“The Pacific Research Platform Connects to CSU San Bernardino”

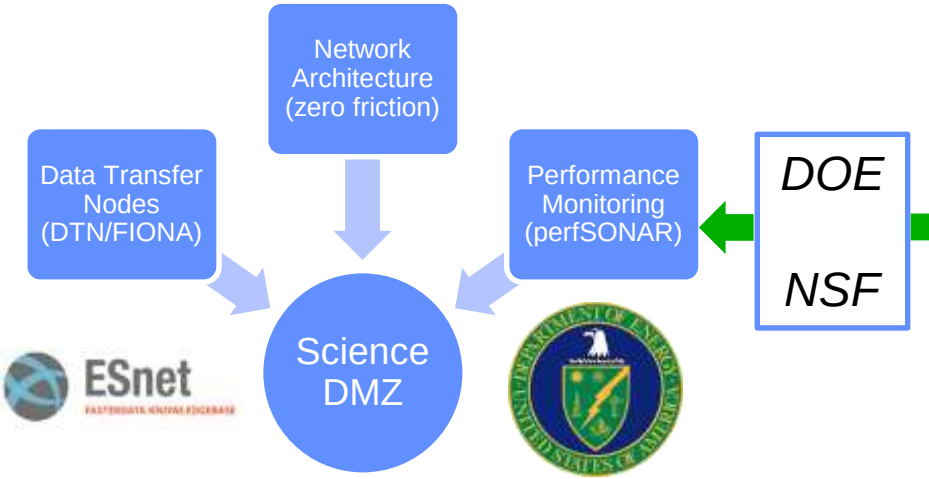
Invited Remote Keynote
High Performance Computing Initiative
California State University San Bernardino
March 18, 2022

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

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

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



Source: John Hess, CENIC

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

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.

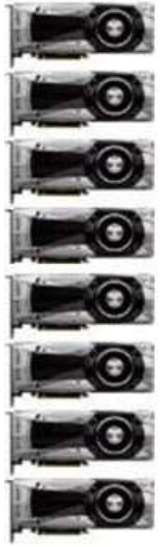
Software Specifications

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

2018/2019: Installing Community Shared FIONA CPU/GPU/Storage Systems on Campuses and Working With Campus CIOs on DMZs

UC Santa Cruz



UC Irvine



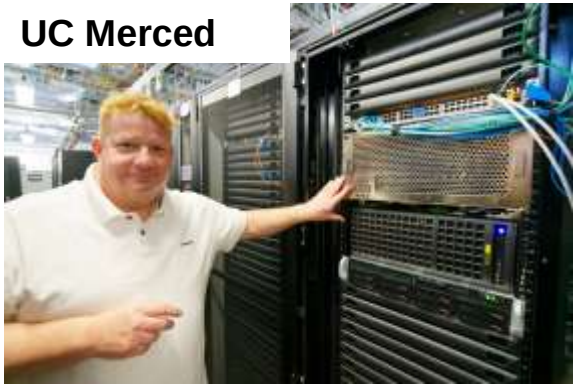
UC Santa Barbara



Stanford



UC Merced



UC Riverside



PRP
PACIFIC RESEARCH PLATFORM

Our PRP/CHASE-CI Team is Shipping a PRP FIONA2 To CSUSB Today!



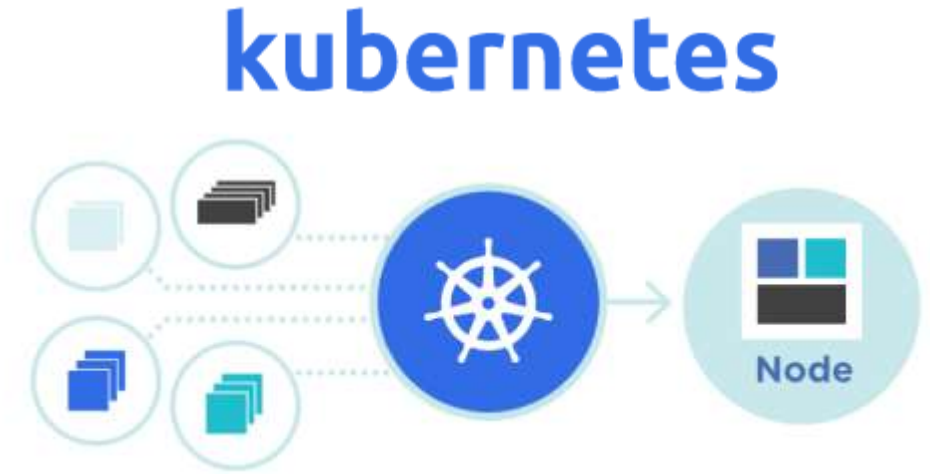
Rack Mounted FIONA Contains:
10 Gbps NIC
24 CPU-cores w/256 GB RAM
3 TB rotating storage
2 Nvidia A6000 32-bit GPUs w/48GB GRAM each
6 Empty GPU Slots for CSUSB to Fill When Ready

PACIFIC RESEARCH PLATFORM

Thanks to CSU's Dung Vu, James Macdonell, Gerard Au, Gerardo Garcia-Sotelo and UCSD's Tom DeFanti, John Graham, & Isaac Nealey for the technical preparation before shipment.

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.

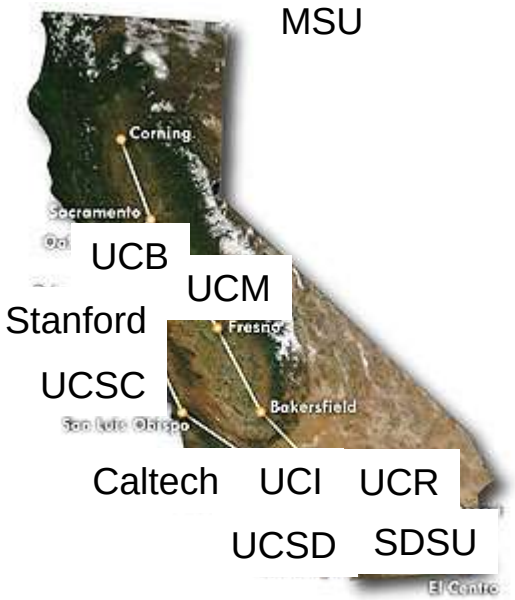
ROOK

Open source file, block and object storage for your cloud-native environment.

