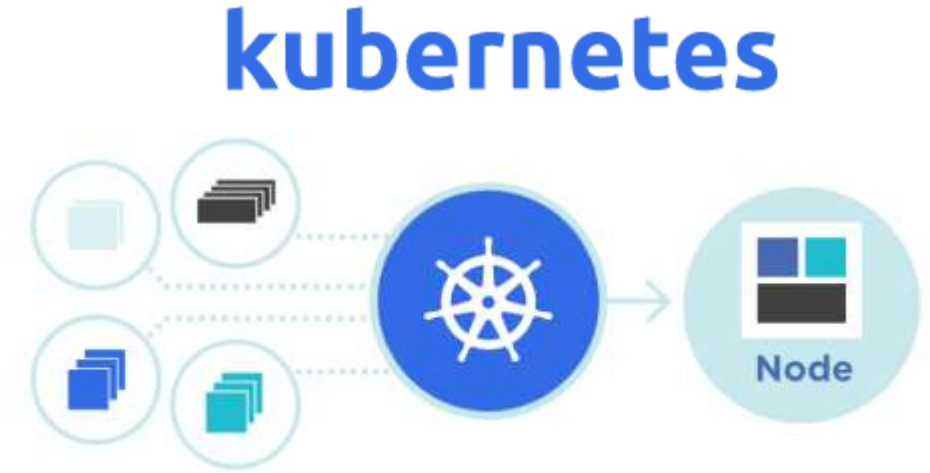
THE QUILT

INTERNET2

20 YEARS QUALCOMM INSTITUTE

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

User Applications



Containers

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Clouds

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CLOUD NATIVE COMPUTING FOUNDATION

PRP's *Nautilus Hypercluster* Adopted Kubernetes to Orchestrate Software Containers and Rook, Which Runs Inside of Kubernetes, to Manage Distributed Storage



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.

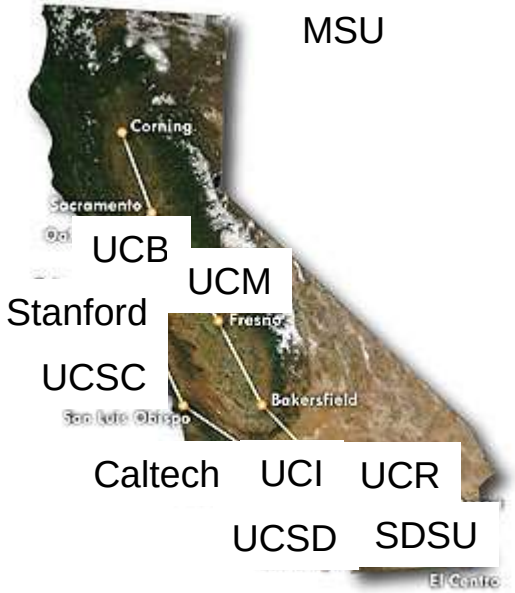
"Kubernetes with Rook/Ceph Allows Us to Manage Petabytes of Distributed Storage and GPUs for Data Science,
While We Measure and Monitor Network Use."
--John Graham, Calit2/QI UC San Diego

