Discovery, unconstrained by geography.

Inder Monga,

Interim Director, CTO, ESnet

ESnet

ESnet is starting Run 3 in August

ESnet by Facts

The basic facts (new or notable):

High-speed international networking facility, optimized for DOE science missions:

- connecting 50 labs, plants and facilities with >150 networks, universities, research partners globally
- 340Gbps transatlantic extension in production (Dec 2014)
- university connections to better serve LHC science
- $35M in FY15, 42FTE
- older than commercial Internet, growing ~twice as fast
- the DOE user facility that serves all others

$62M ARRA grant funded 100G upgrade in 2011:

- fiber assets + access to spectrum, shared with Internet2
- new era of optical networking, abundant capacity
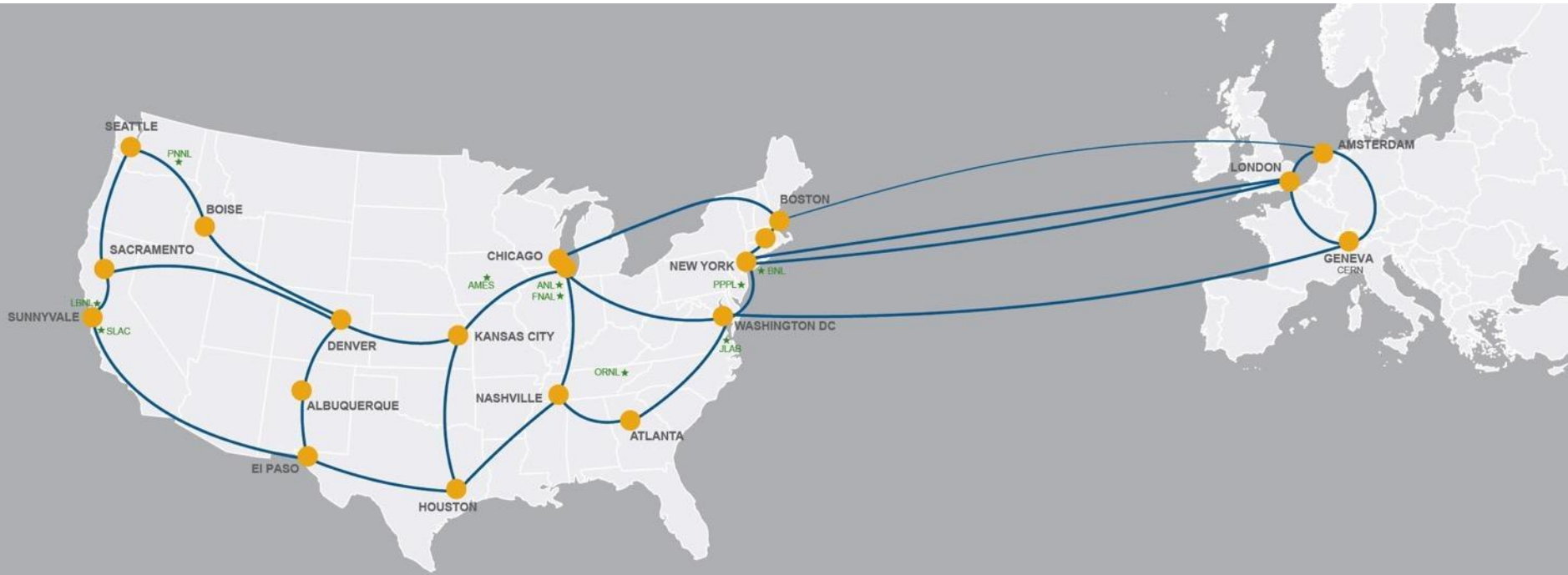- world's first 100G network at continental scale

Culture of urgency:

- several recent awards
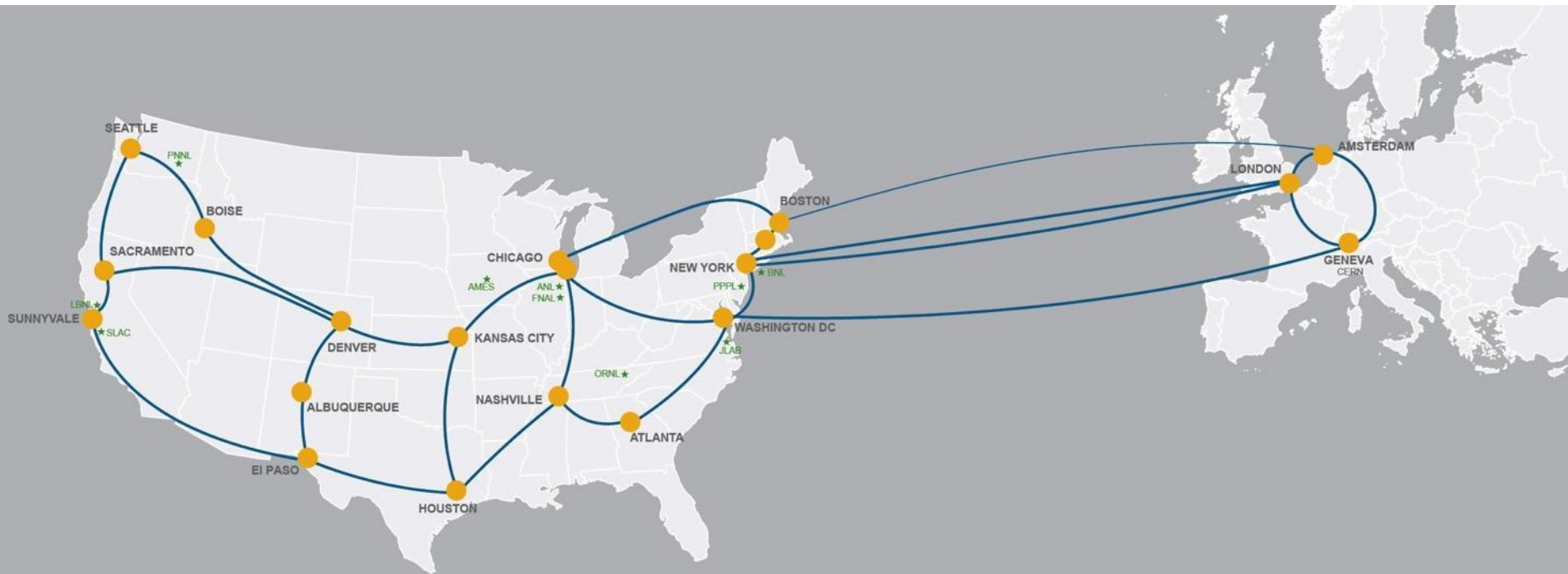- 80% engineers, highly motivated

ESnet

Our vision:

Scientific progress will be **completely unconstrained** by the physical location of instruments, people, computational resources, or data.

