Toward the Global Research Platform

PACIFIC RESEARCH PLATFORM

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Keynote Presentations given in Singapore March 27, 2018 and 2nd NRP workshop in Bozeman, MT, August 6-7, 2018

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California Institute for Telecommunications and Information Technology's
Qualcomm Institute
University of California San Diego
Distinguished Professor Emeritus, University of Illinois at Chicago

What is PRP

- The NSF funded The Pacific Research Platform (PRP) to the UCSD 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 3rd year of successfully bringing new, unanticipated science applications, as well as test new means to dramatically improve throughput.
- 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.
- There is demand from the high-performance networking and scientific communities to extend the PRP nationally, and indeed worldwide.

The goal: to prototype a future in which a fully-funded multi-national Global Research Platform emerges

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Science DMZ

- **Based on Community Input and on ESnet's Science DMZ Concept, NSF Has Funded Over 100 Campuses to Build DMZs**
- **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** are regularly used to characterize and troubleshoot the network
  - **Security policies and enforcement mechanisms** are tailored for high performance science environments

Science DMZ
Coined 2010

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ESnet
FASTERDATA KNOWLEDGEBASE

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

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Providing Needed Performance

R&E networks must meet performance needs of a diverse mix of users & applications

That includes everything from:

- **Low latency for high volume interactive K-12 student testing**
- **Through interactive video performance**
- **To "big data" flows among labs**

Reliability, flexibility and resiliency are essential

That's been hard for networks to do

- **Internet2 has tried multiple times via end-2-end performance projects (e.g. the 'user expectations' efforts), as have others.**
- **And, there are many network performance tools, and they do lots of useful things**
- **But tools used by most of R&E don't do direct, active, deterministic, measurement of actual traffic between sites**

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With NSF, CENIC & PNWGP Support

- **Active measurement is a good way to get, and to help sustaining true end-to-end user performance**
- **Based on ESnet's knowledge base fasterdata.es.net**
- **Supported by the large NSF funded 'Science DMZ' project called *Pacific Research Platform* (PRP)**
- **And by a new one called *Towards the NRP***

ESnet:
Energy Sciences Network

CENIC
The Corporation for Education Network Initiatives

PACIFIC NORTHWEST GIGAPOP

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The Pacific Research Platform Networks Connects Campuses to Create a Regional End-to-End *Big Data Superhighway*

Source: John Hess, CENIC

NSF Grant
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, UCI (former UCSD)
- Frank Wuerthwein, UCSD Physics and SDSC

Letters of Commitment from:

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

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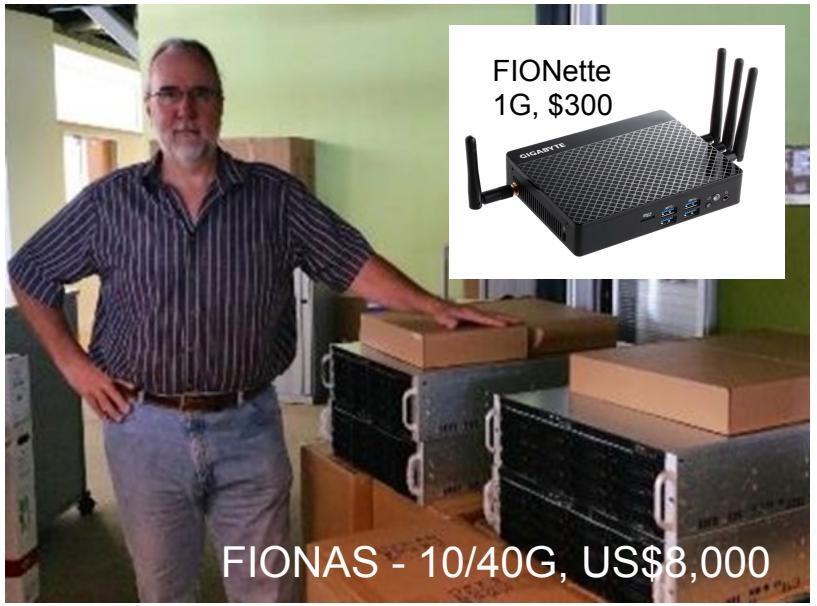
Big Data Science Data Transfer Nodes (DTNs) Flash I/O Network Appliances (FIONAs)

Key Innovation: UCSD Designed FIONAs to solve the Disk-to-Disk data transfer problem at full speed on 10/40/100G Networks

- FIONAs PCs [a.k.a ESnet DTNs]:
  - **~$8,000 Big Data PC with:**
    - 10/40 Gbps Network Interface Cards
    - 3 TB SSDs or 100+ TB Disk Drive
  - **Extensible for Higher Performance to:**
    - +NVMe SSDs for 100Gbps Disk-to-Disk
    - +Up to 8 GPUs [4M GPU Core Hours/Week]
    - +Up to 196 TB Disks as Data *Capacitors*
    - +Up to 38 Intel CPU cores or AMD Epyc
  - **~$1,100 10Gbps FIONAs now available**
- FIONettes are $300 EL-30-based FIONAs
  - **1Gbps NIC With USB-3 for Flash Storage or SSD**



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

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FIONAs on the PRP and Partners sites