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Nautilus

20 YEARS QUALCOMM INSTITUTE

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



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

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

NSF Just Funded Two Extensions:
CHASE-CI ABR and ENS

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

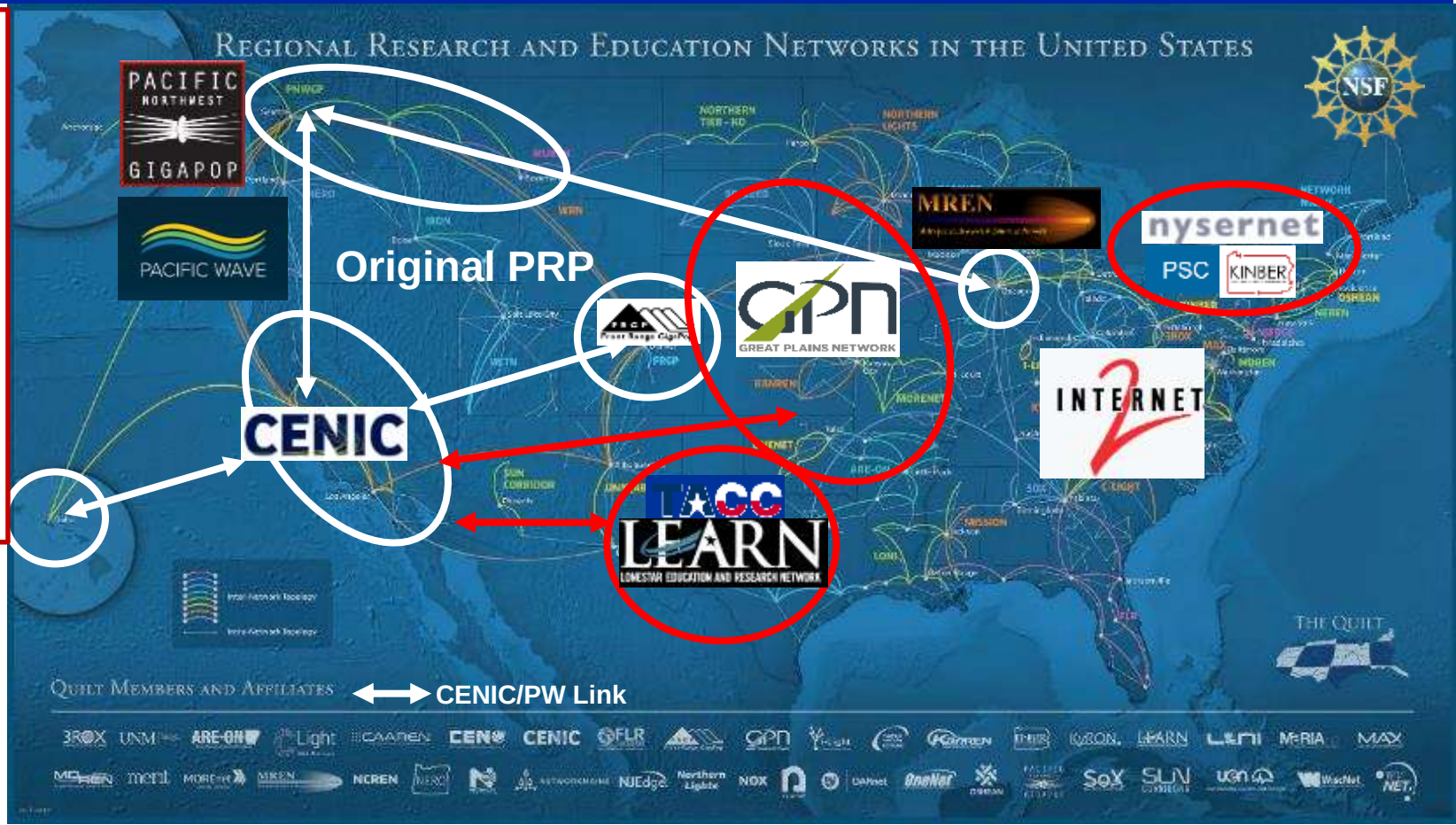
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SDSC UC San Diego it²

2018-2021: Toward the National Research Platform (TNRP) - Using CENIC & Internet2 to Connect Quilt Regional R&E Networks

"Towards The NRP"
3-Year Grant Funded by NSF
$2.5M
October 2018
Award #1826967

PI Smarr
Co-PIs Altintas
Papadopoulos
Wuerthwein
Rosing
DeFanti



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The PRP Web Site Has Detailed Information On How to Join PRP's Nautilus