"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

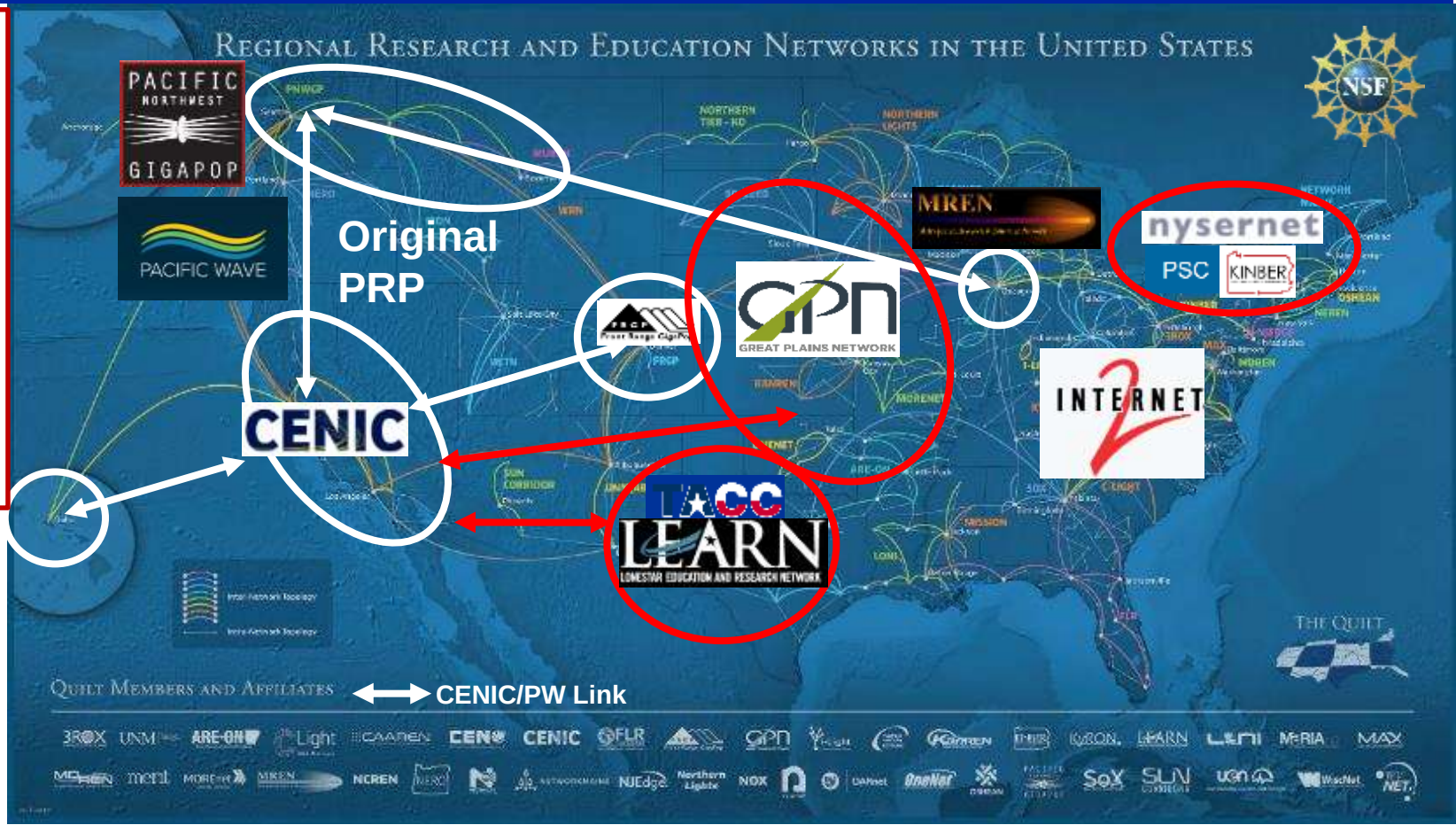
SDSC UC San Diego

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

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

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

PRP
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
7462	452	4000 TB

PRP PACIFIC RESEARCH PLATFORM

CENIC

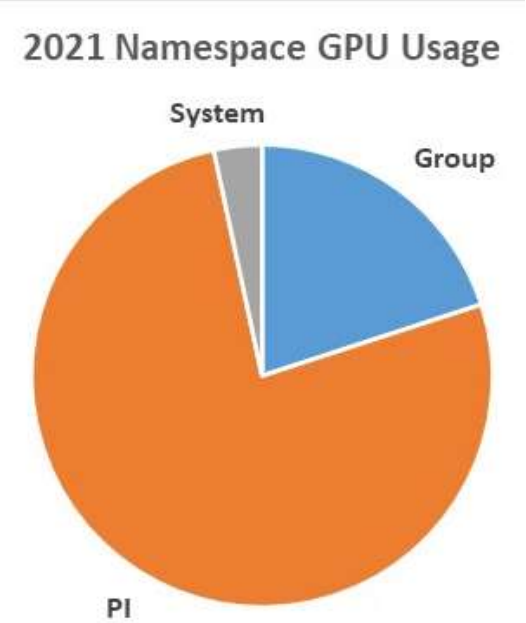
THE QUILT

INTERNET2

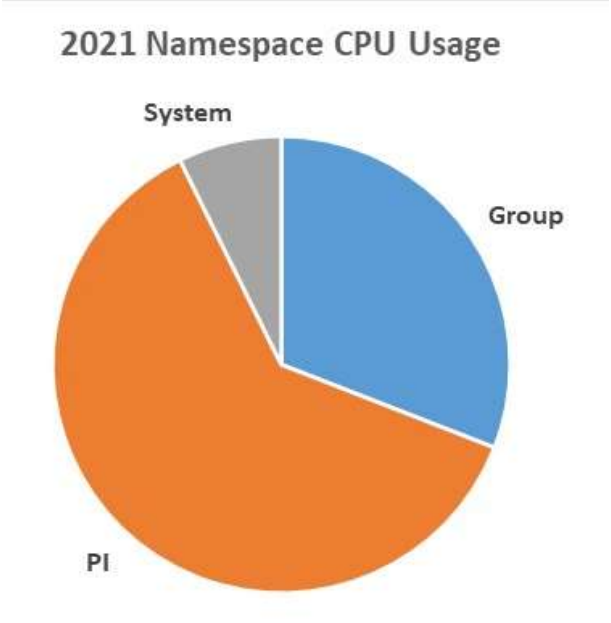
20 YEARS QUALCOMM INSTITUTE

