"The Rise of Supernetwork Data Intensive Computing"

Invited Remote Lecture to SC21

The International Conference for High Performance Computing, Networking, Storage, and Analysis

St. Louis, Missouri

November 18, 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

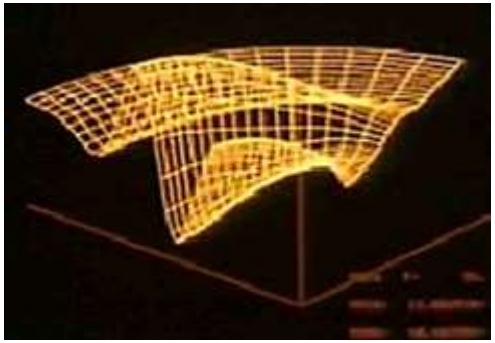
PACIFIC RESEARCH PLATFORM

Abstract

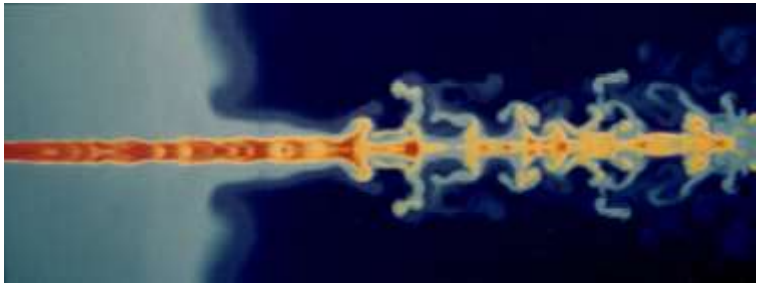
Over the last 35 years, a fundamental architectural transformation in high performance data-intensive computing has occurred, driven by the rise of optical fiber Supernetworks connecting the globe. Ironically, this cyberinfrastructure revolution has been led by supercomputer centers, which then became SuperNodes in this distributed system. I will review key moments, including the birth of the NSF Supercomputer Centers and NSFnet, the gigabit testbeds, the NSF PACI program, the emergence of Internet2 and the Regional Optical Networks, all eventually enabling, through a series of NSF grants, the National and Global Research Platforms. Over this same period a similar cyberinfrastructure architecture allowed the commercial clouds to develop, which are now interconnected with this academic distributed system. Critical to this transformation has been the continual exponential rise of data and a new generation of distributed applications utilizing this connected digital fabric. Throughout this period, the role of the US Federal Government has been essential, anchored by the 1991 High-Performance Computing Act, which established the Networking and Information Technology Research and Development (NITRD) Program. Particularly important to the initiation of this distributed computing paradigm shift was the continued visionary leadership of Representative, then Senator, then Vice President Al Gore in the 1990s.

PRP
PACIFIC RESEARCH PLATFORM

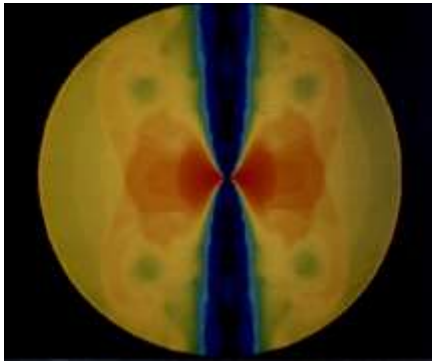
1975-1985: My Early Research was on Computational Astrophysics Before There Were National Academic Supercomputer Centers



Gravitational Radiation From Black Hole Collisions
With Eppley
1978



Cosmic Jets Emerging From Galactic Centers
With Norman and Winkler
1981



Gas Accretion Onto a Black Hole
With Wilson and Hawley
1982







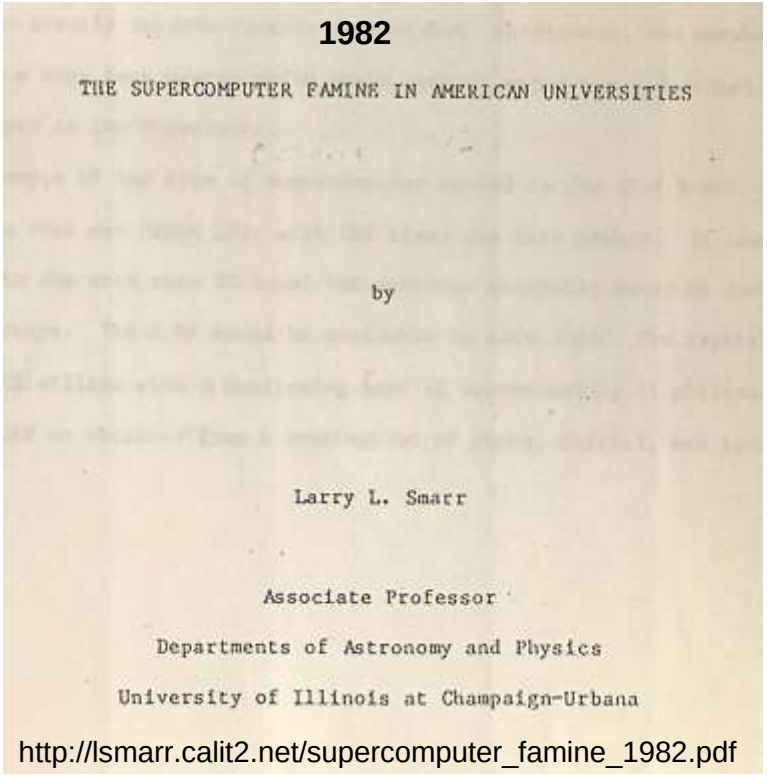


PACIFIC RESEARCH PLATFORM

I Spent a Decade Supercomputing at LLNL (with Jim Wilson) and Then at The Max Planck Institute for Physics and Astrophysics (with Mike Norman and Karl-Heinz Winkler)

1982-1983: Documenting The Unmet Supercomputing Needs of a Broad Range of Disciplines Led to the NCSA Proposal to NSF

1982



THE SUPERCOMPUTER FAMINE IN AMERICAN UNIVERSITIES

by

Larry L. Smarr

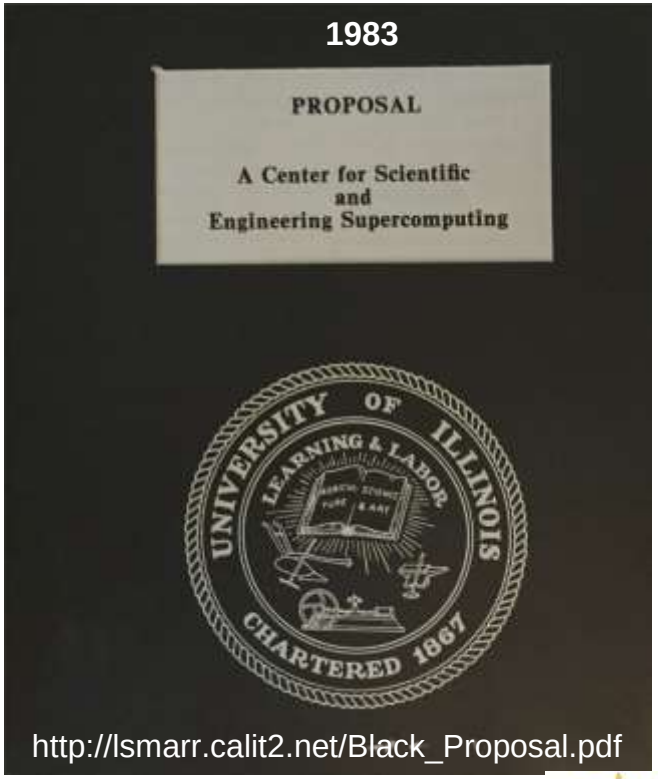
Associate Professor

Departments of Astronomy and Physics

University of Illinois at Champaign-Urbana

http://lsmarr.calit2.net/supercomputer_famine_1982.pdf

1983



http://lsmarr.calit2.net/Black_Proposal.pdf

1984: NSF Creates Office of Advanced Scientific Computing (John Connolly, Director)
Issues National Competition for Supercomputer Centers

PACIFIC RESEARCH PLATFORM

NSF

1985: NSF Adopted a DOE High-Performance Computing Model For Two of the New NSF Supercomputer Centers

1985







NCSA Was Modeled on LLNL

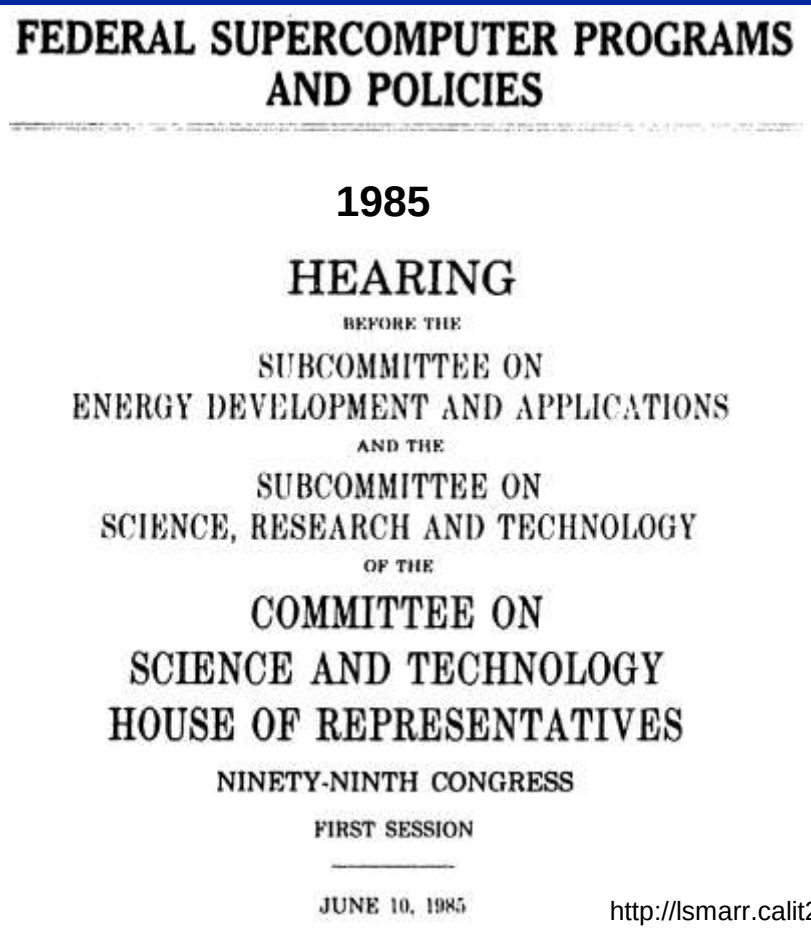
SDSC Was Modeled on MFEnet

PRP PACIFIC RESEARCH PLATFORM

NCSA

SDSC

SuperNetworks Have Co-Evolved with Supercomputers For 35 Years



FEDERAL SUPERCOMPUTER PROGRAMS AND POLICIES

1985

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY DEVELOPMENT AND APPLICATIONS

AND THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

JUNE 10, 1985

"We ought to consider
a national initiative
to build interstate highways
for information
with a fiber optics network
connecting the
major computational centers
in this country"

-Senator Al Gore

"The University of Illinois
will be experimenting with
fiber optic
"information flow pipes,"
which promise to be able
to reach
billions of bits per second.""