~40 FIONAs as GridFTP (MaDDash) + perfSONAR Systems

- **PRP Partners: 10 UCs, Caltech, U of Southern California, U Washington, U of Illinois Chicago, SDSC**
- **Plus U Utah, Montana State, U Chicago, Clemson U, U Hawaii, NCAR, Guam**
- **Plus Internationals: U Amsterdam, KISTI (Korea), Singapore (soon)**

Many States and Regionals Building FIONAs and Creating MaDDashes

- **FIONA Build Specs on PRP Website http://prp.ucsd.edu**
- **Weekly Engineering Calls with Notes Going to 60+ Technical Participants**

Monitoring and Debugging Dashboard
PERFormance Service Oriented Network monitoring ARchitecture

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CENIC ESnet SDSC CITRIS AND THE BANATAO INSTITUTE NSF it²

Performance Instrumentation

- We use purpose-built ‘FIONA’ servers that are tuned to test end-to-end 1G, 10G, 40G and 100G connections, our version of ESnet’s DTNs
- perfSONAR and GridFTP logs are then turned into visualizations
- Disk-to-disk transfers of 10GB were performed 4x a day until the PRP networks and the campus endpoints were tuned and capable of full bandwidth utilization with essentially no TCP backoff
- New efforts are expanding the types of testing and visualizations, using Kubernetes as an orchestration engine to automate this distributed cluster of FIONAs

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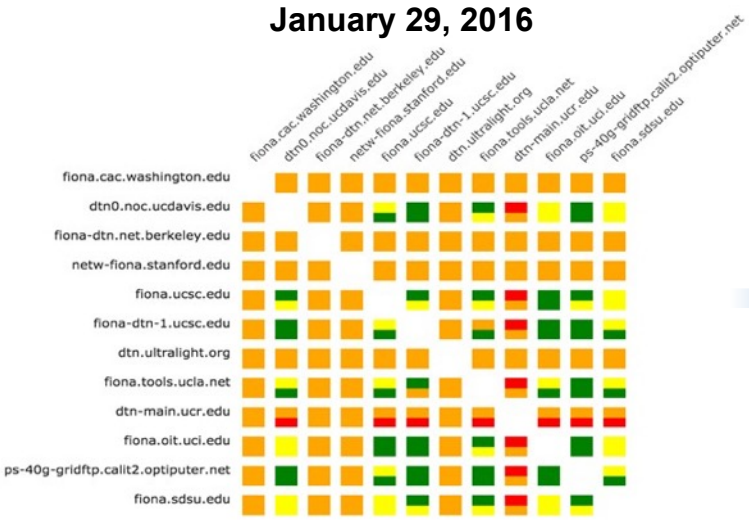
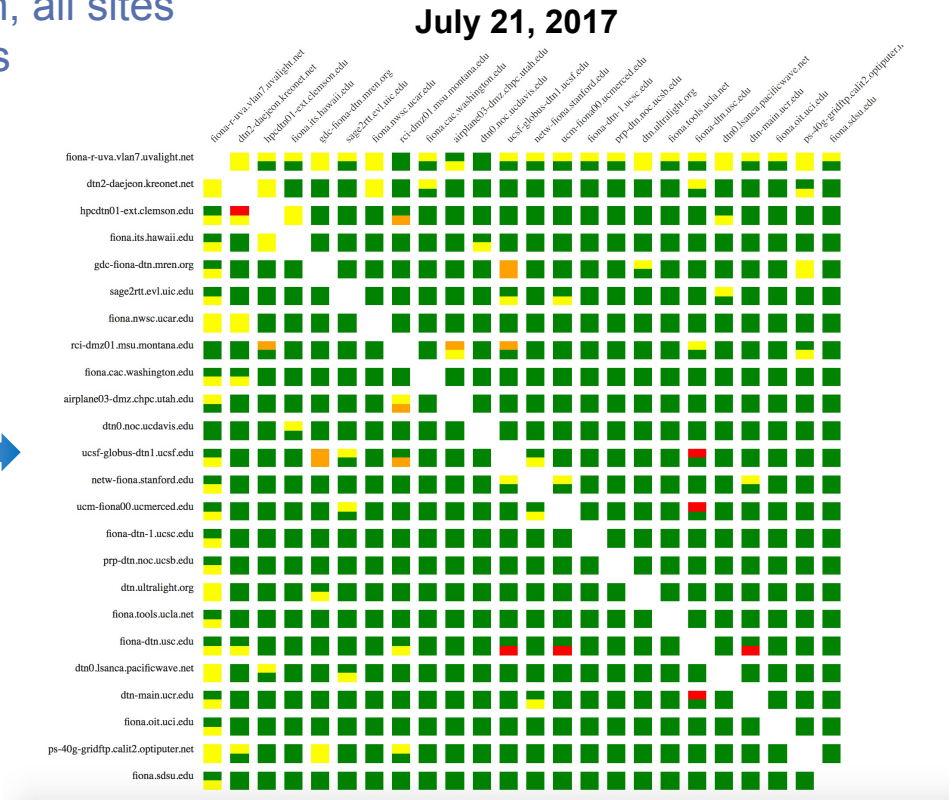
Disk-to-Disk Throughput measurement testing

- 10Gb file transfer 4 times/day dual direction, all sites
- From monitoring start: 12 DTNs to 24 DTNs connected at 10-40G in 1.5 yrs