ESnet

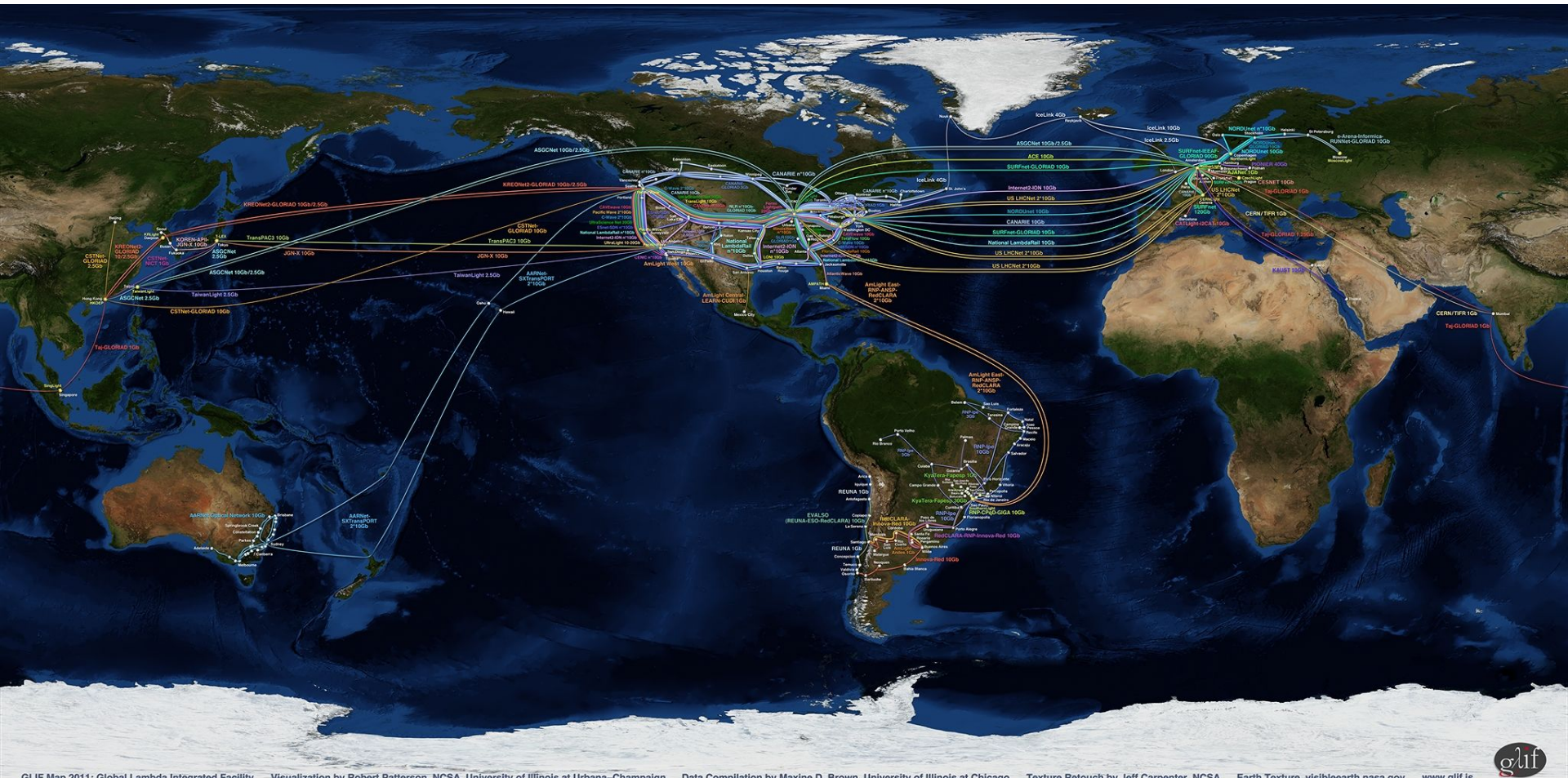# 5th Generation ESnet: Current Network Footprint

ESnet is a dedicated mission network engineered to accelerate a broad range of science outcomes.

We do this by offering unique capabilities, and optimizing the network for data acquisition, data placement, data sharing, data mobility.

# One of the oldest, fastest parts of the Internet.

GLIF Map 2011: Global Lambda Integrated Facility   Visualization by Robert Patterson, NCSA, University of Illinois at Urbana–Champaign   Data Compilation by Maxine D. Brown, University of Illinois at Chicago   Texture Retouch by Jeff Carpenter, NCSA   Earth Texture, visibleearth.nasa.gov   www.glif.is

Densely interconnected to institutions, R&E networks, commercial service providers, cloud providers etc.

150+ peers, 300+ peering points, 1.4 Tbps of peering capacity

Small but effective organization
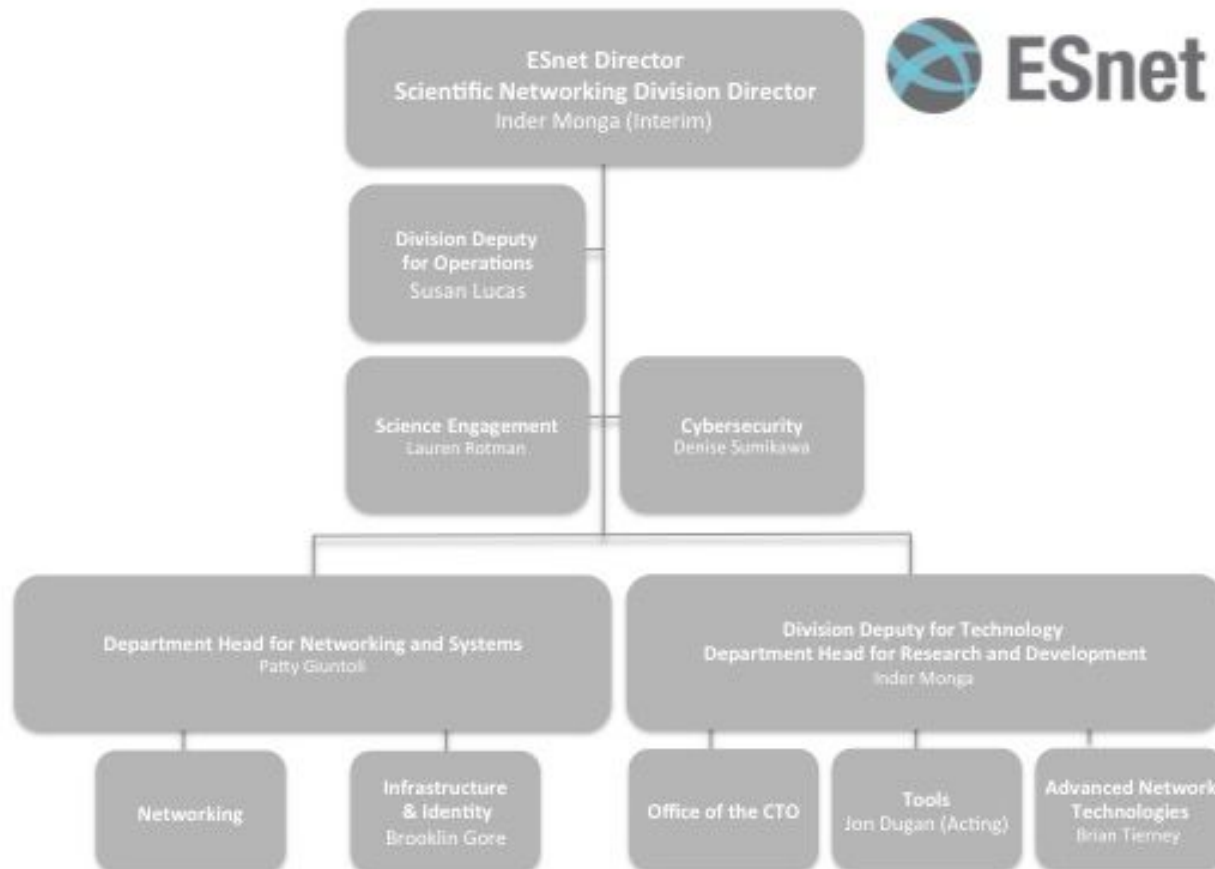
Punching above our weight.