-NCSA Director
Larry Smarr

PACIFIC RESEARCH PLATFORM

http://lsmarr.calit2.net/hrg-1985-tec-0068_from_1_to_806_s.pdf

Remote Interactive Visual 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 computers."
— Larry Smarr, Director, NCSA

SIGGRAPH 1989



Cray 2 Driven by Sun Workstation



www.youtube.com/watch?v=C3d_6lw8_0M



"We're using satellite technology… to demonstrate 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

PRP PACIFIC RESEARCH PLATFORM

AT&T & Sun

NCSA

1991: Networking Information Technology Research and Development (NITRD)

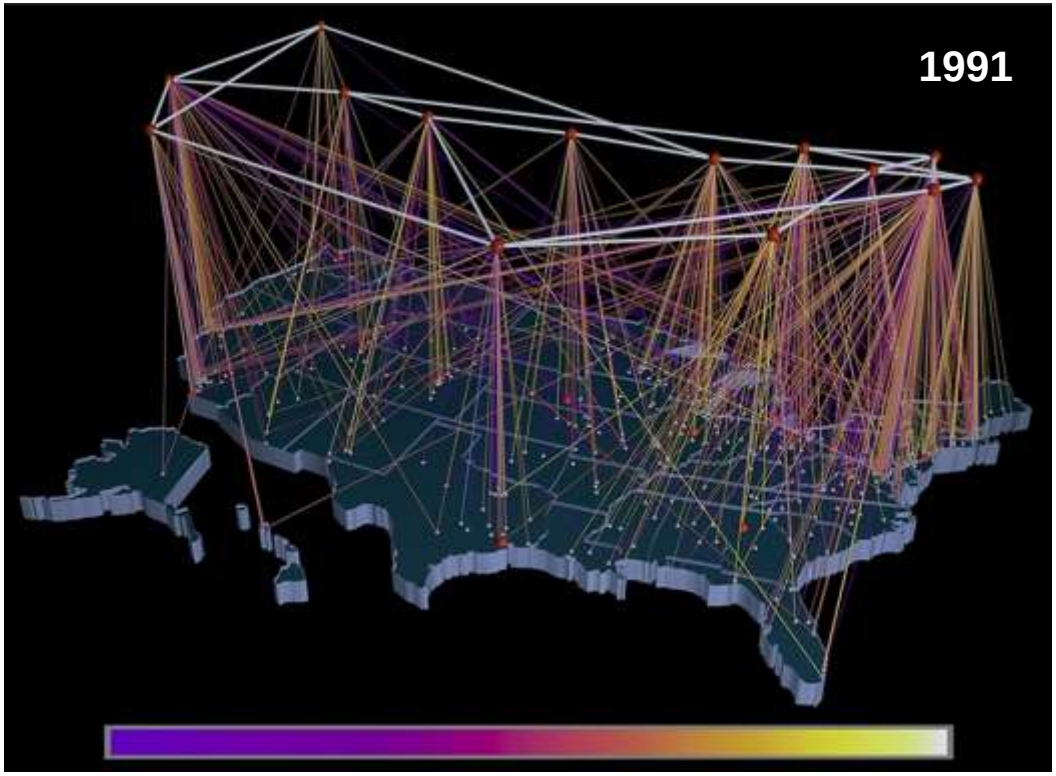
- **NITRID Was Enacted in 1991 by Congress Through the High-Performance Computing and Communication Act**
- **Brought Multiple Federal Agencies Together to Plan and Coordinate Frontier Computing, Networking, Software, and Data**
- **Bill Was Sponsored and Driven by Senator Al Gore**



December 2, 2021

PACIFIC RESEARCH PLATFORM

The Bandwidth and Number of Endpoints on NSFNET Grew Rapidly

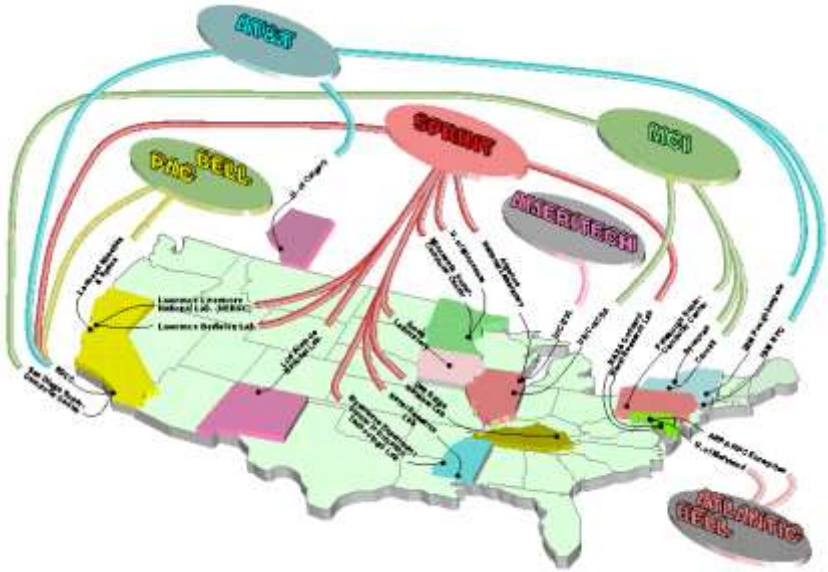


Visualization of Inbound Traffic on the NSFNET T1 Backbone (September 1991) by NCSA's Donna Cox and Robert Patterson; Data Collected by Merit Network, Inc.

PACIFIC RESEARCH PLATFORM

Supercomputing ’95:
I-WAY: A Model for Distributed Collaborative Computing

- **The First National 155 Mbps Research Network**
  - **Inter-Connected Telco Networks Via IP/ATM With:**
    - **Supercomputer Centers**
    - **Virtual Reality Research Locations, and**
    - **Applications Development Sites**
  - **Into the San Diego Convention Center**
  - **65 Science Projects**
- **I-Way Featured:**
  - **Networked Visualization Applications**
  - **Large-Scale Immersive Displays**
  - **I-Soft Programming Environment**
    - **Led to the Globus Project**



For details see:
“Overview of the I-WAY: Wide Area Visual Supercomputing”
DeFanti, Foster, Papka, Stevens, Kuhfuss
www.globus.org/sites/default/files/iway_overview.pdf

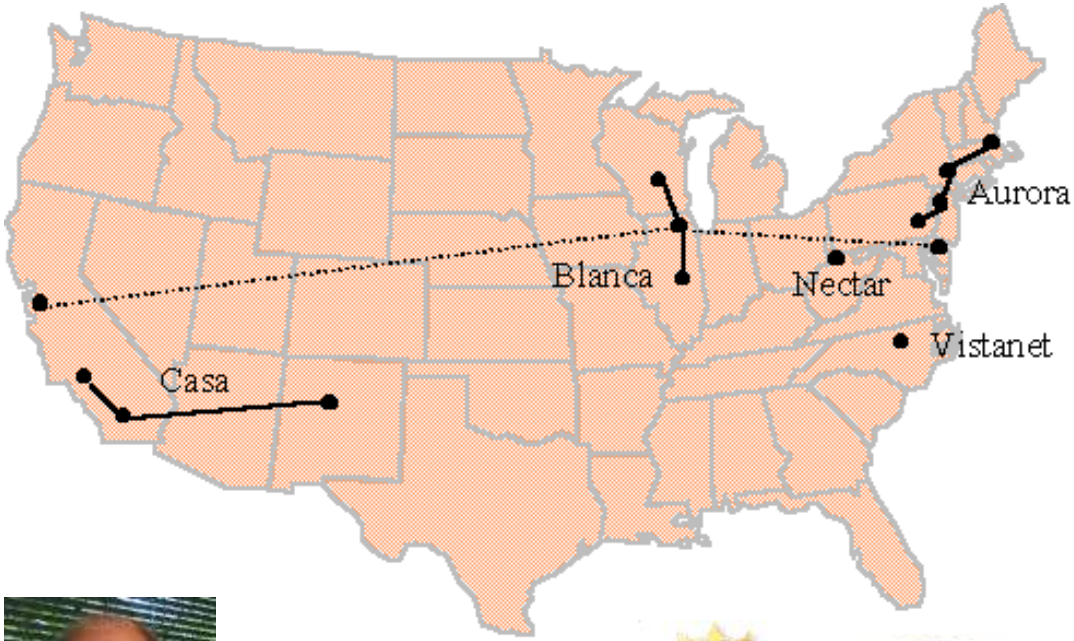
SC95 Chair Sid Karin
SC95 Program Chair, Larry Smarr

PRP PACIFIC RESEARCH PLATFORM

1990-1996 CNRI's Gigabit Testbeds
Demonstrated Host I/O Was the Distributed Computing Bottleneck

"Host I/O proved to be
the Achilles' heel
of gigabit networking –
whereas LAN and WAN technologies were
operated in the gigabit regime, many
obstacles impeded
achieving gigabit flows
into and out of
the host computers
used in the testbeds."

