“Looking Back, Looking Forward NSF CI Funding 1985-2025”

The Third National Research Platform Workshop

Minneapolis, MN

September 24, 2019

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

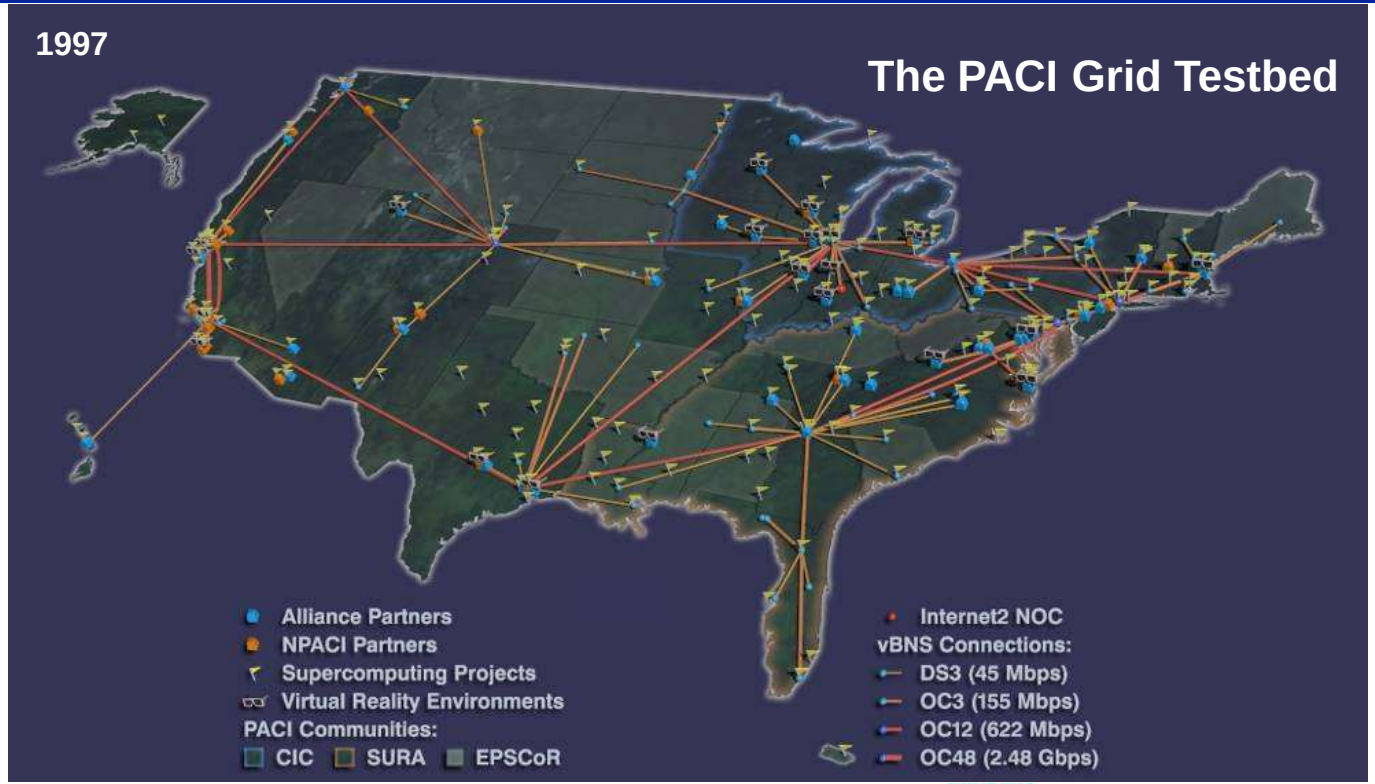
Jacobs School of Engineering, UCSD

http://lsmarr.calit2.net

PACIFIC RESEARCH PLATFORM

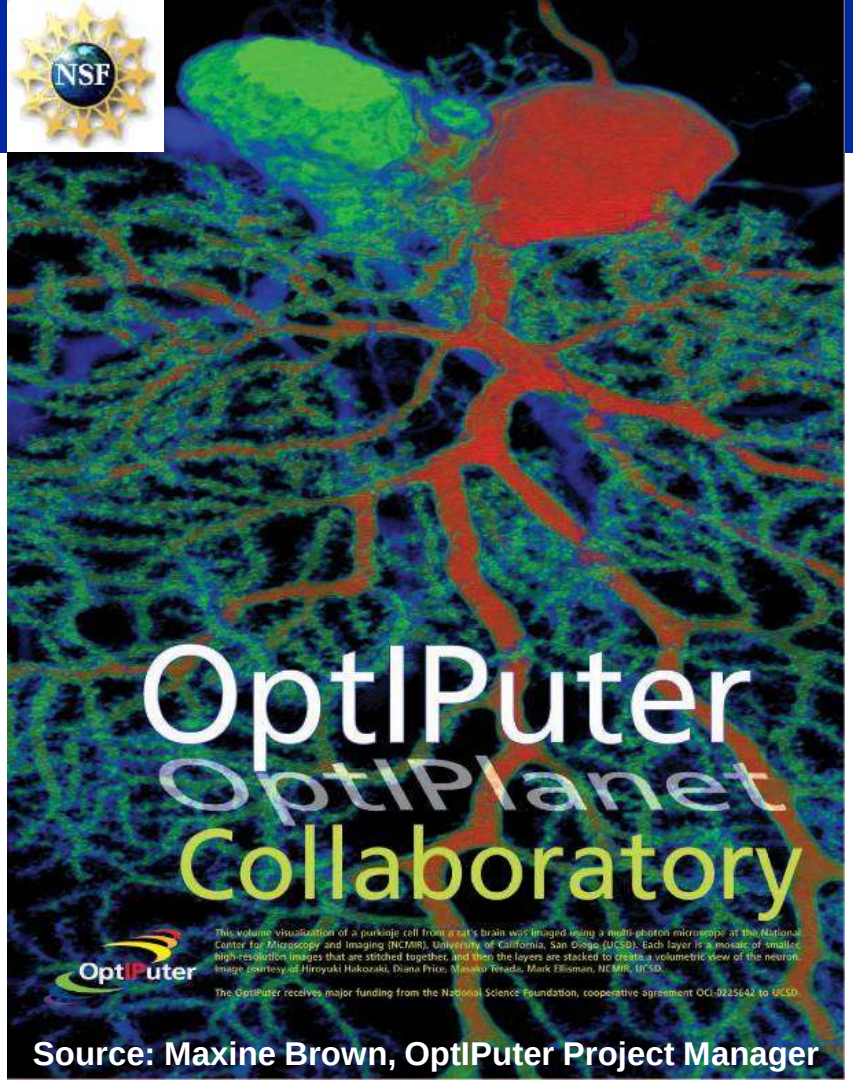
1985-2000 NSF Funds Supercomputer Centers, NSFnet, vBNS, and PACI: Creating the First National Research Platform

vBNS led to



PACIFIC RESEARCH PLATFORM

National Computational Science ALLIANCE



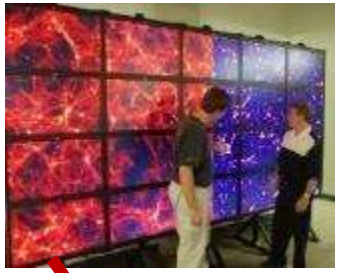
Source: Maxine Brown, OptIPuter Project Manager

The OptIPuter
Exploits a New World
in Which
the Central Architectural Element
is Optical Networking,
Not Computers.

Distributed Cyberinfrastructure
to Support
Data-Intensive Scientific Research
and Collaboration

PI Smarr,
2002-2009

Integrated "OptIPlatform" Cyberinfrastructure System: A 10Gbps Prototype of an NRP



End User OptIPortal



Instruments





HD/4k Video Cams

HPC



Campus Optical Switch

10G Lightpath



TeraGrid

LS 2009 Slide



Data Repositories & Clusters



HD/4k Video Images

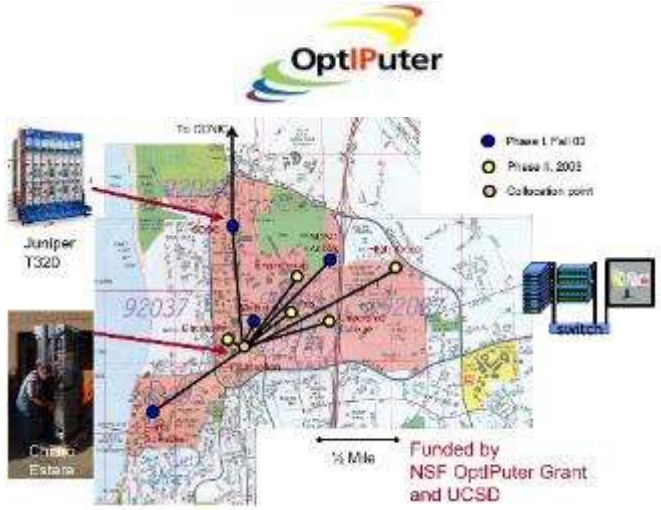
PRP PACIFIC RESEARCH PLATFORM

OptIPuter

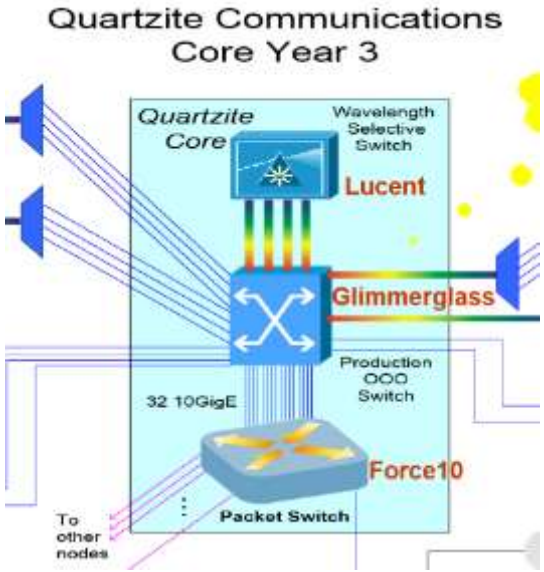
SDSC

it²

2000-2015 Using UCSD Campus as Development Prototype: NSF OptIPuter, Quartzite, Prism Awards

