“Toward the Global Research Platform”

Keynote Presentation SC Asia

Singapore

March 27, 2018

Dr. Tom DeFanti

Research Scientist, Co-PI The Pacific Research Platform and CHASE-CI

California Institute for Telecommunications and Information Technology’s

Qualcomm Institute

University of California San Diego

Distinguished Professor Emeritus, University of Illinois at Chicago

PACIFIC RESEARCH PLATFORM

Abstract

Abstract: The US National Science Foundation-funded (award # 1541349) “The Pacific Research Platform (PRP)” to the University of California San Diego for 5 years starting October 1, 2015. It emerged out of the unmet demand for high-performing bandwidth to connect data generators and data consumers. The PRP is in its third year of building a broad base of support from application scientists, campus CIOs, regional network leaders, and network engineers, and continues to successfully bring in new, unanticipated science applications, as well as test new means to dramatically improve throughput. The PRP is, in fact, a grand volunteer community in an ever-expanding region where 35 CIOs and 50 application scientists initially signed letters of support for the original NSF proposal, all as unfunded partners. The PRP was scaled to be a regional program by design, mainly focusing on West Coast US institutions, although it now includes several long-distance US and transoceanic Global Lambda Integrated Facility (GLIF) partners to verify that the technology used is not limited to the size and homogeneity of CENIC, the regional network serving California. There is pent-up demand from the high-performance networking and scientific communities to extend the PRP nationally, and indeed worldwide. This motivated the PRP to host The First National Research Platform Workshop in Bozeman, MT, in August 2017. At that meeting, a strong US and international community emerged, well documented in the report published on the PRP website (pacificresearchplarform.org). This presentation will discuss will cover lessons learned from PRP applications, technology, and science engagement activities, as well as how best to align future PRP networking strategies with the GRP’s emerging groundswell of enthusiasm. The goal is to prototype a future in which a fully-funded multi-national Global Research Platform emerges.

This presentation includes ideas, words and visuals from many sources,
Most prominently: the PI of the PRP and CHASE-CI, Larry Smarr, UCSD

Thirty Years After US NSF Adopts US DOE Supercomputer Center Model
NSF Adopts DOE ESnet's Science DMZ for High Performance Applications

- **A Science DMZ integrates 4 key concepts into a unified whole:**
  - **A network architecture designed for high-performance applications, with the science network distinct from the general-purpose network**
  - **The use of dedicated systems as data transfer nodes (DTNs)**
  - **Performance measurement and network testing systems that are regularly used to characterize and troubleshoot the network**
  - **Security policies and enforcement mechanisms that are tailored for high performance science environments**

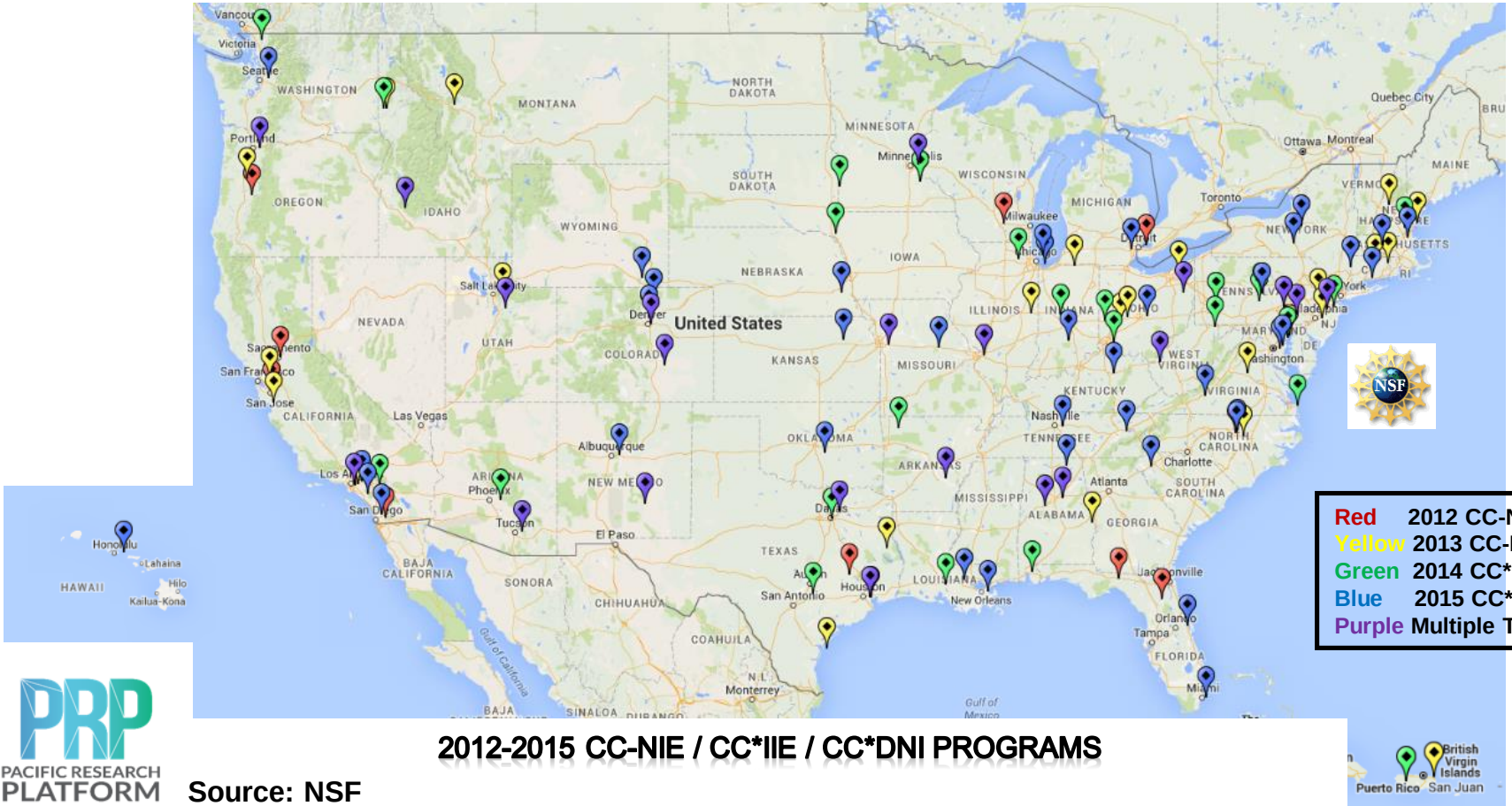
Science DMZ
Coined 2010

ESnet
FASTERDATA KNOWLEDGEBASE

PRP
PACIFIC RESEARCH PLATFORM

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

Based on Community Input and on ESnet's Science DMZ Concept, NSF Has Funded Over 100 US Campuses to Build DMZs

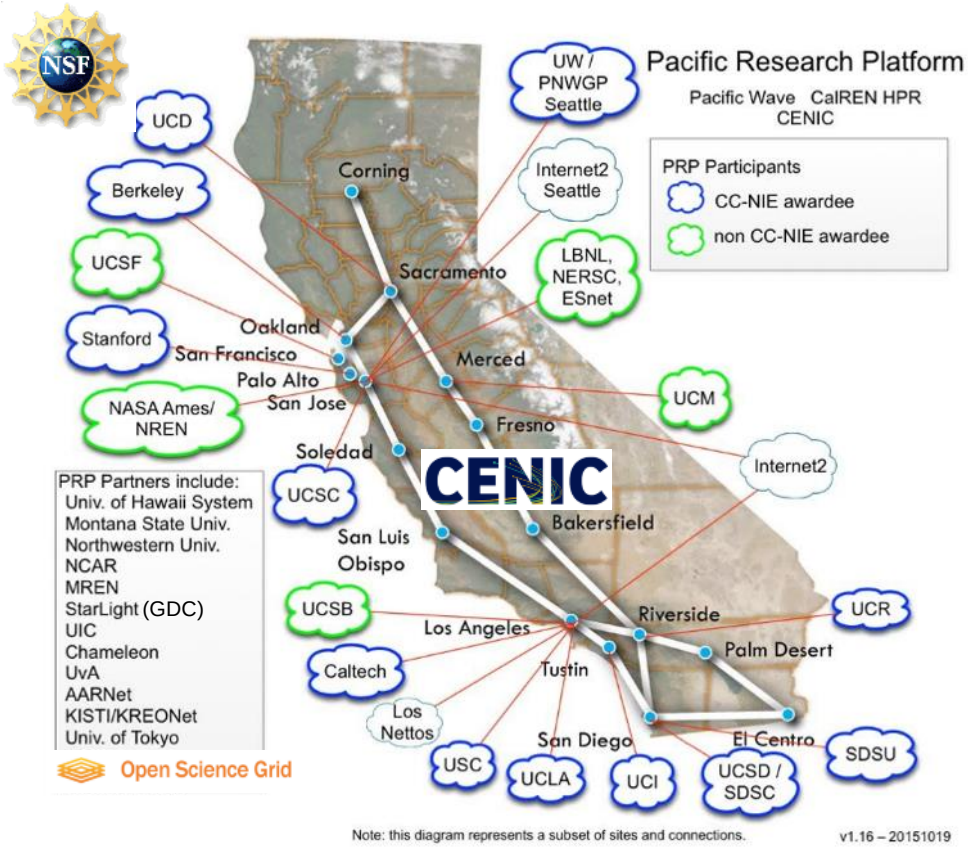


2012-2015 CC-NIE / CC*IIE / CC*DNI PROGRAMS

Source: NSF

PACIFIC RESEARCH PLATFORM

Logical Next Step: The Pacific Research Platform Networks Campus DMZs to Create a Regional End-to-End Science-Driven "Big Data Superhighway" System



Source: John Hess, CENIC

NSF CC*DNI DIBBsCooperative Agreement $6M 10/2015-10/2020

PI: Larry Smarr, UC San Diego Calit2

Co-PIs:

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

Letters of Commitment from:

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

PACIFIC RESEARCH PLATFORM

Key Innovation: UCSD Designed FIONAs To Solve the Disk-to-Disk Data Transfer Problem at Full Speed on 10/40/100G Networks

- FIONAs PCs [ESnet DTNs]:
  - **~$8,000 Big Data PC with:**
    - **10/40 Gbps Network Interface Cards**
    - **3 TB SSDs**
  - **Higher Performance at higher cost:**
    - **+NVMe SSDs & 100Gbps NICs Disk-to-Disk**
    - **+Up to 8 GPUs [4M GPU Core Hours/Week]**
    - **+Up to 196 TB of Disks used as Data *Capacitors***
    - **+Up to 38 Intel CPU cores or AMD Epyc cores**
  - **US$1,100 10Gbps FIONA (if 10G is fast enough)**
- FIONettes are US$300 EL-30-based FIONAs
  - **1Gbps NIC With USB-3 for Flash Storage or SSD**
  - **Perfect for Training and smaller campuses**