Source: John Graham, Calit2/QI

PRPGridFTP

Throughput >= 5000Mbps | Throughput < 5000Mbps | Throughput <= 1000Mbps | Unable to retrieve data

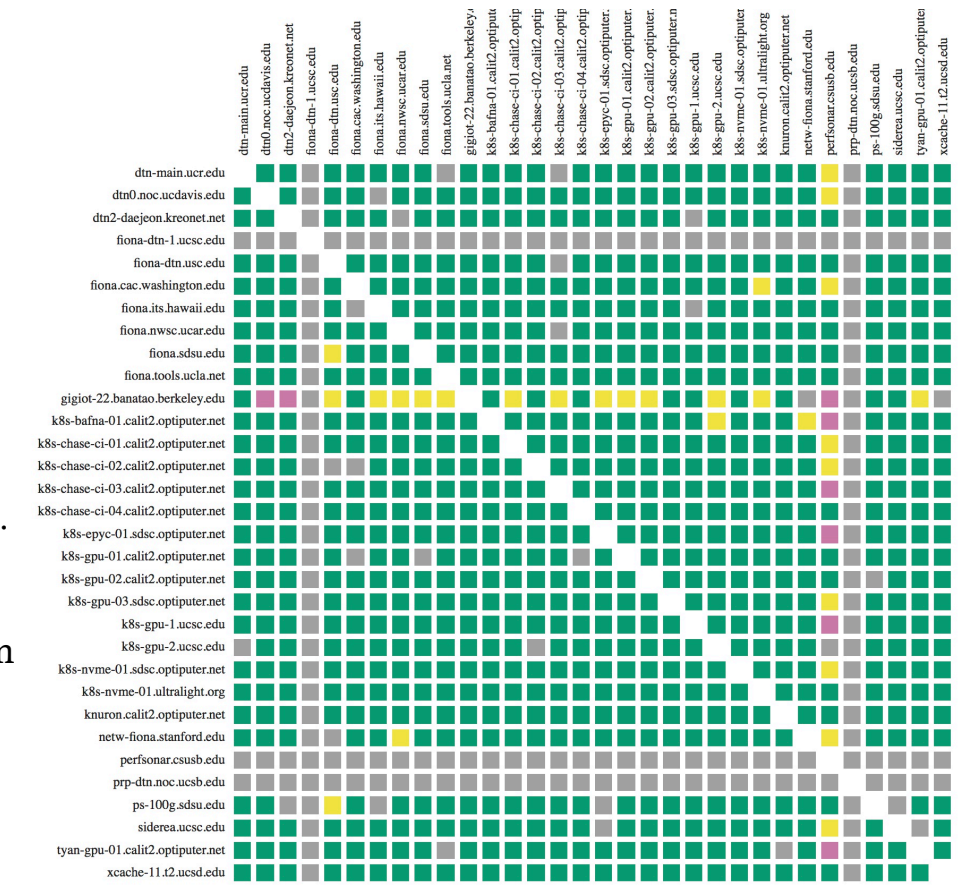
Nautilus mesh: traceroute measurement testing

Shows flows that took different paths to the same destination

- **Number of paths is <=1**
- **Number of paths is >=1**
- **Number of paths is >=2**
- **Unable to retrieve data**

Traceroute - network diagnostic tool for
- displaying the route (path)
- and measuring transit delays of packets across an Internet Protocol (IP) network.

The history of the route is recorded as the round-trip times of the packets received from each successive host (remote node) in the route (path)