- Brazil (422)
- UK (180)
- Czech Republic (142)
- Netherlands (138)
- Croatia (112)
- Internet2 (>100)
- Hungary (94)
- Australia (80)
- Norway (78)
- Switzerland (76)

- Greece (68)
- France (66)
- Italy (61)
- Germany (54)
- Ireland (52)
- Slovenia (51)
- Belgium (50)
- Portugal (47)
- ESnet (42)

Caveats: varying service and business models make comparisons difficult, but the large-scale pattern is instructive. (Headcount numbers interpolated from bar graph on page 80 of the most recent *GÉANT Association Compendium*, or described elsewhere in that report.)

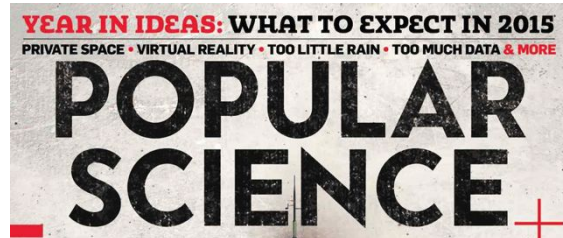**ESnet**

A reputation for innovation and excellence.

R&D 100 2013

CENIC

FIERCE
FierceGovernment

InformationWeek
Government

ONF
OPEN NETWORKING
FOUNDATION

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

YEAR IN IDEAS: WHAT TO EXPECT IN 2015
PRIVATE SPACE · VIRTUAL REALITY · TOO LITTLE RAIN · TOO MUCH DATA & MORE
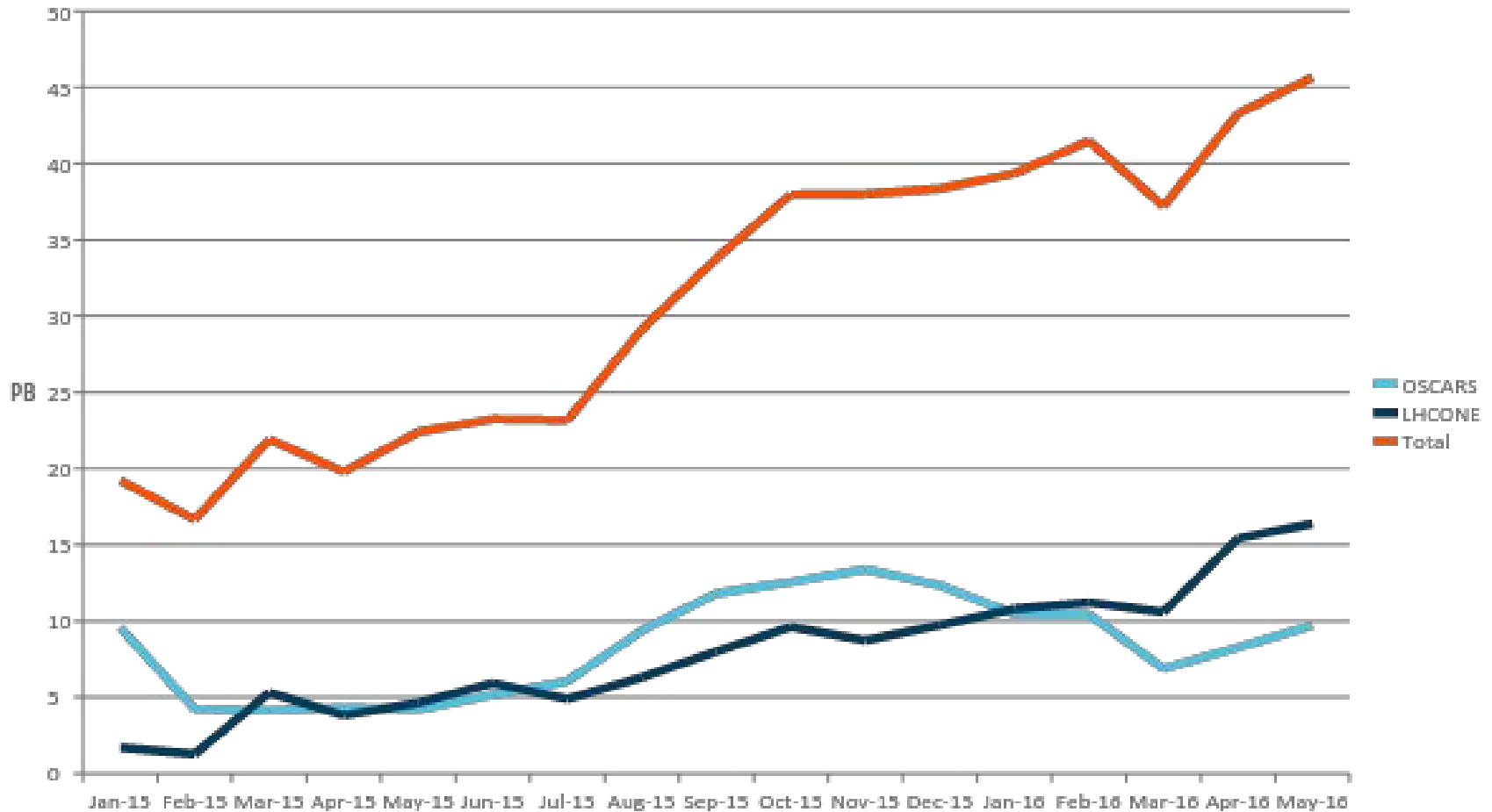POPULAR SCIENCE

"The entire staff conscientiously and continually lead their field."