START | TUTORIAL | RUNNING | STORAGE | DEVELOPMENT | BACK TO NAUTILUS | BACK TO PRP

Get access
Quick Start
Policies
Available Resources
FAQ
Contact

Where to start

www.pacificresearchplatform.org

- **Start** - how to get access to the cluster and intros
  - Get access: Getting authenticated in the cluster
  - Quick start: Basic info, links to external tutorials
  - Policies: **VERY IMPORTANT** section! Please read to avoid issues running in the cluster
  - Available resources: Additional resources you can get in the cluster
- **Tutorials** - step-by-step tutorials for working with the cluster
  - Docker: Using docker locally, finding and building containers
  - Basic kubernetes: Exrloding the system, running simple pods
  - Scaling and exposing: Scaling, load balancing, exposing services to outside
  - Scheduling: Scheduling and requesting resources
  - Batch jobs: Running batch jobs
  - Images: How to choose the right container image or build your own
  - Storage: Using persistent storage in the cluster
- **Running**: running various kinds of jobs in the cluster efficiently
  - Jupyter&Tensorflow2 example: A comprehensive example on how to run the image we provide, containing most popular python libraries for ML
  - Running batch jobs
  - Dealing with high I/O

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The New Pacific Research Platform Video Highlights 3 Different Applications



Pacific Research Platform Video:
www.thequilt.net/campus-cyberinfrastructure-program-resource/
www.pacificresearchplatform.org

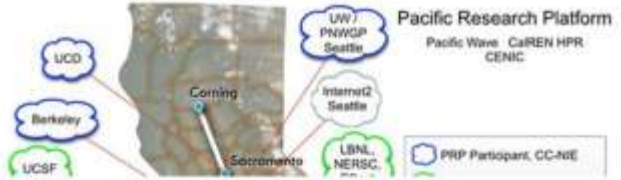
Federating PRP With the Open Science Grid (OSG) Brings OSG Software and Services to a Regional-Scale DMZ

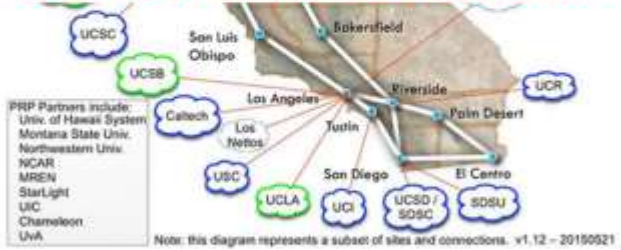
Open Science Grid

Adding

OSG Software & Services + **Pacific Research Platform as a regional science DMZ**

on top of a regional science DMZ





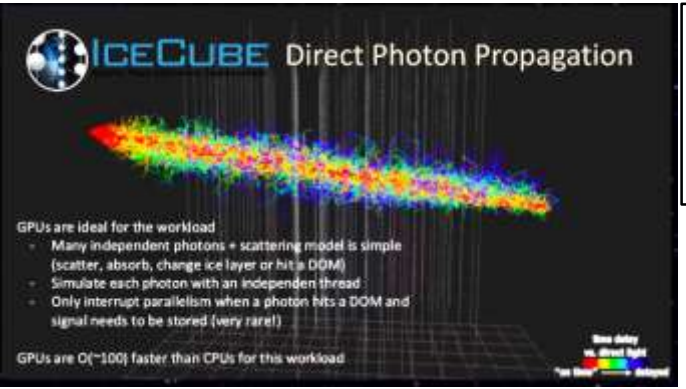
Collaboration of OSG with Calit2, CITRIS, and SDSC

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Source: Frank Würthwein, OSG, UCSD/SDSC, PRP