--Final Report
The Gigabit Testbed Initiative
December 1996
Corporation for
National Research Initiatives (CNRI)



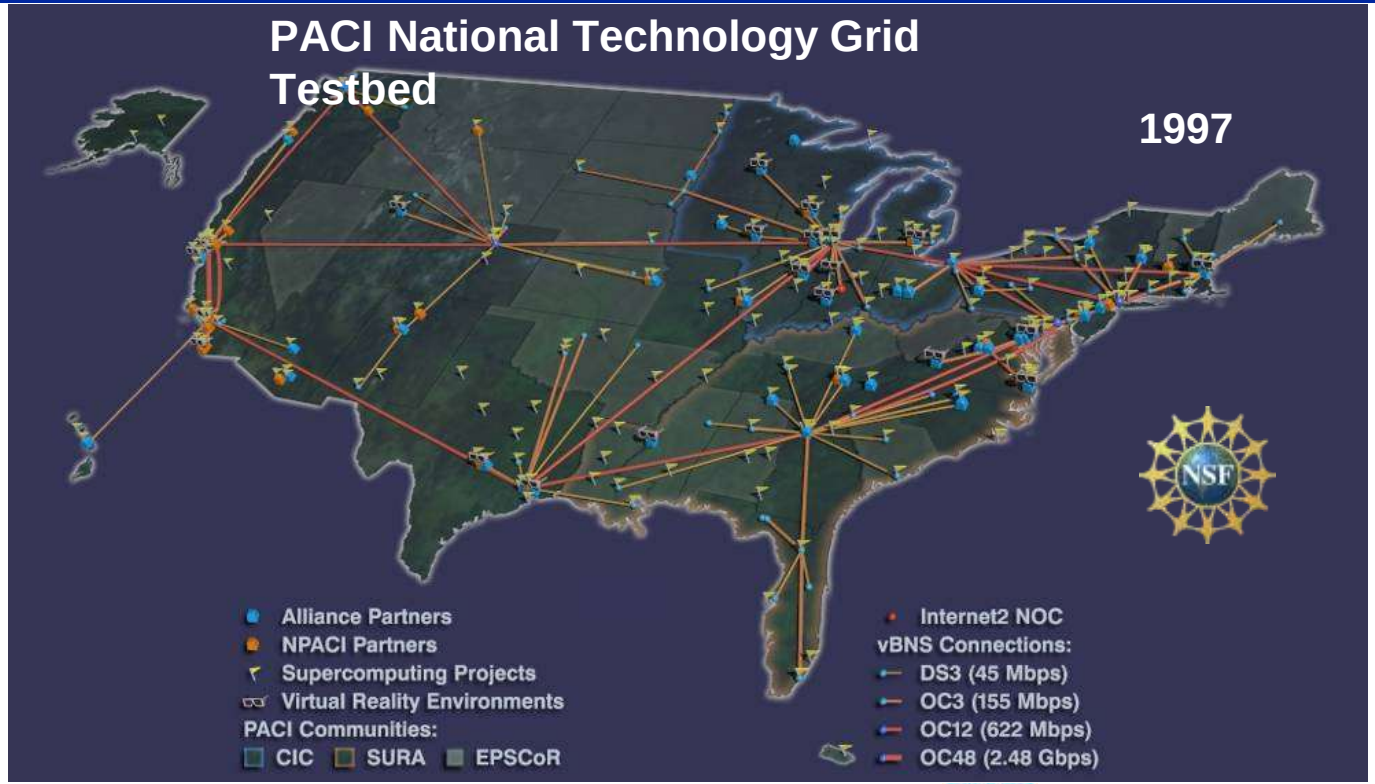


Robert Kahn
CNRI Chairman, CEO & President

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.

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

Dave Bader Created the First Linux COTS Supercluster -*Roadrunner*- on the National Technology Grid, with the Support of NCSA and NSF



ALBUQUERQUE JOURNAL

YOUTH CRIME
Bill would fund state programs that crack down on juvenile offenders
• D3

Metro & New Mexico

THURSDAY, APRIL 8, 1999

BUSINESS • 2
WEATHER • 8
DEATHS • 8

SECTION D

UNM To Crank Up $400,000 Supercomputer Today

Machine One of 100 Speediest in World

By John Fleck
Journal Staff Writer

A cluster of computers looking like a stack of oversized dorm room refrigerators is about to plug the University of New Mexico into an ambitious new supercomputer "mega-brain" spanning the nation.

Dignitaries from around the country will gather at UNM's Albuquerque High Performance Computing Center today to throw the switch on the "Roadrunner Supercluster."

Fresh out of the box, the Roadrunner is one of the 100 fastest computers in the world.

But its rocket-sled speed is just part of a more ambitious idea — an attempt to give scientists around the country access to a distributed supercomputing "brain" stretching from Boston to Maui, ready to solve their toughest problems.

The Roadrunner Supercluster will be part of what researchers are calling the "National Technology Grid," a collection of supercomputers across the country wired together to help handle scientists' growing demand for computer time.

Sitting at their own desks, the researchers could hook in to the grid and begin solving large scale problems without having to worry about where the computer doing the work is located, explained Larry Smarr, director of the National Computational Science Alliance, the federally funded group that paid for the new machine.

"The goal is to be completely seamless," the University of Illinois-based Smarr said in telephone interview this week.

UNM professor David Bader envisions a day when a researcher studying an ecosystem — Chesapeake Bay, say, or the Rio Grande Valley — can log in and rapidly spin through vast amounts of satellite data on climate and ground cover for their part of land.

"They wouldn't need to be located at a specialized supercomputer research center to do their work," explained Smarr — they could just plug into the grid and let the computers take care of the rest, much as you plug a toaster into the wall without having to worry about which power plant is generating the electricity.

"That's the vision," said Bader, who has spent the last week testing the brand new Roadrunner machine in preparation for today's unveiling.

Smarr, one of the leaders of the nation's supercomputer research community, is scheduled to join Sen. Pete Domenici, R-N.M., and others to formally throw the switch turning on the computer at a ceremony this afternoon.

The $400,000 computer, built by Alta Technology Corp., bears the mark of a new breed of mainstream prized machines that are making inroads in the high-performance research market.

Instead of using specialized high-performance computer chips made especially for supercomputing, it's built around 128 top-of-the-line Intel Pentiums, the same breed of computer chips used in desktop computers.

Programmers split up a large problem into smaller pieces, farming them out so that each of the 128 chips can work on a portion of the problem and then share results.

"You get to profit from the collapse of PC prices," explained Victor Eijkhout, a computer scientist at the New Mexico Institute of Mining and Technology who does research on a similar "cluster" machine at Tech.

Similar machines also have been built at Sandia and Los Alamos national labs for nuclear weapons and physics research, and the experience of the New Mexico research community is one reason UNM was chosen to host the new machine, Smarr said.

UNM is one of six "supernodes" on the National Technology Grid. In addition to the Roadrunner Cluster, the grid will be connected to UNM's Maui High Performance Computing Center, an Air Force-funded research complex in Hawaii run by the university for the military.

BIG BRAIN: University of New Mexico professor David Bader tests the Roadrunner Supercluster. It will be dedicated today.

NCSA Director Larry Smarr (left),
UNM President William Gordon,
and U.S. Sen. Pete Domenici
Turn on the Roadrunner Supercomputer
in April 1999



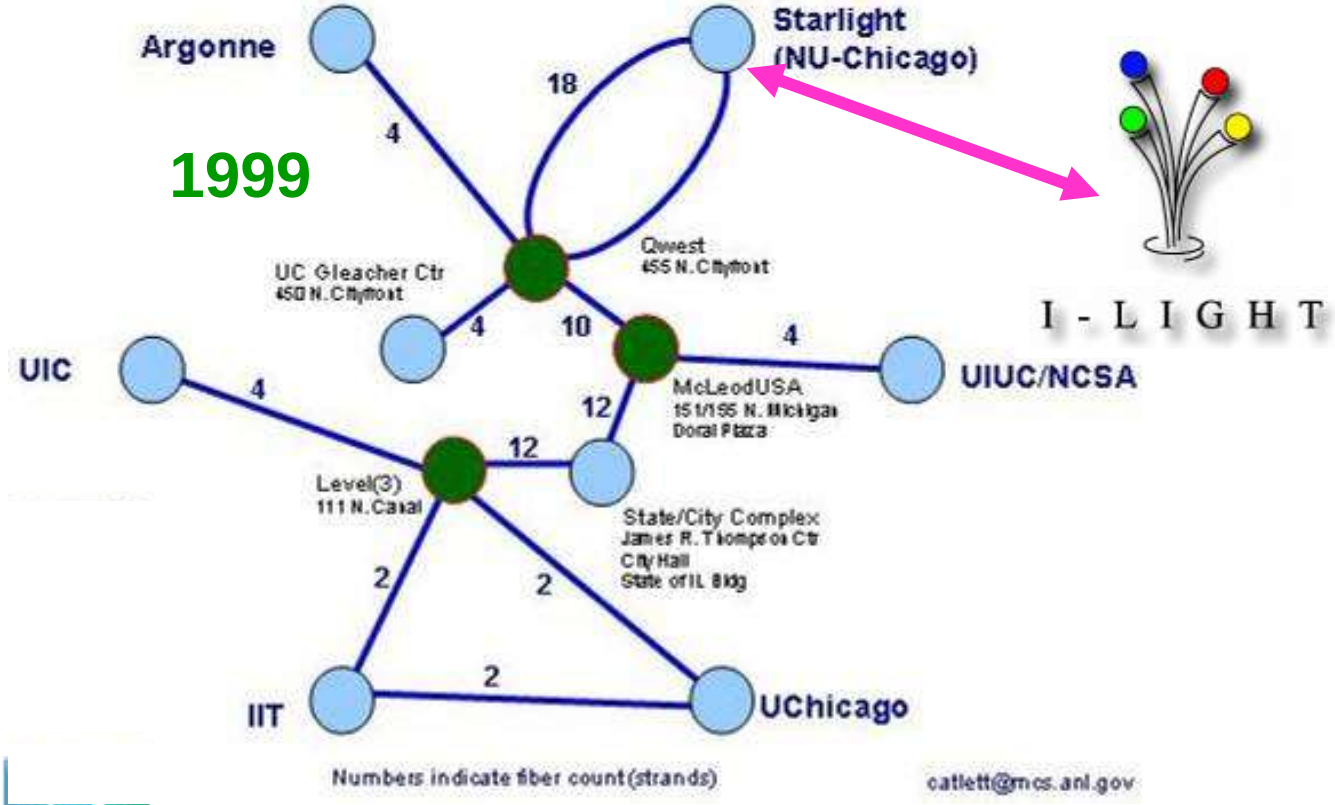
David Bader Selected to Receive the 2021 IEEE Computer Society Sidney Fernbach Award

PRP
PACIFIC RESEARCH PLATFORM

NSF

National Computational Science ALLIANCE

Illinois's I-WIRE and Indiana's I-LIGHT Dark Fiber Networks Inspired Many Other State and Regional Optical



I - L I G H T



Today California's CENIC R&E Backbone Includes ~ 8,000 Miles of CENIC-Owned and Managed Fiber

CENIC

PACIFIC RESEARCH PLATFORM

Source: Larry Smarr, Rick Stevens, Tom DeFanti, Charlie Catlett

1999: The President's Information Technology Advisory Committee (PITAC) Report Led to Funding NSF's Information Technology Research (ITR) for National Priorities Program



Meeting with Vice President Gore in the White House
To Present Our PITAC Report

PITAC
Co-Chairs:
Ken Kennedy
Bill Joy

PACIFIC RESEARCH PLATFORM

2002-2009: The NSF OptIPuter ITR Grant- 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

The OptIPuter Exploits a New World in Which the Central Architectural Element is Optical Networking, Not Computers to Support Data-Intensive Scientific Research and Collaboration

OptIPuter
NSF ITR Grant
$13.5M
PI Smarr,
Co-PIs DeFanti, Papadopoulos, Ellisman
2002-2009