Phil Papadopoulos, SDSC &
Tom DeFanti, Joe Keefe & John Graham, Calit2

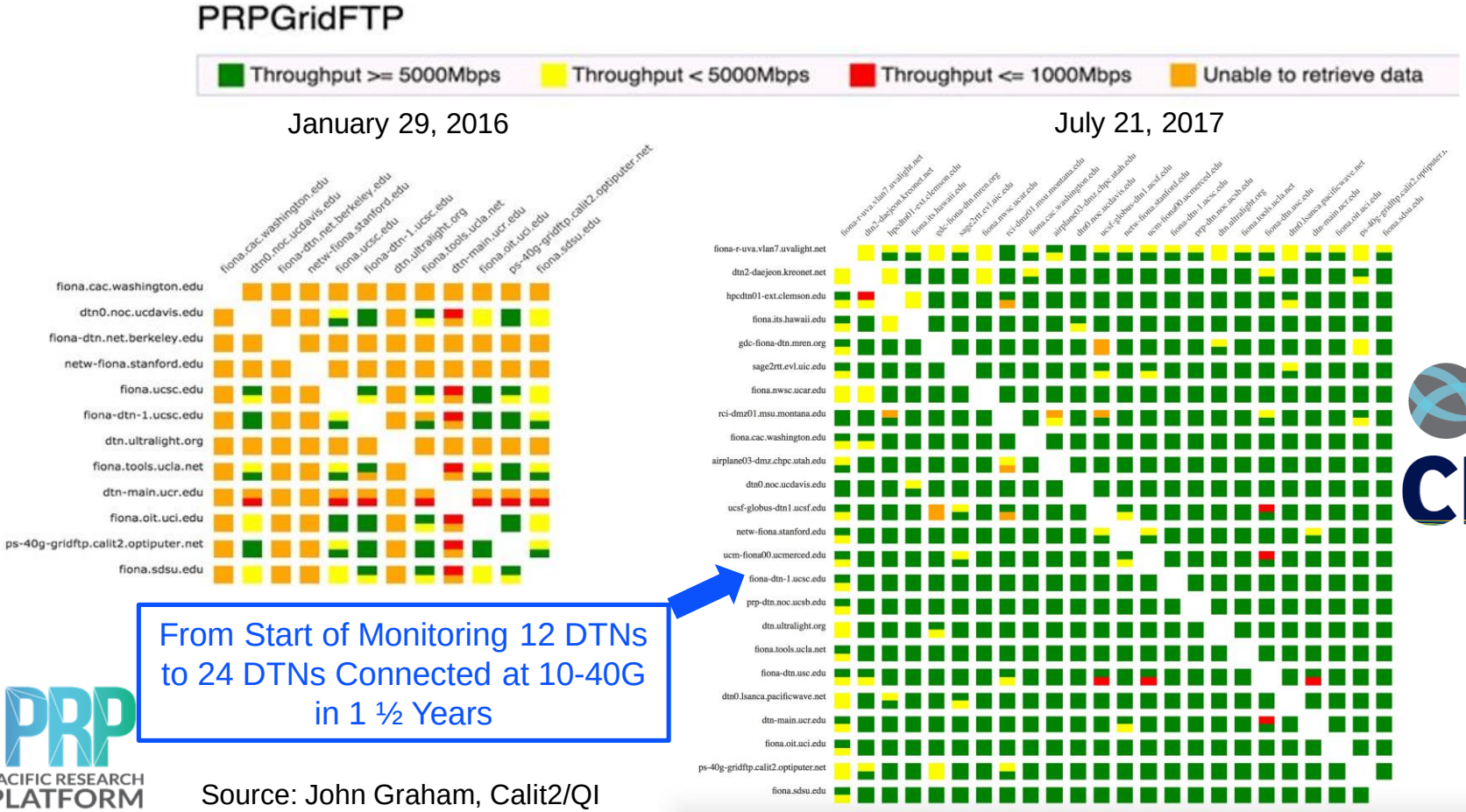
FIONAs on the PRP and Partners

- ~40 FIONAs are on the PRP as GridFTP (MaDDash) + perfSONAR Systems
  - PRP Partners: all 10 UCs, Caltech, Stanford, USC, SDSC, UW, UIC
  - Plus U Utah, Montana State, U Chicago, Clemson U, U Hawaii, NCAR, Guam
  - Plus Internationals: Uv Amsterdam, KISTI (Korea), Singapore

- Many States and Regionals Building FIONAs and Creating MaDDashes
  - FIONA Build Specs on pacificresearchplatform.org Website
  - Weekly Engineering Calls with Notes Going to 60+ Technical Participants
  - Fasterdata.es.net has lots of DTN and DMZ wisdom and data

PRP PACIFIC RESEARCH PLATFORM CENIC ESnet SDSC CITRIS AND THE BANATAO INSTITUTE it2

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/QI

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We Use Kubernetes to Manage FIONAs 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

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CLOUD NATIVE COMPUTING FOUNDATION

it2

Rook is Ceph Cloud-Native Object Storage ‘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.

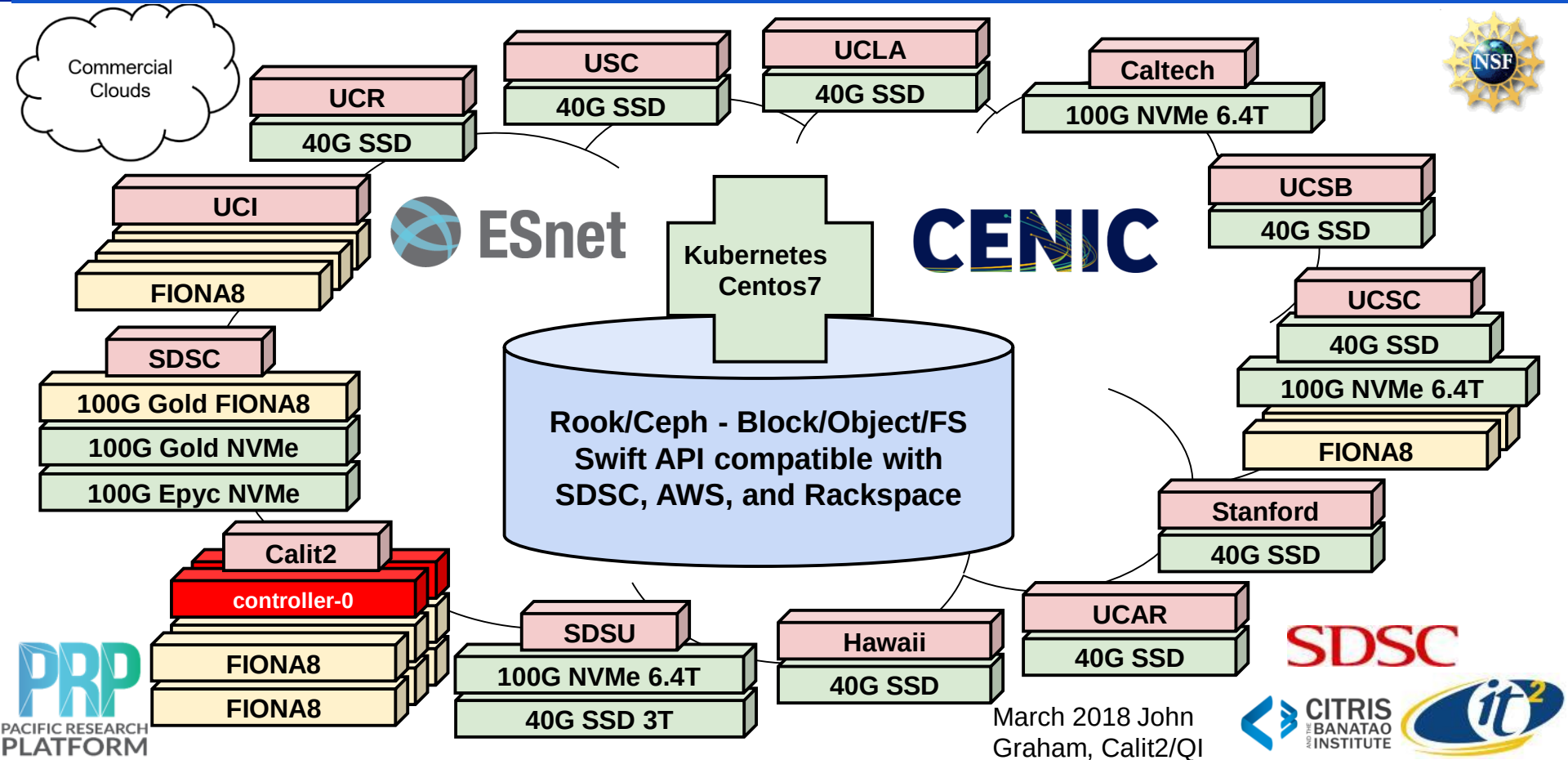
Cloud-native environment integration

Rook runs as a cloud-native service for optimal integration with applications in need of block, object, or file storage.

PACIFIC RESEARCH PLATFORM

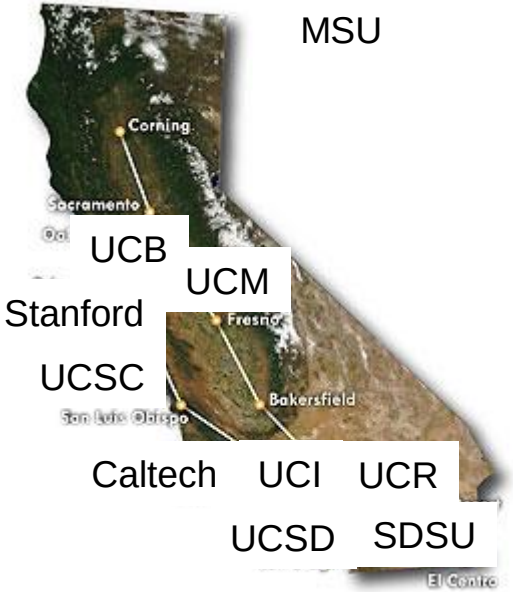
Source: John Graham, Calit2/QI

We Built Nautilus - A Multi-Tenant Containerized PRP HyperCluster for Big Data Applications Running Kubernetes with Rook/Ceph Cloud Native Storage and GPUs for Machine Learning



March 2018 John Graham, Calit2/QI

New NSF CHASE-CI Grant Creates a Community Cyberinfrastructure: Adding a Machine Learning Layer Built on Top of the Pacific Research Platform



-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

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JACOBS SCHOOL OF ENGINEERING
SDSC UC San Diego

Machine Learning Researchers Need a New Cyberinfrastructure

“Until cloud providers are willing to find a solution to place commodity (32-bit) game GPUs into their servers and price services accordingly, I think we will not be able to leverage the cloud effectively.”

