“Toward a Global Research Platform for Big Data Analysis”

Keynote Presentation:
Hawaii International Conference on System Sciences - 51 (HICSS-51)
Hilton Waikoloa Village
Big Island, HI
January 5, 2018

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

Abstract

In every field we see an exponential rise of Big Data, which in turn is demanding new technological solutions in visualization, machine learning, and high performance cyberinfrastructure. I will describe how my NSF-funded Pacific Research Platform (PRP), which provides an Internet platform with 100-1000 times the bandwidth of today's commodity Internet to all the research universities on the West Coast, is being designed from the Big Data application needs of multi-institutional research teams from particle physics to climate to human health. NSF is also funding a Cognitive Hardware and Software Ecosystem Community Infrastructure (CHASE-CI) to be built on top of the PRP, adding GPU and non-von Neumann machine learning capabilities to enable distributed Big Data Analytics. The next stage, well underway, is understanding how to scale this prototype cyberinfrastructure to a National and Global Research Platform.

PRP
PACIFIC RESEARCH PLATFORM

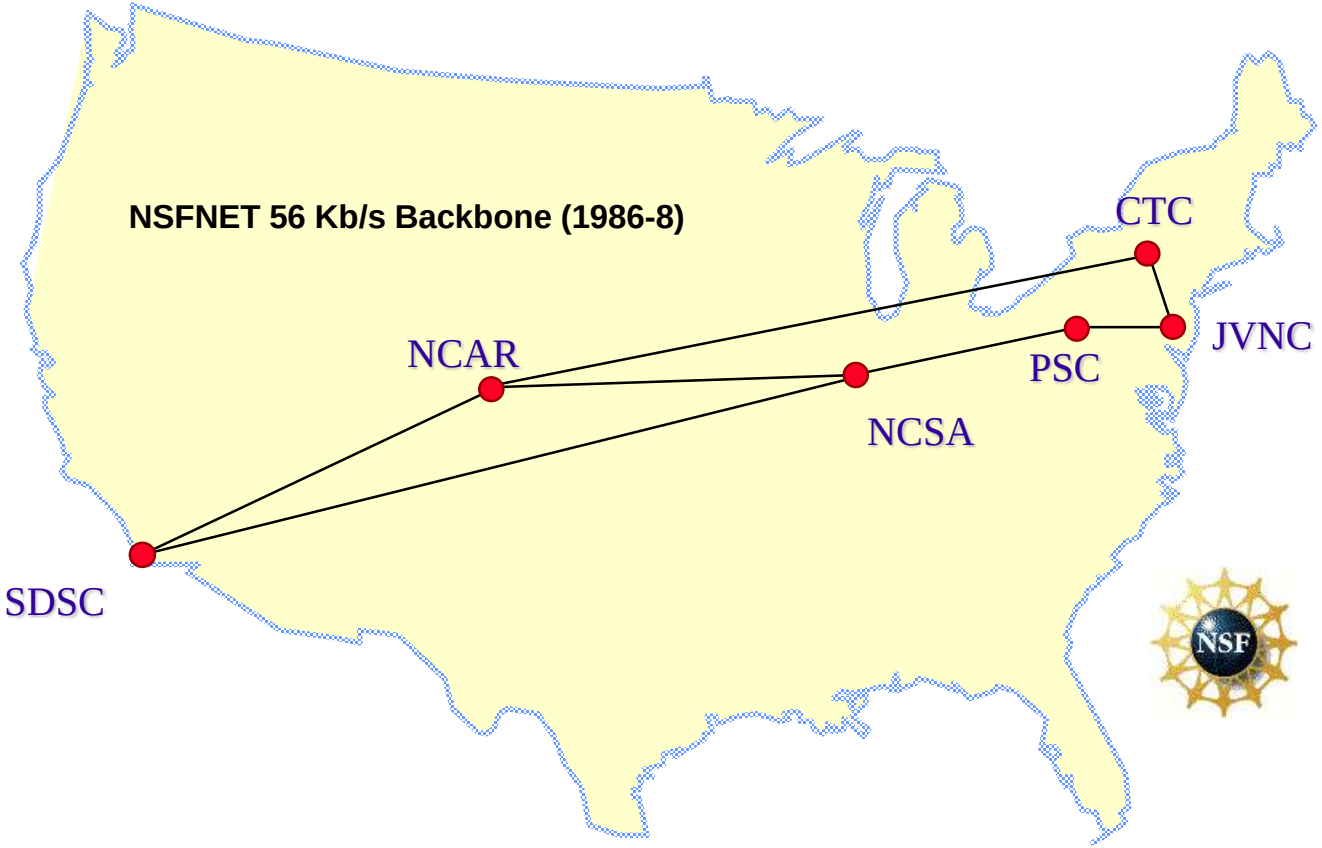
it²

The 30-Year Quest to Create a Tightly-Coupled, Yet Highly Distributed "Computer" for Big Data Analysis

PACIFIC RESEARCH PLATFORM

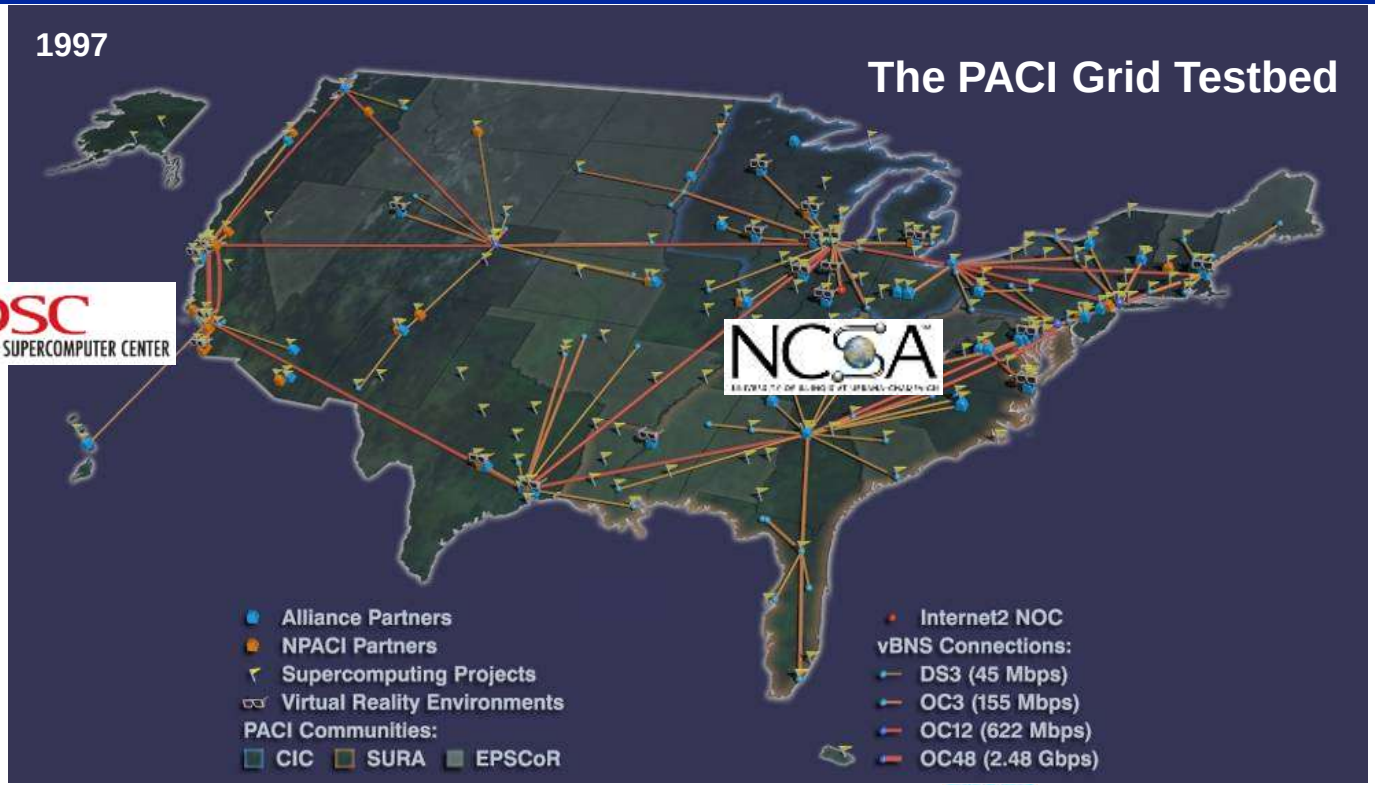
it²

30 Years Ago-NSF Created a Weakly-Coupled National "MetaComputer"



NSFnet Adopted ARPAnet Protocols

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



vBNS led to

INTERNET2

PACIFIC RESEARCH PLATFORM

NPACI

National Computational Science ALLIANCE

it2

Vision:
Use Optical Fiber to Connect
Big Data Generators and Consumers,
Creating a Big Data Tightly-Coupled Distributed "Computer"

"The Bisection Bandwidth of a Cluster Interconnect,
but Deployed on a 20-Campus Scale."