[report from recent operational review]

ESnet

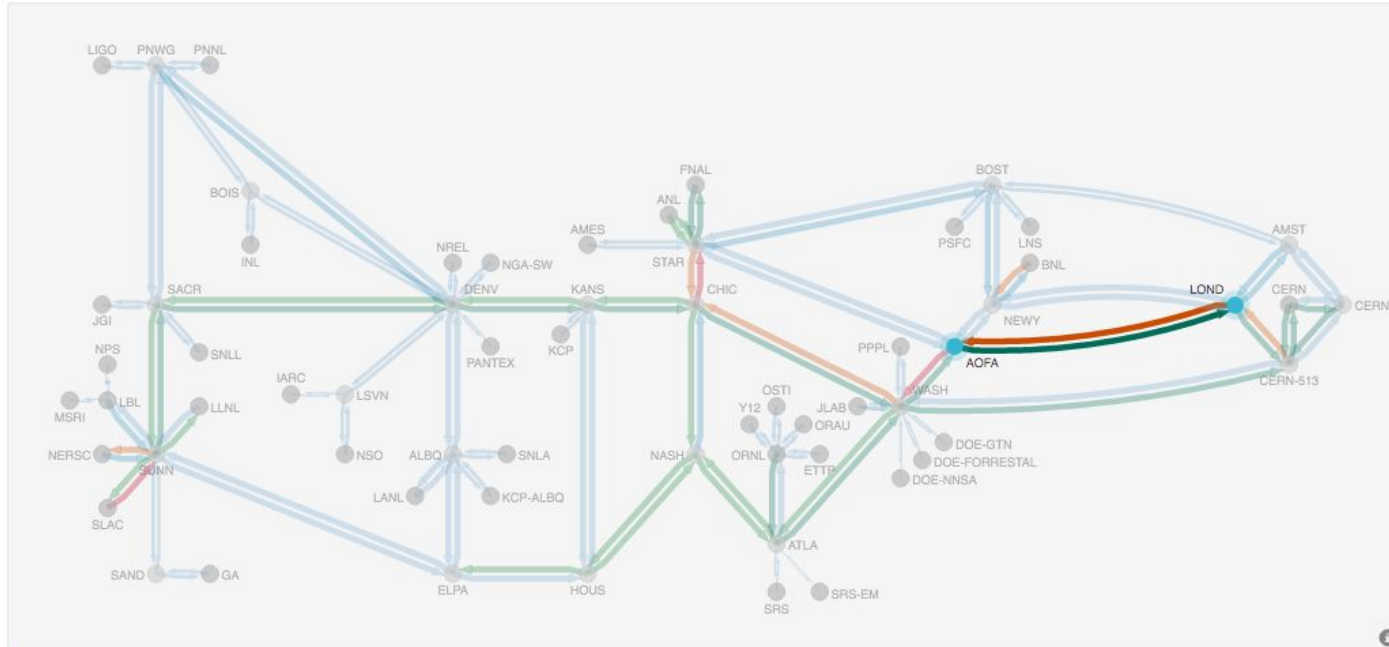# Big Data on ESnet

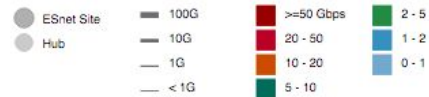# Overall Traffic doubled, LHCONE up 1500+% in Run 2 [January 2015 – May 2016]
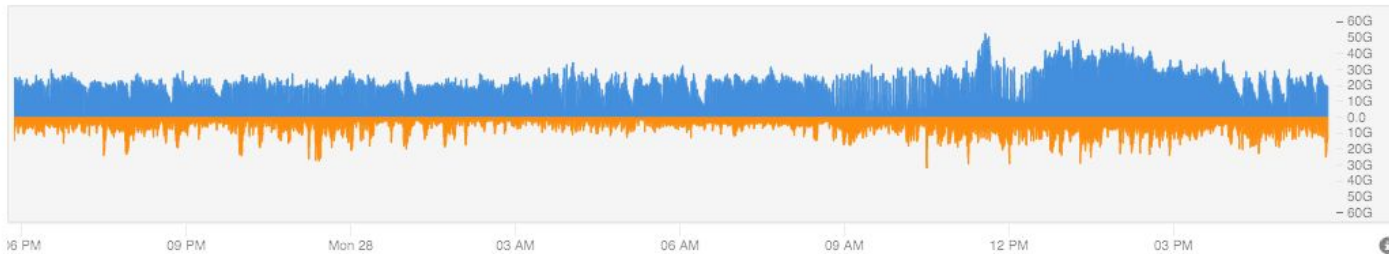
Transatlantic traffic is healthy

We even backup partner NREN's trans-atlantic traffic…
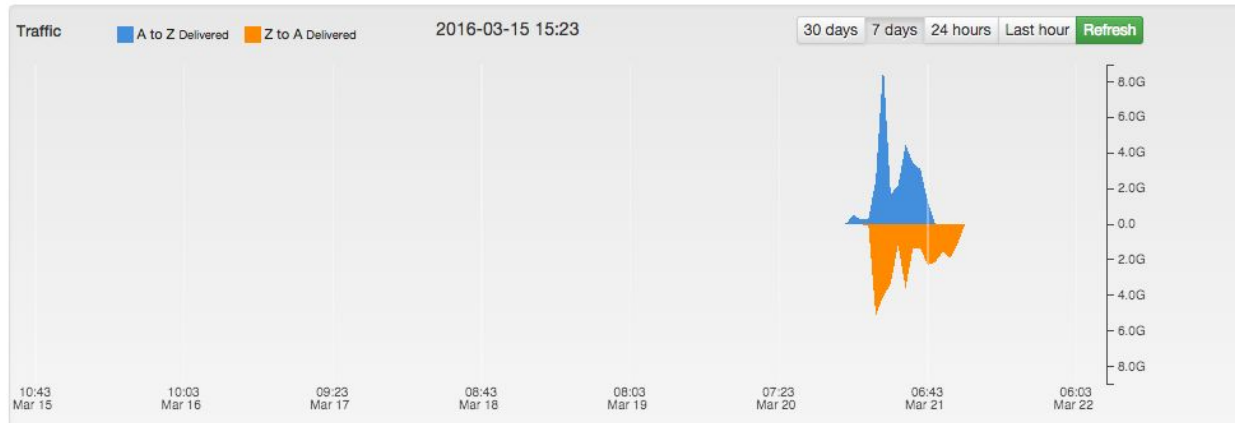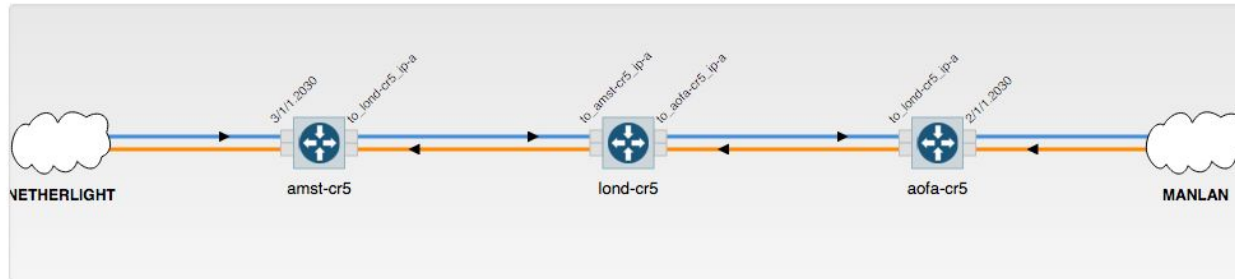
..across multiple exchange points
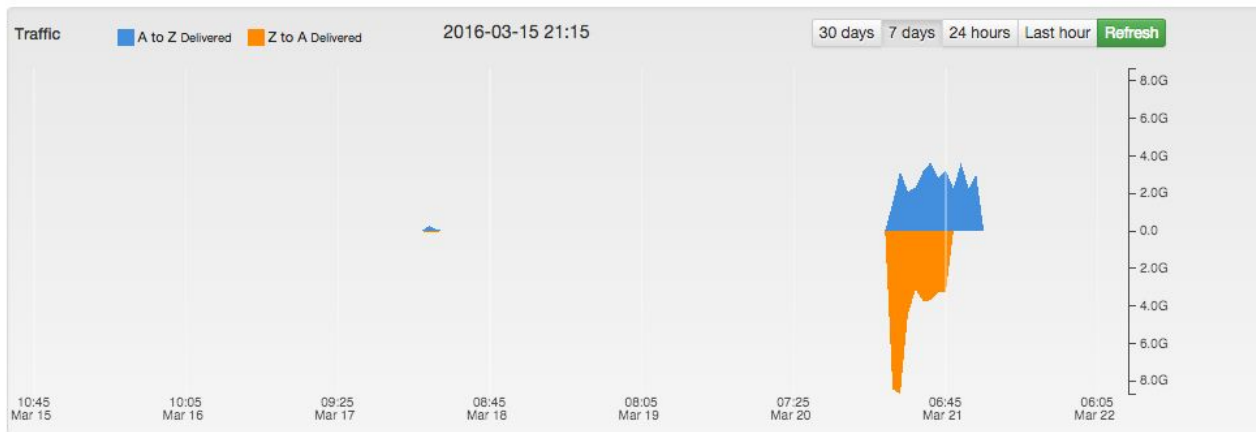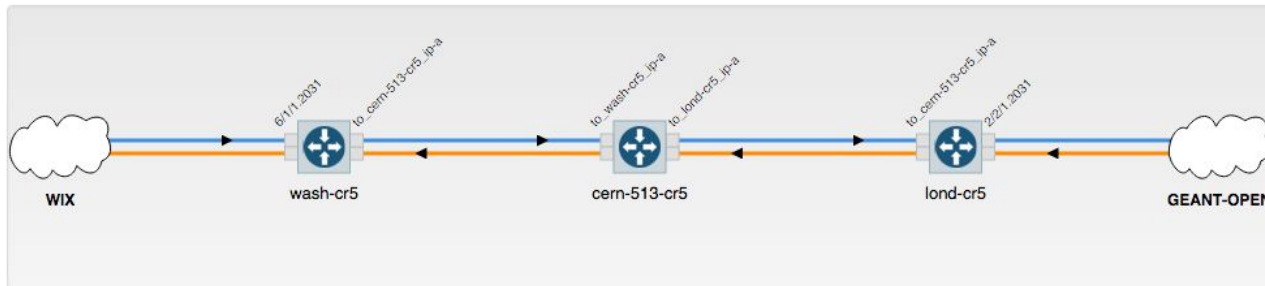
Continually planning for growth