PRP PACIFIC RESEARCH PLATFORM

NSF

OptIPuter

it2

evl

SDSC

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



End User OptIPortal



Instruments



HD/4k Telepresence



HD/4k Video Cams



10G Lightpath



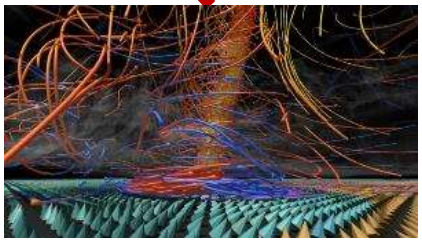
HPC

TeraGrid

Campus Optical Switch



Data Repositories & Clusters



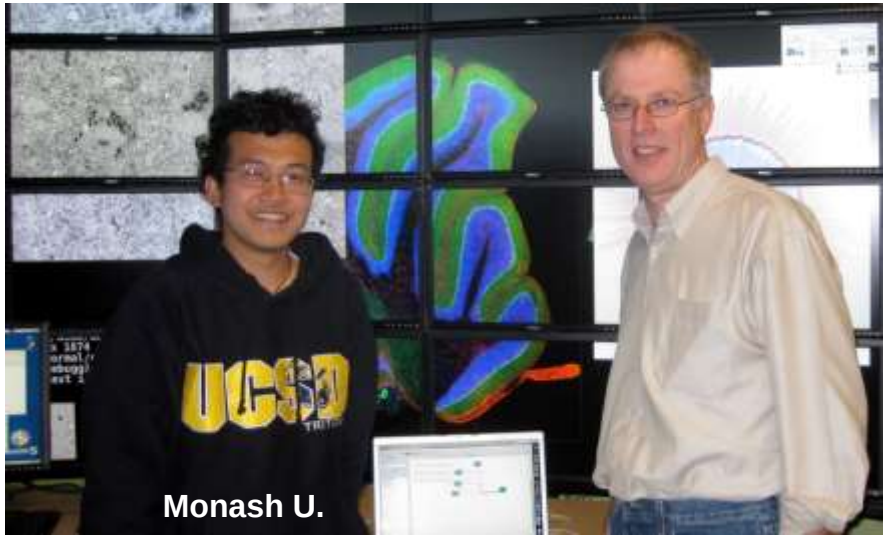
HD/4k Video Images

LS 2009 Slide

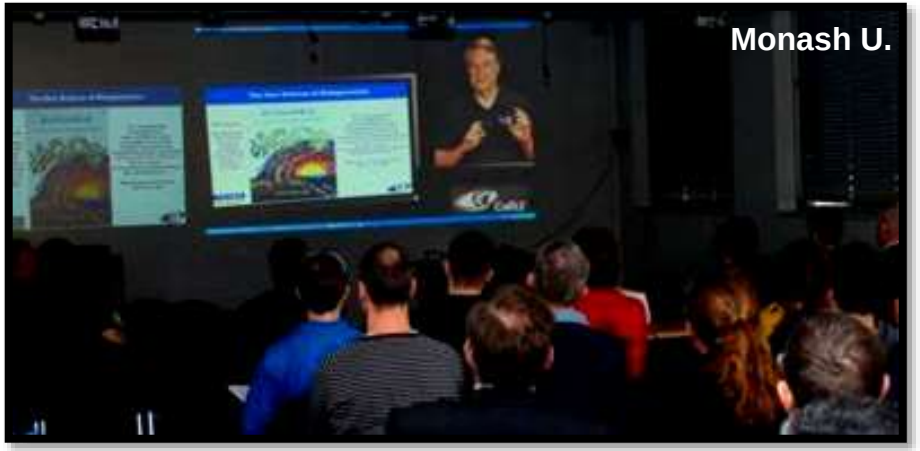
OptIPuter

David Abramson Led OptIPuter Global Workflows and UCSD/Monash Univ. Co-Mentoring of Undergrads and Graduate Students

David Abramson Selected to Receive 2021 ACM-IEEE CS Ken Kennedy Award



First OptIPortal/Kepler
Remote Microscopy Link Feb 2009

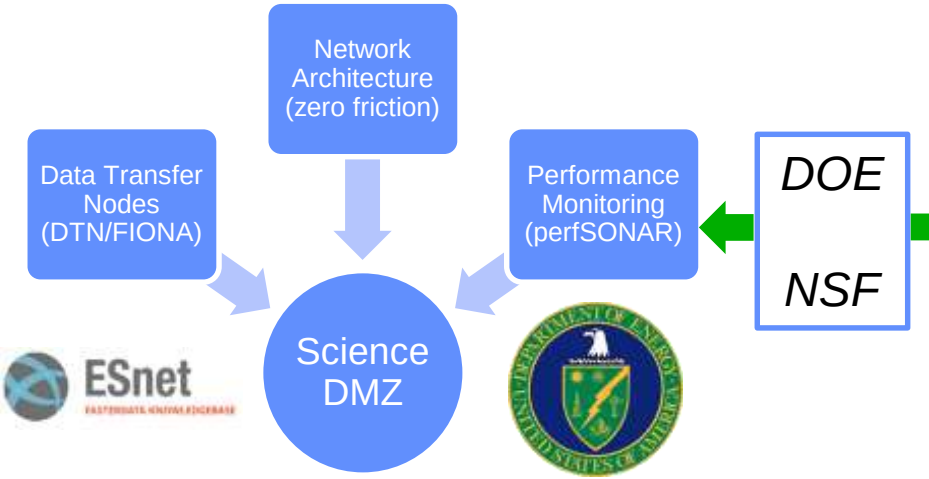




PRP
PACIFIC RESEARCH PLATFORM

2010-2020:
NSF Adopted a DOE High-Performance Networking Model

ScienceDMZ Coined in 2010 by ESnet



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

Slide Adapted From Inder Monga, ESnet

NSF Campus Cyberinfrastructure Program
2012-2020

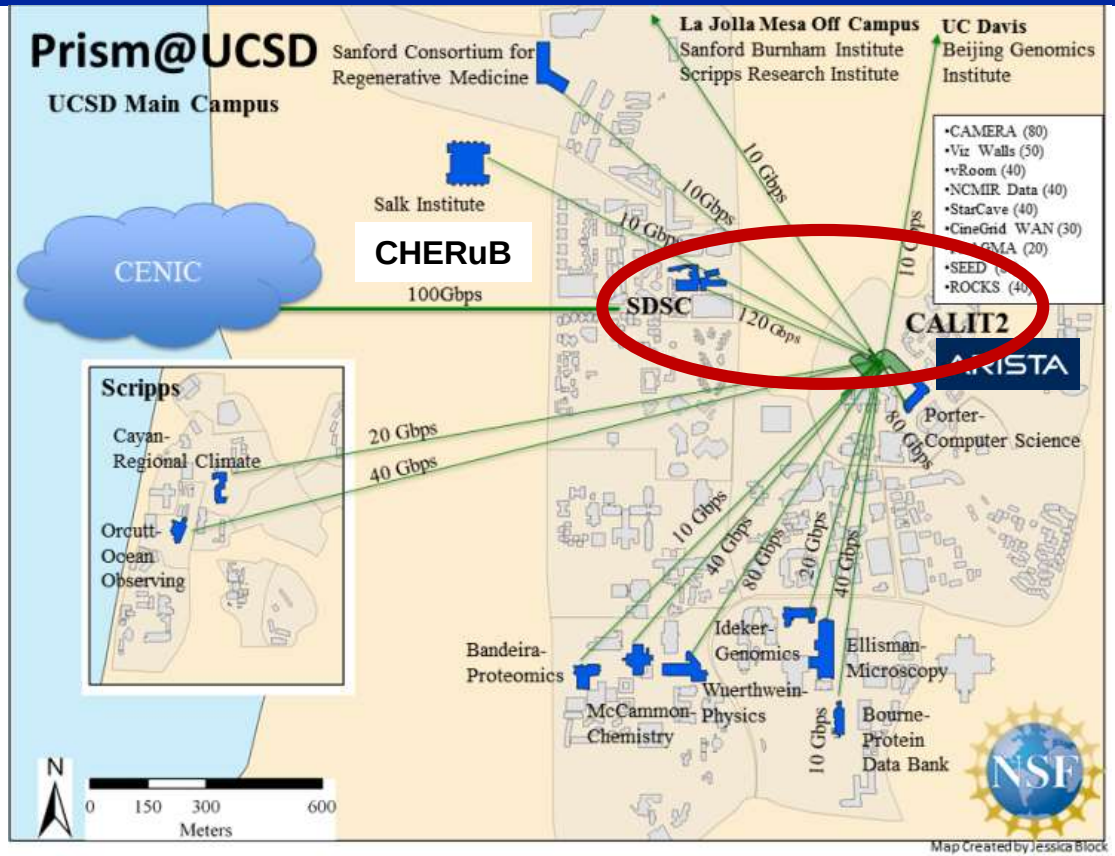


Has Made Over 340 Awards:
Across 50 States and Territories

Slide Adapted From Kevin Thompson, NSF

PACIFIC RESEARCH PLATFORM

2013-2015: UCSD as a Laboratory for a "Big Data" 10-100 Gbps ScienceDMZ
NSF-Funded Campus CI Grants: Prism@UCSD and CHeruB

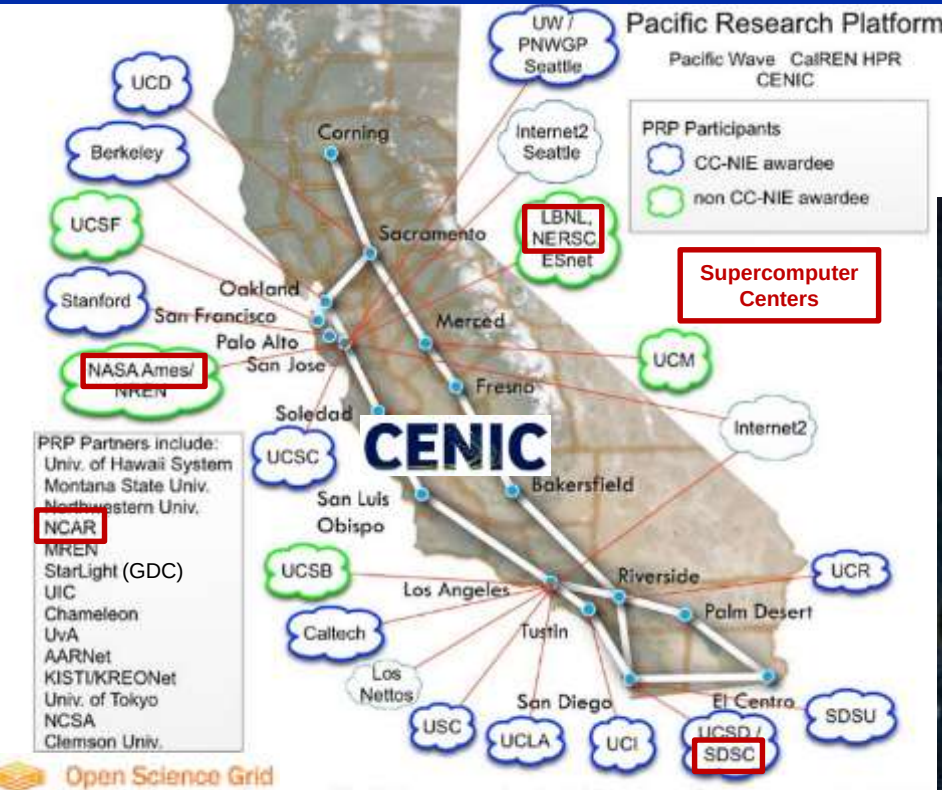


Prism@UCSD, Phil Papadopoulos, SDSC, Calit2, PI (2013-15)
CHERuB, Mike Norman, SDSC PI