“There is an actual scientific infrastructure need here, surprisingly unmet by the commercial market, and perhaps CHASE-CI is the perfect catalyst to break this logjam.”

--UC Berkeley Professor Trevor Darrell

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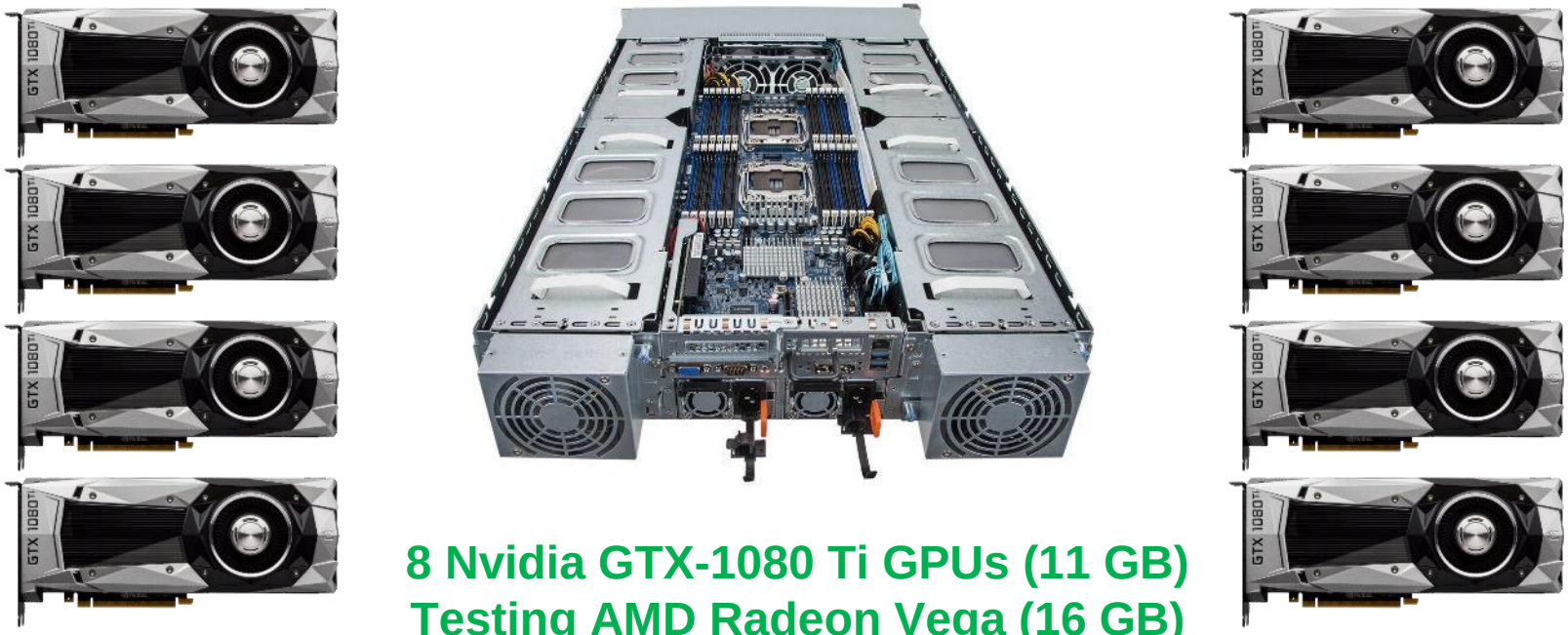
JACOBS SCHOOL OF ENGINEERING

SDSC UC San Diego it²

FIONA8: a FIONA with 8 GPUs
Supports PRP Data Science Machine Learning--4M GPU Core Hours/Week



8 Nvidia GTX-1080 Ti GPUs (11 GB)
Testing AMD Radeon Vega (16 GB)

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24 CPU Cores, 32,000 GPU cores, 96 GB RAM, 2TB SSD, Dual 10Gbps ports
3" High; ~$16,000

it2

Single vs. Double Precision GPUs: Gaming vs. Supercomputing

Nvidia Card	~Cost	32-bit GF	GB	per GF	per GB	cores	8-GPU PC	160 GPU rack
GTX 1080 Ti 11GB	$726	10609	11	$0.07	$66	3584	$13,804	$276,090
P100 16GB	$8,304	8071	16	$1.03	$519	3584	$74,432	$1,488,640
AWS p2.xlarge EC2 (8) K-80 GPUs+disk for 3 years +55% ICR							$370,512	$7,410,240
AWS p2.xlarge EC2 (8) K-80 GPUs+disk for 3 years							$239,040	$4,780,800

8 x 1080 Ti: 1 million GPU core hours every two days.

700 million GPU core hours for $16K in 4 yrs

$22/million GPU core hours.

Plus power, admin costs

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UCSD Game GPUs for Data Sciences Cyberinfrastructure - Devoted to Data Analytics and Machine Learning Research and Teaching

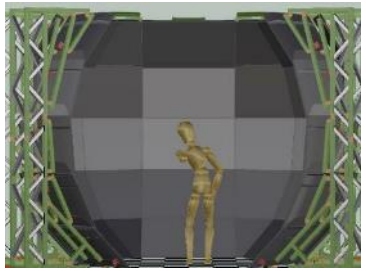
UC San Diego

IT SERVICES

88 GPUs for Students

Open Science Grid

GPUs for OSG Applications



SunCAVE 70 GPUs
WAVE + VROOM 48 GPUs

UCSD Cognitive Science

JACOBS SCHOOL OF ENGINEERING

SDSC

FIONA with 8-Game GPUs

QUALCOMM INSTITUTE

CHASE-CI Grant Provides
256 GPUs to 32 Researchers on 10 Campuses:
>22B GPU Core Hours over 4 years

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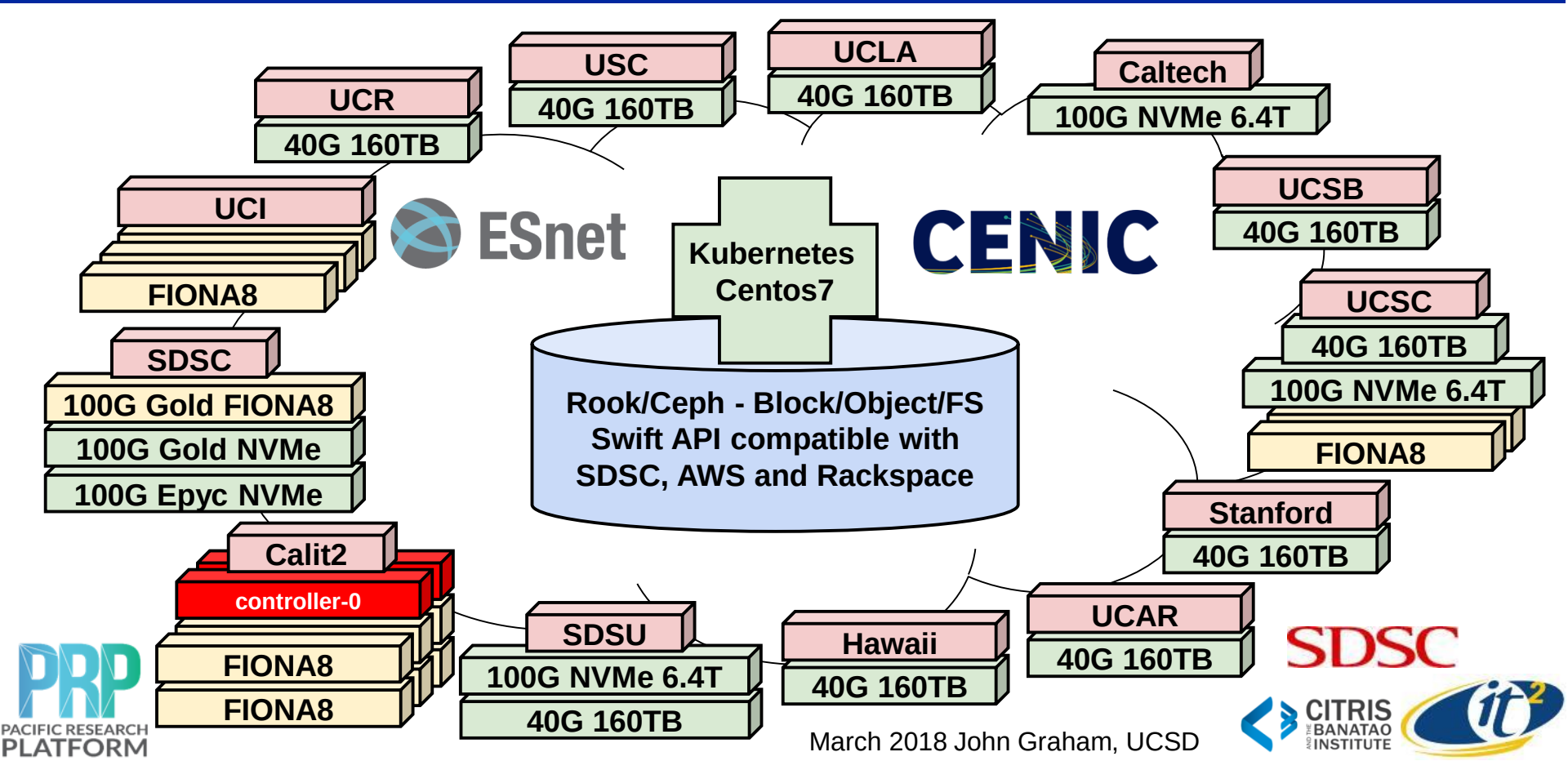
Running Kubernetes/Rook/Ceph On PRP
Allows Us to Deploy a Distributed PB+ of Storage for Posting Science Data



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March 2018 John Graham, UCSD