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This Vision Has Been Building for 15 Years

NSF's OptIPuter Project: Proving Wide-Area-Networks Could Be as Fast as Cluster Backplanes for Data-Intensive Researchers



End User OptIPortal



Instruments



HD/4k Telepresence



HD/4k Video Cams



Campus Optical Switch

10G Lightpaths



HPC

TeraGrid

PI Larry Smarr

OptIPuter

2003-2009

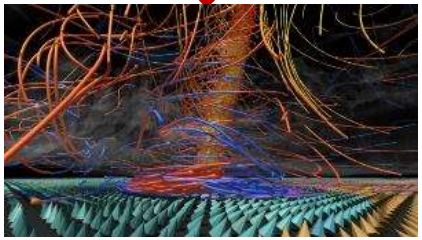
$13,500,000

NSF

LS 2009 Slide



Data Repositories & Clusters



HD/4k Video Images

PRP PACIFIC RESEARCH PLATFORM

SDSC SAN DIEGO SUPERCOMPUTER CENTER

evl electronic visualization laboratory

it2

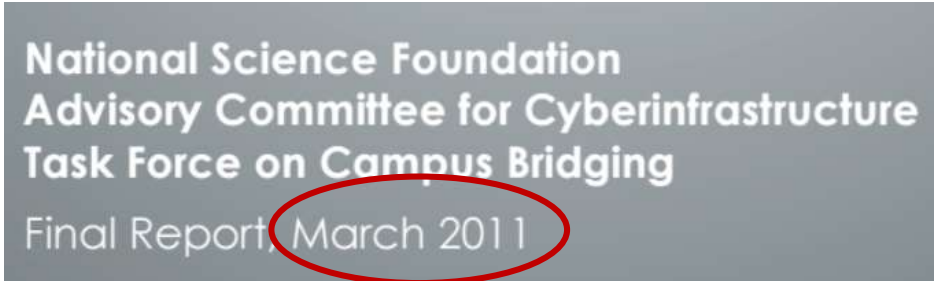
So Why Don't We Have a National Big Data Cyberinfrastructure by Now?

"High-speed data lines crossing the nation are the equivalent of six-lane superhighways, Bement said.

But networks at colleges and universities are not so capable."

"Those massive conduits are reduced to two-lane roads at most college and university campuses,"

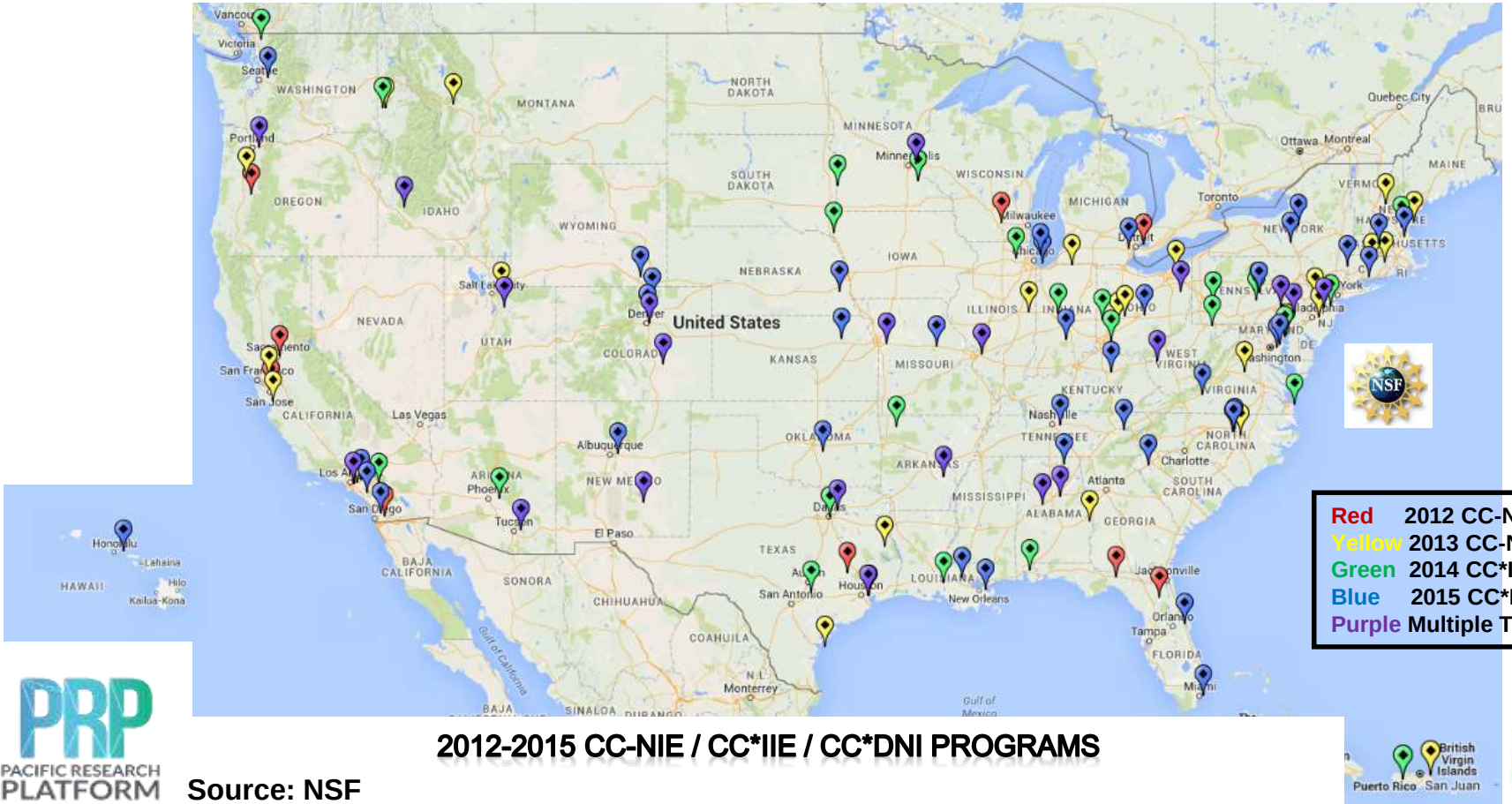
Improving cyberinfrastructure, he said, "will transform the capabilities of campus-based scientists."
-- Arden Bement, director of the National Science Foundation May 2005



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Based on Community Input and on ESnet's Science DMZ Concept, NSF Has Funded Over 100 Campuses to Build Local Big Data Freeways

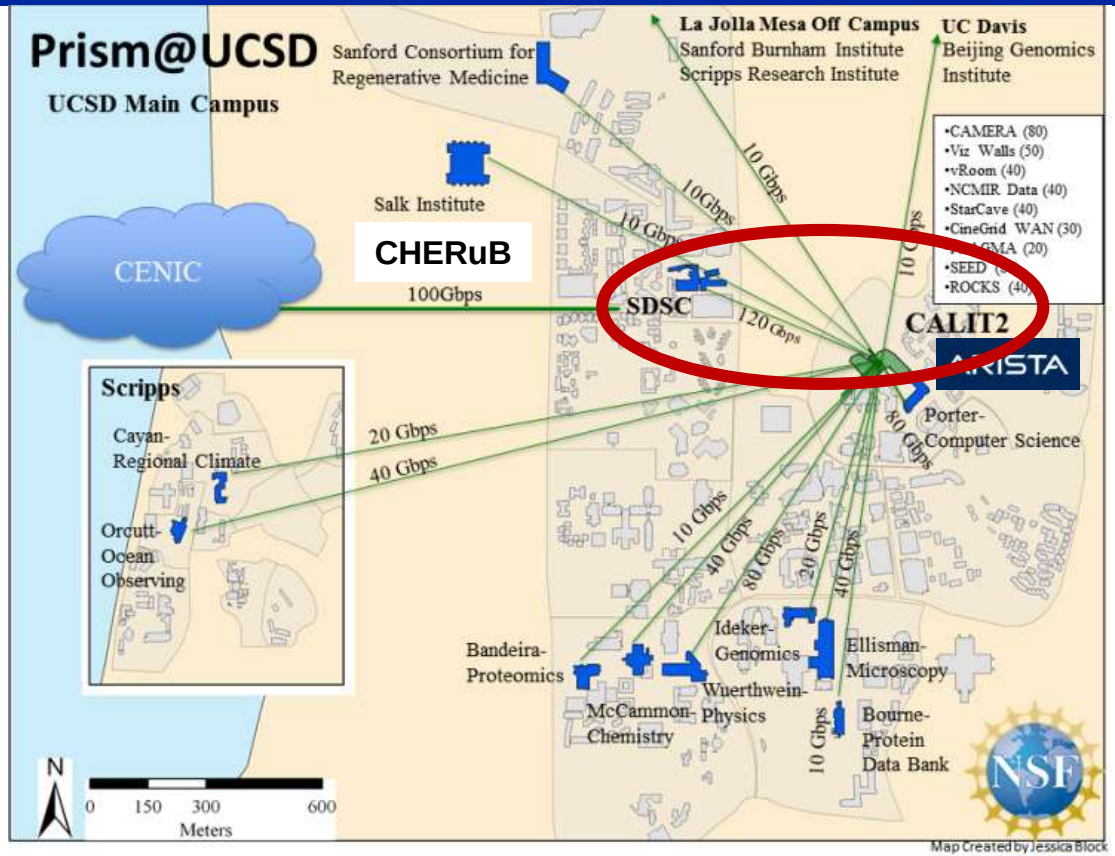


2012-2015 CC-NIE / CC*IIE / CC*DNI PROGRAMS

Source: NSF

PACIFIC RESEARCH PLATFORM

Creating a "Big Data" Freeway on Campus: NSF-Funded CC-NIE Grants Prism@UCSD and CHeruB