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

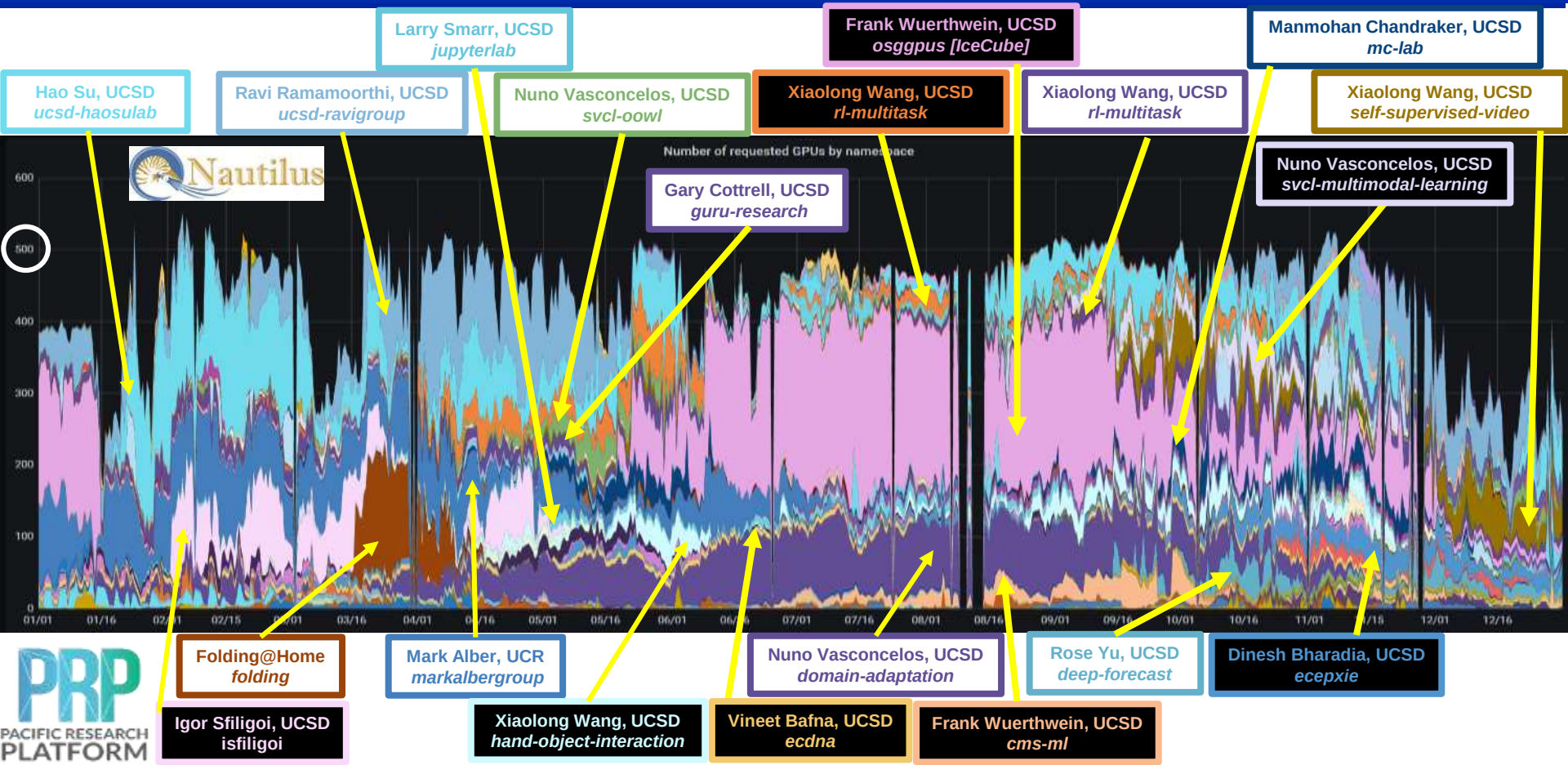
WISCONSIN
WIPAC
Wisconsin IceCube Particle Astrophysics Center
NSF

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

Open Science Grid

Top 20 GPU Users Out of 400 Nautilus Namespace Applications: Together They Consumed Nearly 500 GPUs in 2020



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Community Building
Through Large-Scale Workshops









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2nd Global Research Platform (2GRP) Workshop
September 20-24, 2021

Community Building Though Inclusion and Diversity: Workshops With Minority Serving Universities