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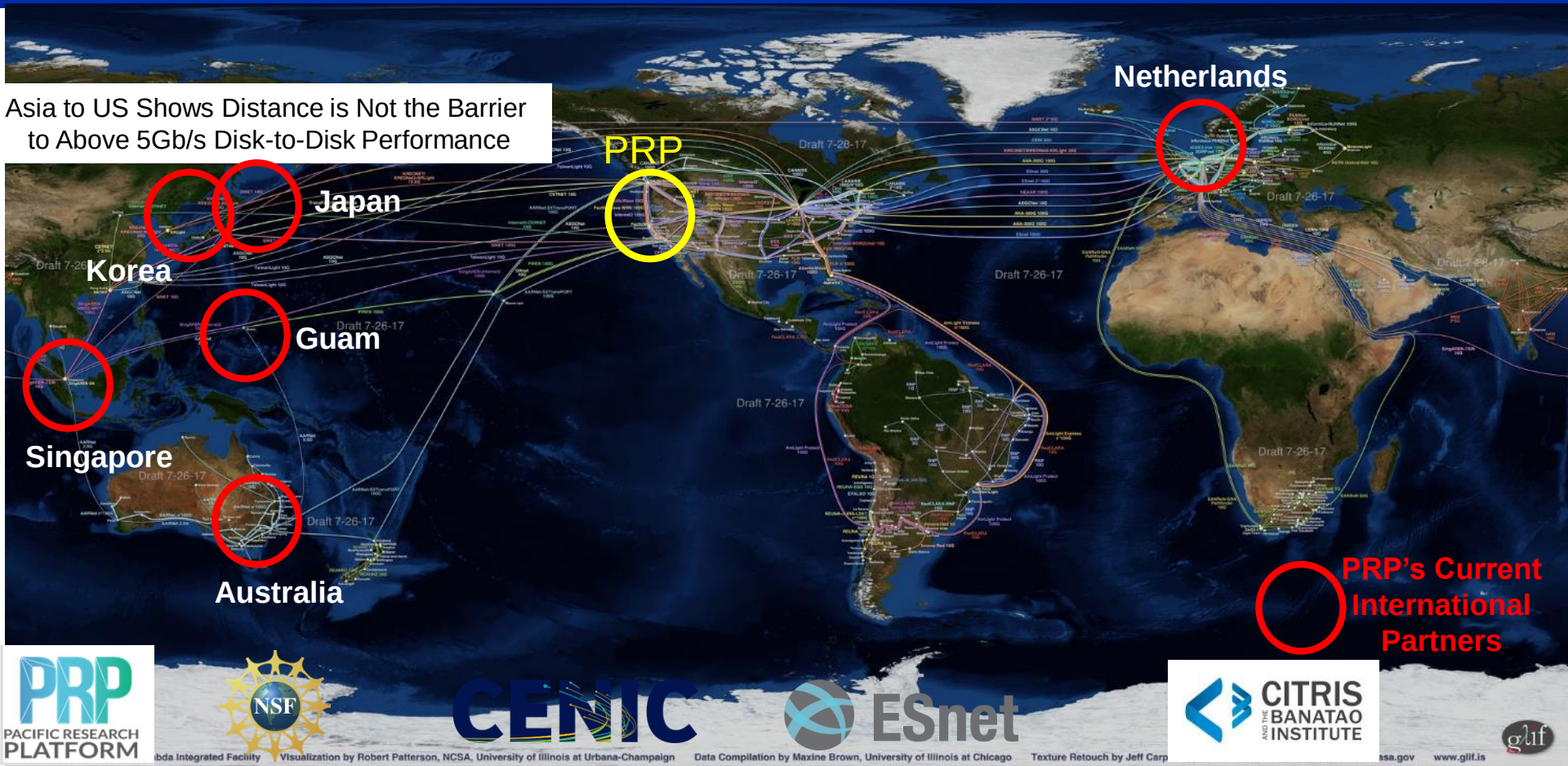
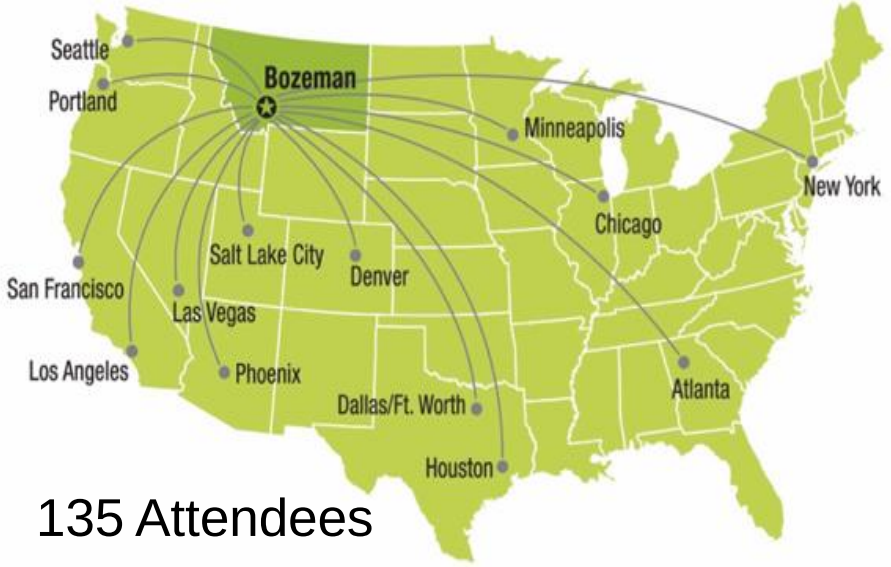
Expanding to the Global Research Platform
Via CENIC/Pacific Wave, Internet2, and International Links



PRP Held
The First National Research Platform Workshop on August 7-8, 2017



135 Attendees

Co-Chairs:
Larry Smarr, Calit2
& Jim Bottum, Internet2
Program Chair:
Tom DeFanti

See agenda, reports, video on
pacificresearchplarform.org

Coming: The Second National Research Platform Workshop (2NRP)
Bozeman, MT August 6-7, 2018—Register Soon at CENIC.ORG!

Local Hosts: Jerry Sheehan, MSU and CENIC

Steering Committee :
Larry Smarr, Calit2
Inder Monga, ESnet
Ana Hunsinger, Internet2

Program Committee:
Jim Bottum
Maxine Brown
Sherilyn Evans
Marla Meehl
Wendy Huntoon
Kate Mace

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Thank You for Your Kind Attention!
Our Support Comes From:

- US National Science Foundation (NSF) awards
  - CNS 0821155, CNS-1338192, CNS-1456638, CNS-1730158, ACI-1540112, & ACI-1541349
- University of California Office of the President CIO
- UCSD Chancellor's Integrated Digital Infrastructure Program
- UCSD Next Generation Networking initiative
- Calit2 and Calit2's Qualcomm Institute
- CENIC, PacificWave and StarLight
- DOE ESnet

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PRP's First 2 Years:
Connecting Multi-Campus Application Teams and Devices

CMS

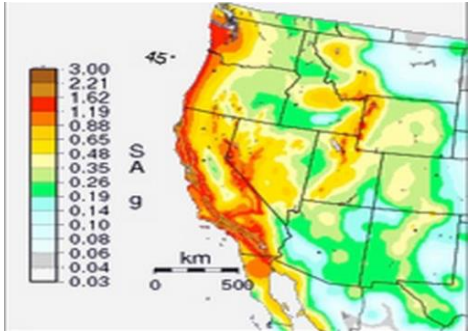
Particle Physics

Biomedical 'omics

INTERMEDIATE PALOMAR TRANSIENT FACTORY

Telescope Surveys

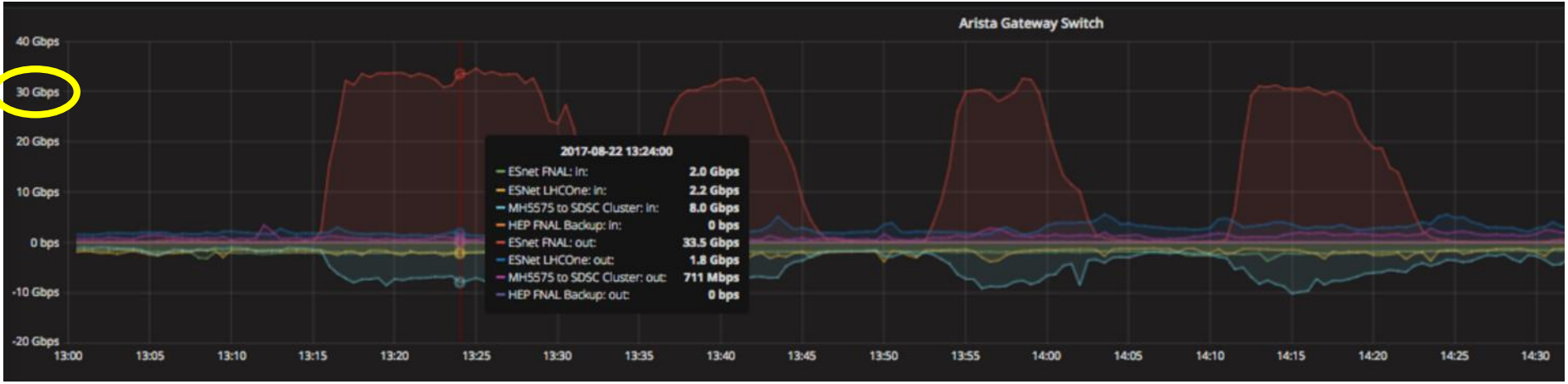
Earth Sciences



Visualization, Virtual Reality, Collaboration

Data Transfer Rates From 40 Gbps DTN in UCSD Physics Building, Across Campus on PRISM DMZ, Then to Chicago's Fermilab Over CENIC/ESnet

Based on This Success,
Upgrading 40G DTN to 100G
For Bandwidth Tests & Kubernetes
to OSG, Caltech, and UCSC