Calendar 2021 GPU & CPU Namespace Usage By Type

~200 Active Nautilus Namespaces



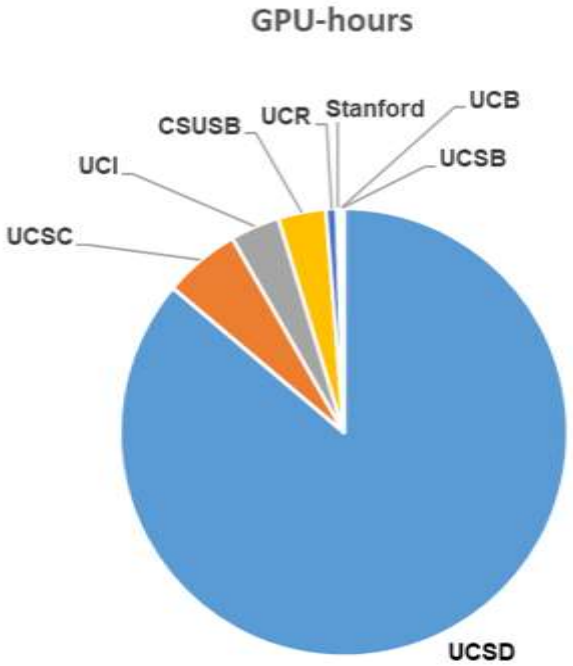
2,999,817 GPU-hours



14,923,987 CPU core-hours

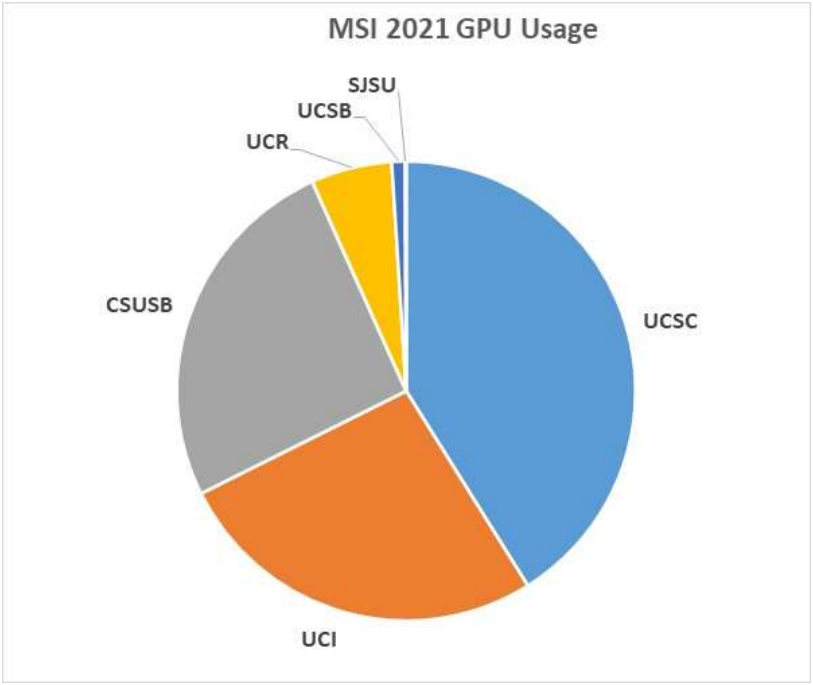
PACIFIC RESEARCH PLATFORM

PRP Nautilus 2021 PI Namespace-California Campuses: GPU Usage



2,378,401 GPU-hours

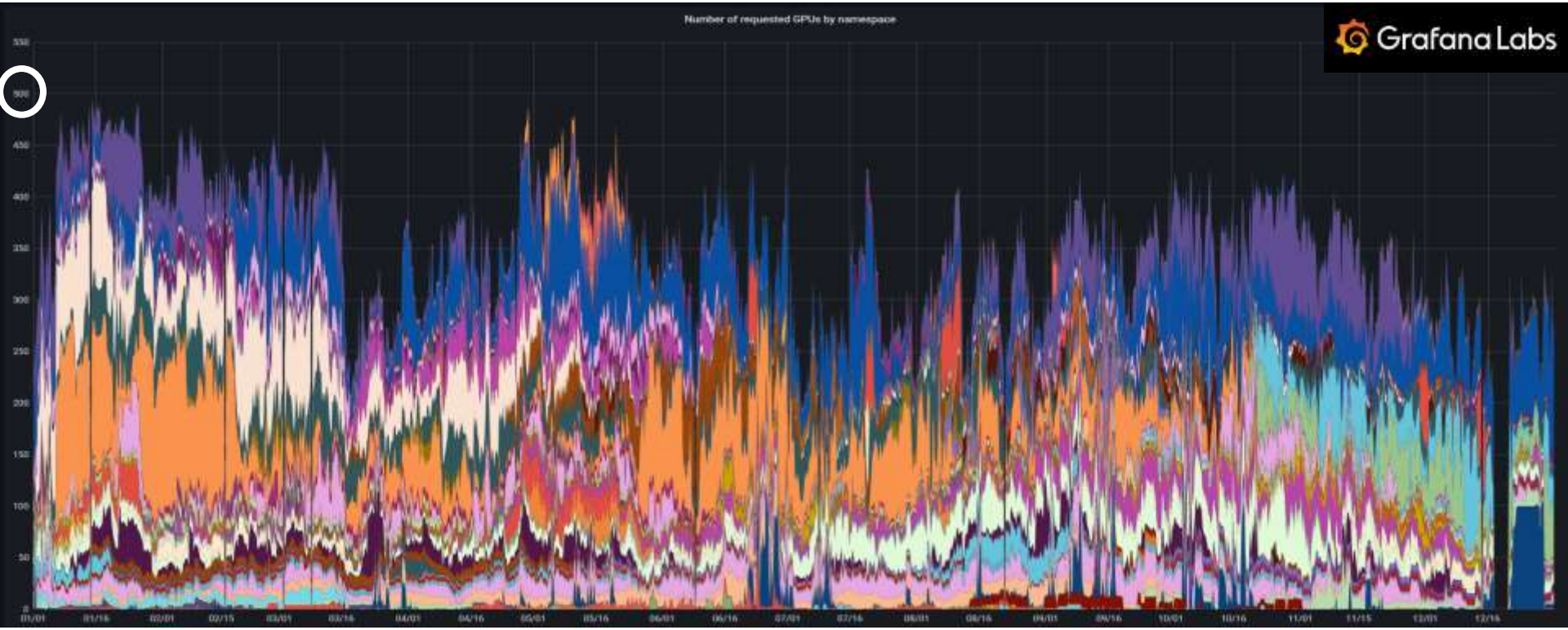
Minority Serving Institutions



320,111 GPU-hours

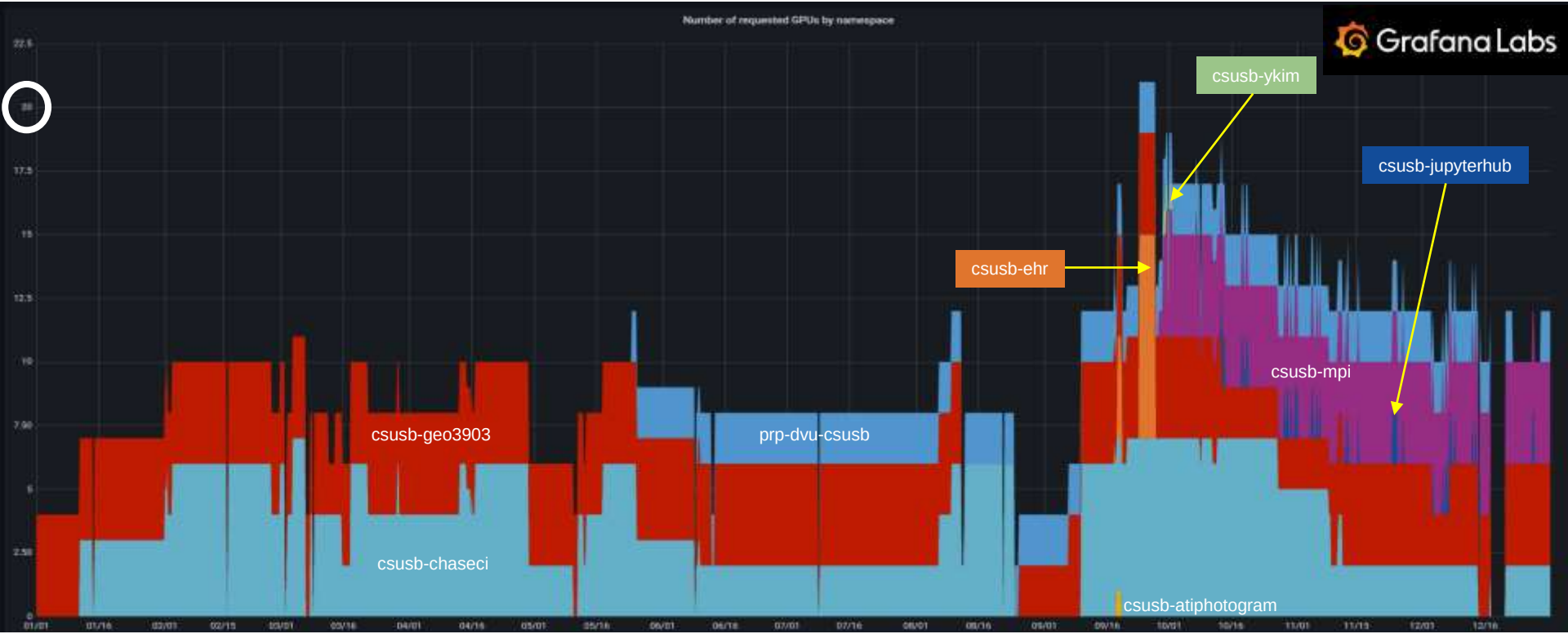
PACIFIC RESEARCH PLATFORM

Calendar 2021 GPU Namespace Usage



PRP
PACIFIC RESEARCH PLATFORM

Eight CSUSB GPU Namespaces Used
A FIONA8 24x7, Peaking at Nearly 3 FIONA8s



PRP
PACIFIC RESEARCH PLATFORM

UCSD's Information Technology Services Has Adapted PRP FIONA8s To Support Data Science Courses

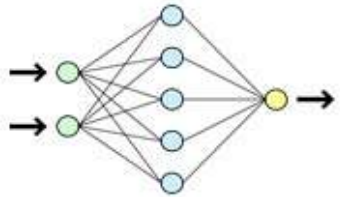
- **Student-Focused GPU/CPU Cluster For:**
  - Undergraduate & Graduate Coursework
  - For-Credit Independent Study
  - Thesis/Dissertation Research
  - Capstones & Projects
- **Research-Driven Architecture**
- **Managed by Central IT Services**
- **Racked FIONA Clusters**
  - 124 32-bit GPUs
  - 660 CPU-cores