PRP PACIFIC RESEARCH PLATFORM

it² SDSC

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

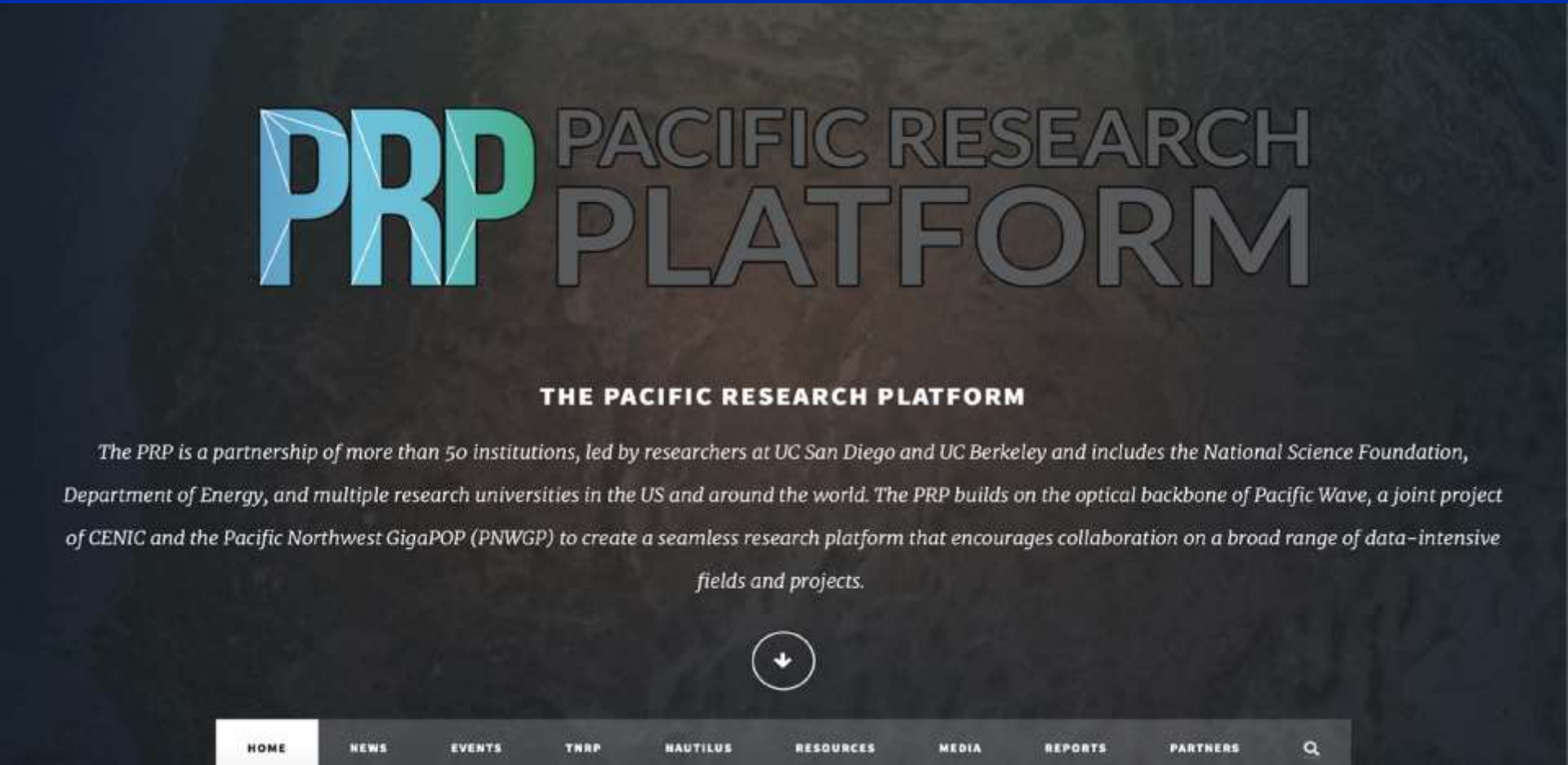


PRP PACIFIC RESEARCH PLATFORM

Source: John Hess, CENIC

CITRIS BANATAO INSTITUTE SDSC it²

PRP Website Has All Details Needed to Get Started
https://pacificresearchplatform.org/



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

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

Today's Roadrunner!

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.

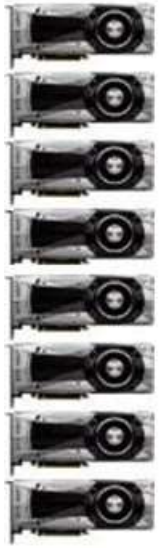
Software Specifications

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

PRP PACIFIC RESEARCH PLATFORM

NSF

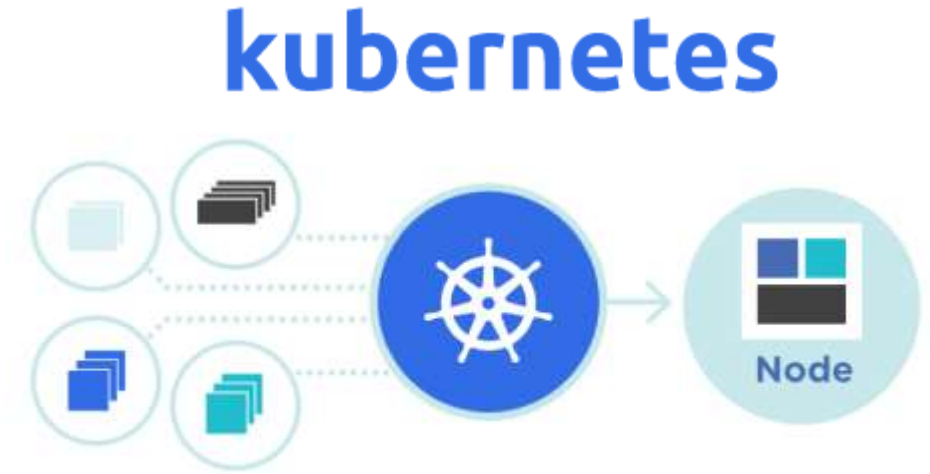
FIONAs Designed by UCSD's Phil Papadopoulos, John Graham, Joe Keefe, and Tom DeFanti

SDSC

20 YEARS QUALCOMM INSTITUTE

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

User Applications



Containers

PRP PACIFIC RESEARCH PLATFORM

Clouds

PRP PACIFIC RESEARCH PLATFORM

CLOUD NATIVE COMPUTING FOUNDATION

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.