Source: Frank Wuerthwein, UCSD, SDSC

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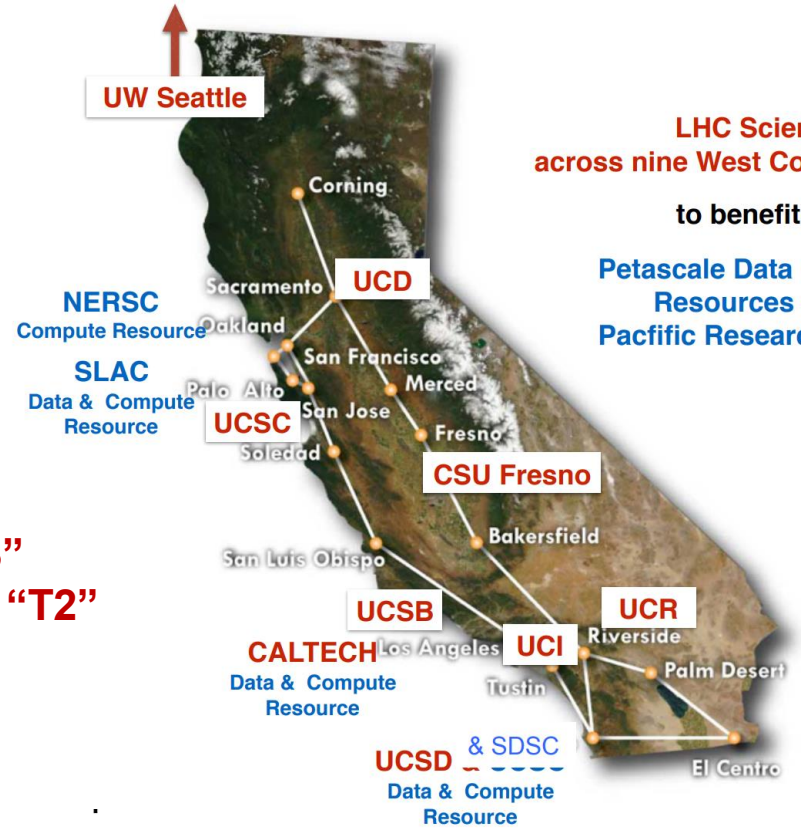
LHC Data Analysis Running on PRP



LHC Scientists
across nine West Coast Universities

to benefit from

Petascale Data & Compute
Resources across
Pacfific Research Platform

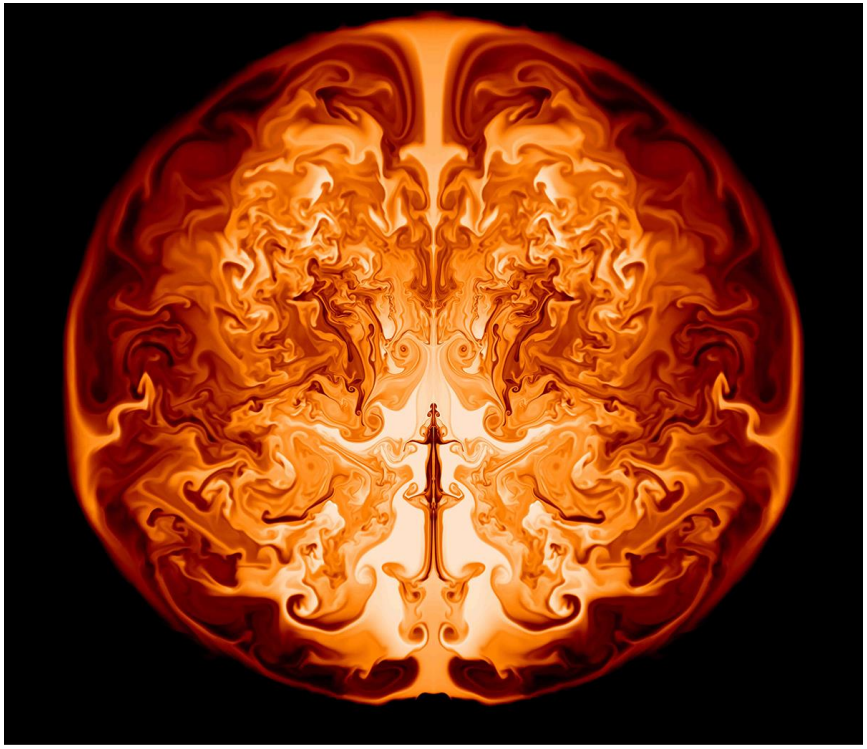
Two Projects:

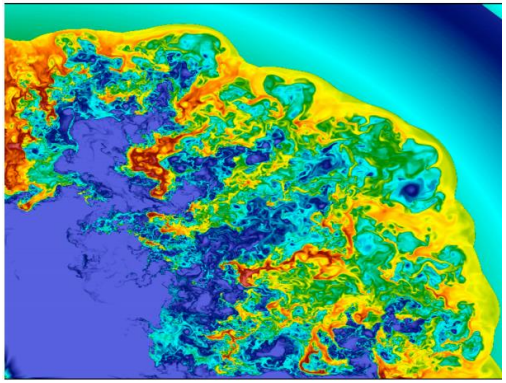
- **OSG Cluster-in-a-Box for "T3"**
- **Distributed Xrootd Cache for "T2"**

.

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

PRP Over CENIC
Couples UC Santa Cruz Astrophysics Cluster to LBNL NERSC Supercomputer





A 2D superluminous supernova simulation generated with the CASTRO code. (Image: Ken Chen, National Astronomical Observatory of Japan)

K. Chen, S. Woolsey, T. Sukhbold, The Astrophysical Journal, 832, 1, Nov. 2016

CENIC 2018 Innovations in Networking Award for Research Applications

NERSC Project PI:
S. Woolsey, UC Santa Cruz

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BERKELEY LAB Bringing Science Solutions to the World

NERSC

SDSC

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100 Gbps FIONA at UCSC Allows for Downloads to the UCSC Hyades Cluster from the LBNL NERSC Supercomputer for DESI Science Analysis

INTERMEDIATE PALOMAR TRANSIENT FACTORY

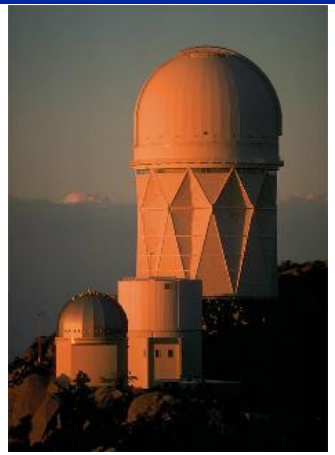
300 images per night.
100MB per raw image

120GB per night

Source: Peter Nugent, LBNL
Professor of Astronomy, UC Berkeley

Precursors to LSST and NCSA

NSF-Funded Cyberengineer
Shaw Dong @UCSC
Receiving FIONA
Feb 7, 2017



Dark Energy Spectroscopic Instrument

250 images per night.
530MB per raw image

800GB per night

BERKELEY LAB
Bringing Science Solutions to the World

NERSC

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CENIC

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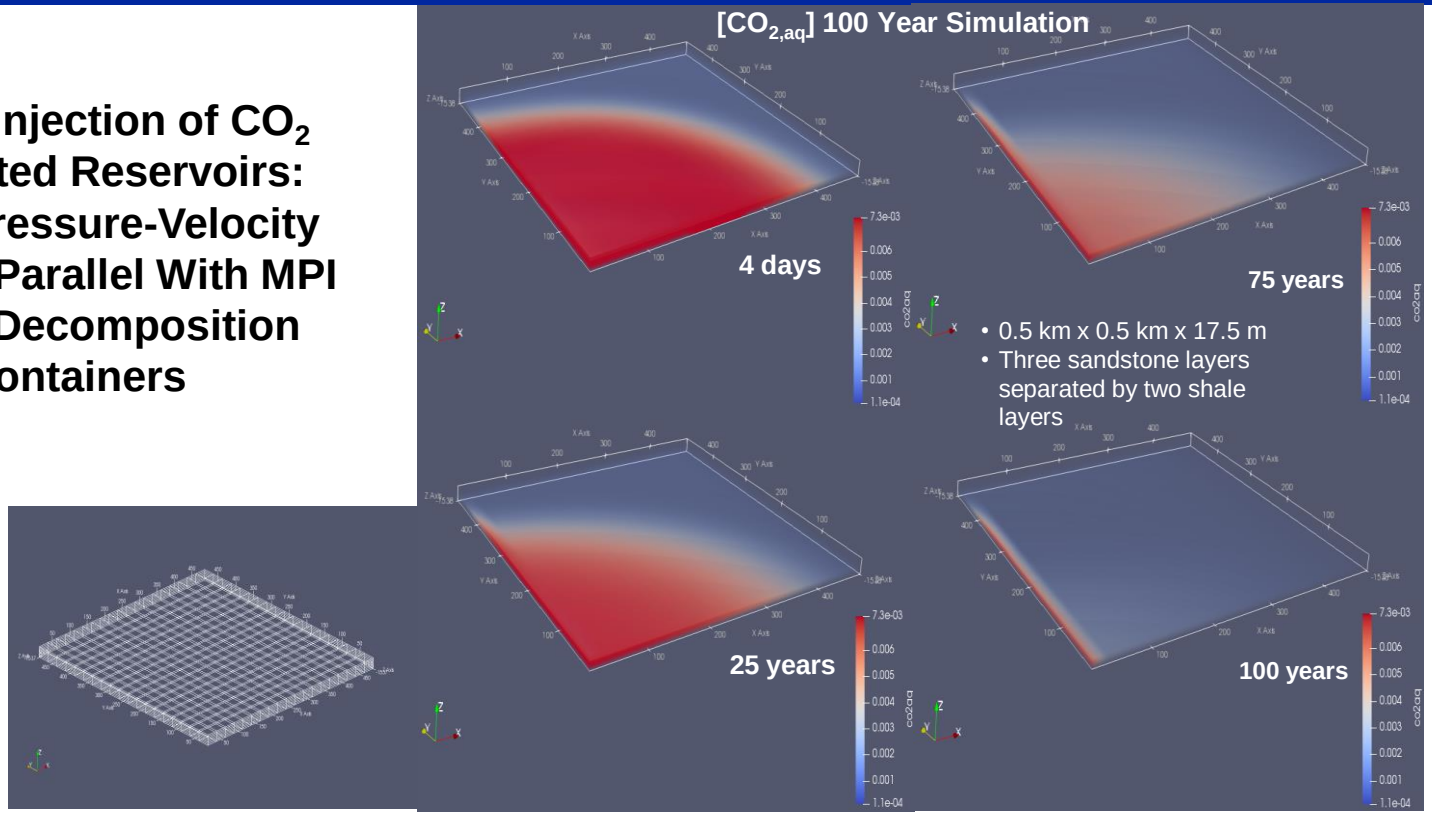
Distributed Computation on PRP Nautilus HyperCluster Coupling SDSU Cluster and SDSC Comet Using Kubernetes Containers

Simulating the Injection of CO_2 in Brine-Saturated Reservoirs: Poroelastic & Pressure-Velocity Fields Solved In Parallel With MPI Using Domain Decomposition Across Containers



Developed and executed MPI-based PRP Kubernetes Cluster execution

Source: Chris Paolini and Jose Castillo, SDSU

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PRP Enables
Distributed Walk-in Virtual Reality CAVEs

PRP

WAVE@UC San Diego

WAVE @UC Merced

Transferring 5 CAVEcam Images from UCSD to UC Merced:
2 Gigabytes now takes 2 Seconds (8 Gb/sec)