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

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SDSC it²

Terminating the Fiber Optics - Data Transfer Nodes (DTNs): Flash I/O Network Appliances (FIONAs)

UCSD Designed FIONAs
To Solve the Disk-to-Disk
Data Transfer Problem
For Big Data
at Full Speed
on 10G, 40G and 100G Networks



FIONette—1G, $1,000



PRP PACIFIC RESEARCH PLATFORM

SDSC

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

it²

How UCSD DMZ Network Transforms Big Data Microbiome Science: Preparing for Knight/Smarr 1 Million Core-Hour Analysis

NIH

NCBI
National Center for Biotechnology Information

INTERNET2

CENIC

Center for Microbiome Innovation

Knight Lab
FIONA





Gordon

Knight 1024 Cluster
In SDSC Co-Lo





1.3Tbps

CHERuB
100Gbps

Data Oasis
7.5PB,
200GB/s

120Gbps

SDSC

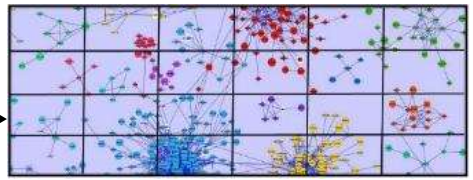
ARISTA

10Gbps

40Gbps



Prism@UCSD



Emperor & Other Vis Tools

64Mpixel Data Analysis Wall



QUALCOMM INSTITUTE

IBM Cloud

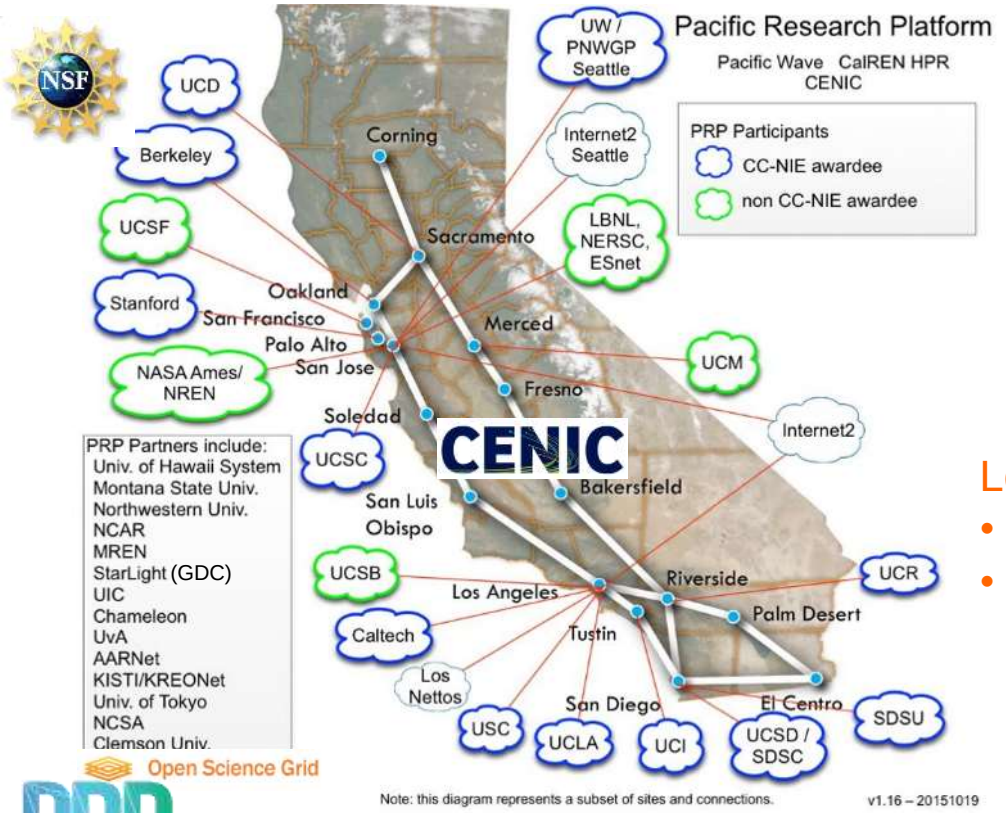
IBM Watson

PRP
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IGM
Institute for Genomic Medicine

it2

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



Source:
John Hess, CENIC

NSF CC*DNI Grant
$5M 10/2015-10/2020

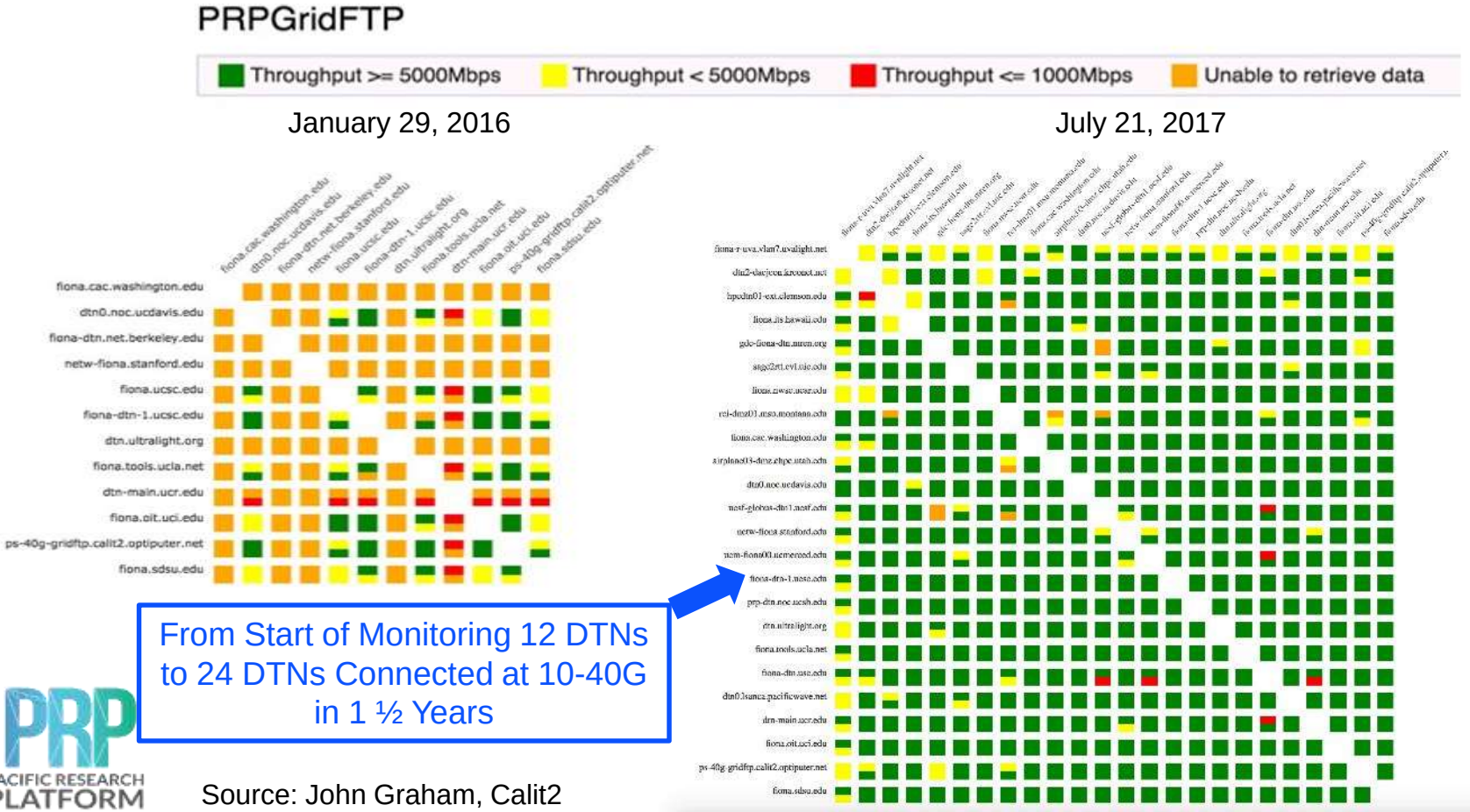
PI: Larry Smarr, UC San Diego; Calit2
Co-PIs:

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

Letters of Commitment from:

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

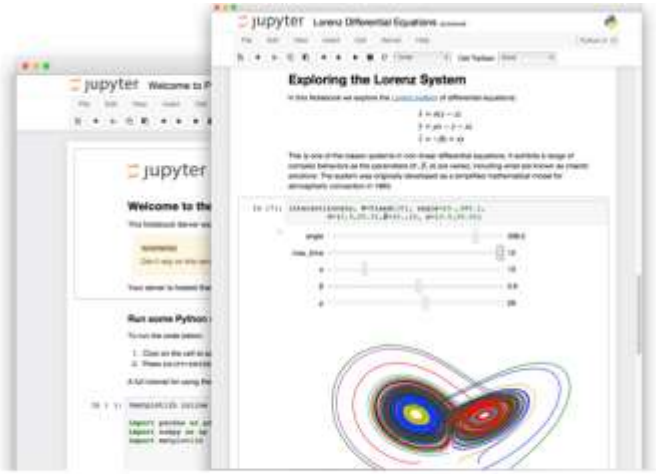
We Measure Disk-to-Disk Throughput with 10GB File Transfer 4 Times Per Day in Both Directions for All PRP Sites



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

Source: John Graham, Calit2

Jupyter Has Become the Digital Fabric for Data Sciences



The Jupyter Notebook

The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text. Uses include: data cleaning and transformation, numerical simulation, statistical modeling, data visualization, machine learning, and much more.

Language of choice

The Notebook has support for over 40 programming languages, including Python, R, Julia, and Scala.

Share notebooks

Notebooks can be shared with others using email, Dropbox, GitHub and the Jupyter Notebook Viewer.

Interactive output

Your code can produce rich, interactive output: HTML, images, videos, LaTeX, and custom MIME types.

Big data integration

Leverage big data tools, such as Apache Spark, from Python, R and Scala. Explore that same data with pandas, scikit-learn, ggplot2, TensorFlow.

http://jupyter.org/

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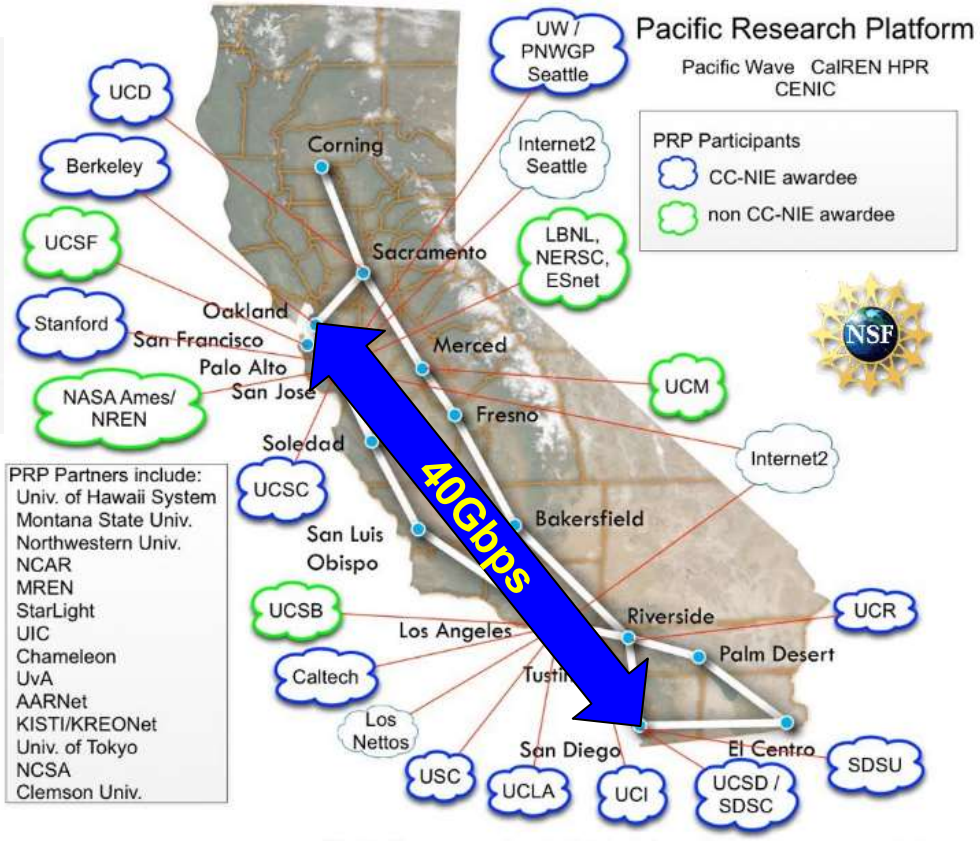
PRP UC-JupyterHub Backbone Connects FIONAs At UC Berkeley and UC San Diego

Source: John Graham, Calit2

jupyterhub

A multi-user version of the notebook designed for companies, classrooms and research labs

Goal: Jupyter Everywhere



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We Aggressively Use Kubernetes to Manage 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.

"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

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CLOUD NATIVE COMPUTING FOUNDATION

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Rook is Ceph Cloud-Native Object Storage ‘Inside’ Kubernetes



Battle-tested, production storage

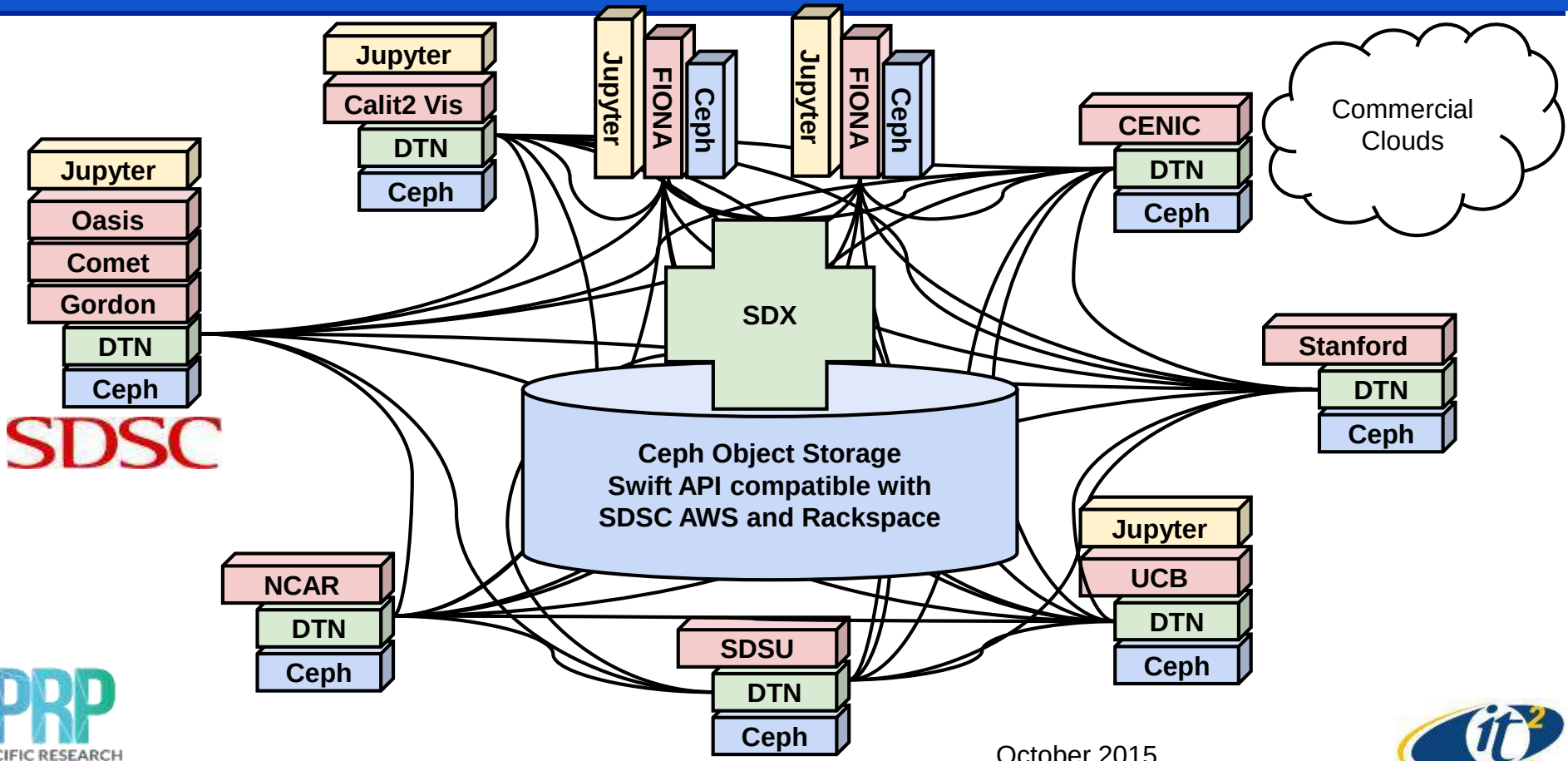
Rook is based on an embedded version of Ceph, which has 10+ years of production deployments and runs some of the worlds largest clusters.