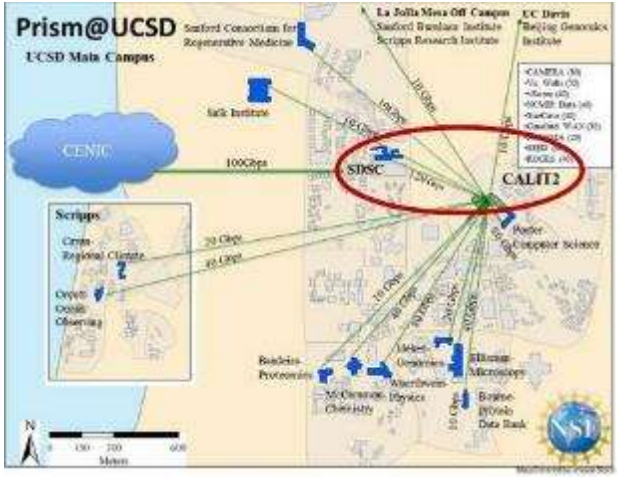


PI Smarr
2002-2009



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

PI Papadopoulos
2004-2007



PI Papadopoulos
2013-2015

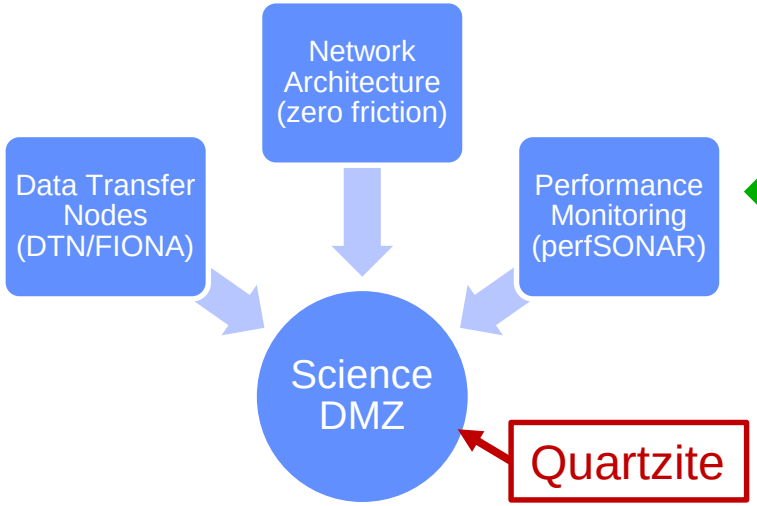
PRP PACIFIC RESEARCH PLATFORM

SDSC

it²

2010-2018: 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/

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

PRP PACIFIC RESEARCH PLATFORM

ESnet FASTERDATA KNOWLEDGEBASE

NSF

it²

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



Source: John Hess, CENIC

NSF CC*DNI Grant
$6.3M 10/2015-10/2020
Year 5 Starts in 1 Week!

PI: Larry Smarr, UC San Diego Calit2
Co-PIs:

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

Letters of Commitment from:

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

ESnet: Given Fast Networks, Need DMZs and Fast/Tuned DTNs

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PRP Engineers Designed and Built Several Generations of Optical-Fiber Big-Data 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 192 TB Rotating Storage

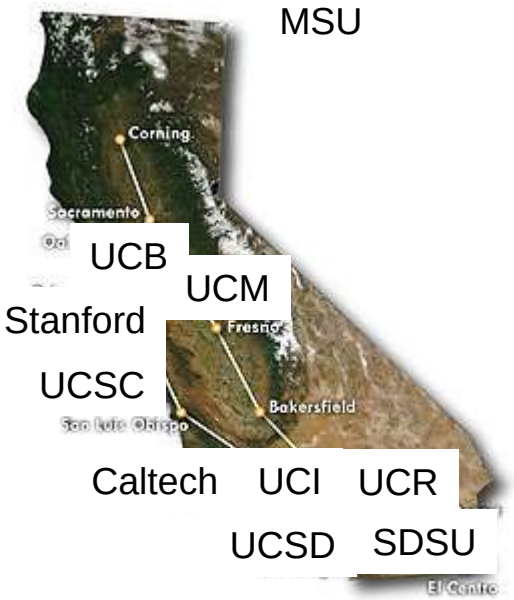




Add Up to 8 Nvidia GPUs Per 2U FIONA
To Add Machine Learning Capability

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

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



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

PRP PACIFIC RESEARCH PLATFORM

JACOBS SCHOOL OF ENGINEERING

SDSC UC San Diego it²

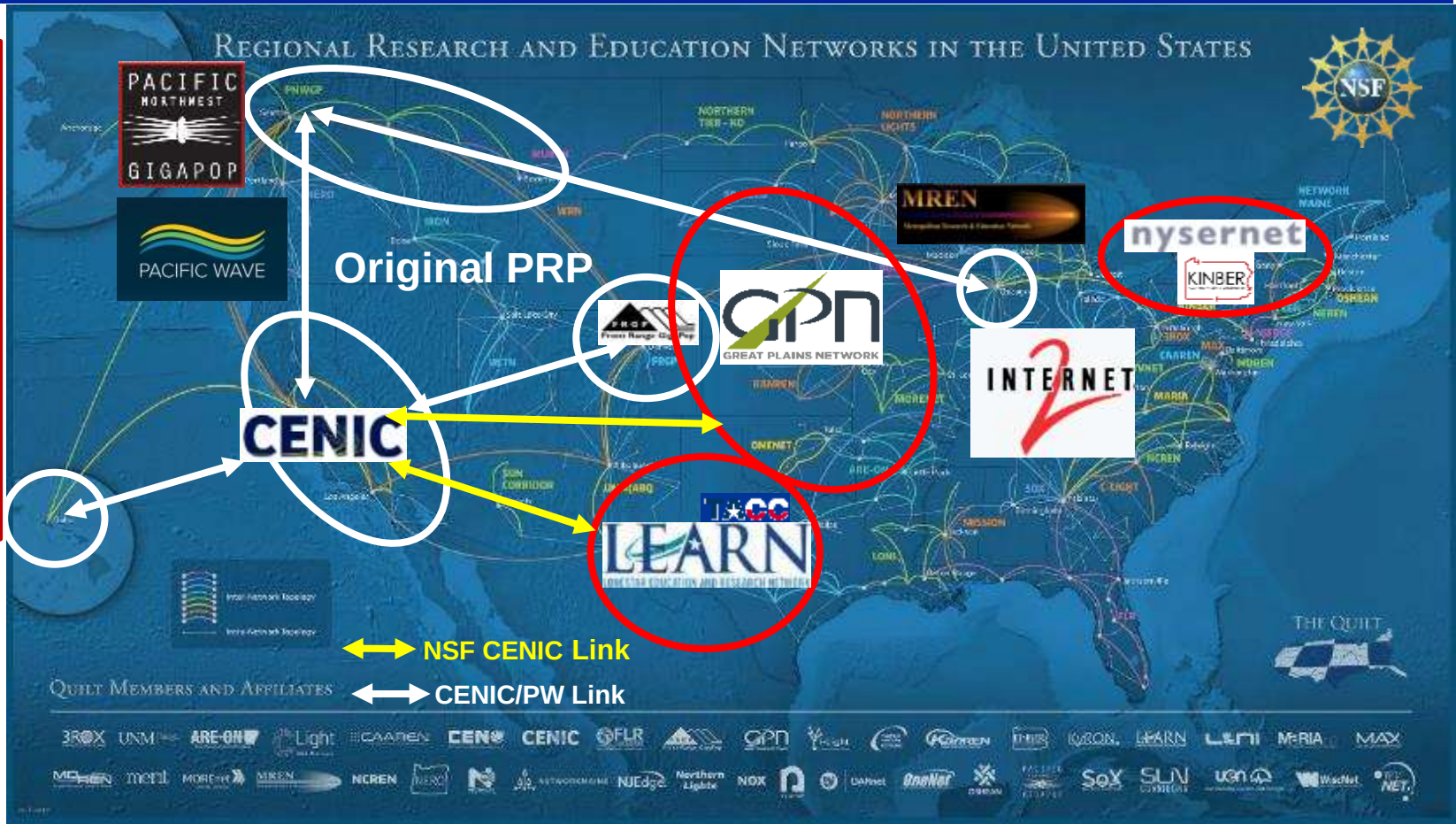
2018-2021: Toward the NRP - Using CENIC & Internet2 to Connect Quilt Regional R&E Networks