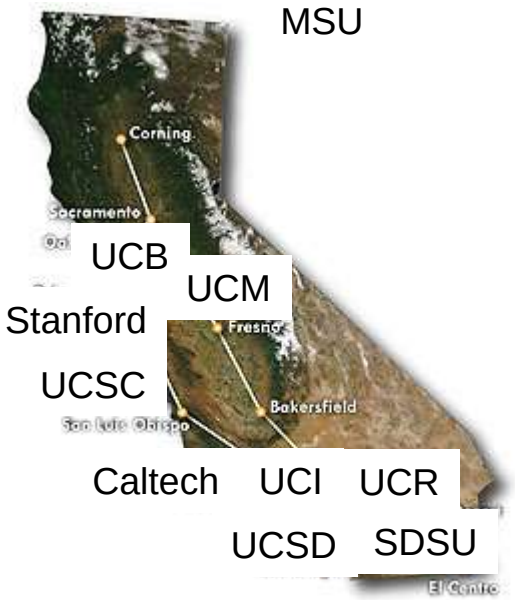
Planet Scale

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

PRP
PACIFIC RESEARCH PLATFORM

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

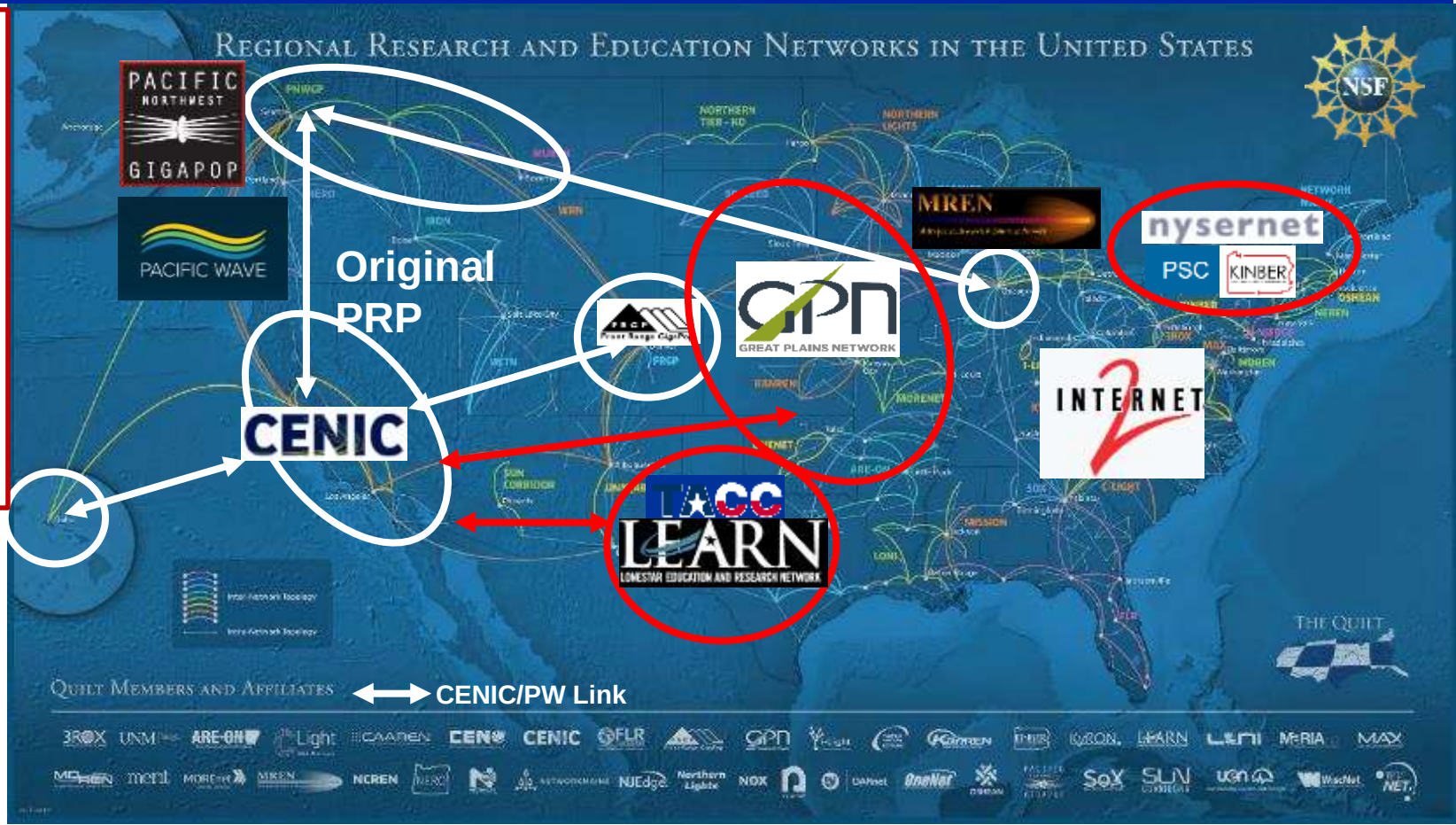
SDSC UC San Diego

PRP
PACIFIC RESEARCH PLATFORM

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



PACIFIC RESEARCH PLATFORM

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

Nautilus

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

Installed CPUs	Installed GPUs	Rotating Storage
7478	516	4000 TB

PRP PACIFIC RESEARCH PLATFORM

CENIC

THE QUILT

INTERNET2

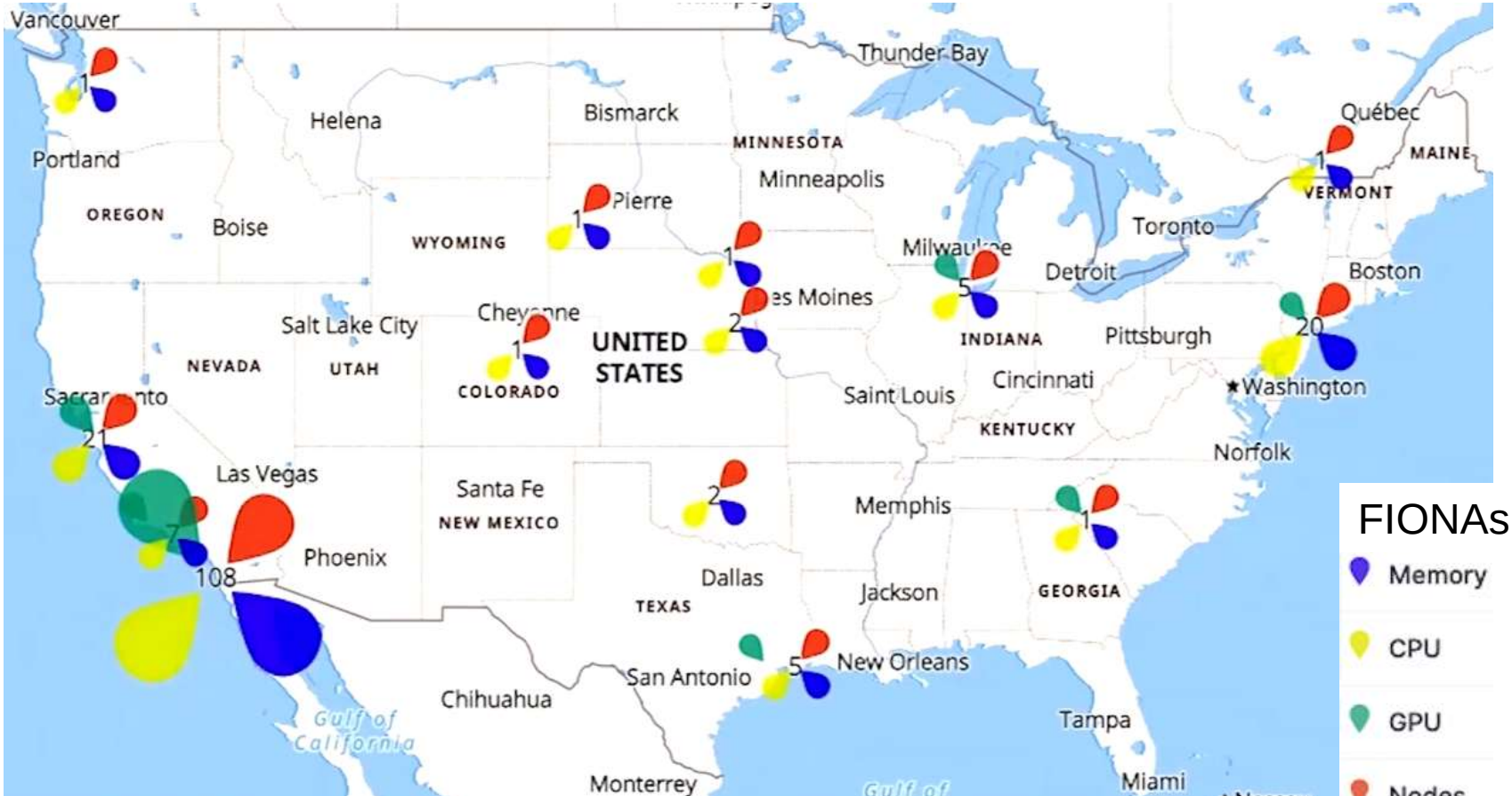
20 YEARS QUALCOMM INSTITUTE

PRP's Nautilus is Global in Scale



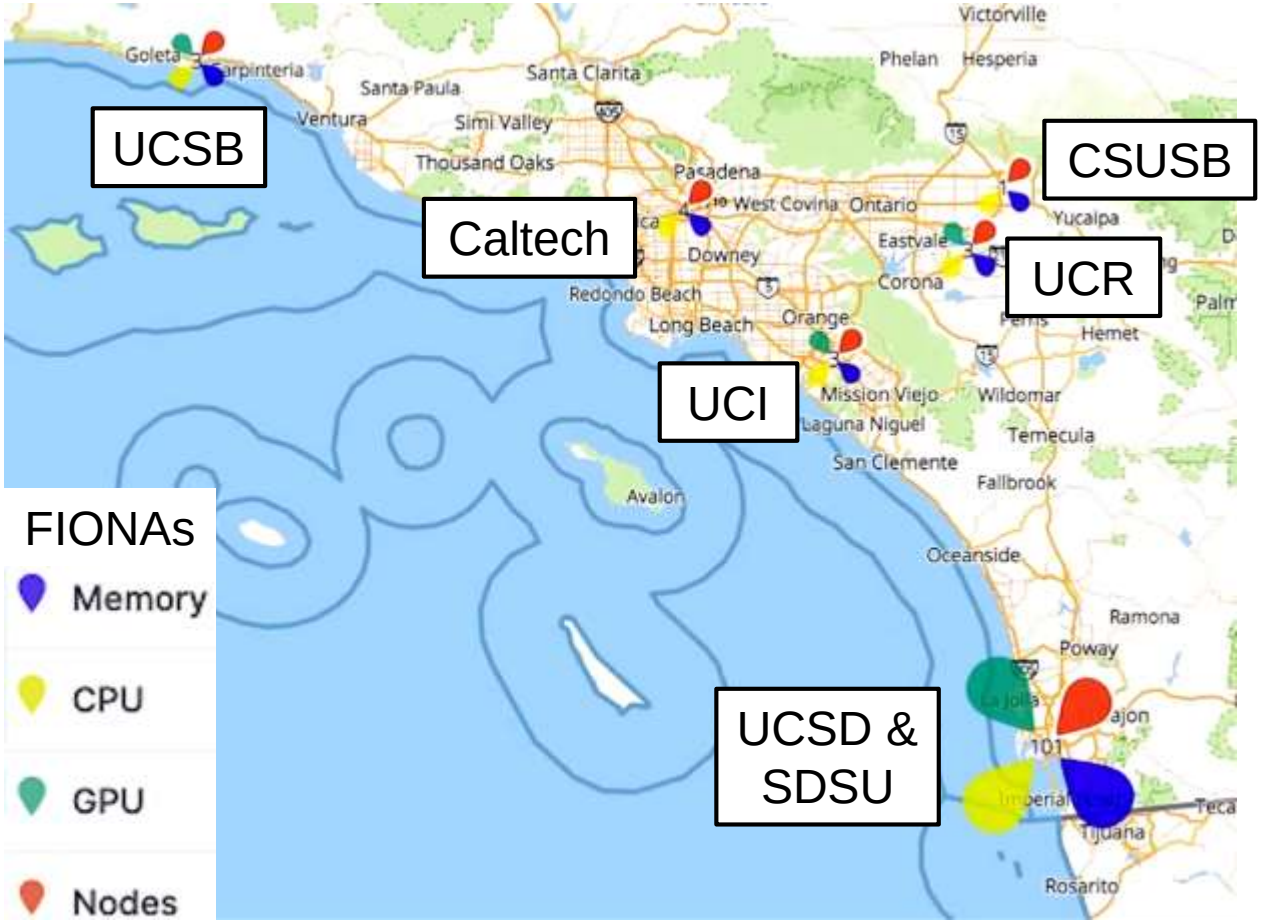
PRP
PACIFIC RESEARCH PLATFORM

PRP's Nautilus Spans the United States



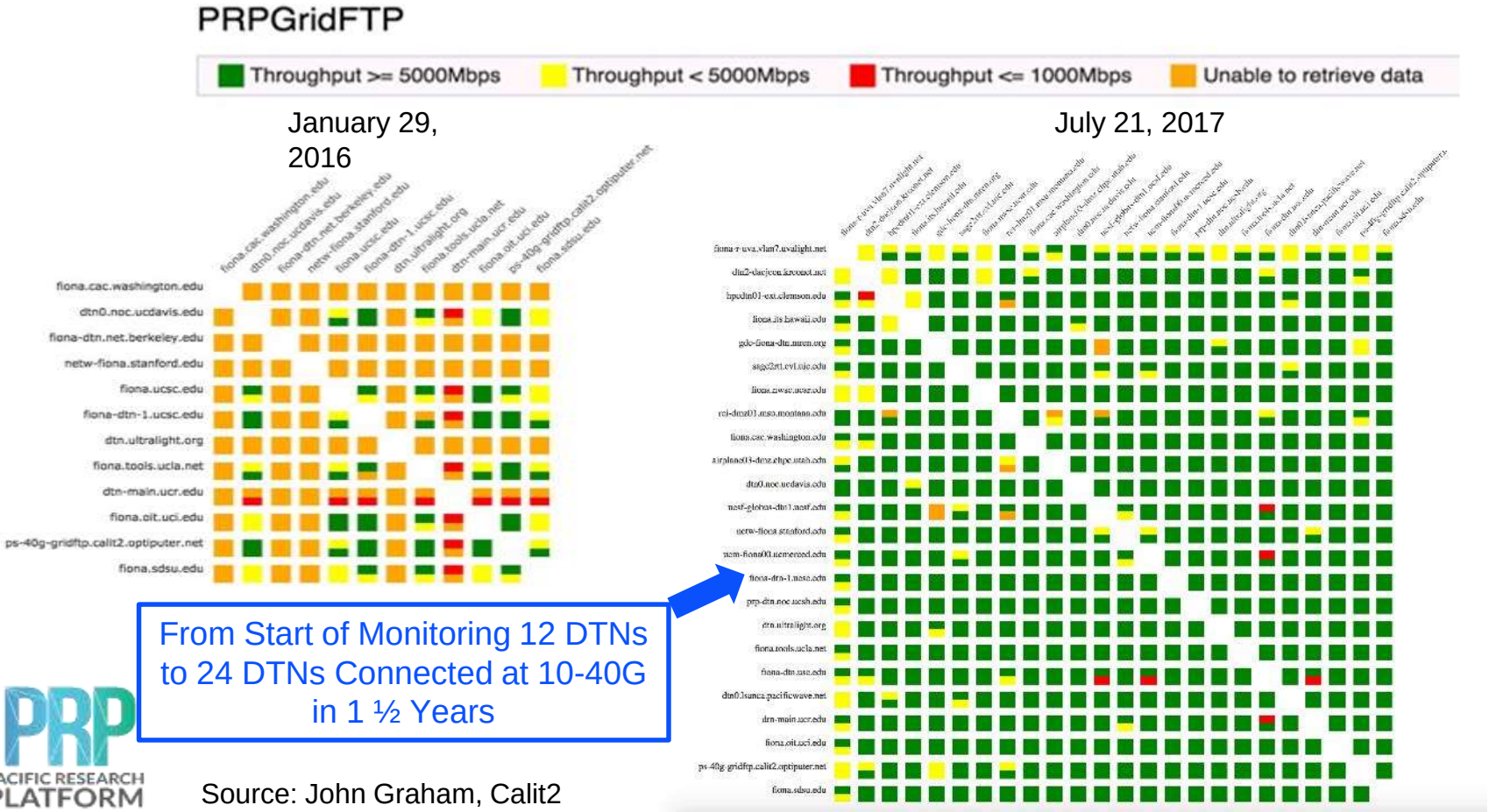
PRP
PACIFIC RESEARCH PLATFORM

PRP's Nautilus is Centered in SoCal



PRP
PACIFIC RESEARCH PLATFORM

We Measure Disk-to-Disk Throughput with 10GB File Transfer 4 Times Per Day in Both Directions for All PRP Sites



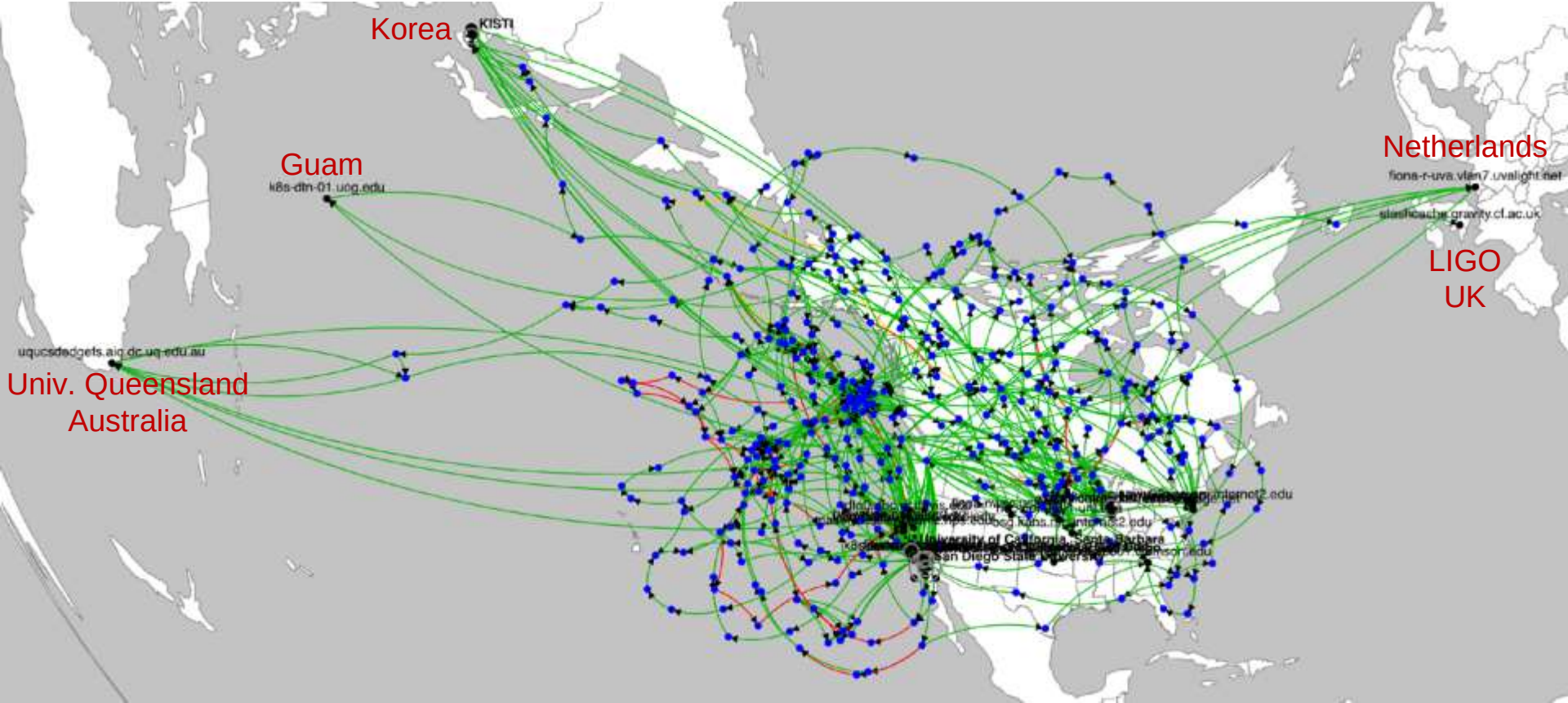
From Start of Monitoring 12 DTNs to 24 DTNs Connected at 10-40G in 1 ½ Years

Source: John Graham, Calit2