2NRP Montana State University







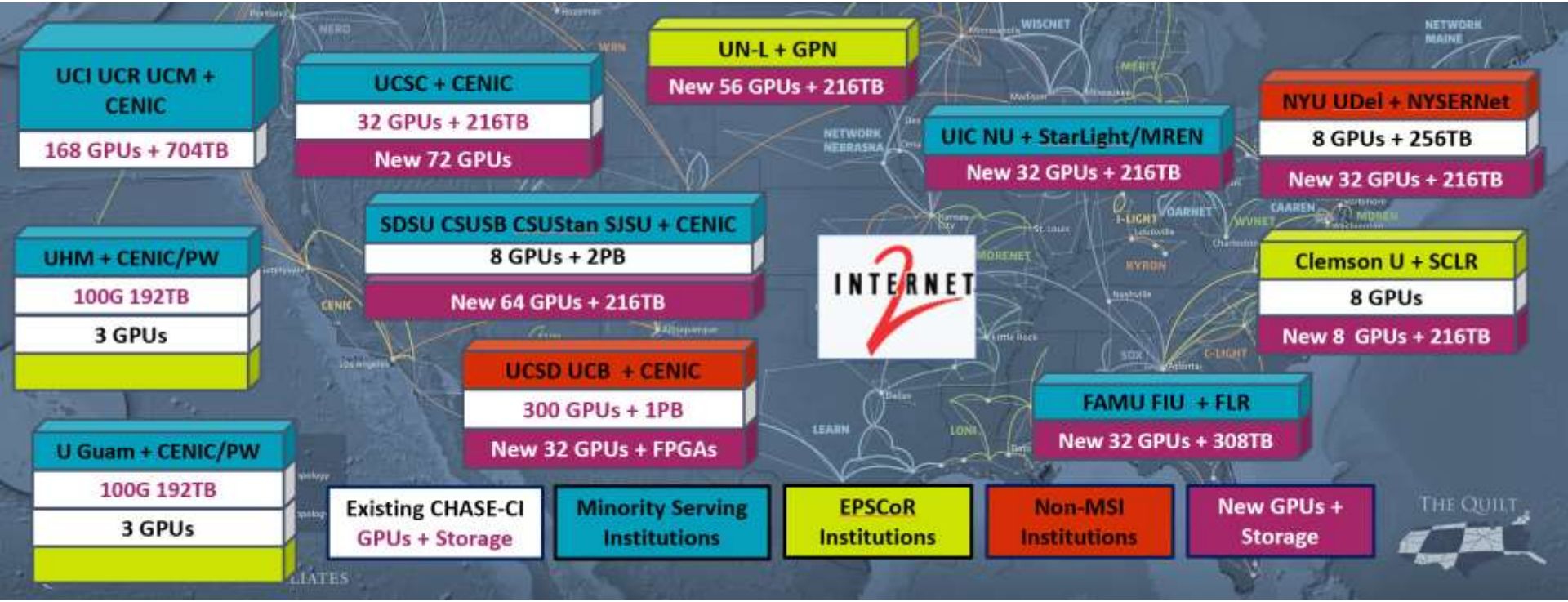
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The Next Three Phases
As We Approach a National Research Platform

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2021-2024 NRP Future I: *Proposed* Extension of Nautilus



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CHASE-CI ENS, Tom DeFanti PI (NSF Award # 2120019)
CHASE-CI ABR, Larry Smarr PI (NSF Award # 2100237)
$2.8M

20 YEARS QUALCOMM INSTITUTE

2021-2026 NRP Future II: PRP Federates with SDSC's EXPANSE Using CHASE-CI Developed Composable Systems