Cloud-native environment integration

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

https://rook.io/

Multi-Tenant Containerized Distributed "Computer" with Cloud Native Storage, GPUs, and JupyterHub -- Running Kubernetes / CoreOS



PRP PACIFIC RESEARCH PLATFORM

October 2015

it²

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



CMS

Particle Physics

Biomedical 'omics

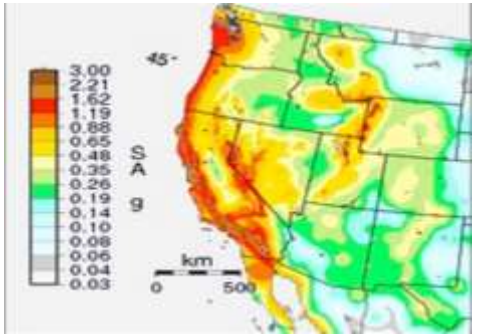




INTERMEDIATE PALOMAR TRANSIENT FACTORY

Telescope Surveys

Earthquake Engineering

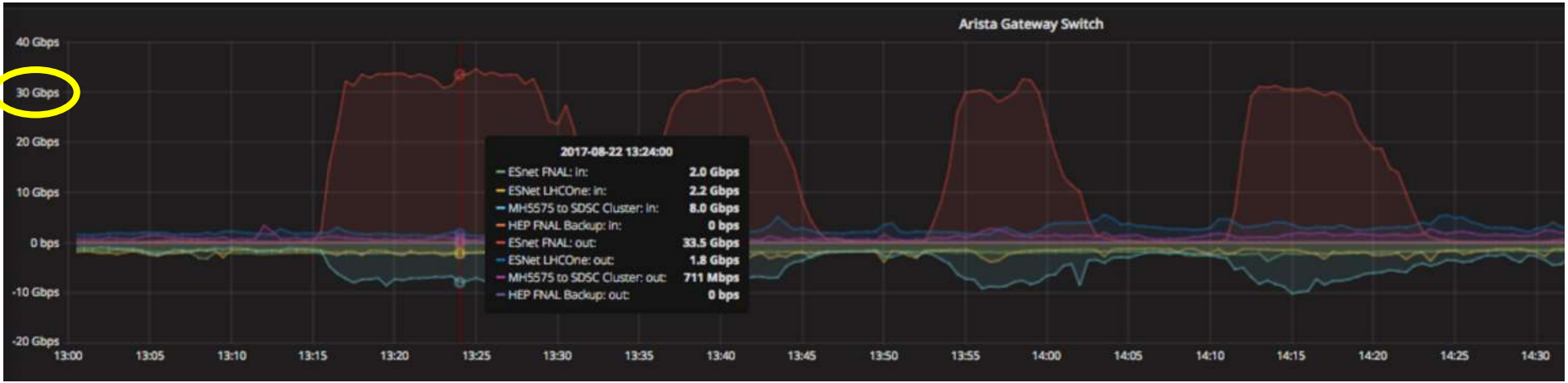


Visualization, Virtual Reality, Collaboration



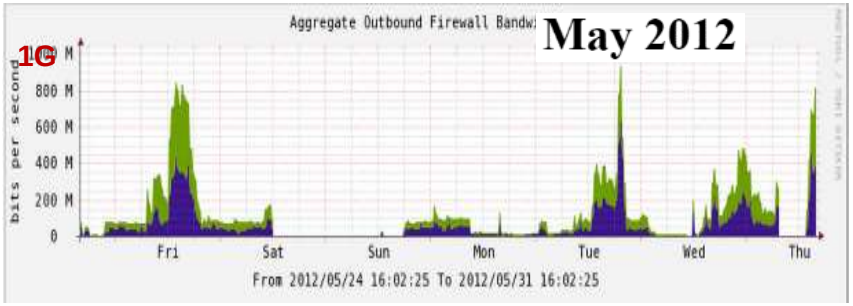
Data Transfer Rates From UCSD Physics Building Servers Across Campus and Then To Chicago's Fermilab

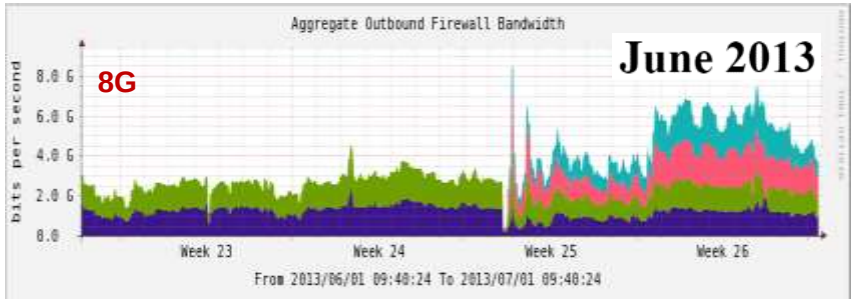
Utilizing UCSD Prism Campus
Optical Network

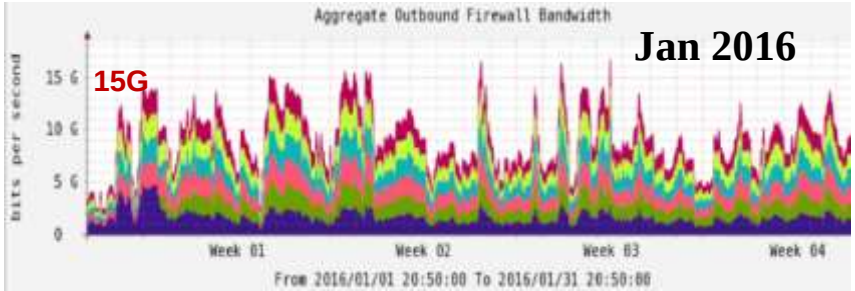


Source: Frank Wuerthwein, UCSD, SDSC

Cancer Genomics Hub (UCSC) Was Housed in SDSC, But NIH Moved Dataset From SDSC to Uchicago - So the PRP Deployed a FIONA to Chicago's MREN









Genomic Data Commons heralds new era of data sharing for cancer research

June 6, 2016

UChicagoNews

Data Source: David Haussler, Brad Smith, UCSC

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PRP Now Enables Distributed Virtual Reality

PRP



WAVE@UC San Diego



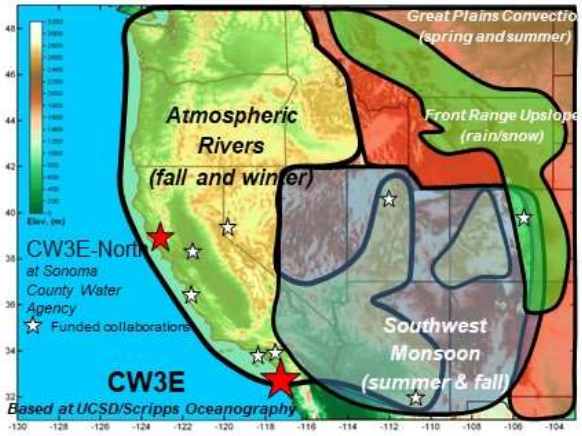
WAVE @UC Merced

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

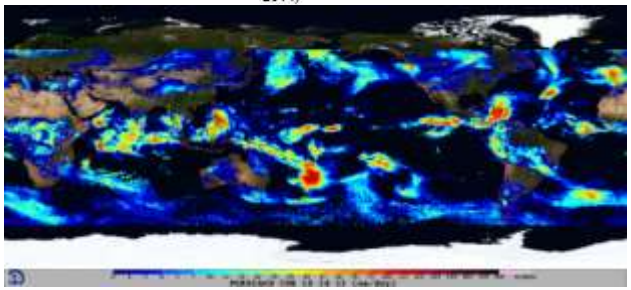
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Collaboration on Atmospheric Water in the West Between UC San Diego and UC Irvine



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

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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