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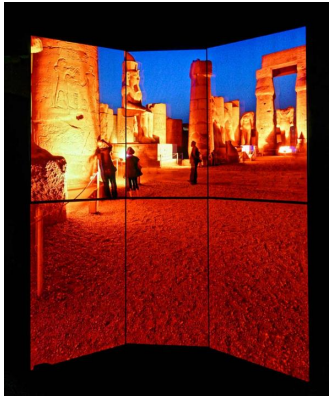
The Prototype PRP Has Attracted New Application Drivers

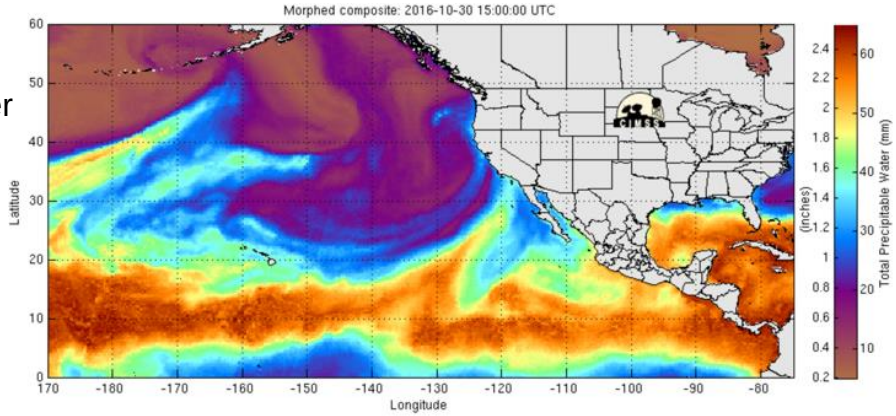
Frank Vernon, Graham Kent, & Ilkay Altintas, Wildfires

Jules Jaffe – Undersea Microscope



Tom Levy
At-Risk Cultural Heritage

Scott Sellars, Marty Ralph
Center for Western Weather and Water Extremes



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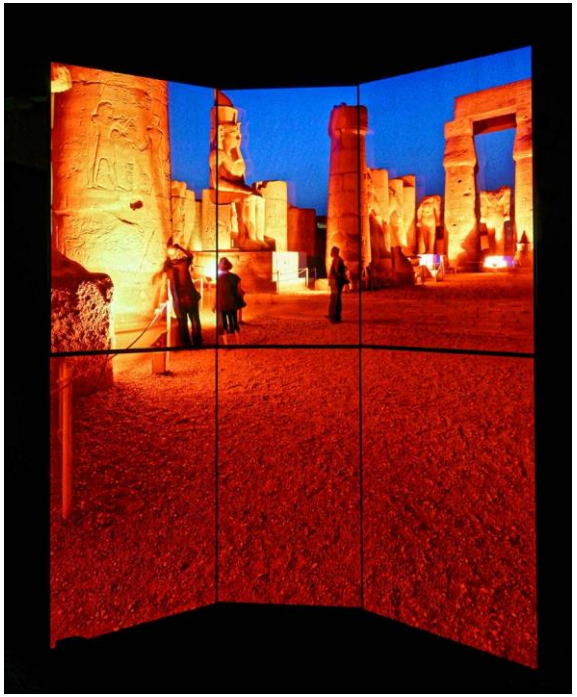
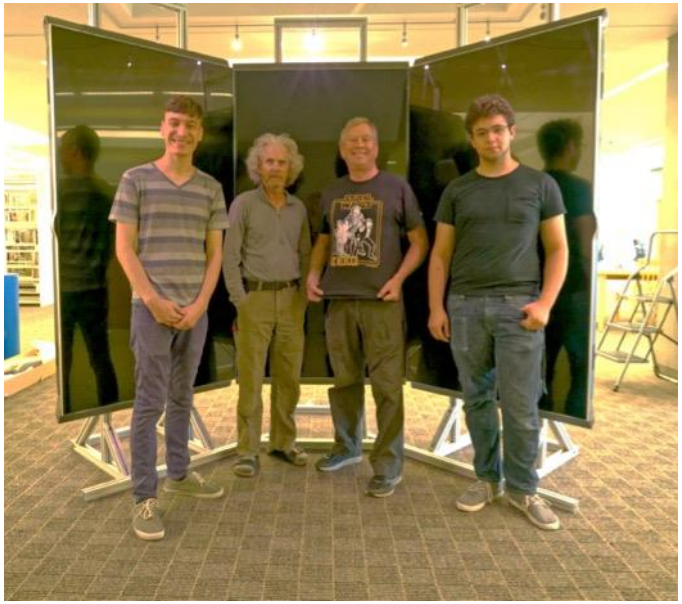
PRP Links At-Risk Cultural Heritage and Archaeology Datasets at UCB, UCLA, UCM and UCSD with CAVEkiosks

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)



48 Megapixel CAVEkiosk
UCSD Library

48 Megapixel CAVEkiosk
UCB Library



24 Megapixel CAVEkiosk
UCM Library

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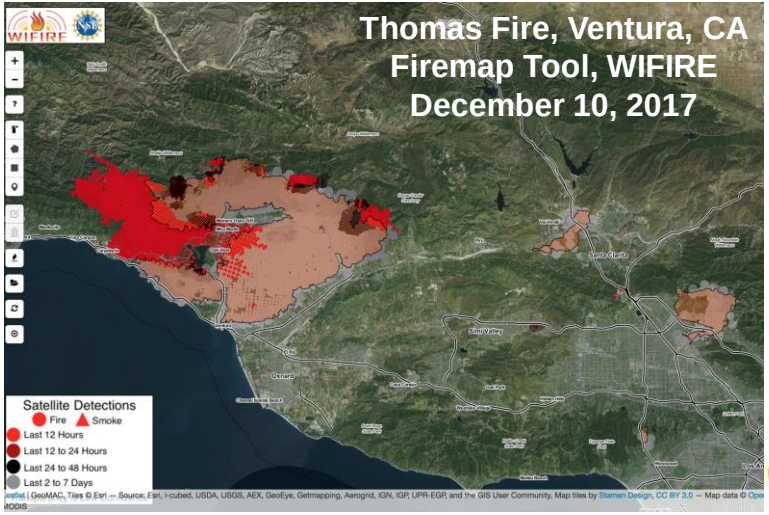
New PRP Application:
Coupling Wireless Wildfire Sensors to Computing

Technology Projects to Combat California Wildfires Are Recognized with CENIC Innovation Award

CENIC 2018
Innovations in Networking Award for Experimental Applications

WIFIRE · NSF · HPWREN · Nevada Seismological Laboratory, Mackay School of Earth Sciences & Engineering, University of Nevada, Reno

Church Fire, San Diego CA
Alert SD&ECameras/HPWREN
October 21, 2017



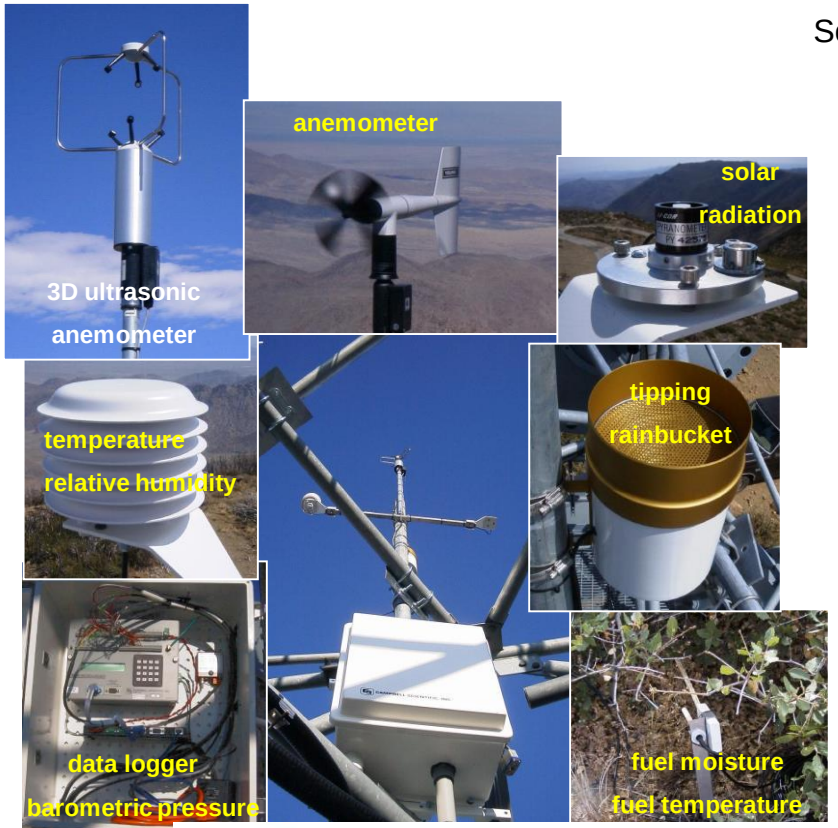
Thomas Fire, Ventura, CA
Firemap Tool, WIFIRE
December 10, 2017

PRP Pacific Research Platform

it2

Mount Laguna Meterological Sensor Instrumentation Provides Real-Time Data Flows Over HPWREN to PRP-Connected Servers