PyTorch

Caffe





NumPy

ANACONDA
Powered by Continuum Analytics

NVIDIA
CUDA

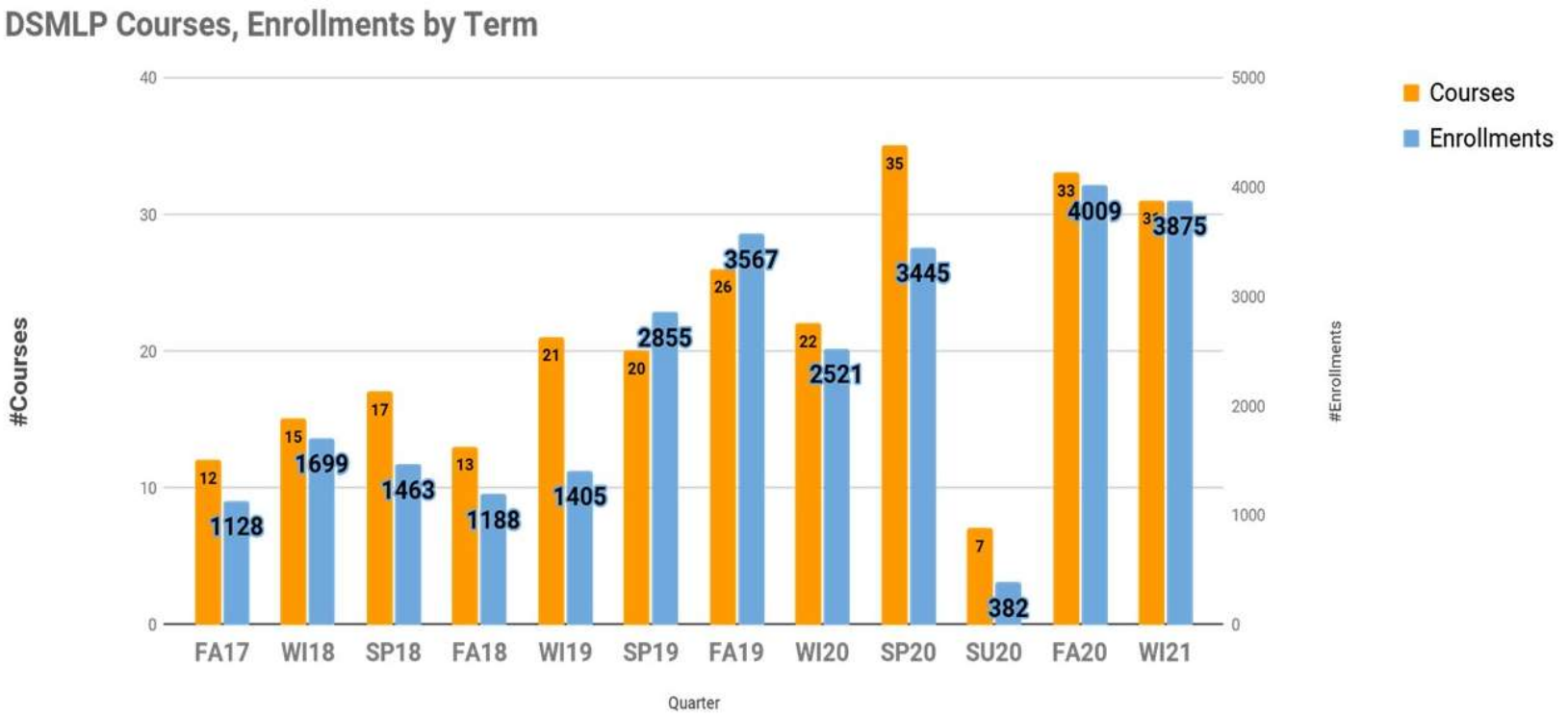
PRP
PACIFIC RESEARCH PLATFORM

IT SERVICES

UC San Diego
Jacobs School of Engineering

UCSD Cognitive Science

The UCSD Data Science and Machine Learning Platform Supports 2-3 Dozen Courses with 2500-4000 Students Per Quarter



Source: Adam Tilghman, ITS
https://datahub.ucsd.edu/hub

PACIFIC RESEARCH PLATFORM

www.hpcwire.com/off-the-wire/uc-san-diegos-jupyterhub-platform-aids-students-with-data-intensive-computing-needs/

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

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

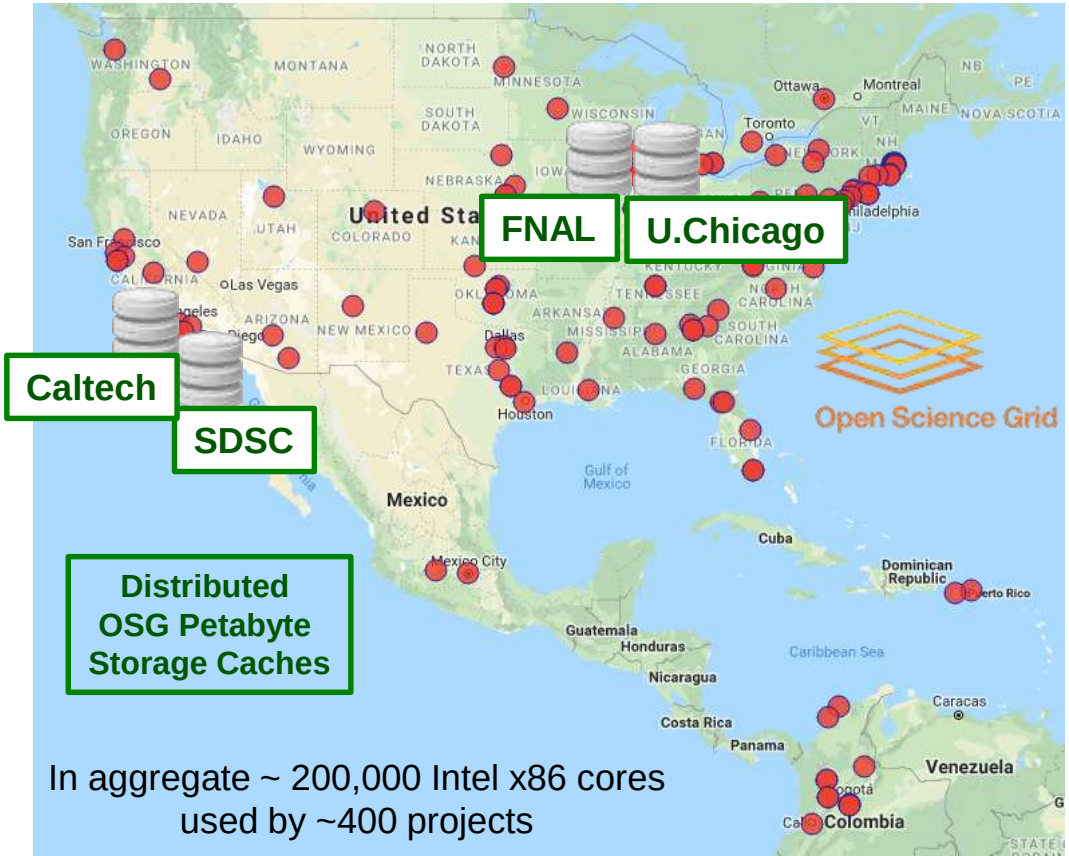
All OSG User Communities
Use HTCondor for Resource Orchestration