Traffic Volume

Available at https://my.es.net/network/traffic-volume

Factor of 10 growth every 47 months
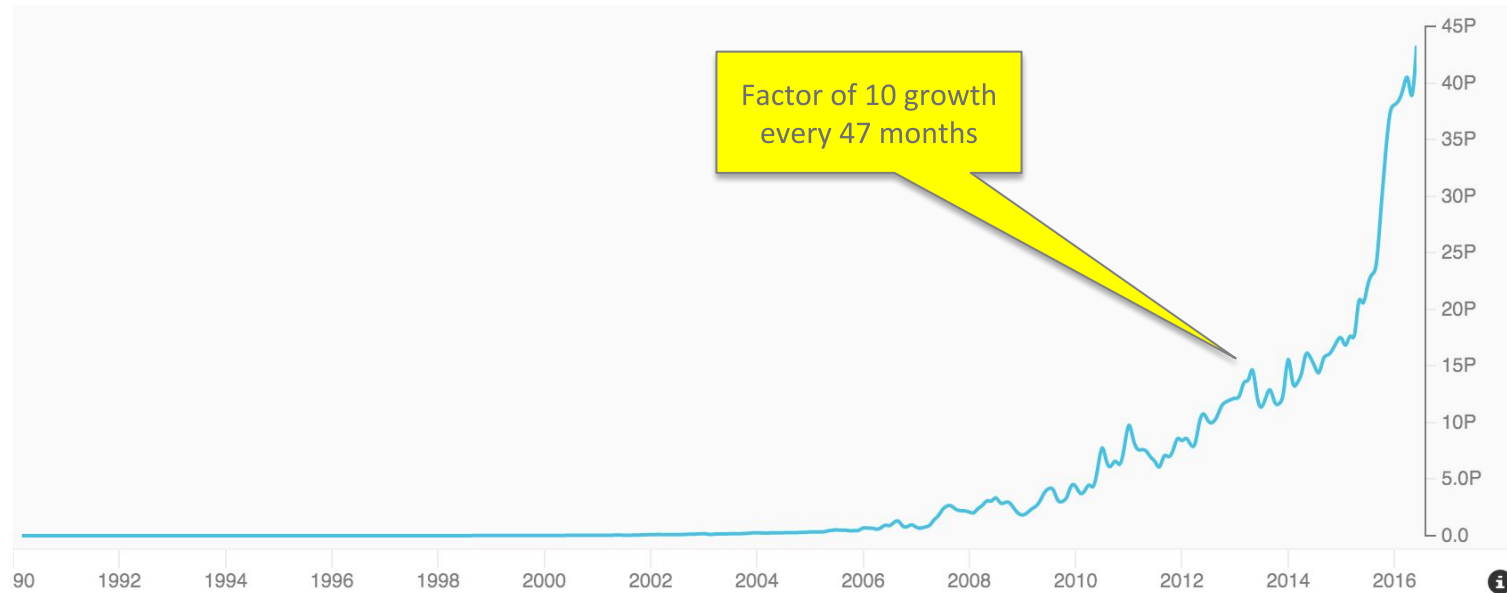
◄ **February 2016** ►

	Bytes	Percent of Total	One Month Change	One Year Change	
OSCARS	10.46 PB	25.2%	+0.0147%	+148%	Pt-to-pt circuits
LHCONE	11.22 PB	27.0%	+3.90%	+770%	LHCONE (T1-T1/2) traffic
Normal traffic	19.82 PB	47.8%	+9.49%	+77.7%	
Total	41.49 PB		+5.44%	+149%	