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

PI Smarr
Co-PIs Altintas Papadopoulos Wuerthwein Rosing DeFanti

SDSC

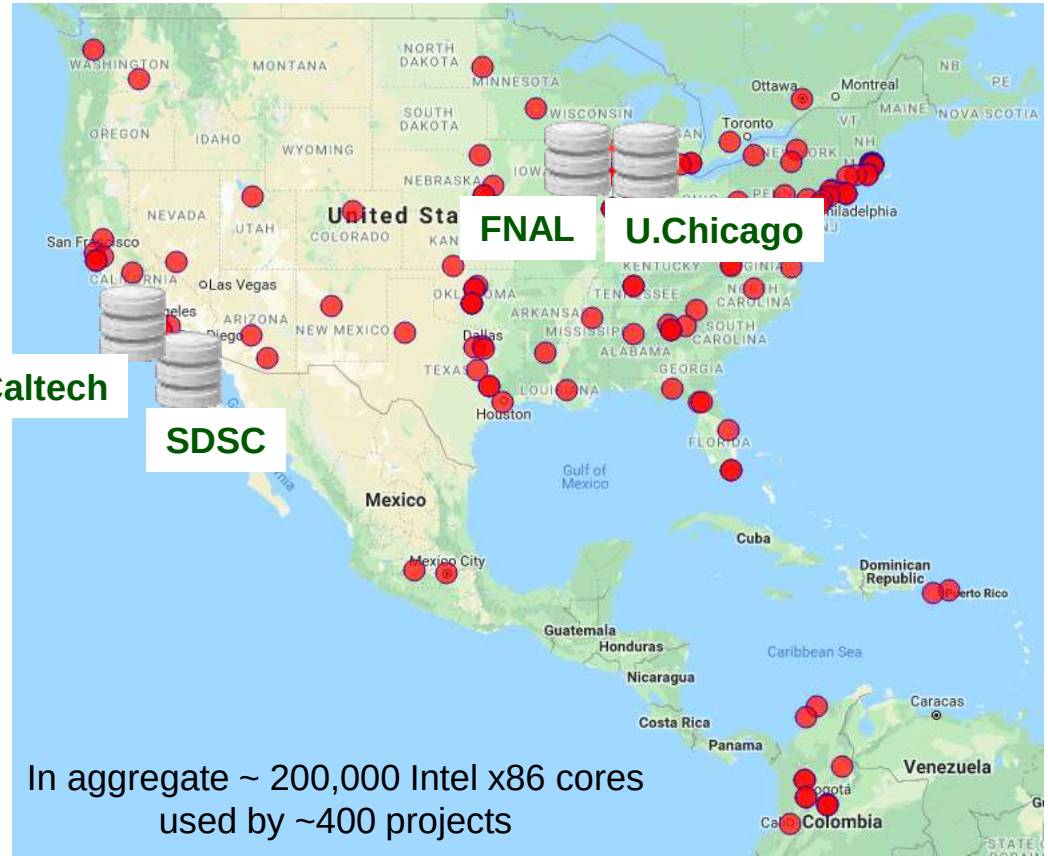
PRP
PACIFIC RESEARCH PLATFORM



OSG (an NRP Providing High Throughput Compute & Data Resources) Has Been Integrated With the PRP

OSG Federates ~100 Clusters Worldwide

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



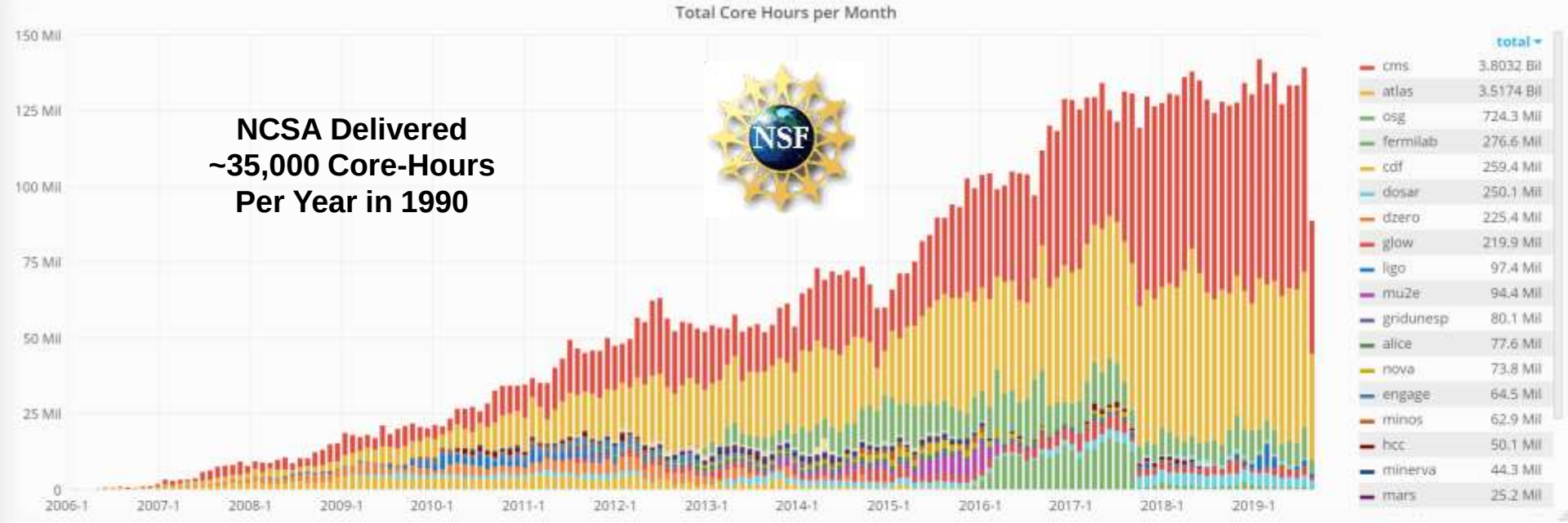
Open Science Grid

PRP PACIFIC RESEARCH PLATFORM

NSF

it²

The Open Science Grid Delivers 1.8 Billion Core-Hours Per Year to Over 50 Fields of Science



NCSA Delivered ~35,000 Core-Hours Per Year in 1990

Active Virtual Organizations	Active Sites	Represented Fields of Science
20	149	50

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GRACC Grid Accounting

https://gracc.opensciencegrid.org/dashboard/db/gracc-home

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,

PRP PACIFIC RESEARCH PLATFORM

CLOUD NATIVE COMPUTING FOUNDATION

it²

PRP Uses Cloud-Native Rook as a Storage Orchestrator, Running '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.

PRP PACIFIC RESEARCH PLATFORM

Source: John Graham, Calit2/QI

it²

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

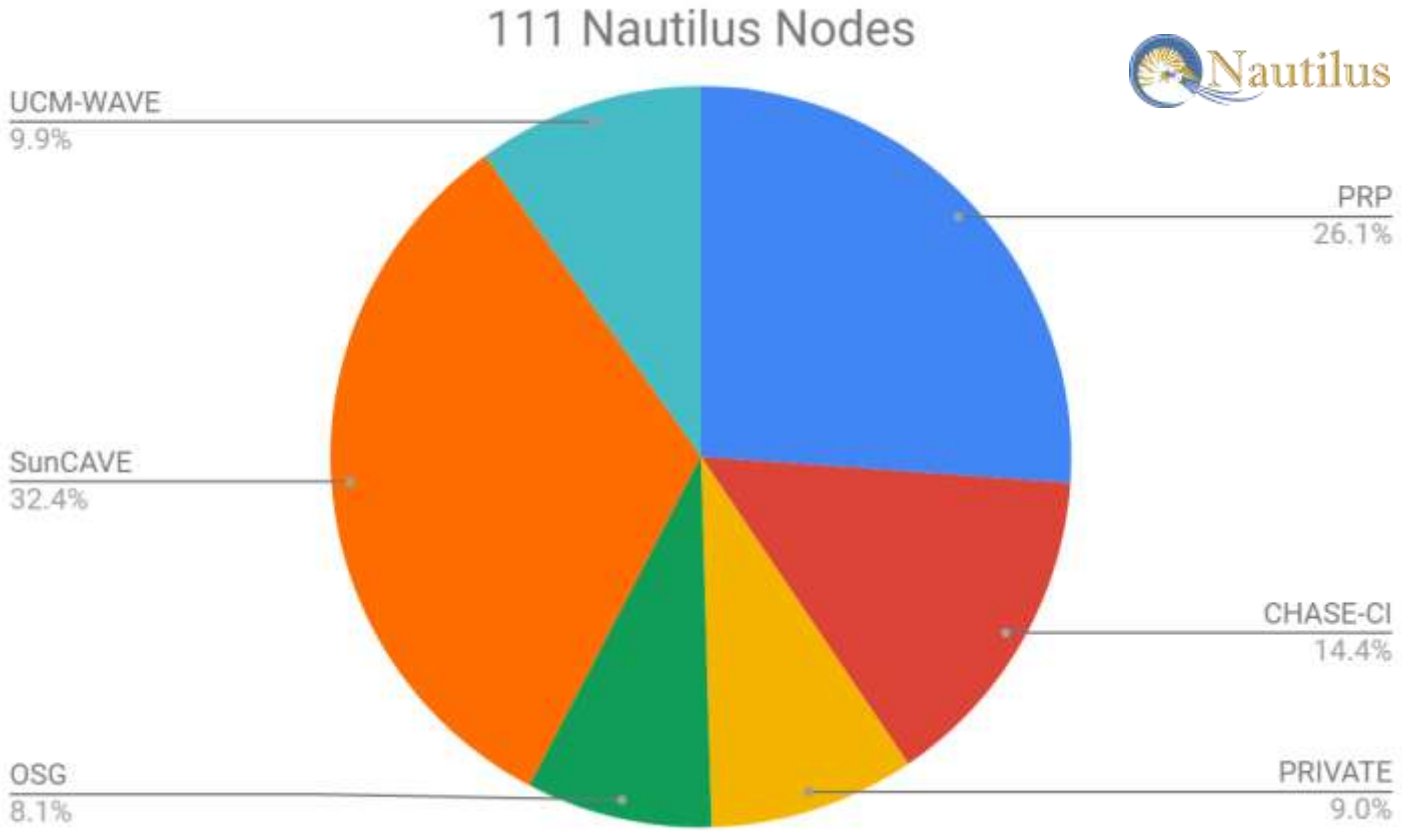
Designed on the same principles that allows Google to run billions of containers a week, Kubernetes can scale without increasing your ops team.