HTCondor
High Throughput Computing

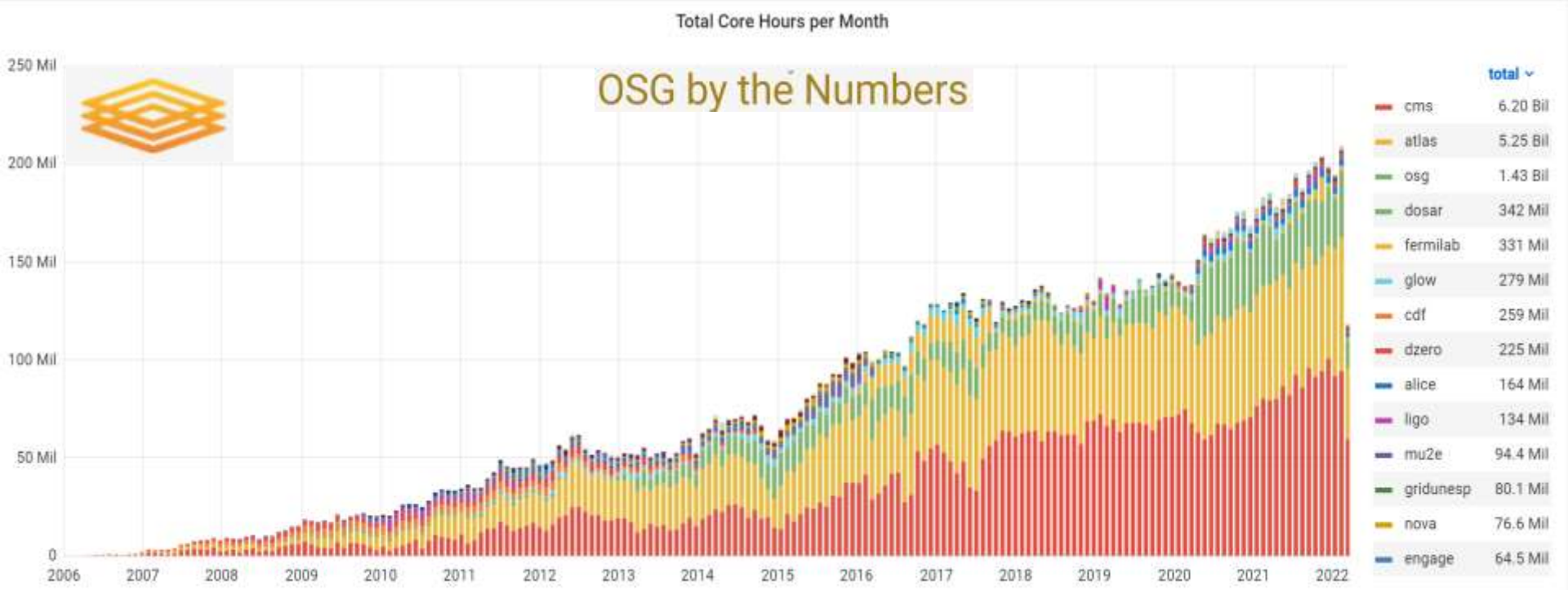
NSF

PRP
PACIFIC RESEARCH PLATFORM

OSG Federates ~100 Clusters Worldwide



OSG Delivers 200X PRP CPU Core-Hours/Month



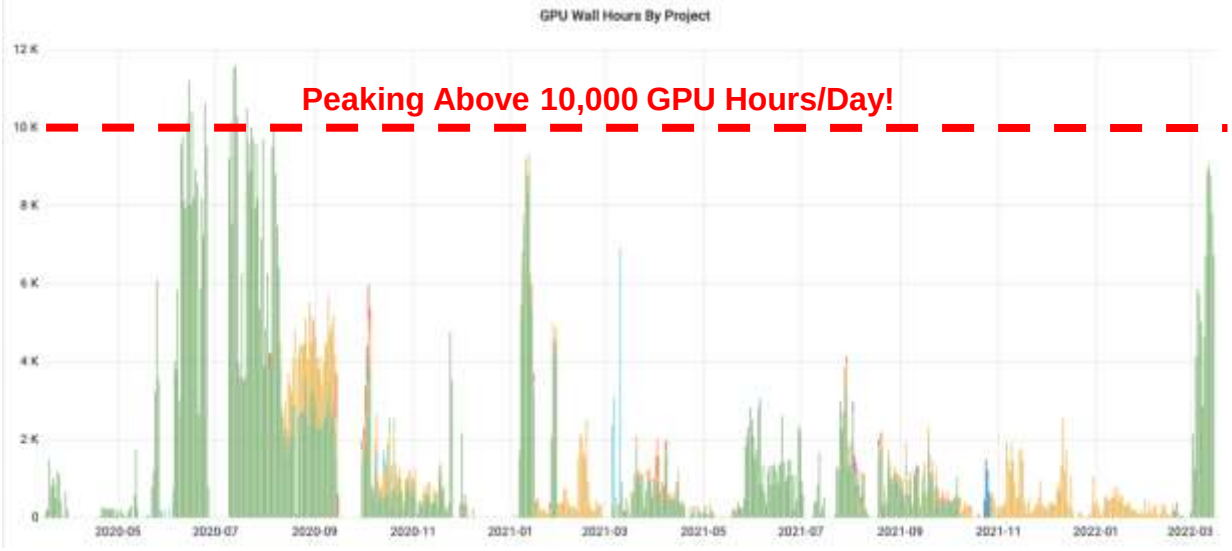
https://gracc.opensciencegrid.org/

PACIFIC RESEARCH PLATFORM

PRP Acts as an OSG Resource Provider

	total
IceCube	899 K
COVID19_FoldingAtHome	173 K
nova	16 K
PixleyLab	9 K
LIGO	7 K
TG-CHE200122	4 K
COVID19_JHU_Howard	2 K
ligo	544
JHU_Howard	134
FSU_Kolberg	8
TG-DDM160003	8
NeuroscienceGateway	1.3
COVID19_UCSD_Hsiao	1.2
OSG-Staff	0.9
USC_Deelman	0.9
fermilab	0.14
IIT_Cheng	0.12
CampusWorkshop_Feb2021	0.11
osg.NeuroscienceGateway	0.11
GATech_PACE	0.057