ESnet

17   6/10/16

ESnet: an Exascale facility in 2020
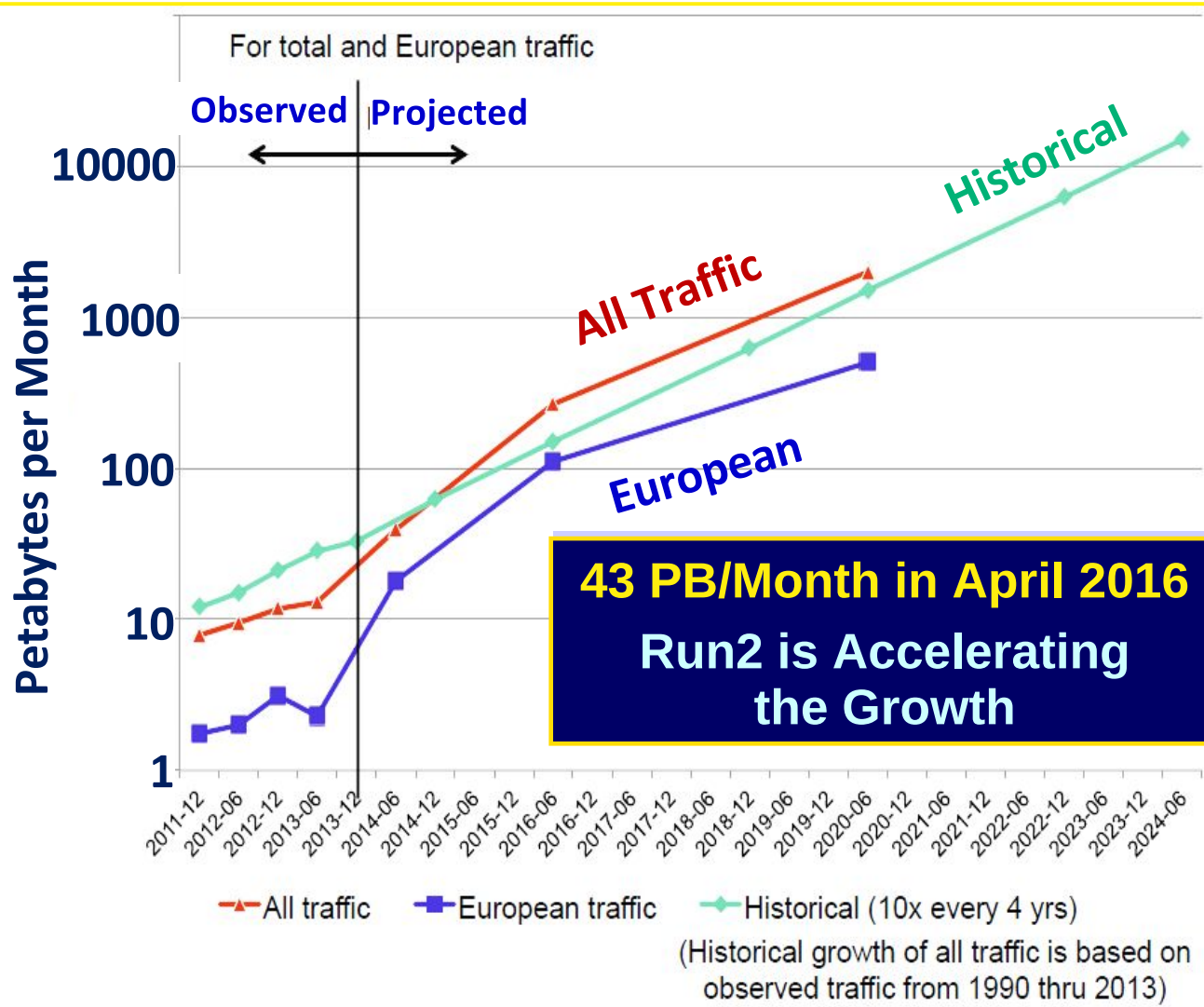
Projected Traffic Reaches
1 Exabyte Per Month. by ~2020
10 EB/Mo. by ~2024

Slide from
Harvey Newman

imonga at es dot net

Strategy and Investments

ESnet

ESnet Research and Software Development Portfolio

Funded Research

Next-Generation Architectures

Network Software

Tools Development
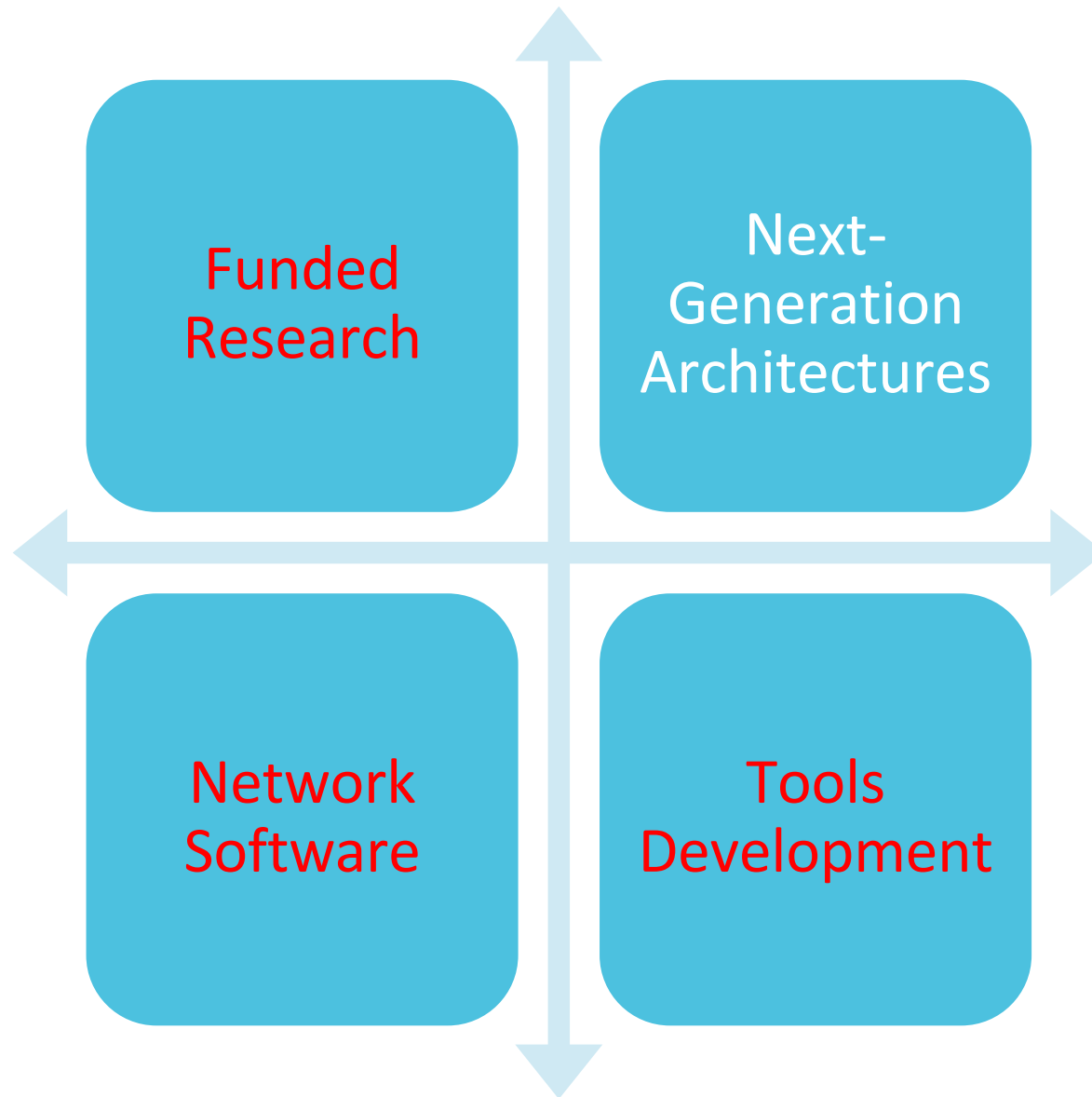
ESnet

Emerging global consensus around **Science DMZ architecture.**

1. Friction-free network path
2. Dedicated data transfer nodes (DTNs)
3. Performance monitoring (perfSONAR)

>120 universities in the US have deployed this ESnet architecture.