"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

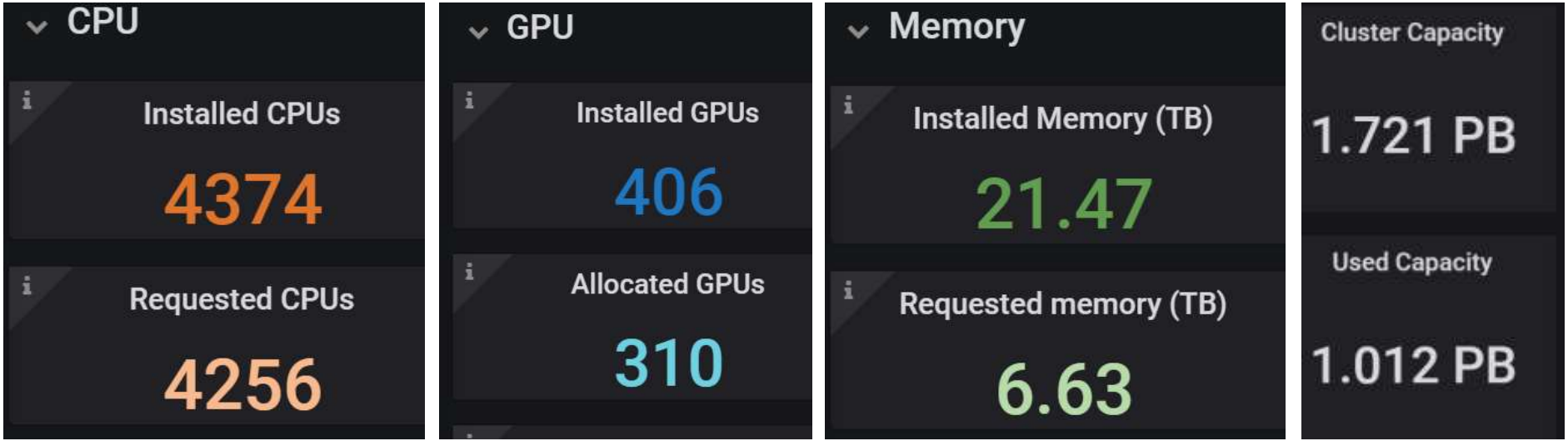
PRP
PACIFIC RESEARCH PLATFORM

it²

Community Participation Enables # of PRP-Paid Nautilus Nodes to be Quadrupled



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



Source: grafana.nautilus.optiputer.net on 9/22/2019

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

Nautilus

Minority Serving Institution

PRP Disks
CHASE-CI
*= July RT

Calit2/UCI
4 FIONA8s*
40G 160TB
40G 160TB HPWREN

UCR
40G 160TB
1 FIONA8

USC
40G 160TB

UCLA
2x40G 160TB
100G NVMe 6.4TB

Caltech
100G NVMe 6.4TB

USD
40G 192TB

CSUSB
10G 3TB

UCSB
40G 192TB
2 FIONA8s*

CENIC

15-Campus Nautilus Cluster:
4360 CPU Cores 134 Hosts
~1.7 PB Storage
407 GPUs, ~4000 cores each