More Than 1 Million GPU-Hours on PRP Used via OSG Integration Within the Last 2 Years



PACIFIC RESEARCH PLATFORM

Source: Frank Würthwein, OSG ExDir, SDSC Director

PRP Federates with SDSC's EXPANSE
Using CHASE-CI Developed Composable Systems

EXPANSE

COMPUTING WITHOUT BOUNDARIES
5 PETAFLOP/S HPC and DATA RESOURCE

SDSC

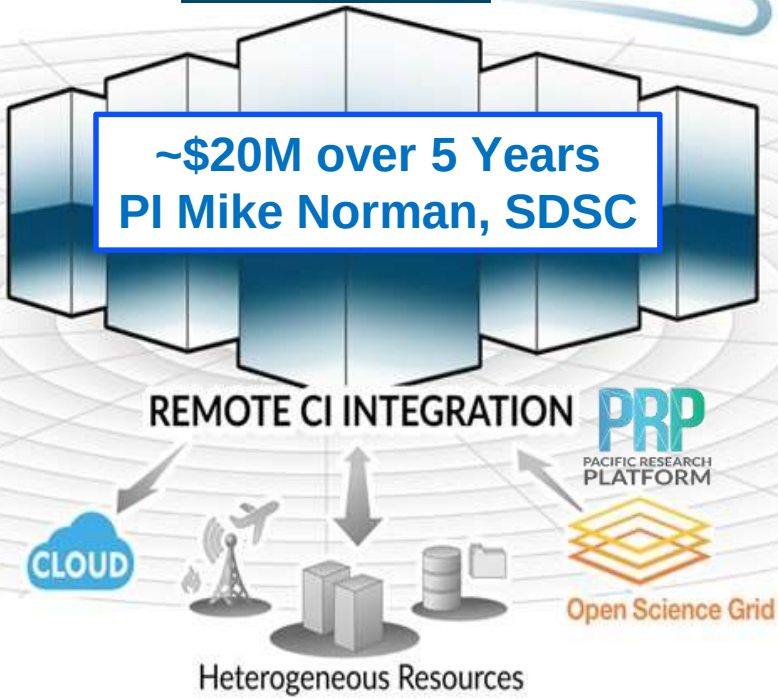
XSEDE

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



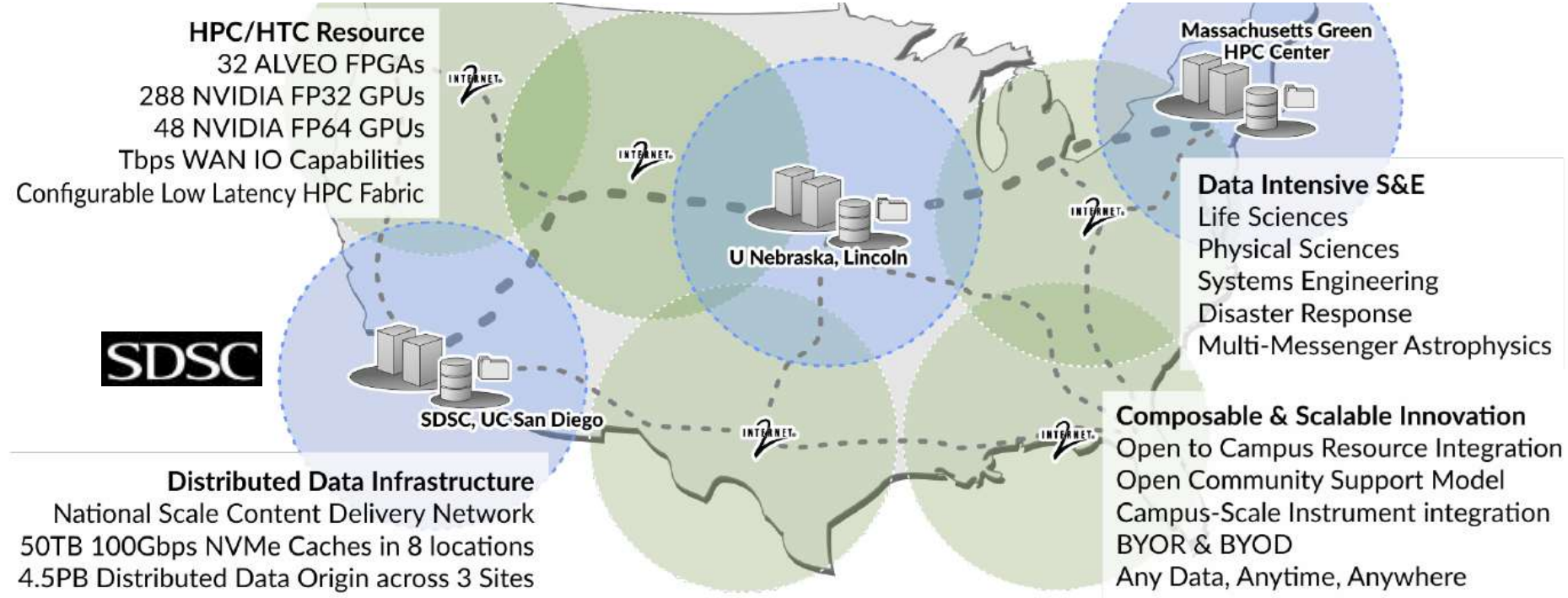
LONG-TAIL SCIENCE

Multi-Messenger Astronomy
Genomics
Earth Science
Social Science

INNOVATIVE OPERATIONS

Composable Systems
High-Throughput Computing
Science Gateways
Interactive Computing
Containerized Computing
Cloud Bursting