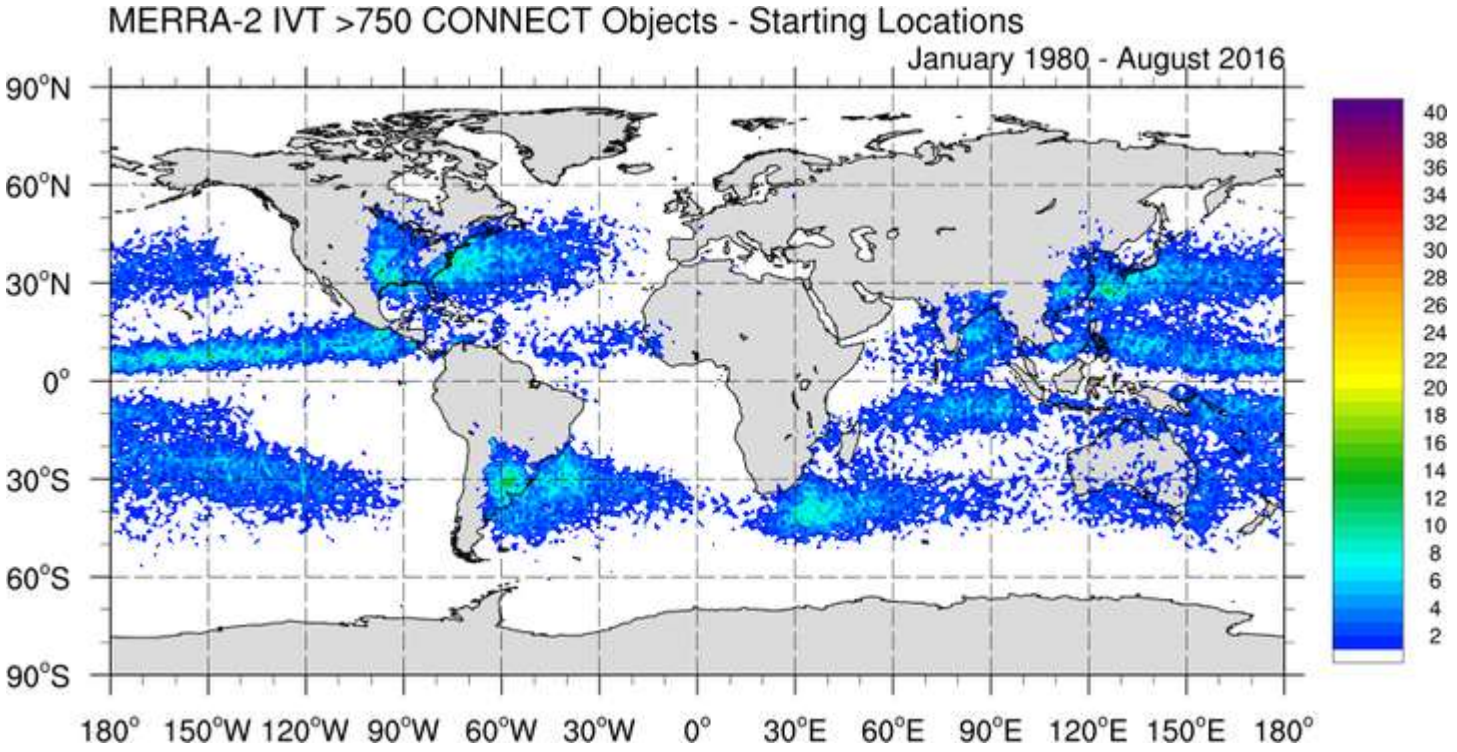
UC, San Diego

GPUs



Calit2's FIONA

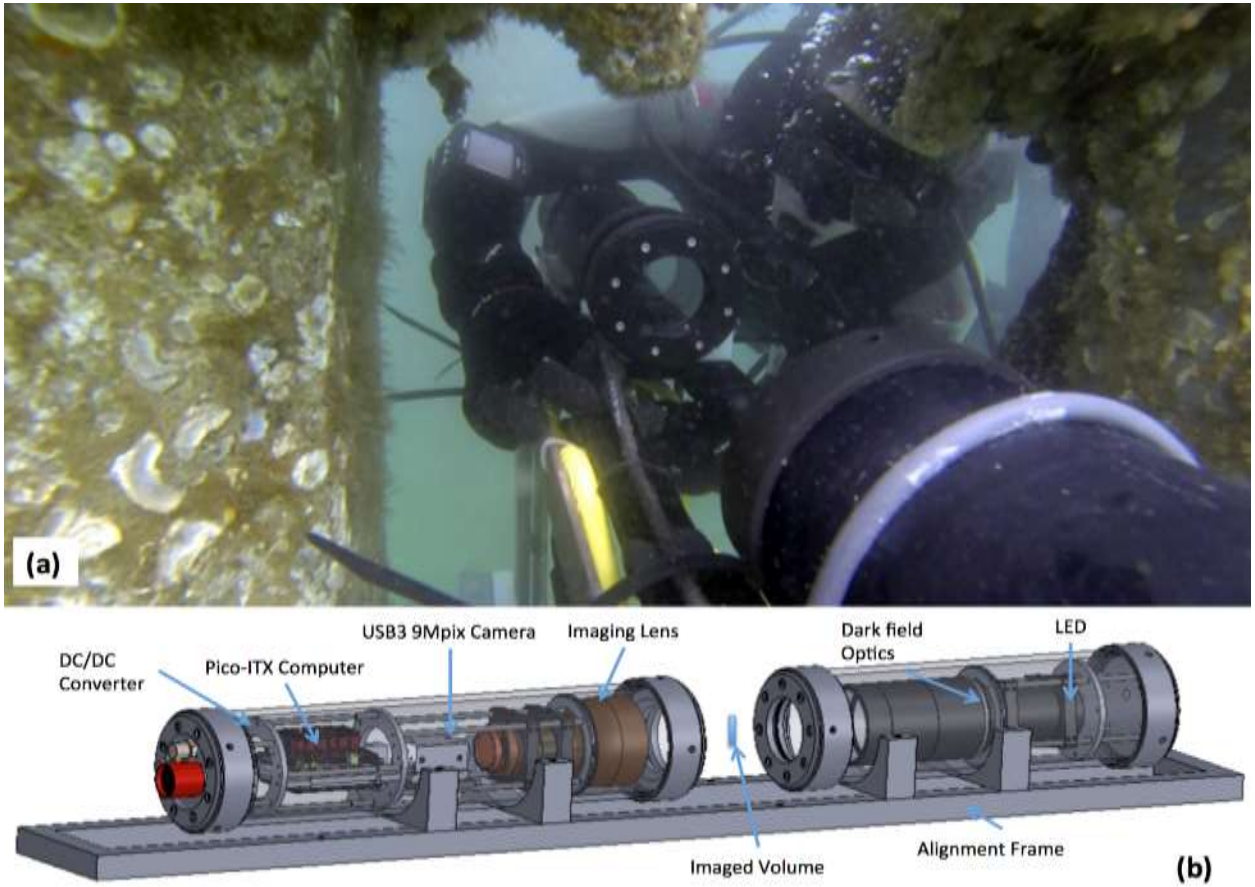
Using Machine Learning to Determine the Precipitation Object Starting Locations



*Sellars et al., 2017 (in prep)