EXPANSE

COMPUTING WITHOUT BOUNDARIES
5 PETAFLOP/S HPC and DATA RESOURCE

SDSC

XSEDE

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

PRP PACIFIC RESEARCH PLATFORM

CLOUD

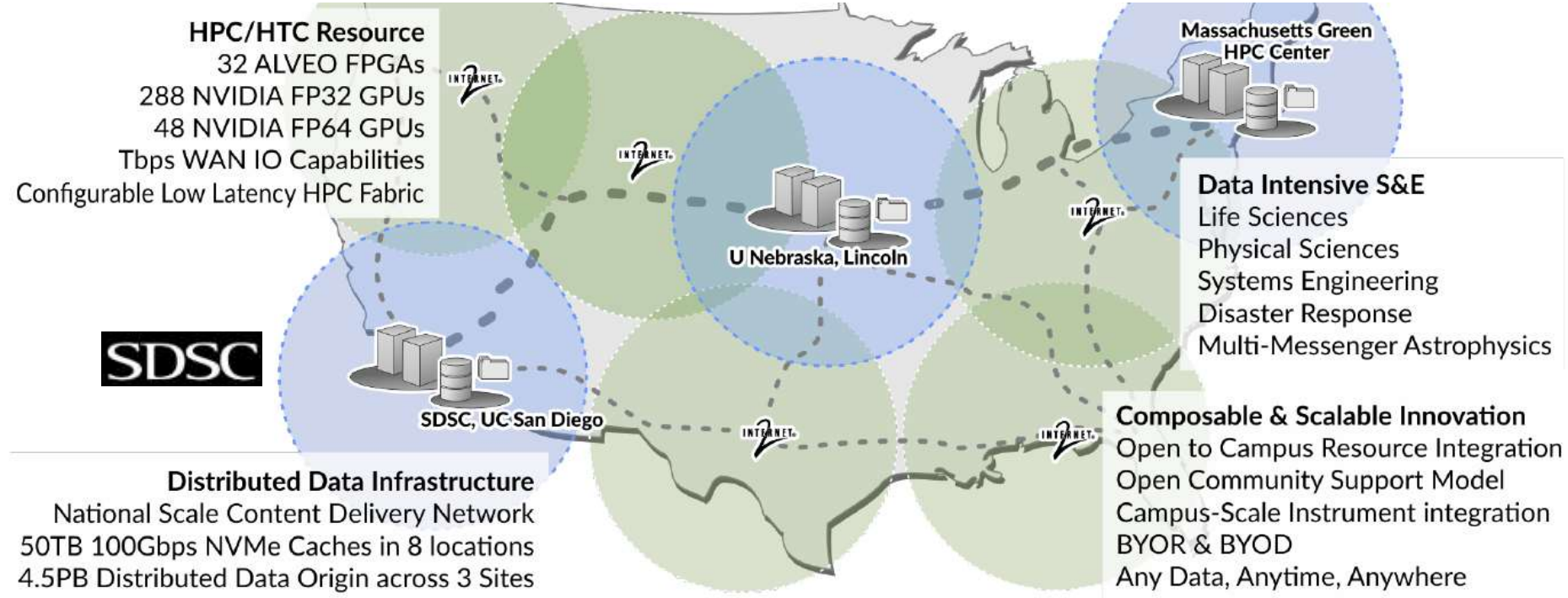
Open Science Grid

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

2021-2026 NRP Future III: PRP Federates with NSF-Funded *Prototype National Research Platform*



PRP PACIFIC RESEARCH PLATFORM

NSF Award OAC #2112167 (June 2021) [$5M Over 5 Years]
PI Frank Wuerthwein (UCSD, SDSC)
Co-PIs Tajana Rosing (UCSD), Thomas DeFanti (UCSD), Mahidhar Tatineni (SDSC), Derek Weitzel (UNL)

PRP's Support and Community:



- National Science Foundation (NSF) awards to UCSD:
  - CNS (1456638, 1730158, 2120019, 2100237) OAC (1540112, 1541349, 1826967, 2112167)
- UCSD; Calit2/Qualcomm Institute; and UCSD's Research IT and Instructional IT
- UCB CITRIS and the Banatao Institute
- UC Office of the President
- Partner Campuses: UCSC, UCI, UCR, UCLA, UCD, UCM, UCSB, USC, Caltech, Stanford, NU, UW, UChicago, UIC, UIUC, UHM, UWM, IU, NPS, CSUSB, CSUS, SDSU, SJSU, UMC, UM, MSU, NYU, UNL, UNM, UNC, UTA, WSU, FAMU, FIU, Clemson, UD, UG, UU, JCU, KISTI, UVA, AIST, NTU, UQ, UTokyo
- Computing Partners: San Diego Supercomputer Center, LBNL/NERSC, NCAR/UCAR & Wyoming Supercomputing Center, NASA NAS/USRA, Texas Advanced Computing Center, NSCC, Open Science Grid, Chameleon Cloud, SLATE, AWS, Google Cloud, Microsoft
- Network Partners: CENIC, Pacific Wave/PNWGP, FRGP, StarLight/MREN, HPWREN, The Quilt, Great Plains Network, KINBER, LEARN, NYSERNet, OARnet, FLR, Internet2, DOE Esnet, AMPATH, AARNet, CESnet, KREOnet, PIREN, SURFnet, SCLR, SingAREN

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