PRP Federates with NSF-Funded *Prototype National Research Platform*



PRP PACIFIC RESEARCH PLATFORM

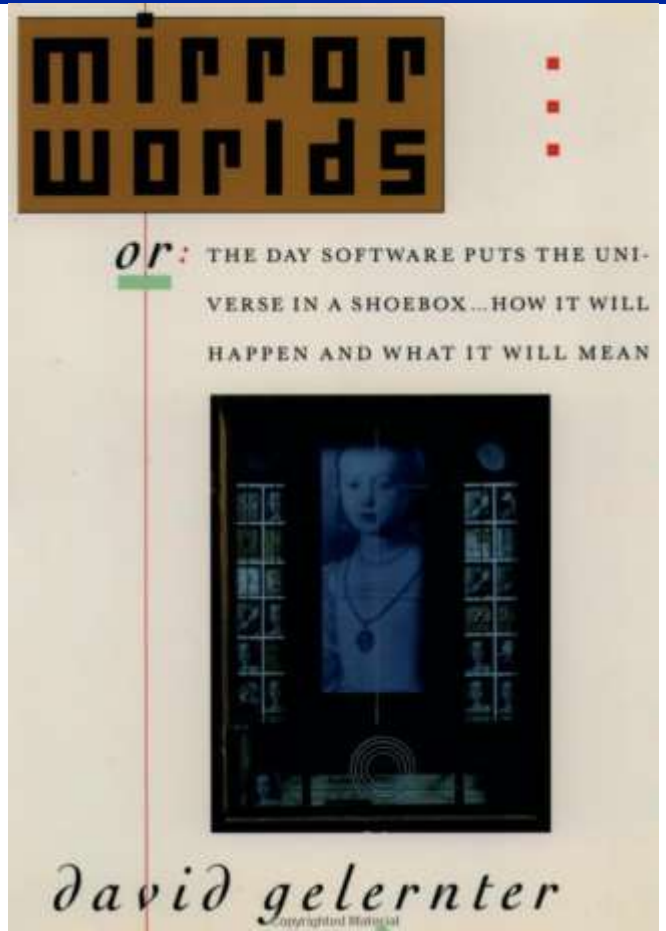
NSF Award OAC #2112167 (June 2021) [$5M Over 5 Years]
PI Frank Wuerthwein (UCSD, SDSC)
Co-PIs Tajana Rosing (UCSD), Thomas DeFanti (UCSD), Mahidhar Tatineni (SDSC), Derek Weitzel (UNL)

The Next Stage:
Can We Create a PRP Digital Twin in Extended Reality (XR)?

PACIFIC RESEARCH PLATFORM

In 1992 Computer Scientist David Gelernter Published a General Theory of Mirror Worlds

Our Current Era
is Experiencing
an Unrelenting
Exponential Increase
of Data Creation
From
A Wide Range
of
“Chunks of Reality”



“Mirror Worlds are software models of some chunk of reality...

Oceans of information pour endlessly into the model…

So much information that the model can mimic the reality’s every move, moment-by-moment.”

PACIFIC RESEARCH PLATFORM

Digital Twins of Manufactured Products Are Becoming the New Normal for Large Companies

www.ibm.com/internet-of-things/trending/digital-twin

"A digital twin is a virtual representation
of a physical object or system across its lifecycle,
using real-time data
to enable understanding, learning and reasoning."

IBM

"The whole Tesla fleet operates as a network.
When one car learns something, they all learn it.
Each driver using the autopilot system
becomes an expert trainer
for how the autopilot should work."
-Elon Musk, CEO Tesla



https://fortune.com/2015/10/16/how-tesla-autopilot-learns/

PRP
PACIFIC RESEARCH PLATFORM

The GreenLight Project (NSF MRI: 2008-2010, $2M): Instrumenting the Energy Cost of Computational Science

- **Sun Microsystems Modular Datacenter**
  - 8 Racks of Diverse (CPU, GPU, FPGA, Disks) Compute/Storage
  - 10 Gbps Optical Fiber Networked Connectivity
- **Measure, Monitor, & Web Publish Real-Time Sensor Outputs**
  - Temperature and Power Consumption Realtime Data Streams
    - 40 Points (5 Spots in 8 Racks)
  - Researchers Explore Tactics For Maximizing Work/Watt
- **Focus on Five At-Scale Computing Communities**
- **Partnering With Minority-Serving Institutions Cyberinfrastructure Empowerment Coalition**







PACIFIC RESEARCH PLATFORM

Source: http://greenlight.calit2.net/
GreenLight PI Tom DeFanti, Calit2@UCSD;
GreenLight co-PIs: Ingolf Krueger, Phil Papadopoulos, Larry Smarr, Amin Vahdat, UCSD

Calit2's GreenLight Project:
Digital Twin of the Modular Data Center in Virtual Reality



Source: Tom DeFanti, GreenLight PI

PACIFIC RESEARCH PLATFORM

2021-22: Can We Create a Digital Twin of the PRP/NRP? Augmented Reality Network Observatory (ARNO)

- **Blow Up the GreenLight Container Data Center and Distribute It as National Research Platform**
- **Every Component of the FIONAs and Networks are Constantly Monitored**
- **Creating High-Resolution Digital Models of the Installation of Each FIONA**
- **The Execution of All Containers Across the NRP Are Monitored**
- **These Data Streams Drive Virtual World Run By Gaming Engines**
- **Collaborative Diagnosis and Repair using AR in HoloLens2**

HoloLens 2

netbox

UNREAL ENGINE

ElastiFlow

AGONES

PRP PACIFIC RESEARCH PLATFORM

Source: John Graham, Jonathon Paden, UC San Diego

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