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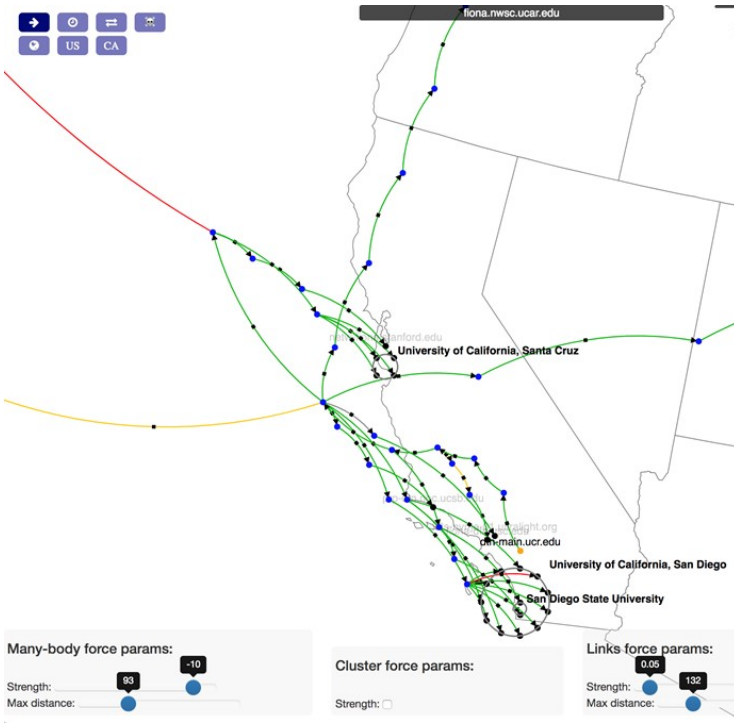
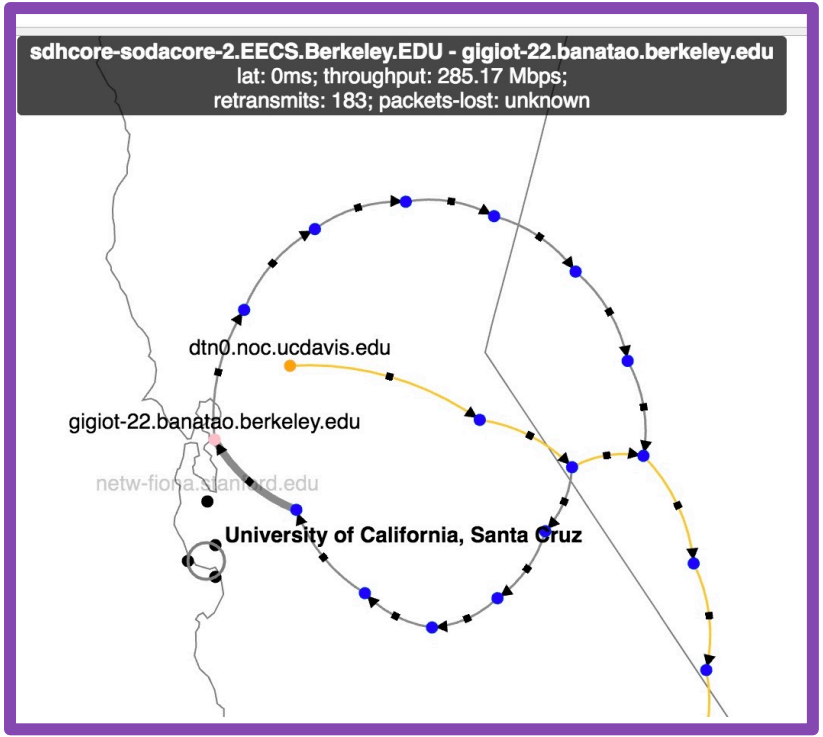
Traceroute: Real-time Visualization of Status of Network Links