UCSC
40G 160TB
100G NVMe 6.4TB
4.5 FIONA8s

NPS
100G 48TB

SDSC @ UCSD
8 FIONA8s + 5 FIONA8s
100G Gold NVMe
100G Epyc NVMe

UCSD
2x40G 160TB HPWREN
17 FIONA8s
35 FIONA2s

SDSU
FPGAs + 2PB BeeGFS
1 FIONA8* 2 FIONA4s
100G NVMe 6.4TB
40G 160TB HPWREN

UCM
40G 160TB
2 FIONA8
10 FIONA2s

UCSF
40G 192TB

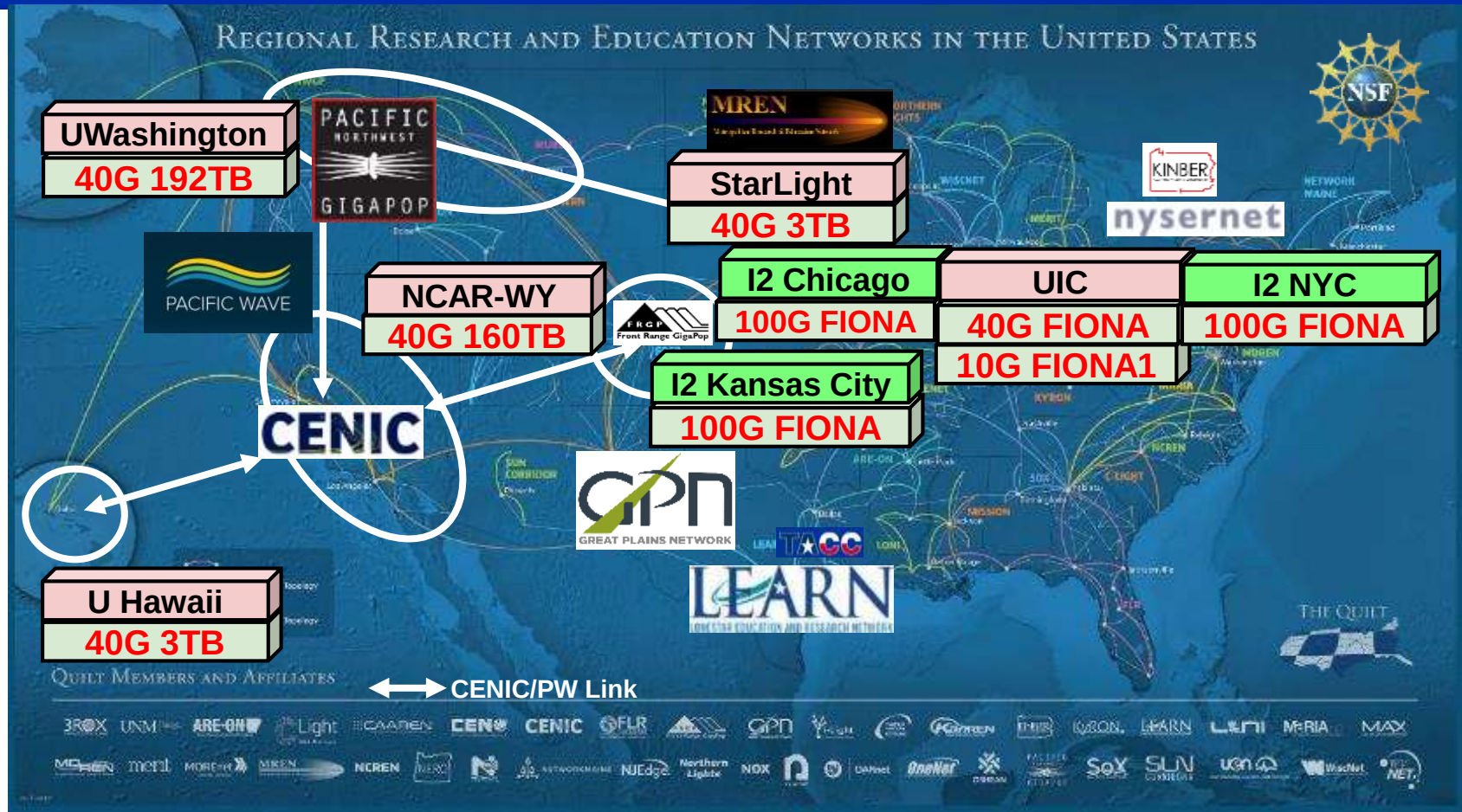
Stanford U
40G 160TB
1 FIONA8*

CITRIS BANATAO INSTITUTE

SDSC

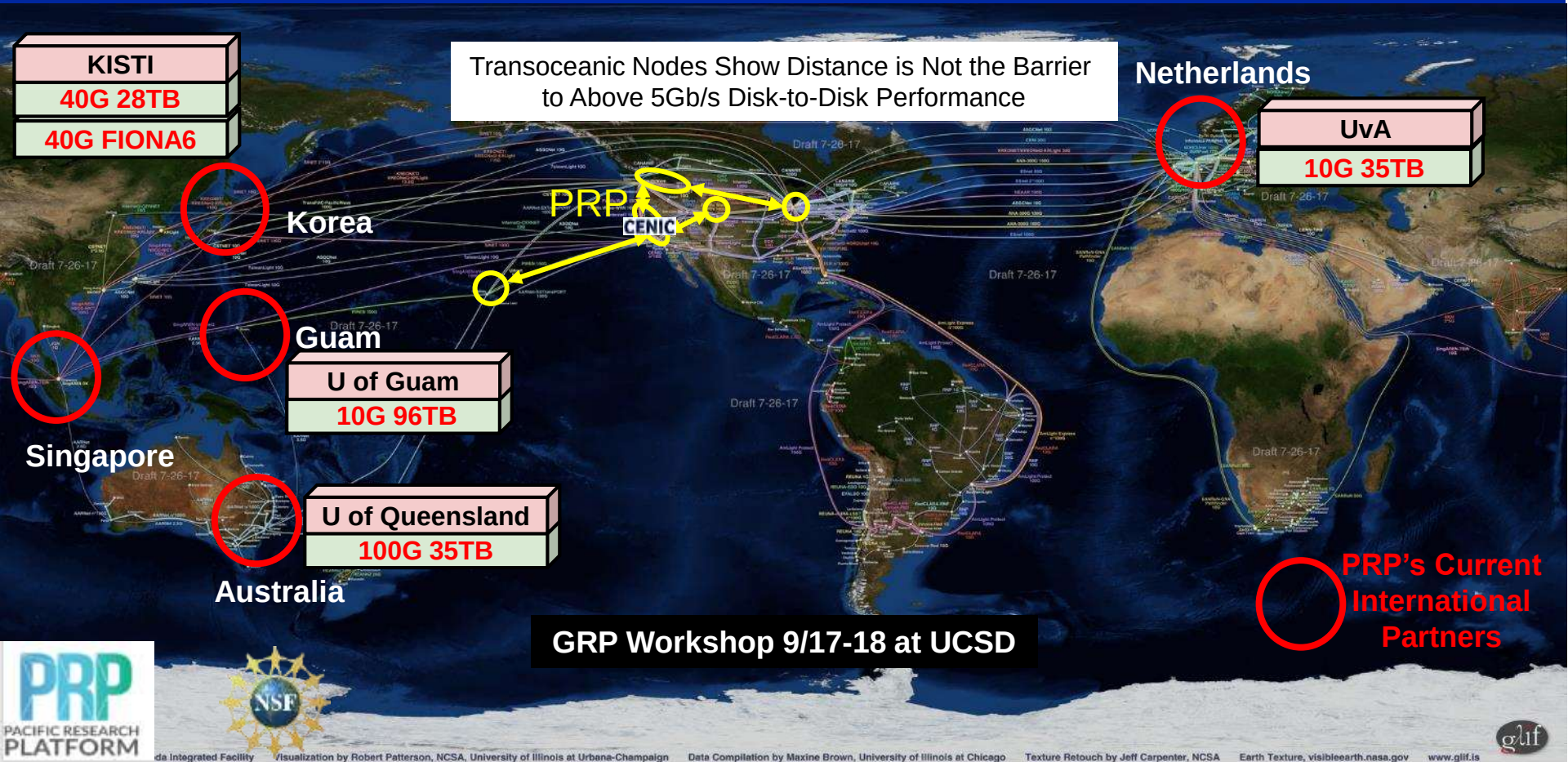
it²

PRP/TNRP's United States Nautilus Hypercluster FIONAs Now Connects 4 More Regionals and 3 Internet2 sites



PRP PACIFIC RESEARCH PLATFORM

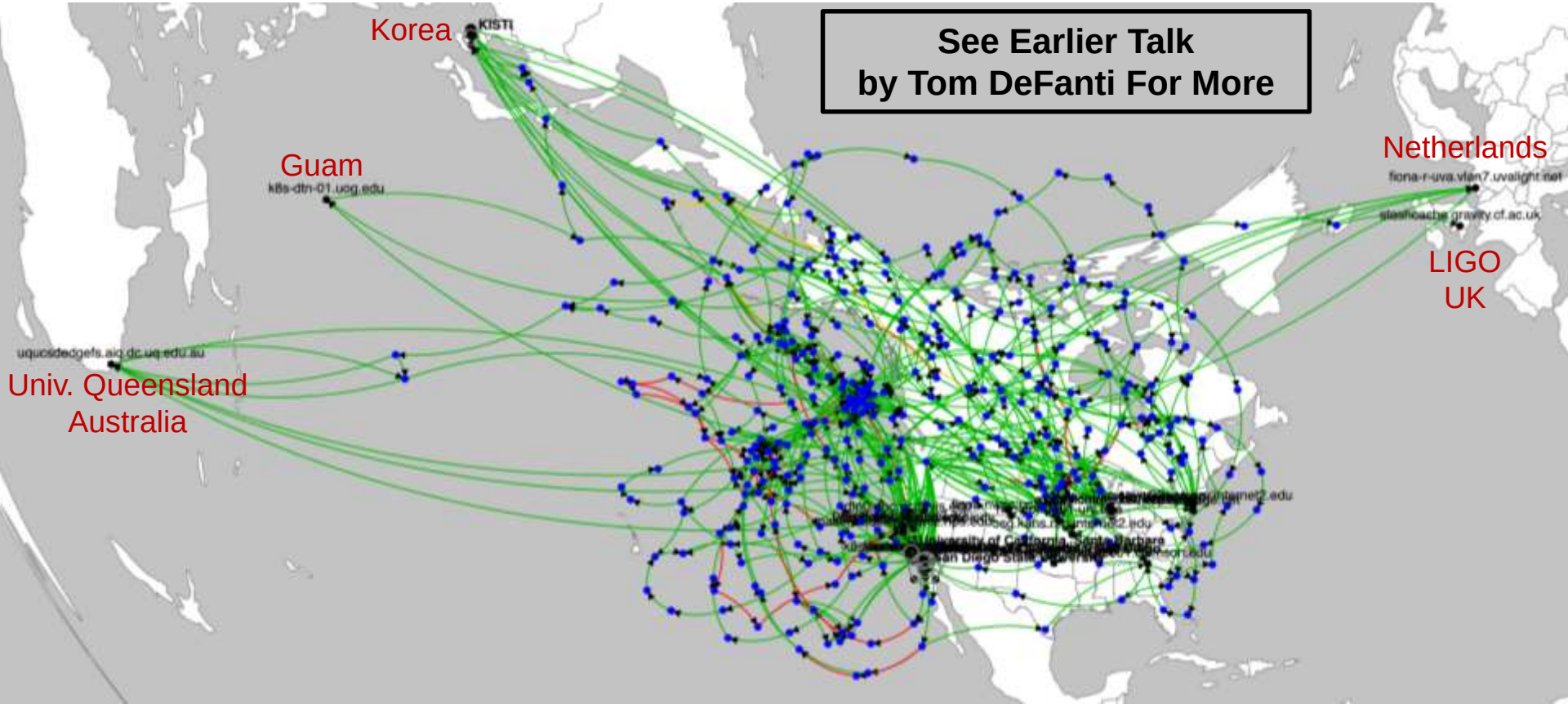
Global PRP Nautilus Hypercluster Is Rapidly Adding International Partners Beyond Our Original Partner in Amsterdam



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



The First GRP Workshop Was Held Last Week



PRP PACIFIC RESEARCH PLATFORM

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



CMS

Particle Physics

Biomedical ‘omics

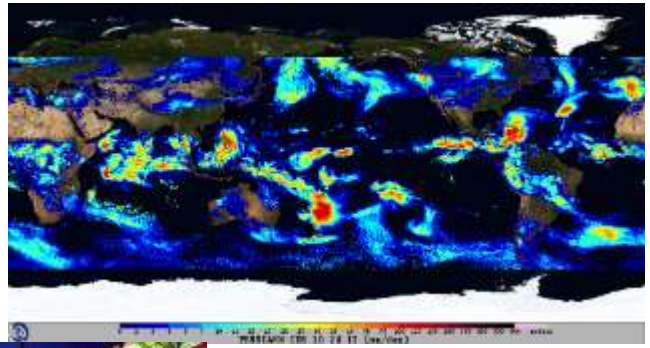


NSF

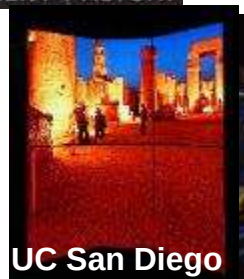


Telescope Surveys

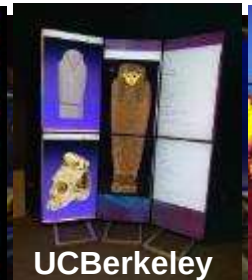
Earth Sciences



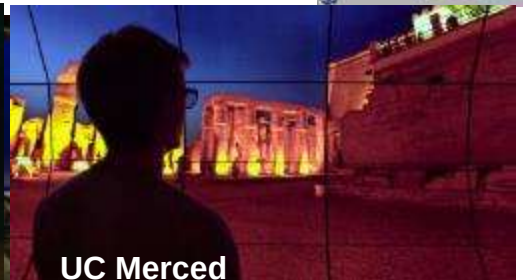
Visualization, Virtual Reality, Collaboration