Source: Hans-Werner Braun, SDSC

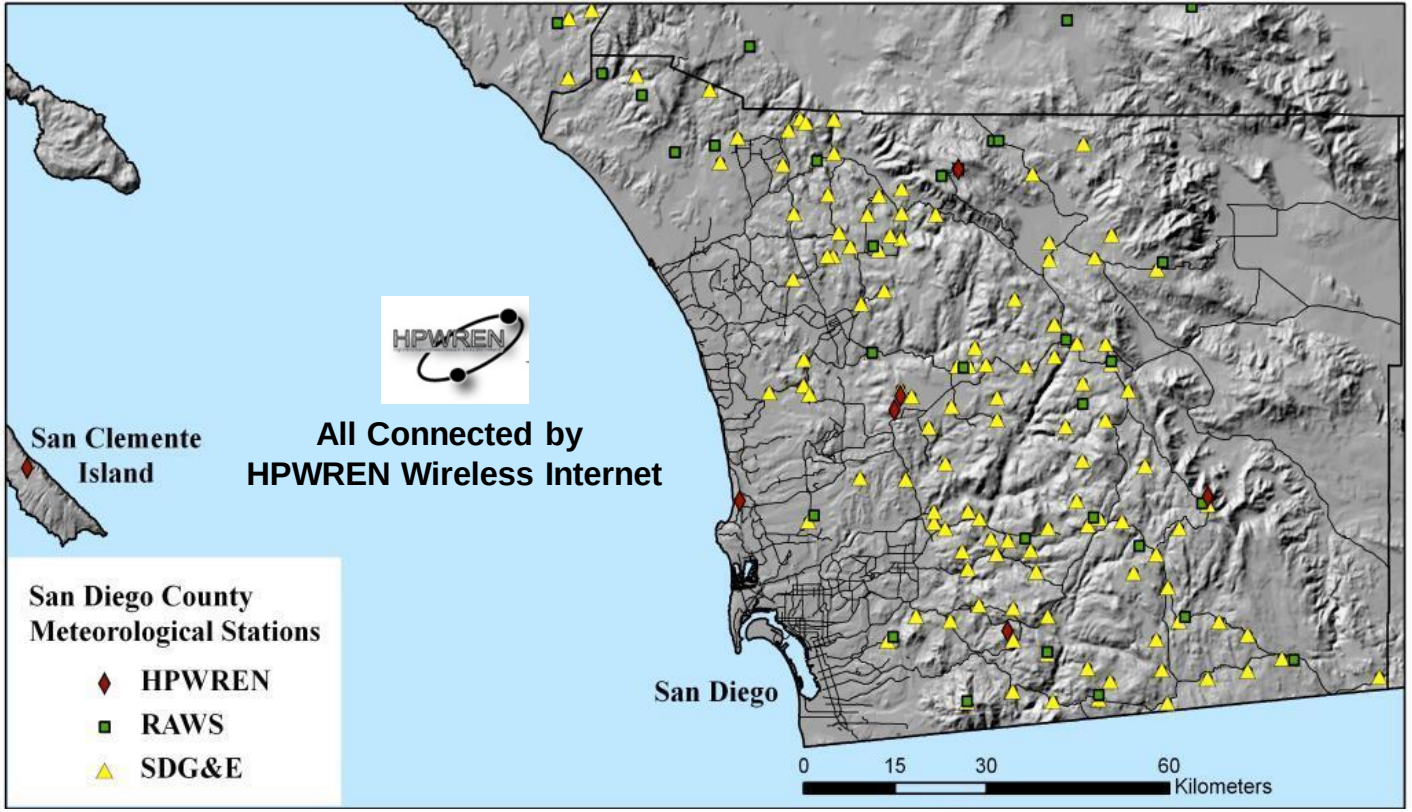


HPWREN

PRP PACIFIC RESEARCH PLATFORM

UC San Diego | SDSC San Diego Supercomputer Center | Scripps Institution of Oceanography | Calit2 | San Diego State University

HPWREN-Connected SoCal Weather Stations: Giving High-Resolution Weather Data in San Diego County



PACIFIC RESEARCH PLATFORM

UC San Diego

SDSC San Diego Supercomputer Center

Scripps Institution of Oceanography

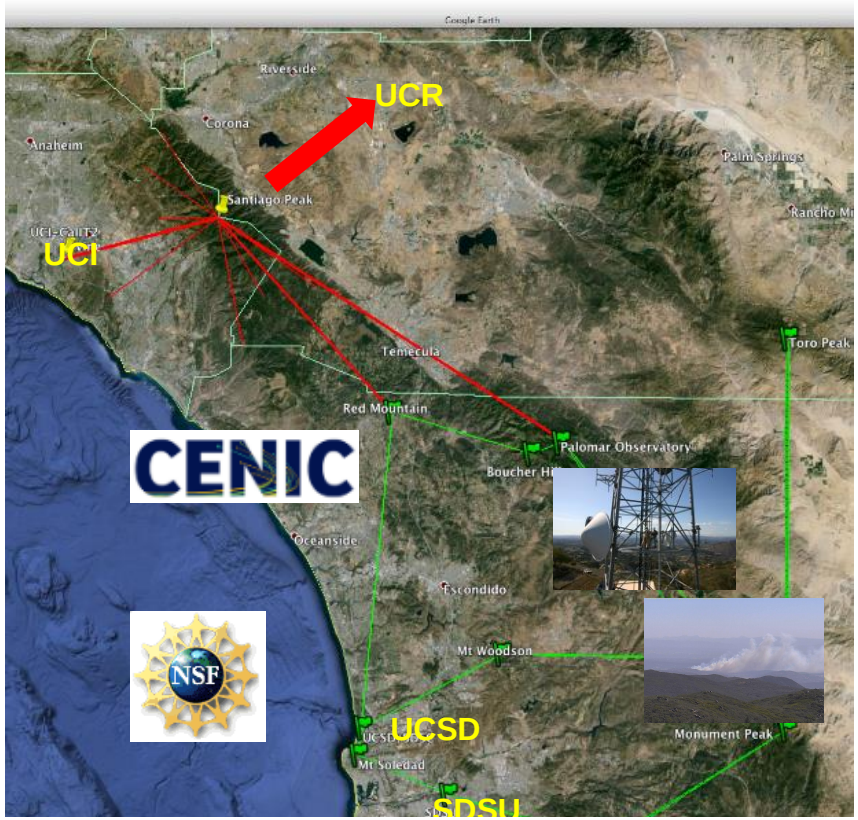
Calit2

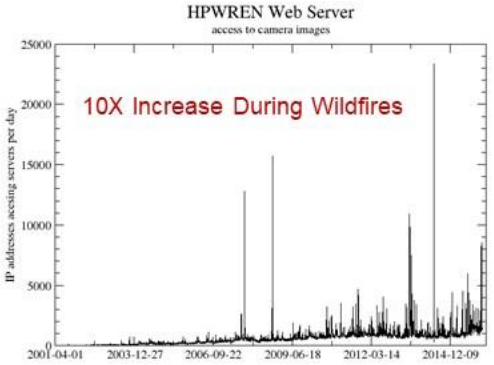
San Diego State University

it2

PRP/CENIC Backbone Sets Stage for 2018 Expansion of HPWREN Wireless Connectivity Into Orange and Riverside Counties

- **PRP CENIC 100G Links UCSD, SDSU & UCI HPWREN Servers**
  - FIONAs Endpoints
  - Data Redundancy
  - Disaster Recovery
  - High Availability
  - Kubernetes Handles Software Containers and Data
- **Potential Future UCR CENIC Anchor**





Data From Hans-Werner Braun

UCI Antenna Dedicated June 27, 2017

Source: Frank Vernon, Hans Werner Braun HPWREN

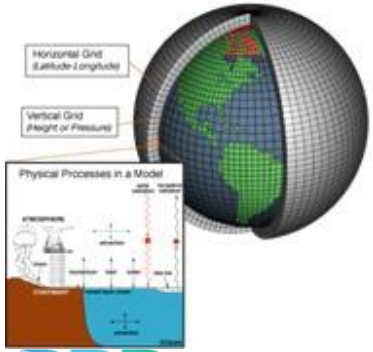
PACIFIC RESEARCH PLATFORM

UC San Diego | SDSC San Diego Supercomputer Center | Scripps Institution of Oceanography | Calit2 | San Diego State University | Pacific Wave

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

Real-Time Meteorological Sensors

Weather Forecast

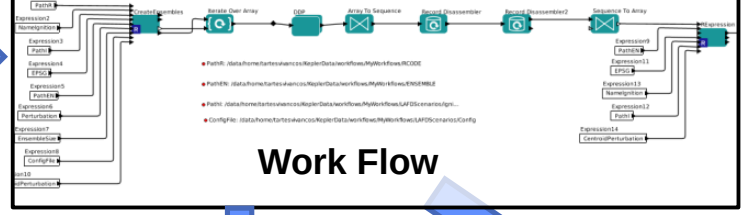


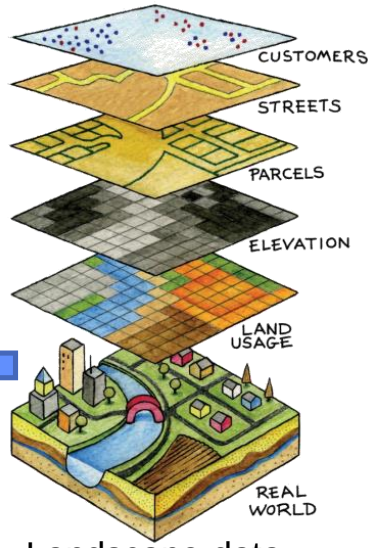
PACIFIC RESEARCH PLATFORM

Source: Ilkay Altintas, SDSC

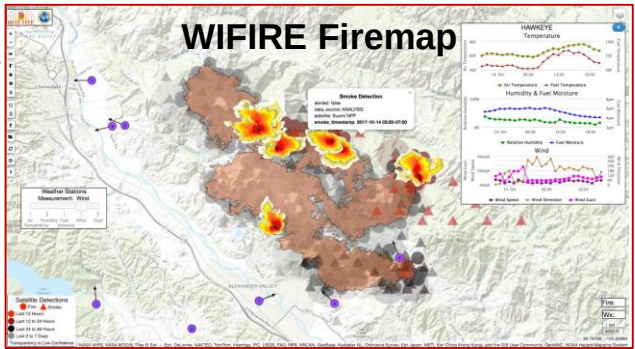
WIFIRE

PRP





Landscape data



Some Machine Learning Case Studies To Improve on WIFIRE

- **Smoke and fire perimeter detection based on imagery**
- **Prediction of Santa Ana and fire conditions specific to location**
- **Prediction of fuel build up based on fire and weather history**
- **NLP for understanding local conditions based on radio communications**
- **Deep learning on multi-spectra imagery for high resolution fuel maps**
- **Classification project to generate more accurate fuel maps (using Planet Labs satellite data)**

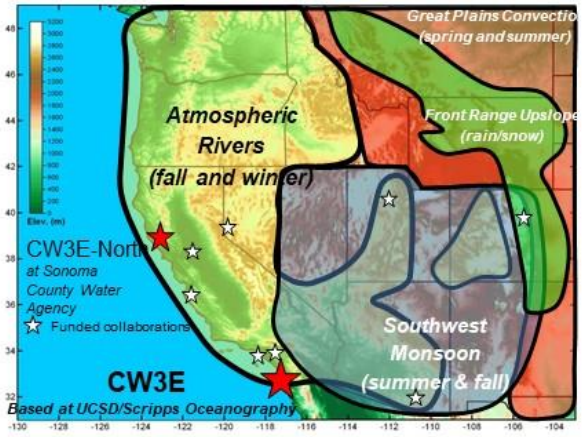
All Require Periodic, Dynamic, and Programmatic Access to Data!