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



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



CMS

Particle Physics

Biomedical 'omics



NSF

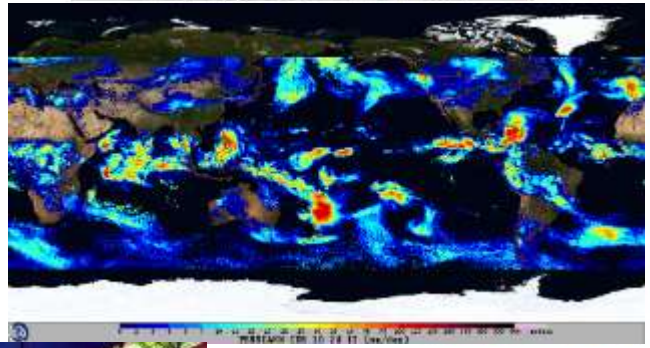
LIGO

IceCube
South Pole Neutrino Observatory



Telescope Surveys

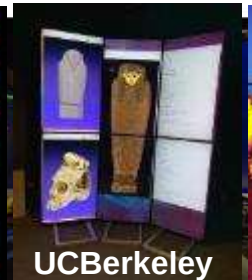
Earth Sciences



Visualization, Virtual Reality, Collaboration



UC San Diego



UCBerkeley



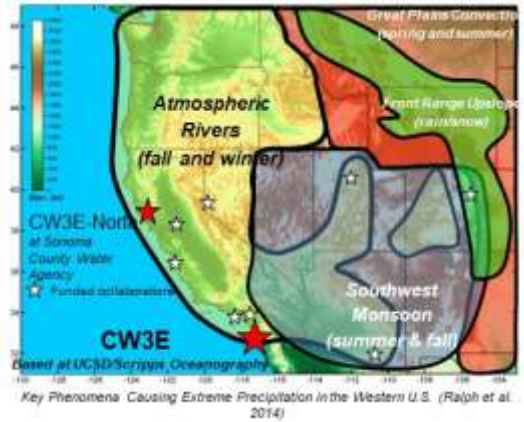
UC Merced

CITRIS THE BAN INST

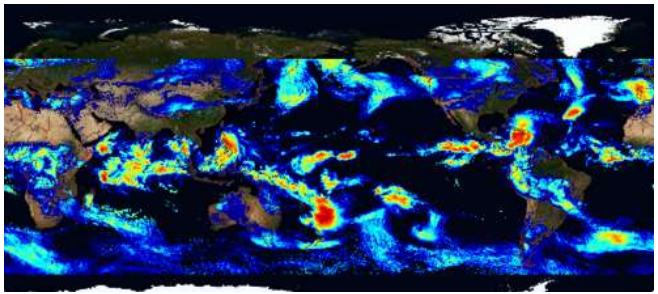
SDSC

it²

PRP Accelerates Data-Intensive Workflow on *Atmospheric Water in the West* Between NASA MERRA Archive, 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

Complete Workflow Time:
19.2 days 52 Minutes!

See Paper by Sellars, et al., IEEE eScience (2019)
http://lsmarr.calit2.net/sellars_accelerating_image_segmentation.pdf

PRP PACIFIC RESEARCH PLATFORM

Scott Sellers, PhD CHRS; Postdoc CW3E

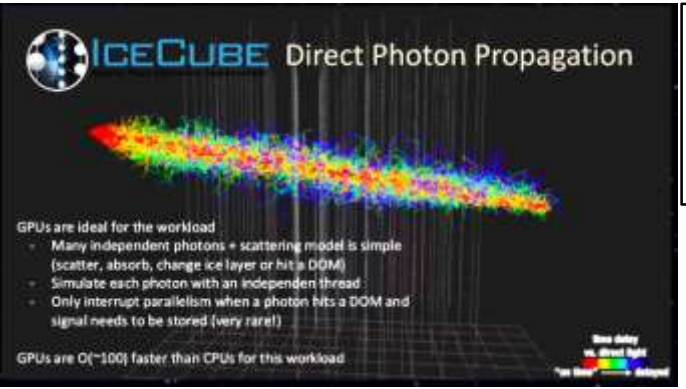
The New Pacific Research Platform Video Highlights 3 Different Applications Out of 600 Nautilus Namespace Projects



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

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

IceCube Used Up to Half of PRP's 500 GPUs in 2020!