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

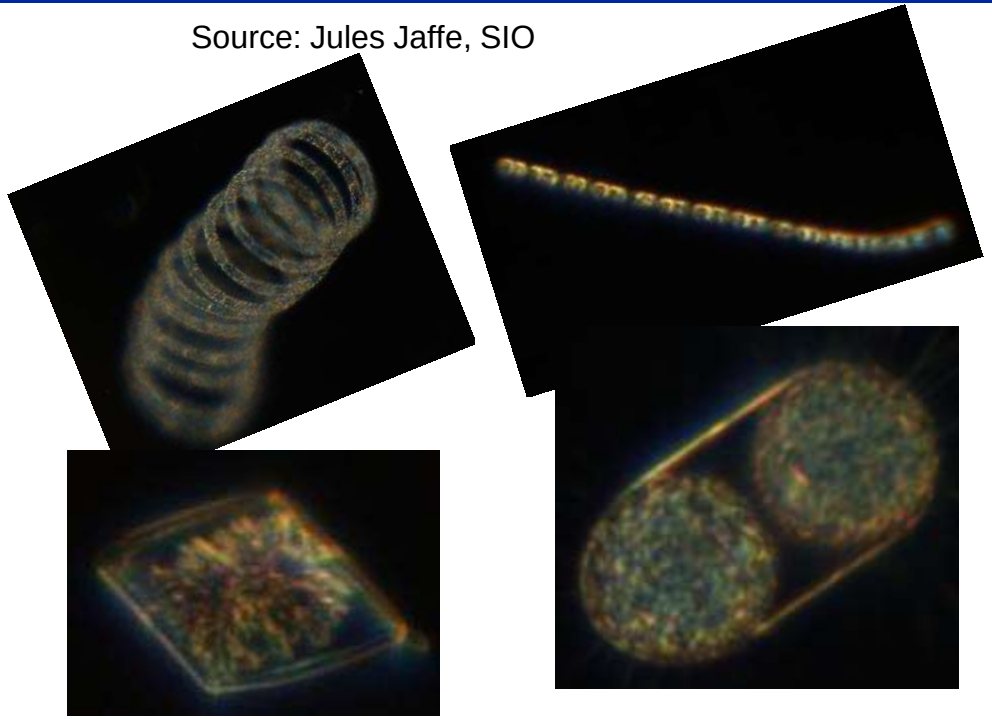


PRP PACIFIC RESEARCH PLATFORM

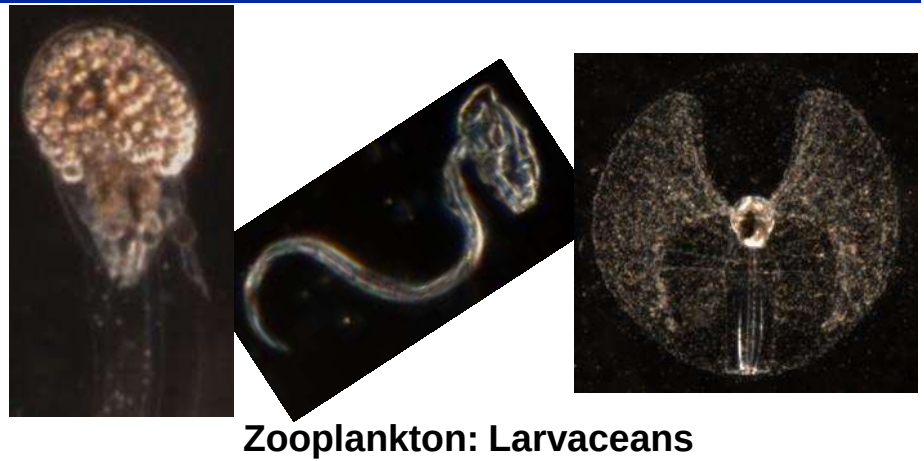
it²

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

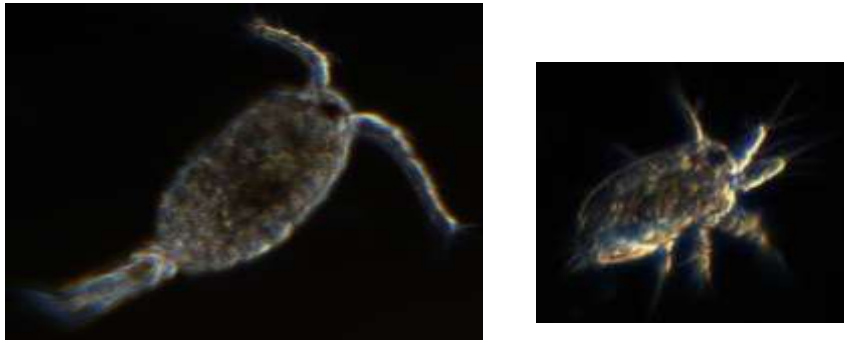
Source: Jules Jaffe, SIO



Phytoplankton: Diatoms



Zooplankton: Larvaceans

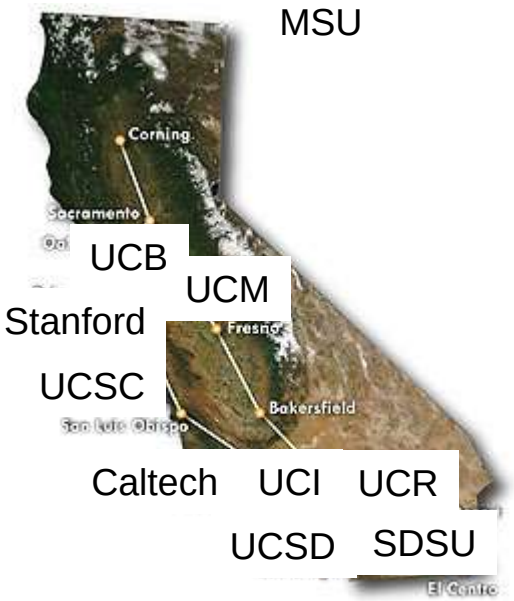


Zooplankton: Copepods

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New NSF CHASE-CI Grant Creates a Community Cyberinfrastructure: Adding 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

PACIFIC RESEARCH PLATFORM

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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Adding GPUs to FIONAs
Supports PRP Data Science Machine Learning



Eight Nvidia GTX-1080 Ti GPUs

~$13K

32GB RAM, 3TB SSD, 40G & Dual 10G ports

Source: John Graham, Calit2

UCSD Adding >350 Game GPUs to Data Sciences Cyberinfrastructure - Devoted to Data Analytics and Machine Learning

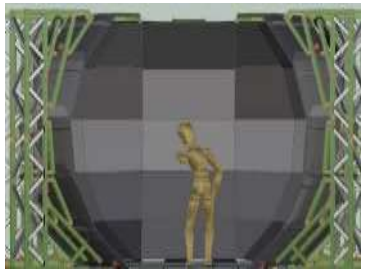
UC San Diego

IT SERVICES

88 GPUs
for Students

Open Science Grid

48 GPUs for
OSG Applications



SunCAVE 70 GPUs
WAVE + Vroom 48 GPUs

UCSD Cognitive Science

JACOBS SCHOOL OF ENGINEERING

SDSC it²

QUALCOMM INSTITUTE



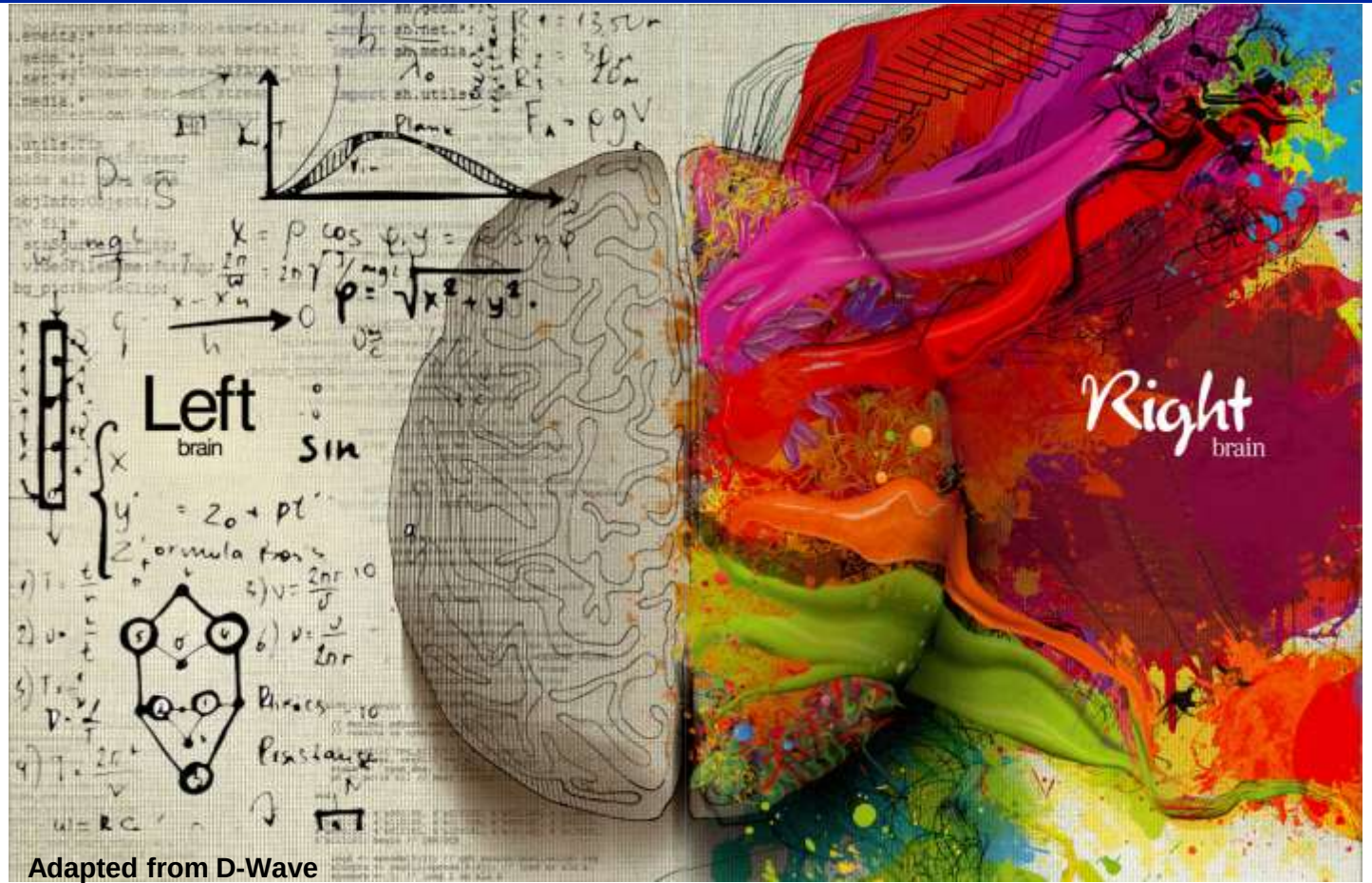
FIONA with
8-Game GPUs

CHASE-CI Grant Provides
96 GPUs at UCSD
for Training AI Algorithms on Big Data

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The Rise of Brain-Inspired Computers:
Left & Right Brain Computing: Arithmetic vs. Pattern Recognition



Adapted from D-Wave

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The Future of Supercomputing Will Blend Traditional HPC and Data Analytics Integrating Non-von Neumann Architectures

“High Performance Computing Will Evolve Towards a Hybrid Model, Integrating Emerging Non-von Neumann Architectures, with Huge Potential in Pattern Recognition, Streaming Data Analysis, and Unpredictable New Applications.”