UC San Diego



UCBerkeley



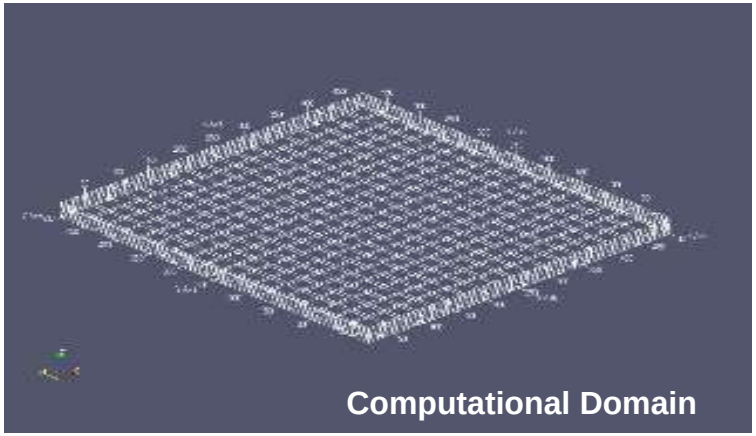
UC Merced

CITRIS
BAN
INST
SDSC
it²

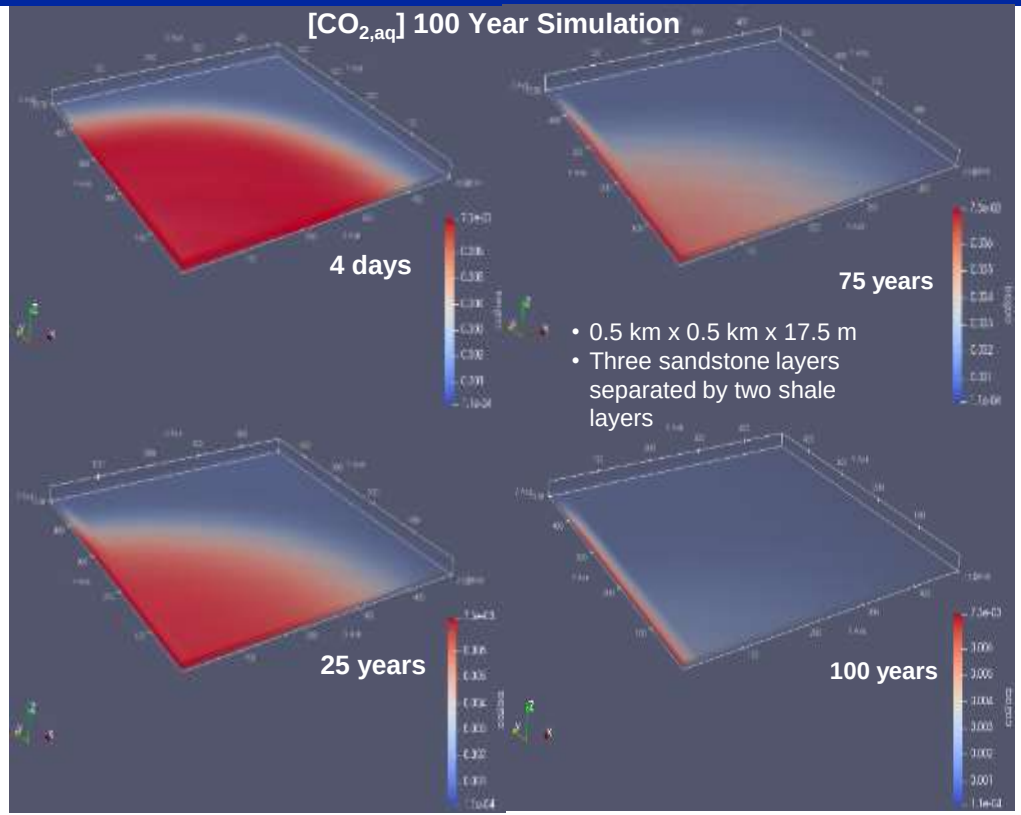
Moving a Supercomputer Application to a Distributed Computation on PRP:

Simulating the Injection of CO_2 in Brine-Saturated Reservoirs:

Poroelastic and Pressure-Velocity Fields Solved In Parallel Over the PRP, Using MPI for Domain Decomposition, Orchestrated by Kubernetes Containers on FIONA Nodes



Numerical methods:
Finite Elements for Solid Phase,
Finite Volume for Aqueous Phase



Evolution of Formation Water Carbonic Acid Concentration in Time, After 4 Days of Injection

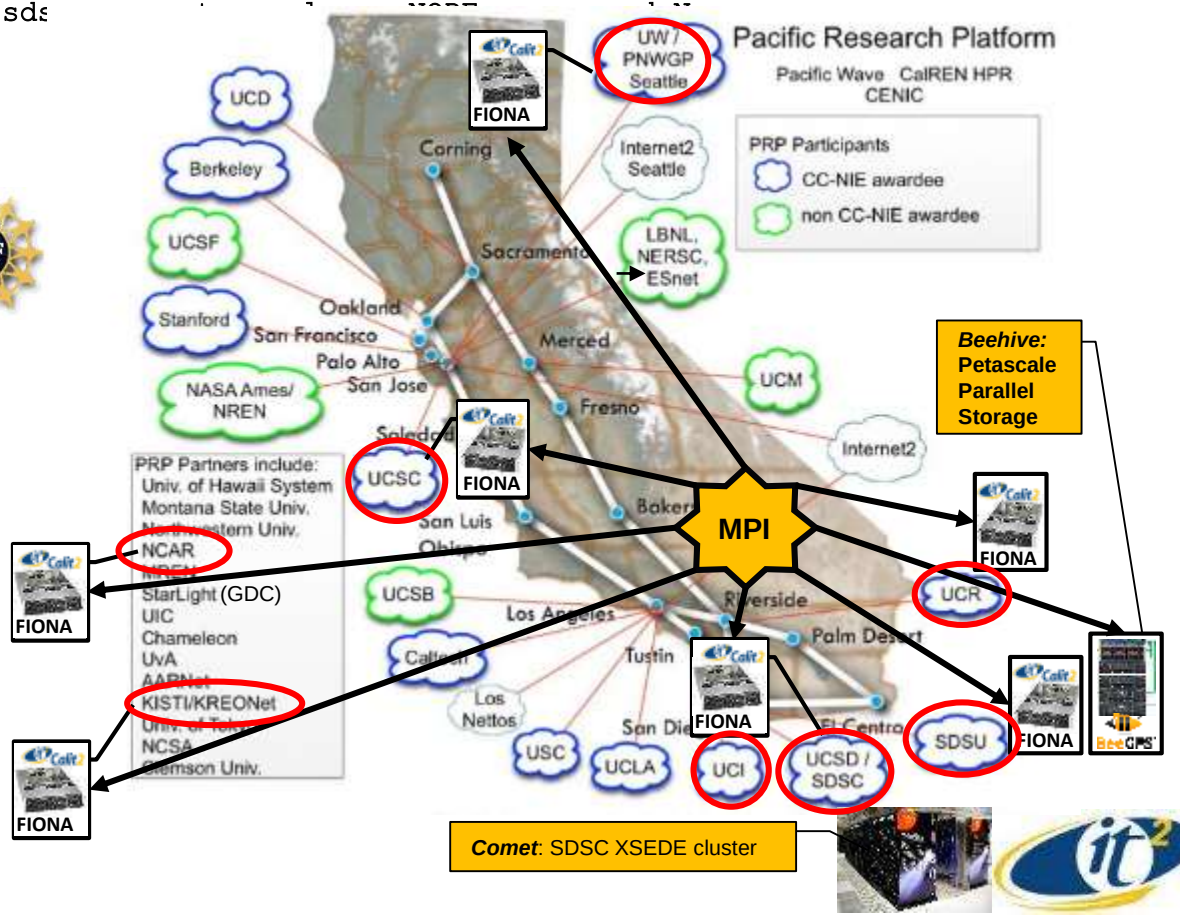
PRP Distributed-Parallel Computation: Using OpenMPI on Kubernetes to Create Distributed Pods

```
[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
```