https://traceroute.nautilus.optiputer.net/



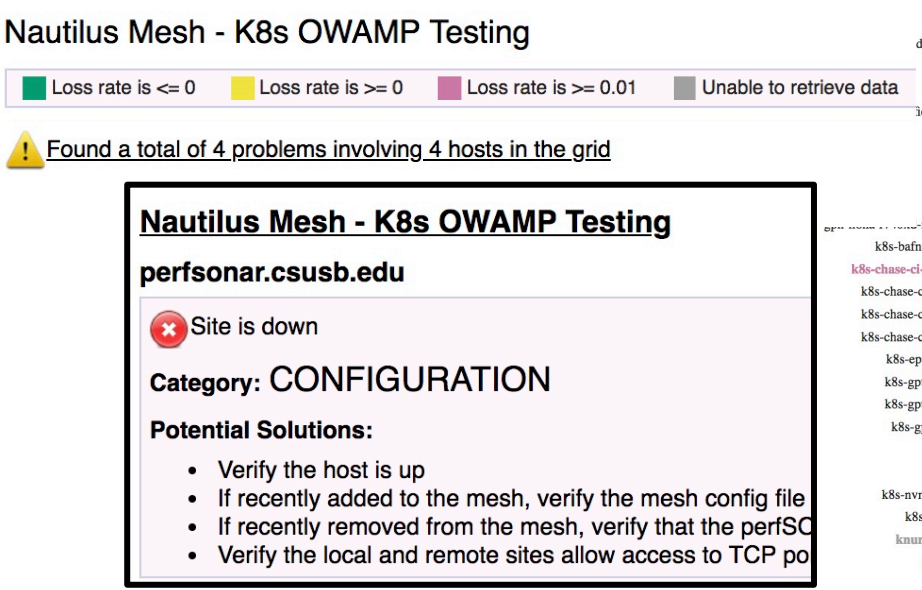


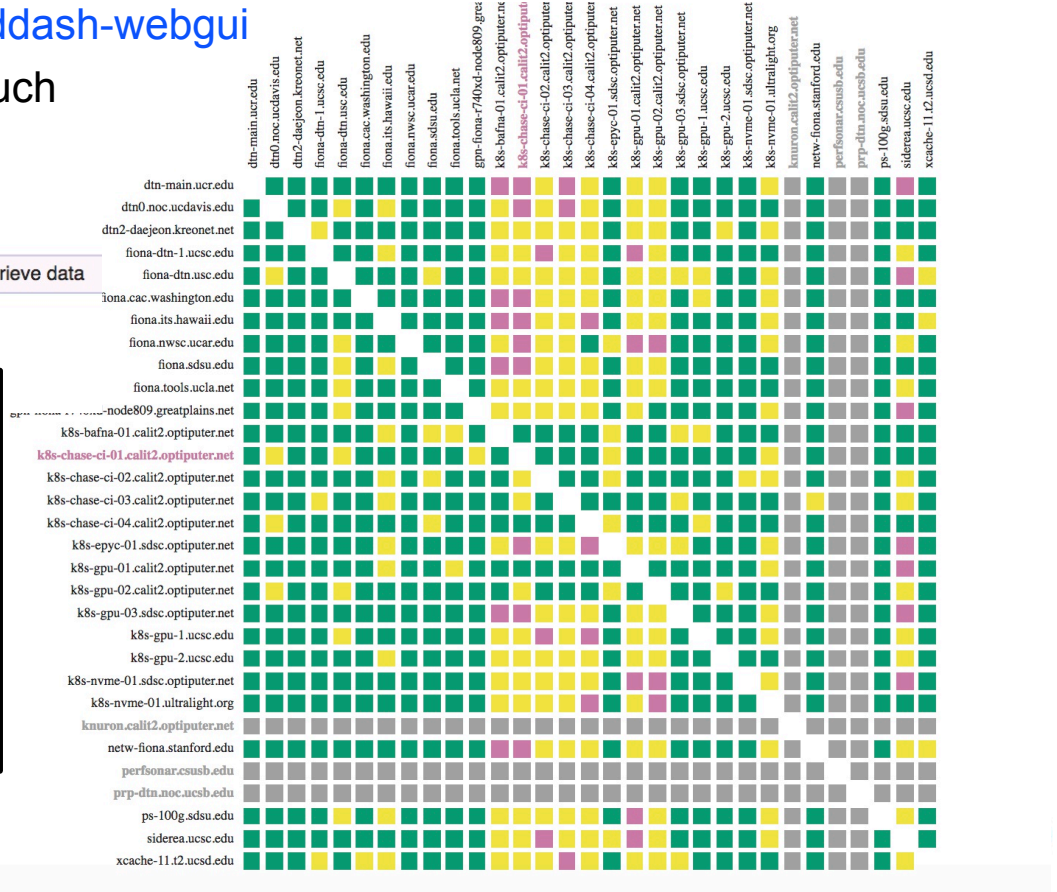
Source: Dmitry Mishin (SDSC), John Graham (Calit2)

One-Way Active Measurement Protocol (OWAMP) testing

https://perfsonar.nautilus.optiputer.net/maddash-webgui

Measures Unidirectional Characteristics such as One-Way Delay and One-Way Loss





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Result: Active, Fact-Based, NET Management

- Our approach gives:
  - Proactive measurements of actual performance
  - Early warning of issues to NOC and engineers
- FIONA devices can run other software to monitor for security incursions and other issues
- Further, the FIONA platform allows really inexpensive network node & end-site based R&E Cloud capabilities

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Installing 16 10&12 TB Drives in June 2018 at UC Merced, UC Riverside and Stanford

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Use Kubernetes to Manage Across the PRPv2


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GOOGLE OPEN SOURCES ITS SECRET WEAPON IN CLOUD COMPUTING

WIRED

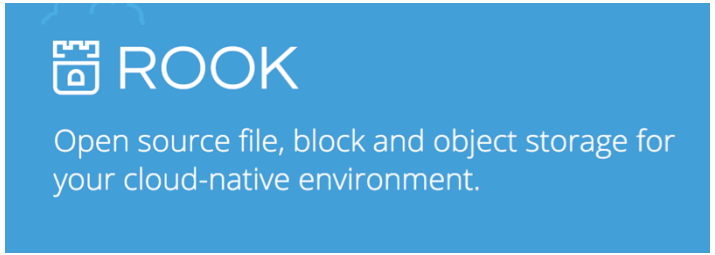
https://kubernetes.io

"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



Battle-tested, production storage:
based on an embedded version of Ceph, with 10+ years of production deployments and runs some of the worlds largest clusters