PRP
PACIFIC RESEARCH PLATFORM

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

Open Science Grid

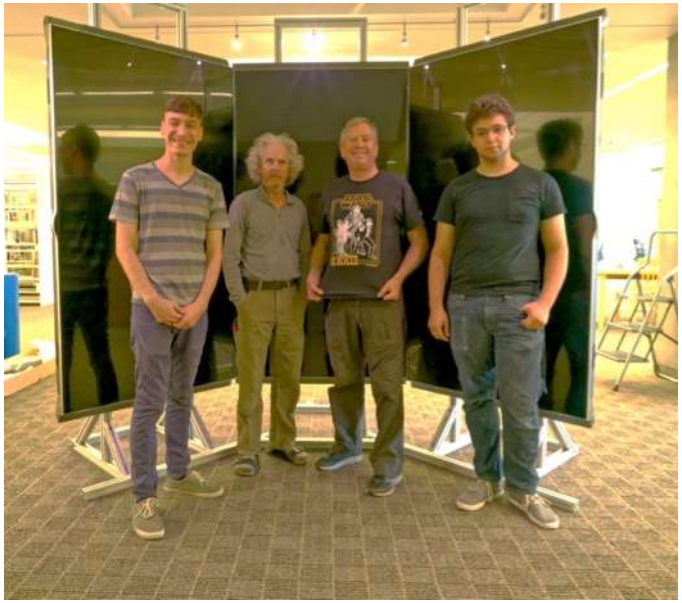
PRP Links At-Risk Cultural Heritage and Archaeology Datasets to Virtual Reality Systems at Multiple Campuses



48 Megapixel CAVEkiosk
UCSD Library



48 Megapixel CAVEkiosk
UCB CITRIS Tech Museum



24 Megapixel CAVEkiosk
UCM Library

PRP
PACIFIC RESEARCH PLATFORM

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)

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



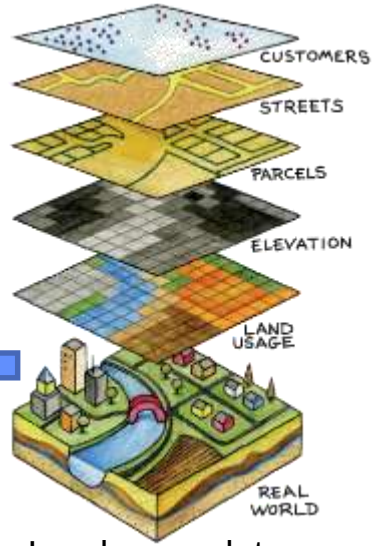
Real-Time Meteorological Sensors



Source: Ilkay Altintas, SDSC

WIFIRE

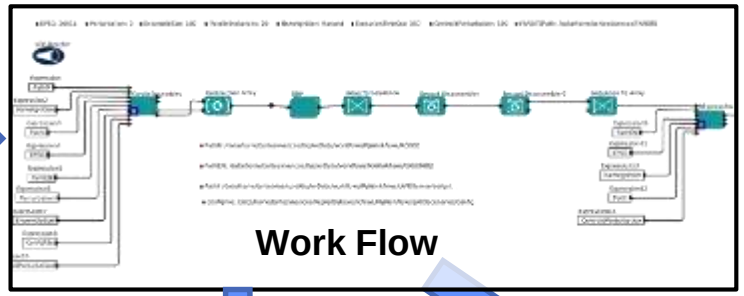




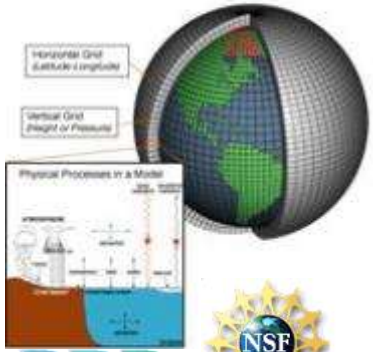
Landscape data

PRP





Weather Forecast









NSF

PRP
PACIFIC RESEARCH PLATFORM

Community Building Though Inclusion and Diversity

- **Grants**
  - **3 Female co-PIs**
  - **1 Hispanic co-PI**
- **Campuses**
  - **8 Minority-Serving Institutions in PRP/CHASE-CI**
- **Workshops**
  - **NRPII Workshop Steering Committee 80% Female**
  - **Multiple MSI, EPSCoR Focused Workshops**






Jackson State University



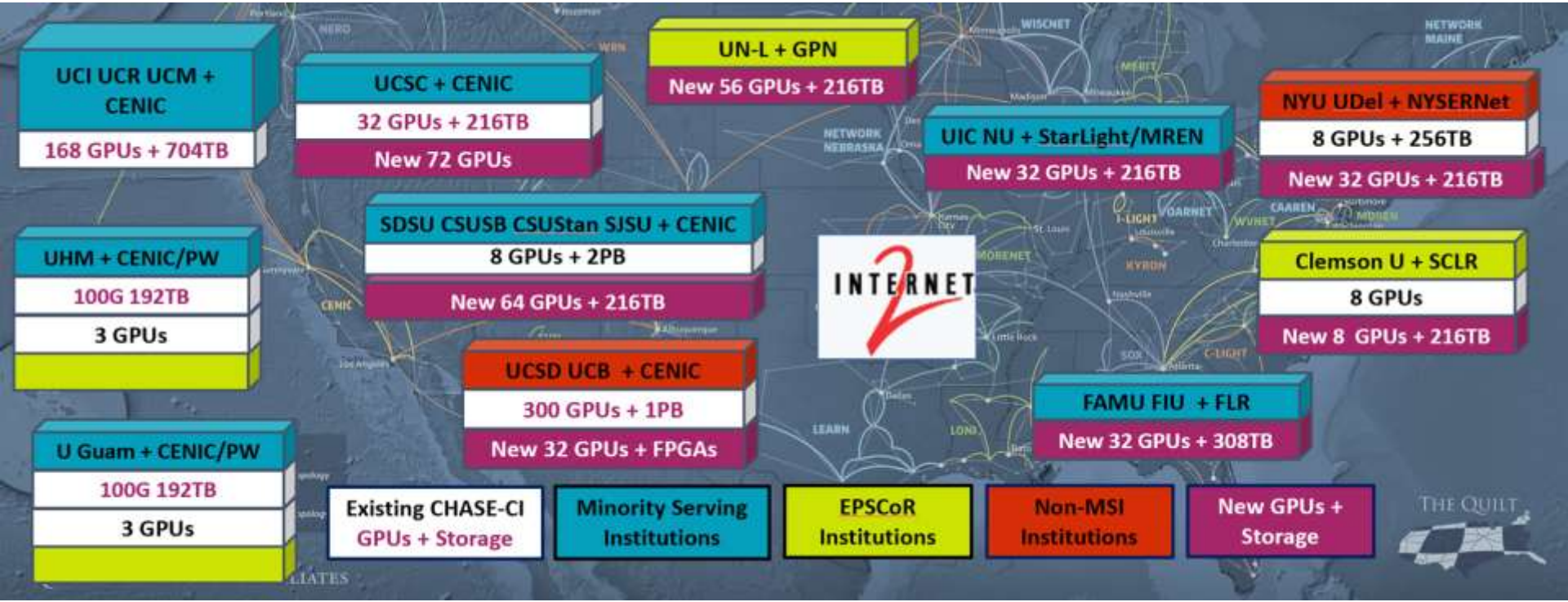

2NRP Montana State University

PRP MSI Workshop

Presenting FIONettes

PRP
PACIFIC RESEARCH PLATFORM

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



PACIFIC RESEARCH PLATFORM

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



LONG-TAIL SCIENCE

Multi-Messenger Astronomy

Genomics

Earth Science

Social Science

INNOVATIVE OPERATIONS

Composable Systems

High-Throughput Computing

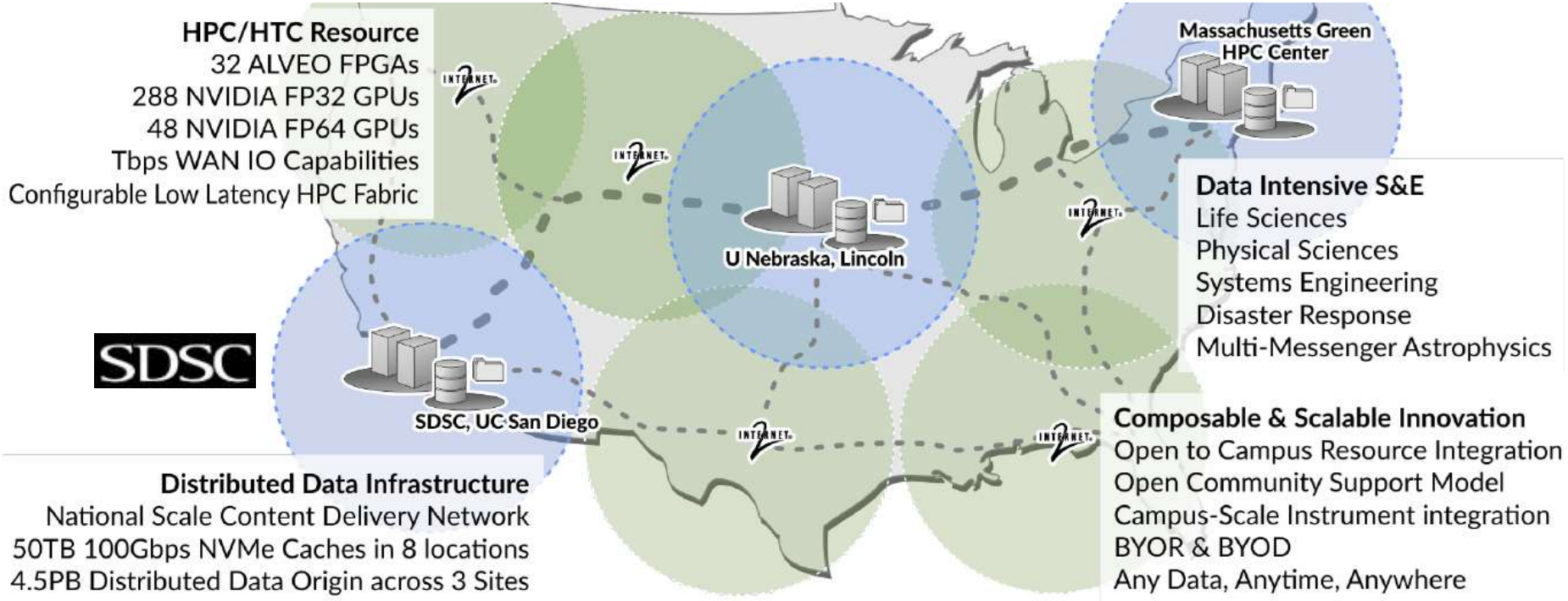
Science Gateways

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/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

PACIFIC RESEARCH PLATFORM