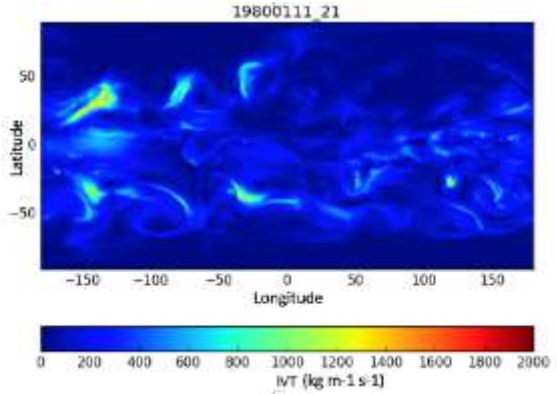
Source: Chris Paolini, SDSU



PRP PACIFIC RESEARCH PLATFORM

PRP Enables Speed-Ups of Complex Distributed Workflows: Scott Sellars' Rapid 4D Object Segmentation of NASA Water Vapor Data

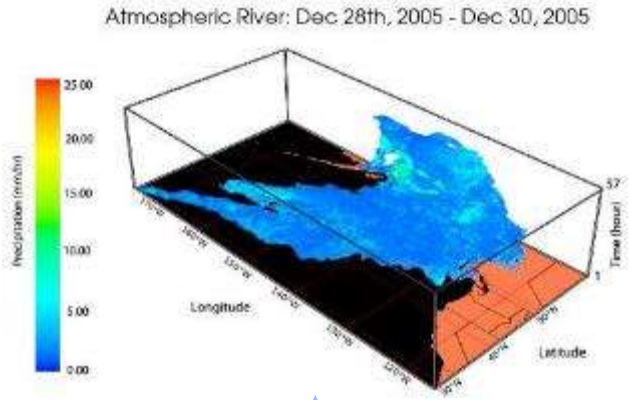
NASA *MERRA v2 – Water Vapor Data Across the Globe



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 Enabled Scott's Workflow to Run 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



Source: Scott Sellers, CW3E

UC, San Diego

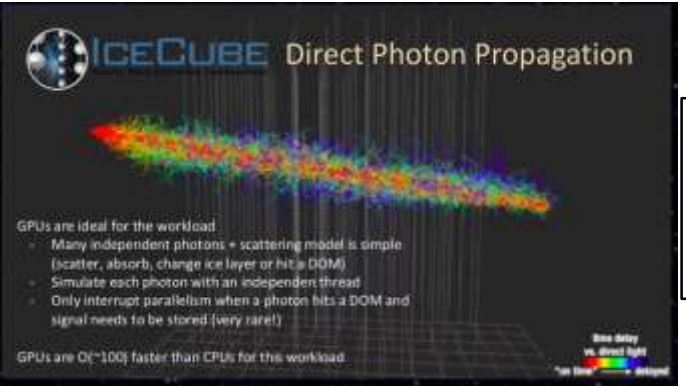
GPUs



Calit2's FIONA

NSF Large-Scale Observatories
Are Beginning to Utilize PRP Compute Resources





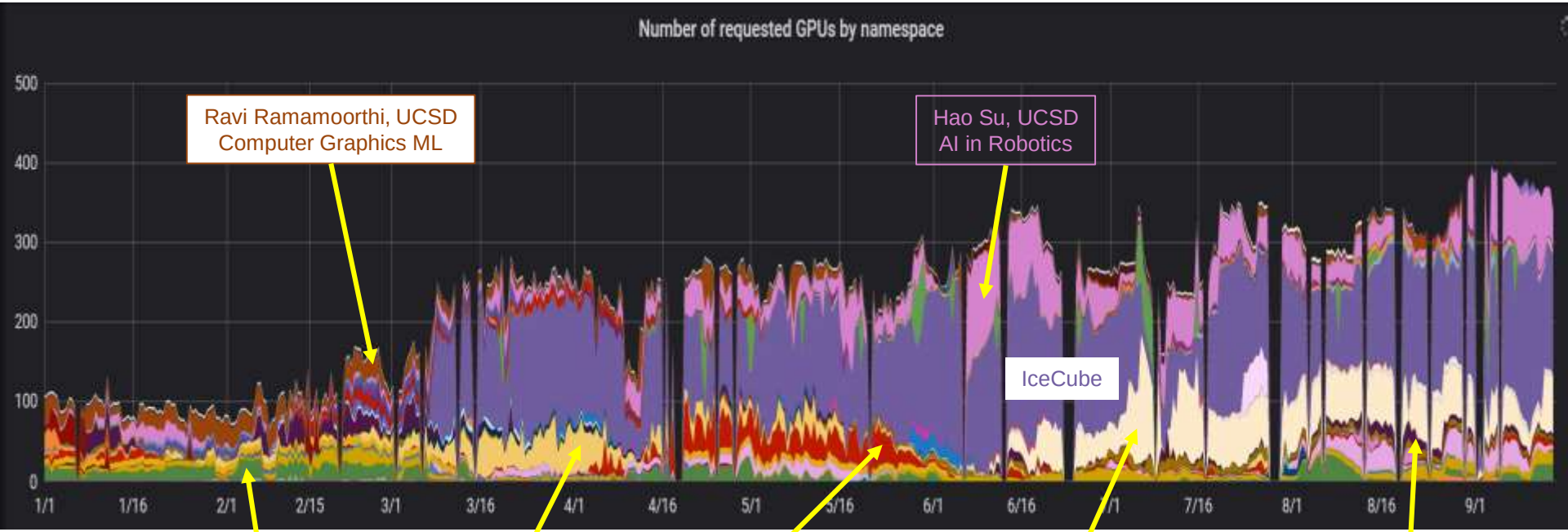
GPU Simulations Needed *to Improve Ice Model*.
=> Results in Significant Improvement in Pointing Resolution for Multi-Messenger Astrophysics

PRP
PACIFIC RESEARCH PLATFORM

IceCube & LIGO Both See Nautilus
as Just Another OSG Resource

it²

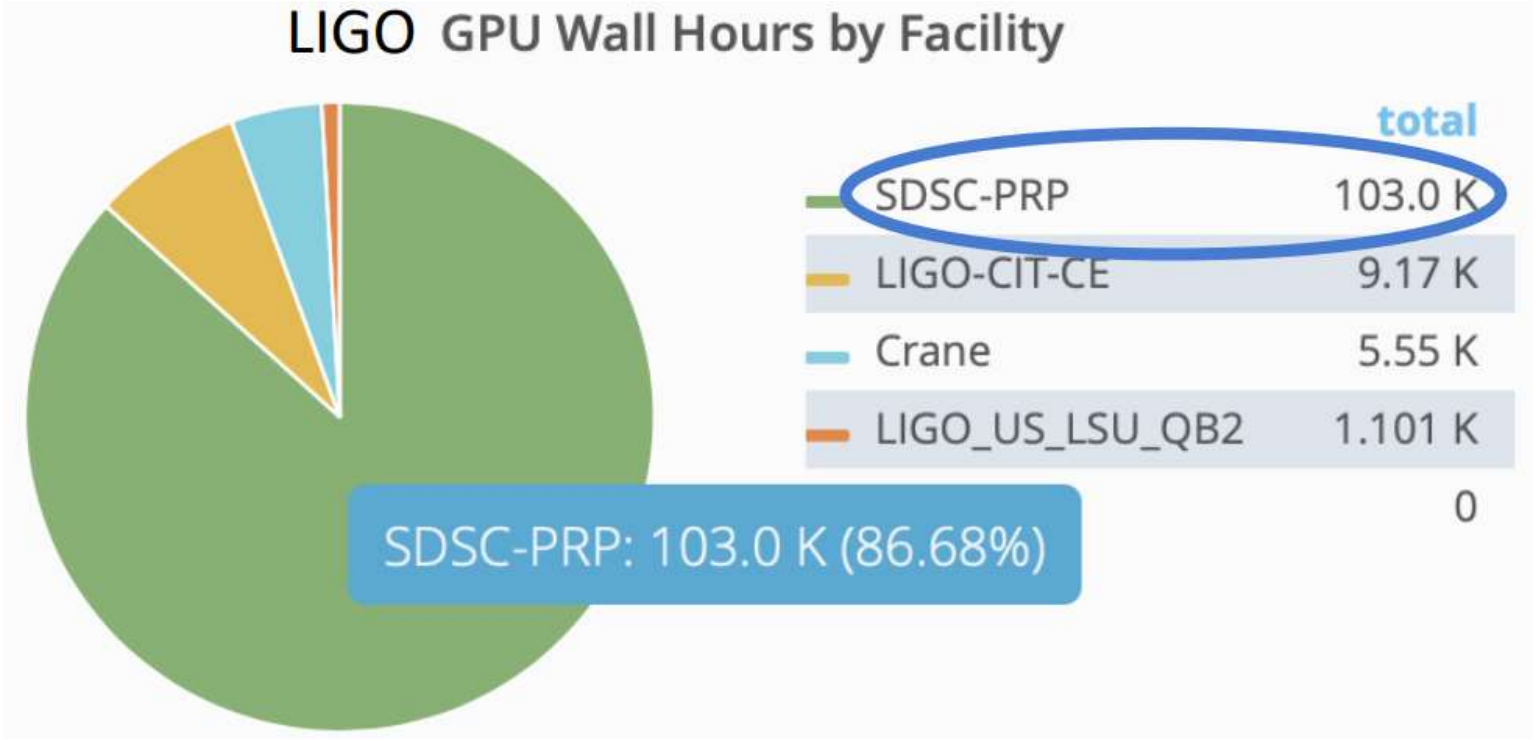
In 2019 a Growing Number of Applications and Campuses Have Driven a 4-Fold Increase in Requested Nautilus GPUs