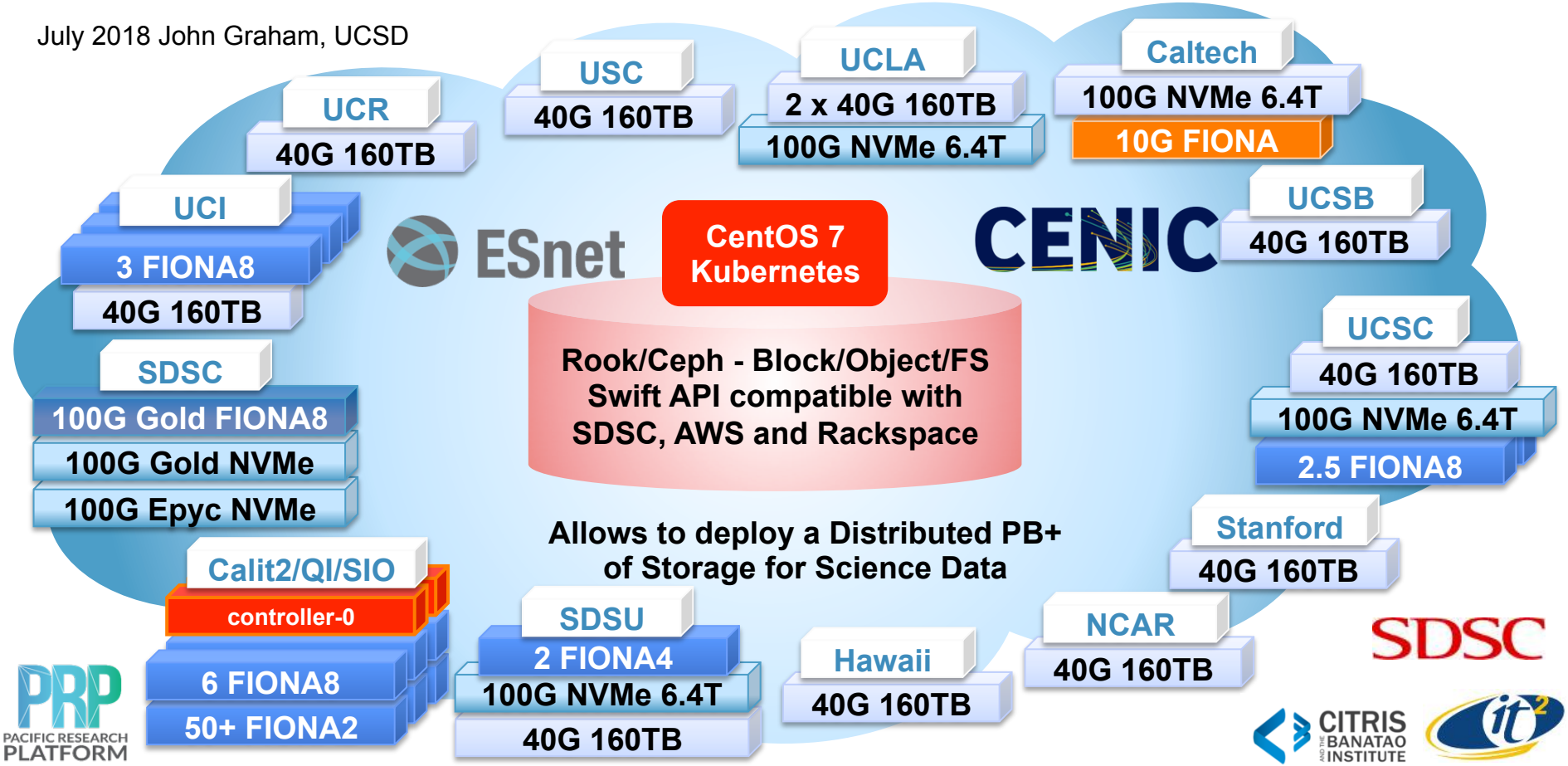
Cloud-native environment integration:
runs as a cloud native service for optimal integration with applications in need of block, object or file storage

Allows the PRP to Deploy Petabytes at $10/TB/year of Distributed Storage and GPUs for Data Science as well as Measure and Monitor Usage

Source: John Graham, Calit2/QI

Nautilus multi-tenant HyperCluster

July 2018 John Graham, UCSD



Grafana Plot of First 730 TB

This is working DMZ Scratch Space, not Archival Research Storage

https://grafana.nautilus.optiputer.net/

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

CMS

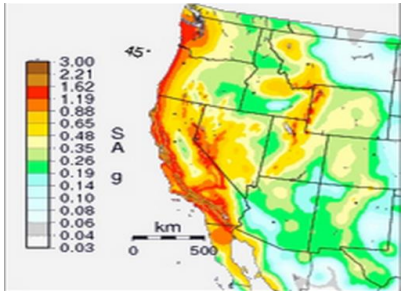
Particle Physics

Biomedical 'omics

INTERMEDIATE PALOMAR TRANSIENT FACTORY

Telescope Surveys

Earth Sciences Engineering



Visualization, Virtual Reality, Collaboration

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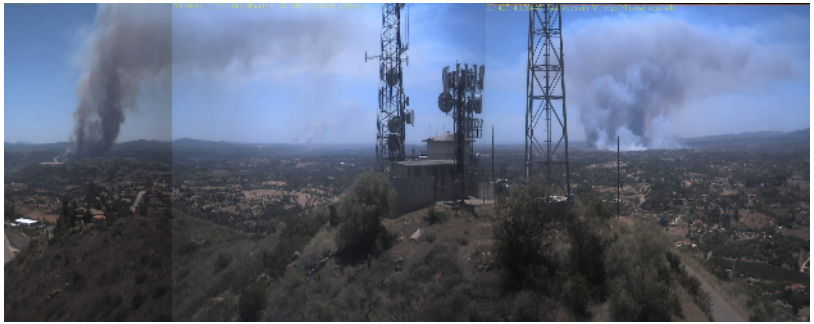
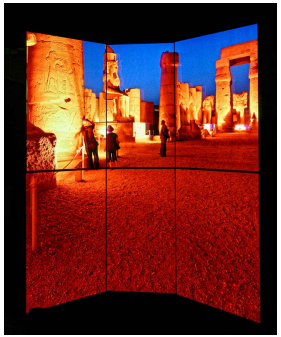
The Prototype PRP Has Attracted New Application Drivers

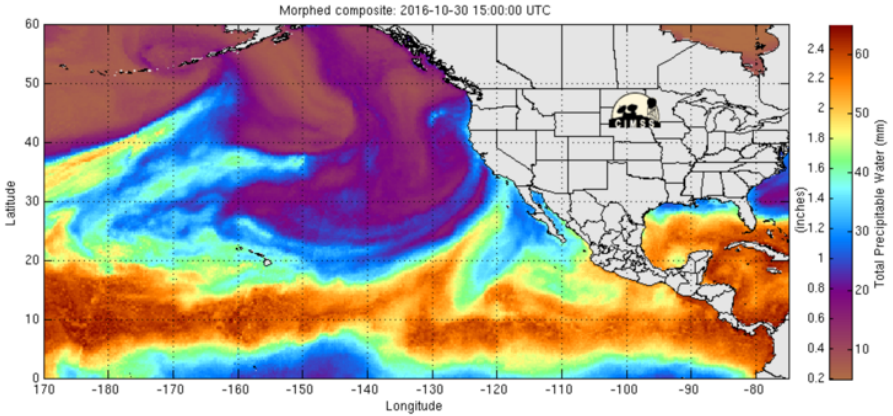


Frank Vernon, Graham Kent, & Ilkay Altintas, **Coupling Wireless Wildfire Sensors to Computing**