PACIFIC RESEARCH PLATFORM

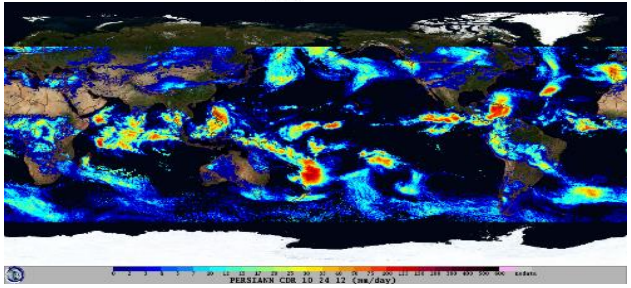
Source: Ilkay Altintas, SDSC; Co-PI CHASE-CI

SDSC

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 Website: cw3e.ucsd.edu

Big Data Collaboration with:

Center for Hydrometeorology & Remote Sensing
University of California, Irvine

Director, Soroosh Sorooshian, UCSD Website http://chrs.web.uci.edu

PACIFIC RESEARCH PLATFORM

Source: Scott Sellers, CW3E

Major Speedup in Scientific Work Flow Using the PRP

Pacific Research Platform (10-100 Gb/s)

Complete workflow time: 20 days→20 hrs→20 Minutes!

UC, Irvine

GPUs

Calit2's FIONA

SDSC's COMET

Source: Scott Sellers, CW3E

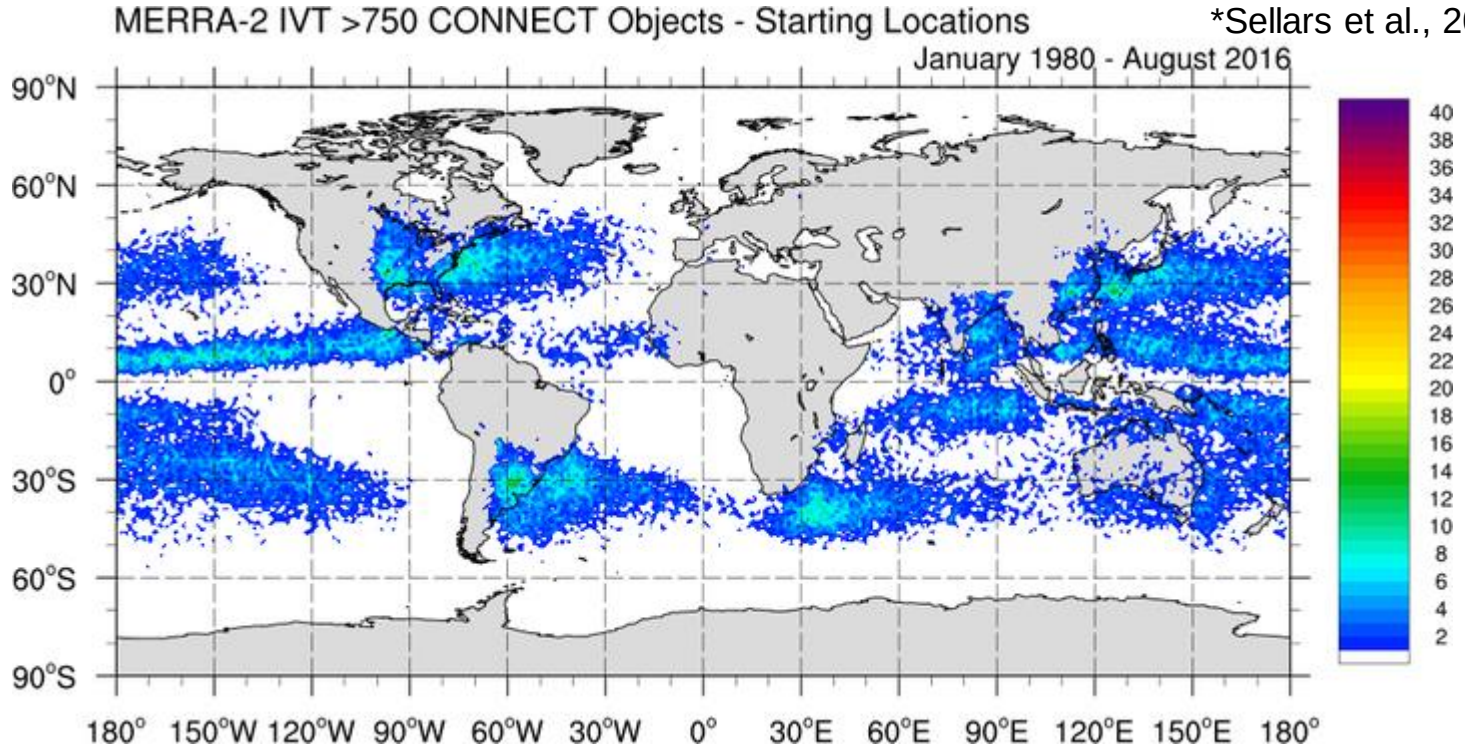
UC, San Diego

GPUs

Calit2's FIONA

Using Machine Learning to Determine the Precipitation Object Starting Locations

*Sellars et al., 2017 (in prep)



PACIFIC RESEARCH PLATFORM

NSF

CENIC

ESnet

CITRIS AND THE BANATAO INSTITUTE

it²

UC San Diego Jaffe Lab (SIO) Scripps Plankton Camera Off the SIO Pier with Fiber Optic Network

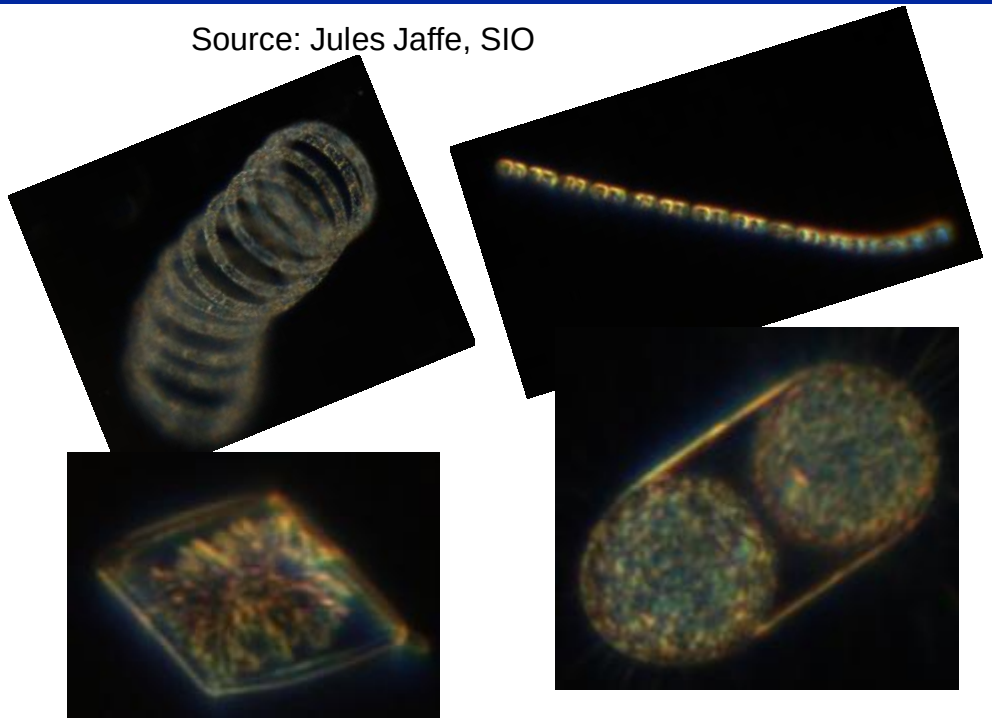
SCRIPPS INSTITUTION OF OCEANOGRAPHY

PRP PACIFIC RESEARCH PLATFORM

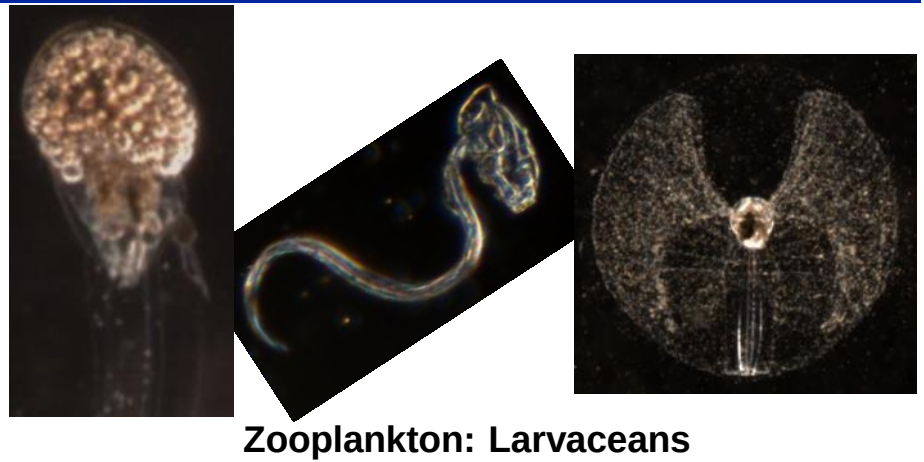
it2

Over 300 Million Images So Far!
Requires Machine Learning for Automated Image Analysis and Classification

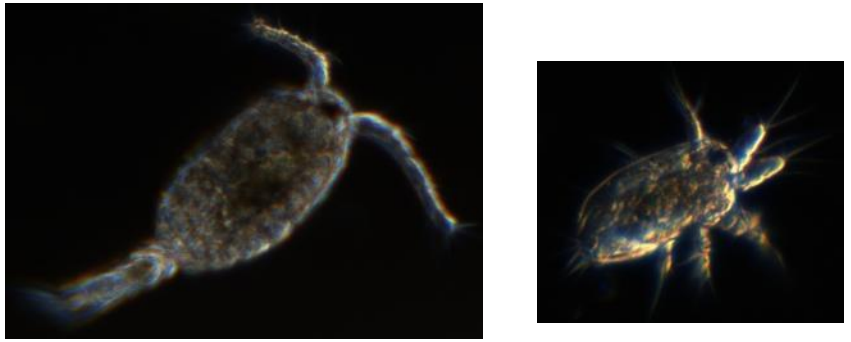
Source: Jules Jaffe, SIO



Phytoplankton: Diatoms



Zooplankton: Larvaceans



Zooplankton: Copepods

PACIFIC RESEARCH PLATFORM

”We are using the FIONAs for image processing... this includes doing Particle Tracking Velocimetry that is very computationally intense.”-Jules Jaffe

it²