PACIFIC RESEARCH PLATFORM

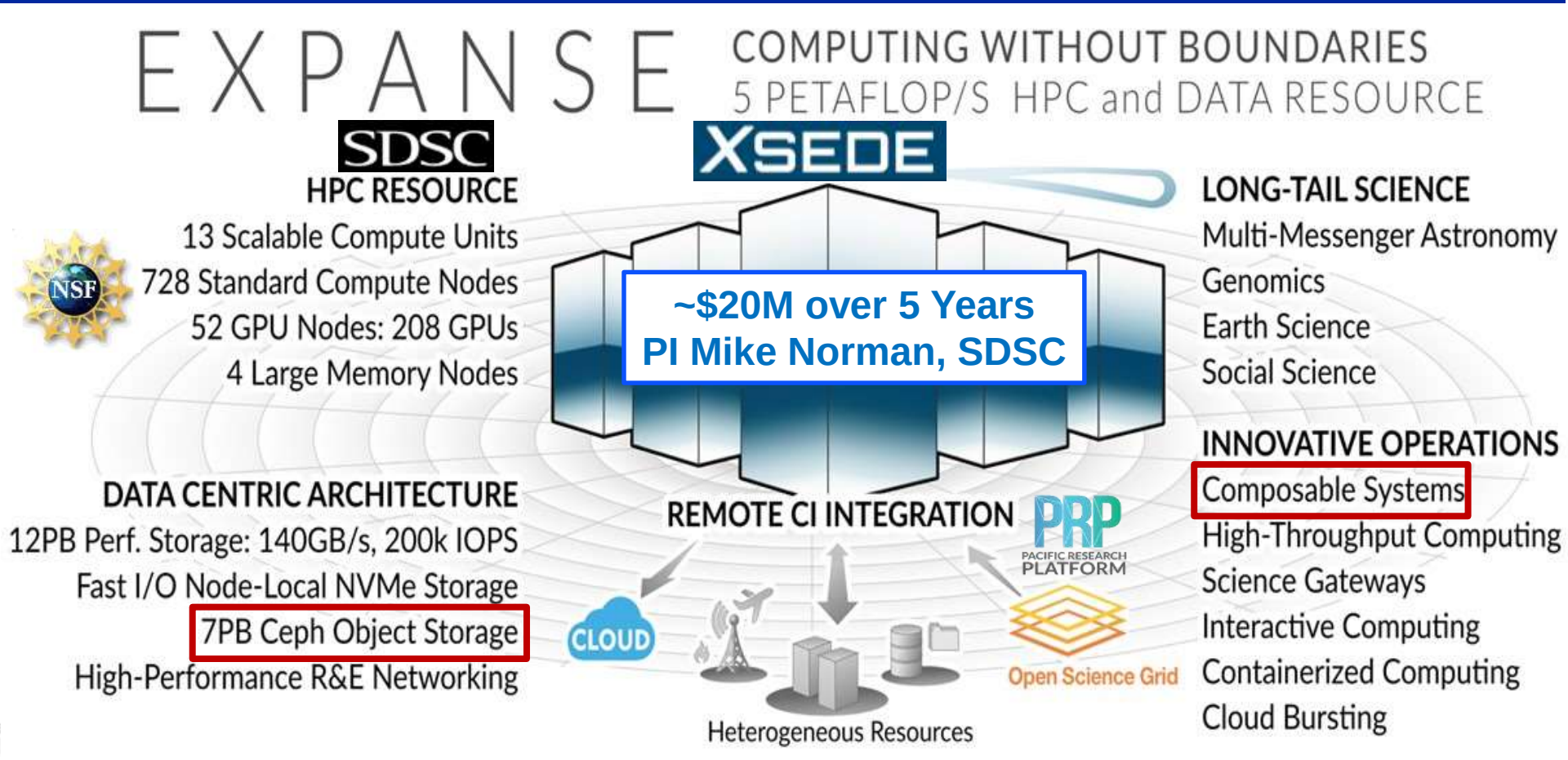
https://grafana.nautilus.optiputer.net

Over the Last 3 Months, PRP Nautilus Has Grown to Providing the Great Majority of LIGO GPU Compute Time

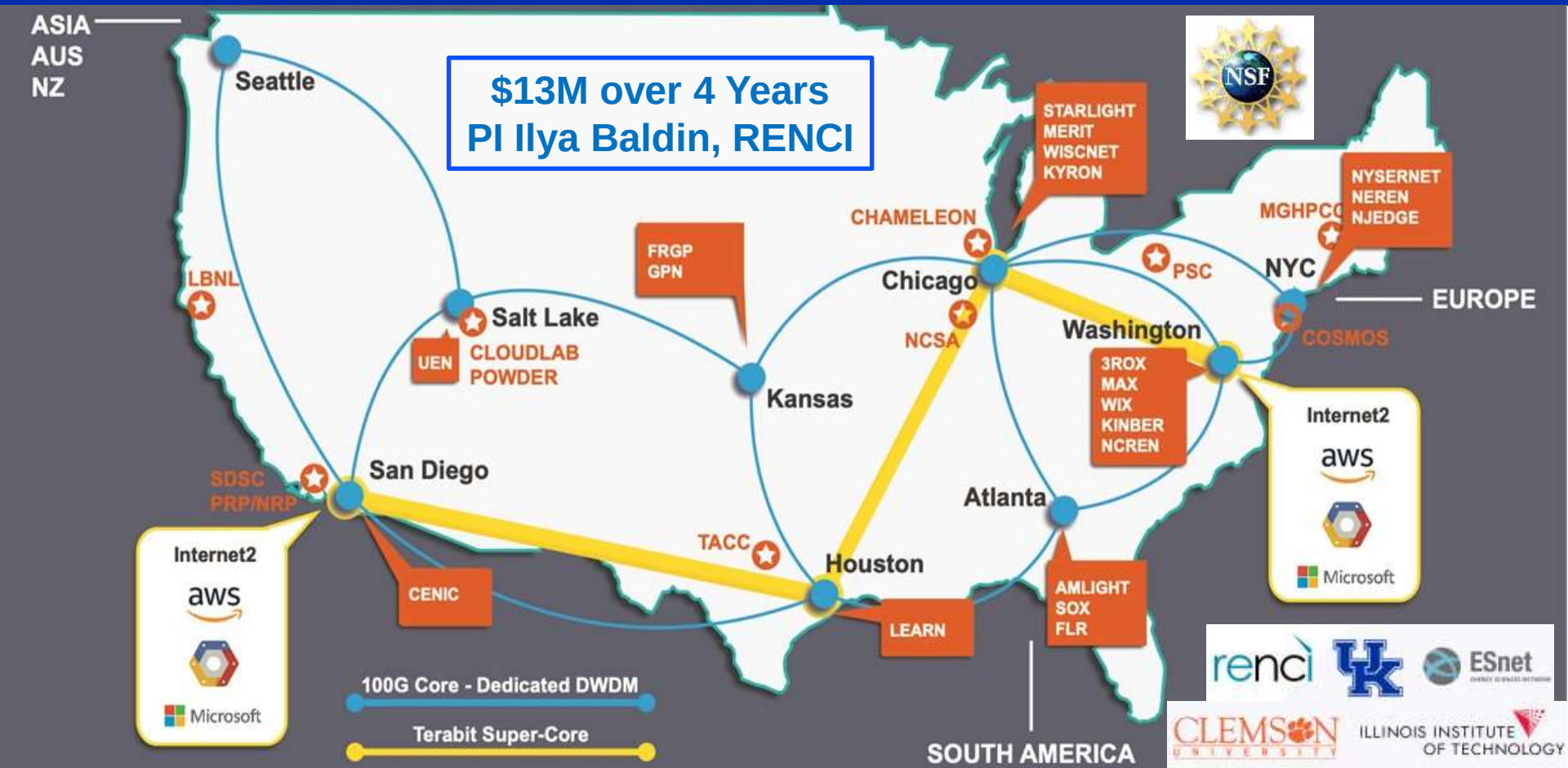


Source: GRP Talk by Igor Sfiligoi, UCSD/SDSC/OSG

2020-2025 NRP Future # 1:
SDSC's EXPANSE Will Use CHASE-CI Developed Composable Systems



2019-2024 NRP Future # 2:
FABRIC Will Engage PRP/TNRP Technologies and Partners



Next Steps:
Formalize Distributed NRP User On-Ramping, Training, and Support

Attend Session “Group Discussion & Wrap Up: What's Next?”
Today 4:15-5:15pm

And “Panel Discussion: How Regional Partnerships with National Performance Engineering and Outreach Initiatives are Enabling Science”
Tomorrow 1:45-2:45pm

or

“Just Do What Dana Brunson* Says” 😀

PRP PACIFIC RESEARCH PLATFORM

INTERNET2

* Internet2 Exec Director for Research Engagement & Co-Manager of XSEDE Campus Engagement Program

XSEDE

it2

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

And Developing: Indiana University's EPOC