Horst Simon, Deputy Director,
U.S. Department of Energy’s
Lawrence Berkeley National Laboratory

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BERKELEY LAB
Bringing Science Solutions to the World

U.S. DEPARTMENT OF ENERGY

Calit2's Qualcomm Institute Has Established a Pattern Recognition Lab For Machine Learning on GPUs and von Neumann and NvN Processors



UCSD ECE Professor Ken Kreutz-Delgado Brings the IBM TrueNorth Chip to Start Calit2's Qualcomm Institute Pattern Recognition Laboratory September 16, 2015

Source: Dr. Dharmendra Modha
Founding Director, IBM Cognitive Computing Group

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Our Pattern Recognition Lab is Exploring Mapping Machine Learning Algorithm Families Onto Novel Architectures

- Deep & Recurrent Neural Networks (DNN, RNN)
- Graph Theoretic
- Reinforcement Learning (RL)
- Clustering and other neighborhood-based
- Support Vector Machine (SVM)
- Sparse Signal Processing and Source Localization
- Dimensionality Reduction & Manifold Learning
- Latent Variable Analysis (PCA, ICA)
- Stochastic Sampling, Variational Approximation
- Decision Tree Learning

PACIFIC RESEARCH PLATFORM

Qualcomm Institute

Brain-Inspired Processors
Are Accelerating the Non-von Neumann Architecture Era





Mar. 29, 2016

Lawrence Livermore and IBM collaborate to build new brain-inspired supercomputer

Lawrence Livermore National Laboratory

Air Force Enlists IBM Research to Build Neuromorphic Supercomputer

Michael Feldman | June 26, 2017 14:01 CEST

"On the drawing board are collections of 64, 256, 1024, and 4096 chips.
'It's only limited by money, not imagination,' Modha says."

Source: Dr. Dharmendra Modha
IBM Chief Scientist for Brain-inspired Computing

PRP
PACIFIC RESEARCH PLATFORM

it²

Next Step: Surrounding the PRP Machine Learning Platform With Clouds of GPUs and Non-Von Neumann Processors

IBM



64-TrueNorth Cluster

IBM Cloud

IBM Watson

64-bit GPUs

XSEDE

Extreme Science and Engineering Discovery Environment

NSF





Microsoft Installs Altera FPGAs into Bing Servers & 384 into TACC for Academic Access

Project Catapult

Established: February 2, 2015

Microsoft

KNL EDGE

HIGHLY SCALABLE NEURAL COMPUTING



CHASE-CI

PRP

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Google's First Machine Learning Chip (TPU) Is 30x Faster Than CPUs And GPUs

BUILDING AN AI CHIP SAVED GOOGLE FROM BUILDING A DOZEN NEW DATA CENTERS



SEP 30, 2016 @ 07:39 PM

Marco Chiappetta,

Forbes / Tech

Amazon Boosts Cloud-Computing Performance With New, GPU-Accelerated AWS Instances

amazon web services

it²

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



150 Attendees

Co-Chairs:
Larry Smarr, Calit2
& Jim Bottum, Internet2

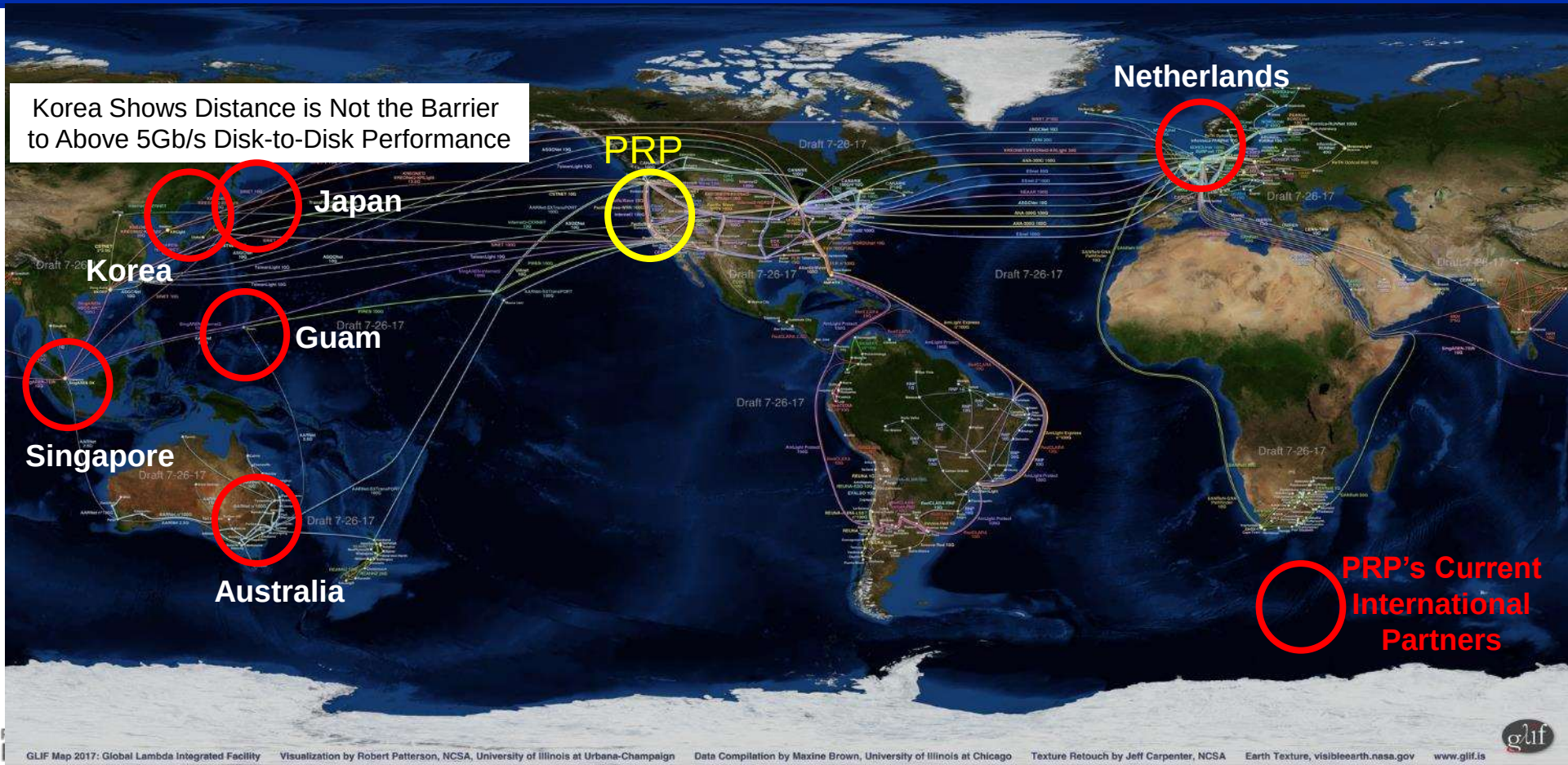
INTERNET2 2017 global SUMMIT April 23-26 Washington DC

Announced in I2 Closing Keynote:
Larry Smarr "Toward a National Big Data Superhighway"
on Wednesday, April 26, 2017

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



Now That We Have a Tightly-Coupled, Yet Highly Distributed "Computer" for Big Data Analysis

There Are So Many Open Research Questions.

How To:

- Encourage Application Teams to Adopt It?
- Strengthen Cybersecurity
- Tightly Integrate Cloud Providers
- Scale Both Technically and Socially?
- Plus Many More…

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Our Support:

- US National Science Foundation (NSF) awards
  - CNS 0821155, CNS-1338192, CNS-1456638, CNS-1730158, ACI-1540112, & ACI-1541349
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- CENIC, PacificWave and StarLight
- DOE ESnet

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