NSF has invested >>$60M to accelerate adoption.

Australian, Canadian universities following suit.

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

ESnet

Coming next? Evolution of **Science DMZ as a** *regional and national* **platform.**

Pacific Research Platform initiative, lead by Larry Smarr (Calit2/UCSD)

- first large-scale effort to coordinate and integrate Science DMZs

- participation by **all major California R&E institutions, CENIC, ESnet**

LHCONE: A global infrastructure for the High Energy Physics (LHC and Belle II) data management

CERNet2/ CSTNet China
IHEP-CMS
IHEP-ATLAS

TEIN Beijing

KREONET2 Korea
KISTI —T1
KNU KCMS
PNU

SINET Japan
KEK T1
ICEPP U.Tokyo

TEIN Mumbai

TIFR
NKN India

TEIN (proposed)

TEIN Singapore

ASGC Taiwan
ASGC-T1
ASGC2
NCU NTU

TEIN Hong Kong

GLORIAD (global)

CANARIE Canada
UVic TRIUMF-T1 UTor
McGill
SimFraU UBC

PacWave / PNWG (Seattle)

ESnet USA
PNNL-T1
BNL-T1 FNAL-T1
SLAC

Starlight (Chicago)

UWisc
AGLT2 MSU
AGLT2 UM UNL
UChi (MWT2)
UCSD
CIC OmniPoP (Chicago)
IU (MWT2)
UIUC (MWT2)
Caltech

PacWave Sunnyvale

PacWave Los Angeles

Internet2 USA
PurU Harvard
Vanderbilt NE SoW
UFlorida

CUDI Mexico
UNAM

MAN LAN (New York)

MIT
Harvard

WIX (Washington)
SOX
AtlanticWave (distributed exchange)

AMPATH NAP of Americas (Miami)

PTTA NAP do Brasil (São Paulo)

ANSP
SPRACE

RNP/IPÊ Brazil

SAMPA (USP)

Redecomep
CBPF HEPGrid (UERJ)

JANET UK
ICL

SURFsara Nikhef Netherlands
NL-T1

NORDUnet Nordic
NDGF-T1
NDGF-T1b
NDGF-T1c

PSNC Poland
PSNC

RUNNET Russia
HEPNET JINR IHEP SU
GRIDPNPI
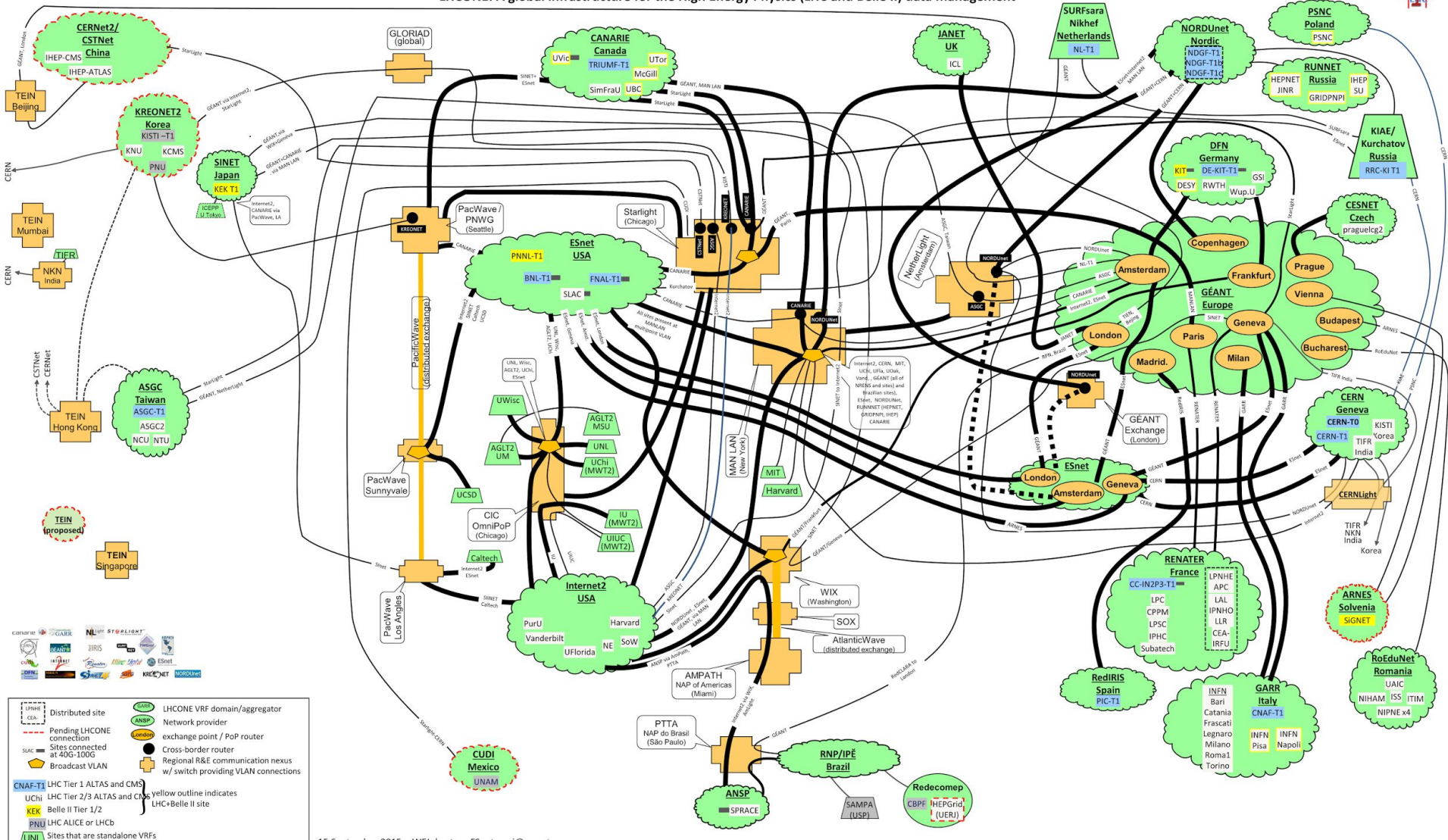
KIAE/ Kurchatov Russia
RRC-KI T1

DFN Germany
KIT DE-KIT-T1 GSI
DESY RWTH Wup.U

CESNET Czech
praguelcg2

NetherLight (Amsterdam)

GÉANT Europe
Copenhagen Prague
Amsterdam Frankfurt Vienna
Paris Geneva Budapest
London Milan Bucharest
Madrid.