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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New NSF CHASE-CI Grant Creates a Community Cyberinfrastructure

MSU
UCB
Stanford
UCM
UCSC
Caltech
UCI
UCR
UCSD
SDSU

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 Faculty & their students at 10 Campuses for Training AI Algorithms on Big Data
- Adding a Machine Learning Layer Built on Top of the Pacific Research Platform

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FIONA8: a FIONA with 8 GPUs
Supports PRP Data Science Machine Learning

Goal: *Machine Learning Researchers Need a New Cyberinfrastructure*

8 Nvidia GTX-1080 Ti GPUs (11 GB)

Dual 8 core 2.1Ghz CPU	**2x NVMe bays**
32GB RAM	**40G ConnectX-4**
6 480GB SSD	**Dual 10G ports**

"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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Community Computing Needed to Process the Data at a Price Advantage vs. AWS

Single vs. Double Precision GPUs: Gaming vs. Supercomputing

Nvidia Card	Cost	32-bit GF	GB	Cost per GF	Cost per GB	cores	8 GPU server	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 k80 GPUs + disk for 3 yrs							$239,040	$4,780,800

5 FIONA8 nodes:

- 40 GPUs
- 15” of rack space
- 3.44 * 10^6 GPU-hours/day

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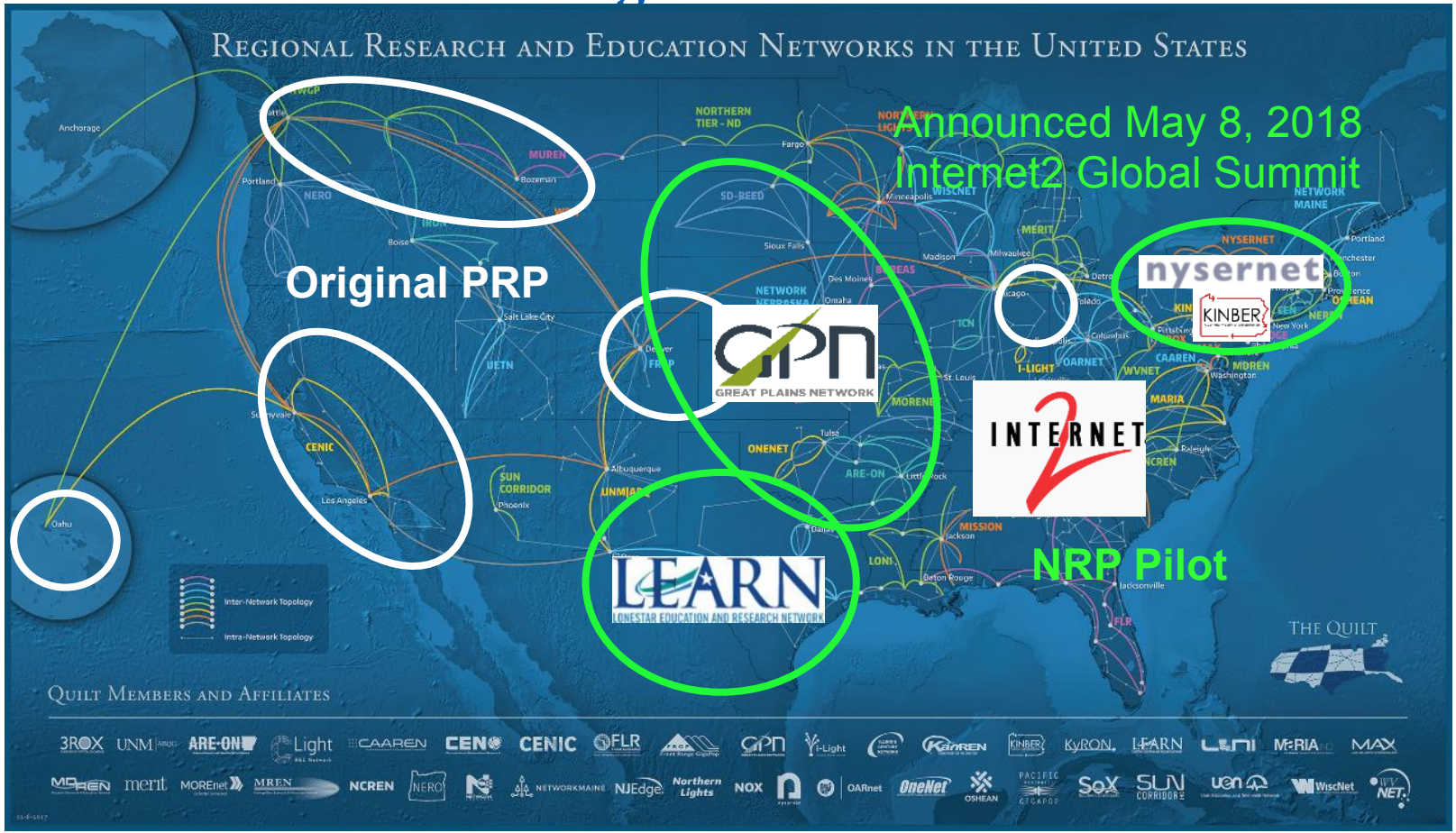
Reaching beyond CENIC/Pacific Wave: Using Internet2 to Connect Regional Networks—NRP Pilot



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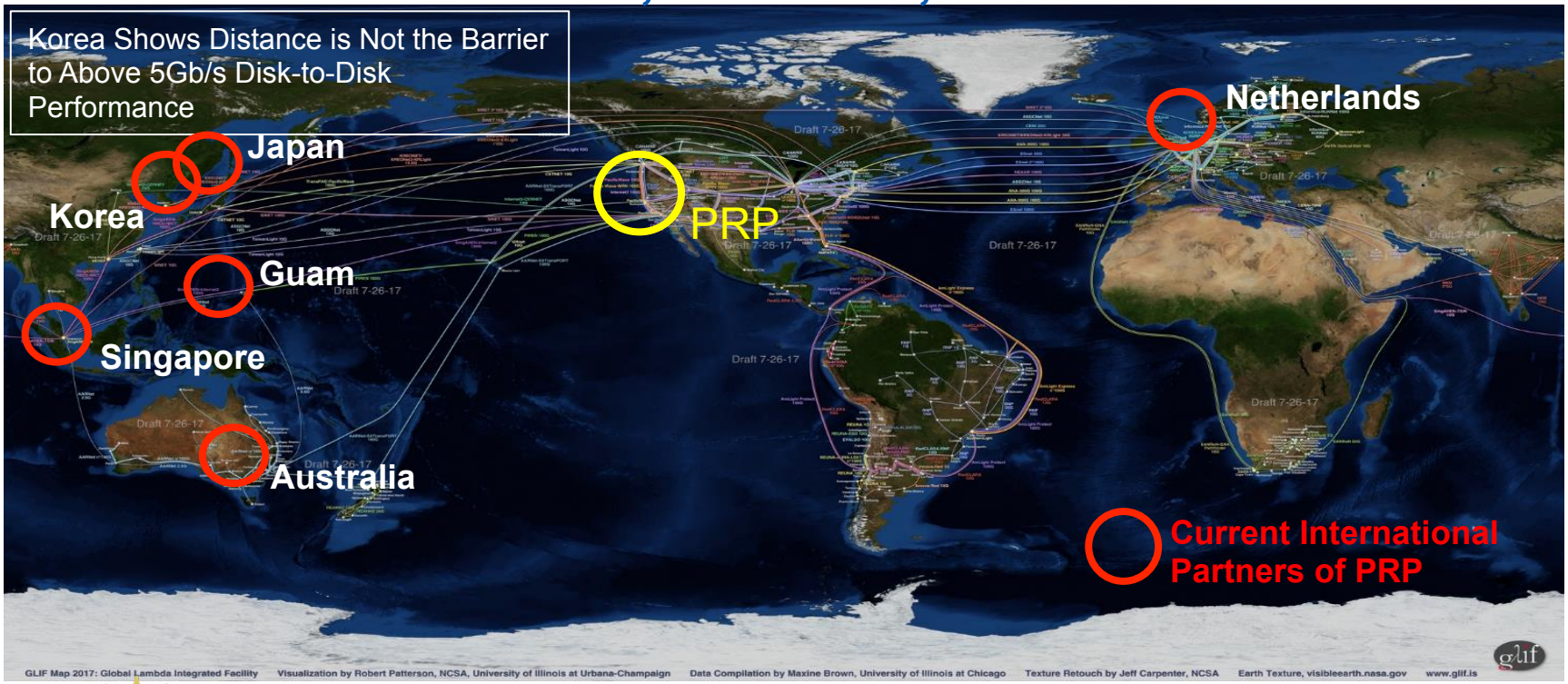
Expanding to the Global Research Platform Via CENIC/Pacific Wave, Internet2, and International Links



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NSF CENIC ESnet CITRIS AND THE BANATAO INSTITUTE

http://pacificresearchplatform.org

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Trust - a key element for success

- Human trust to establish cooperation across institutions
- It took time for PRP participants to work together
  - to learn individual roles and strengths (and weaknesses),
  - to learn to rely on/trust their collaborators
- Trust is a human-intensive endeavor, one relationship at a time, not readily scalable. But can foster:
  - Identify and document successful collaborations (like PRP)
  - Emphasize peer to peer communications (at all levels)

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Key Findings:
from First NRP Workshop, August 2017

- NRP platform must be easy for scientists to implement and use
- Scientists want to do science, not networking or IT
- NRP is a social engineering project as well as a technical networking/IT project
- ScienceDMZ/DTN architecture is an effective science enabler
- Science Engagement process is crucial to scaling up

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Acknowledgements of PRP support:

- 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 Qualcomm Institute
- CENIC, PacificWave and StarLight
- DOE ESnet

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Terima kasih!

Thank you!

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