GÉANT Exchange (London)

ESnet
London Geneva
Amsterdam

CERN Geneva
CERN-T0
CERN-T1 KISTI Korea
TIFR India

CERNLight

TIFR NKN India
Korea

RENATER France
CC-IN2P3-T1 LPNHE
LPC APC
CPPM LAL
LPSC IPNHO
IPHC LLR
Subatech CEA-IRFU

RedIRIS Spain
PIC-T1

INFN Italy
Bari
Catania
Frascati
Legnaro Milano
Roma1
Torino

GARR Italy
CNAF-T1
INFN Pisa INFN Napoli

ARNES Solvenia
SiGNET

RoEduNet Romania
UAIC
NIHAM ISS ITIM
NIPNE x4

Legend

Distributed site
Pending LHCONE connection
SLAC Sites connected at 40G-100G
Cross-border router
Regional R&E communication nexus w/ switch providing VLAN connections

GARR LHCONE VRF domain/aggregator
ANSP Network provider
London exchange point / PoP router
Broadcast VLAN
Yellow outline indicates LHC+Belle II site

CNAF-T1 LHC Tier 1 ALTAS and CMS
UChi LHC Tier 2/3 ALTAS and CMS
KEK Belle II Tier 1/2
PNU LHC ALICE or LHCb
UNL Sites that are standalone VRFs
Communication links: 1/10, 20/30/40, and 100Gb/s

15 September 2015 – WEJohnston, ESnet, wej@es.net

See http://lhcone.net for more detail.

Isolated apps are less flexible than platforms.

Single-purpose apps:

Programmable platform:

```
Password authentication
Password:
Welcome to NetShell

admin@NetShell> cd /lib/layer2/demo
changed to: /lib/layer2/demo

admin@NetShell> vpn create vpn1
VPN vpn1 is created successfully.

admin@NetShell> vpn vpn1 addpop amst
Pop amst is added into VPN vpn1 successfully.

admin@NetShell> vpn vpn1 addpop cern
Pop cern is added into VPN vpn1 successfully.

admin@NetShell> vpn vpn1 addsite amst
The site amst is added into VPN vpn1 successfully

admin@NetShell> []
```

An architecture we foresee: ESnet as *platform* for concurrent, domain-specific network apps.

Requires 'network operating system' for science.

- early-stage project (LBNL LDRD)
- multiple challenges in creating flexible, stable app execution environment

We envision apps that will express high-level *intentions*:

- create and manage virtual networks
- enable programmatic resource allocation
- optimize link utilization

Future apps could support:

- NDN for climate; data management for CMS, ATLAS, Belle-II; security overlay for KBase; replication for ESGF; detector / HPC coupling for light sources
- workflows we haven't imagined

ESnet's 100G SDN Testbed – significant footprint growth and dedicated bandwidth. Unique within community
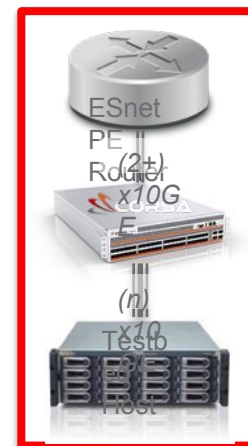
SENSE: SDN for End-to-end Networked Science for Extreme-Scale Science

Inder Monga [Lead-PI] (ESnet), Phil Demar (FNAL), Harvey Newman (Caltech),
Linda Winkler (ANL), Tom Lehman (UMD/MAX), Damain Hazen (NERSC)
Mar 2016 – Feb 2019

Goal

- Leverage the emerging Software Defined Network (SDN) capabilities to develop **intelligent, federated, end-to-end, science networking architecture** friendly to data-intensive and network-aware distributed science applications

Impacts

- Present geographically distributed resources (datacenters, instruments, etc.) as components of a local facility
- Simplifies complex massive datasets distribution with coordinated, multi-domain, smart and secure services
- Enable seamless application-network interaction for new near real-time distributed computing and data analytics
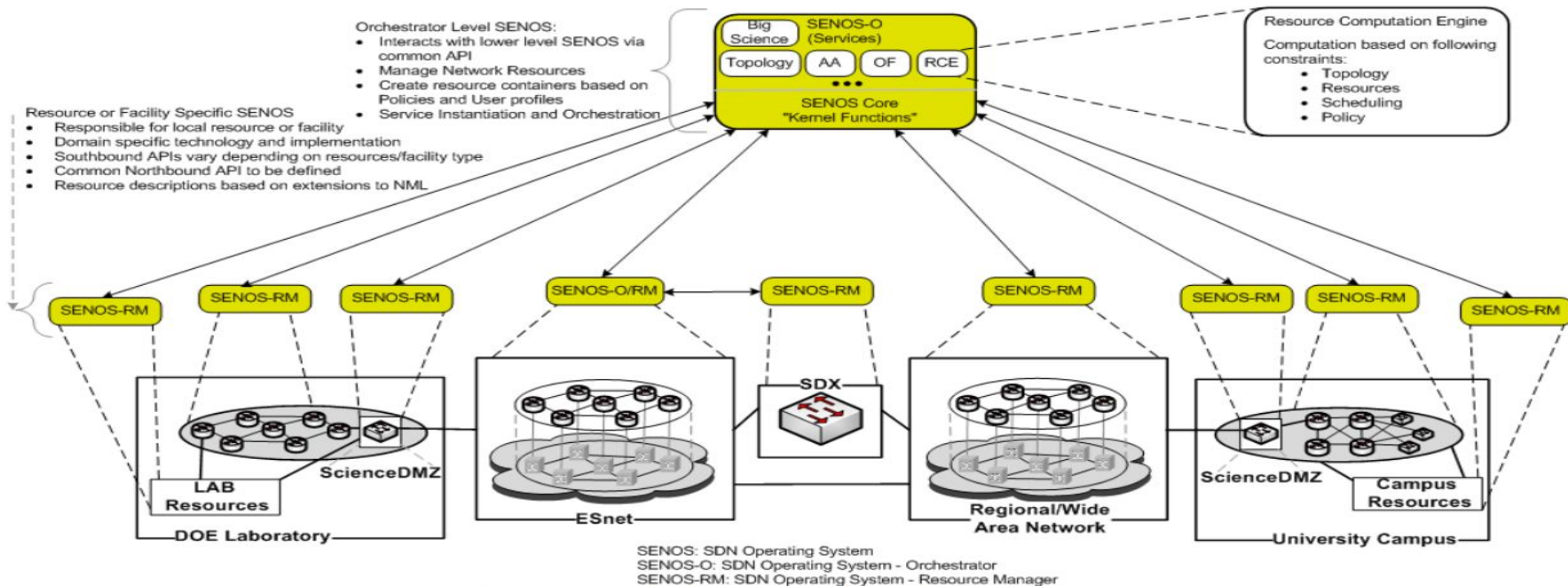

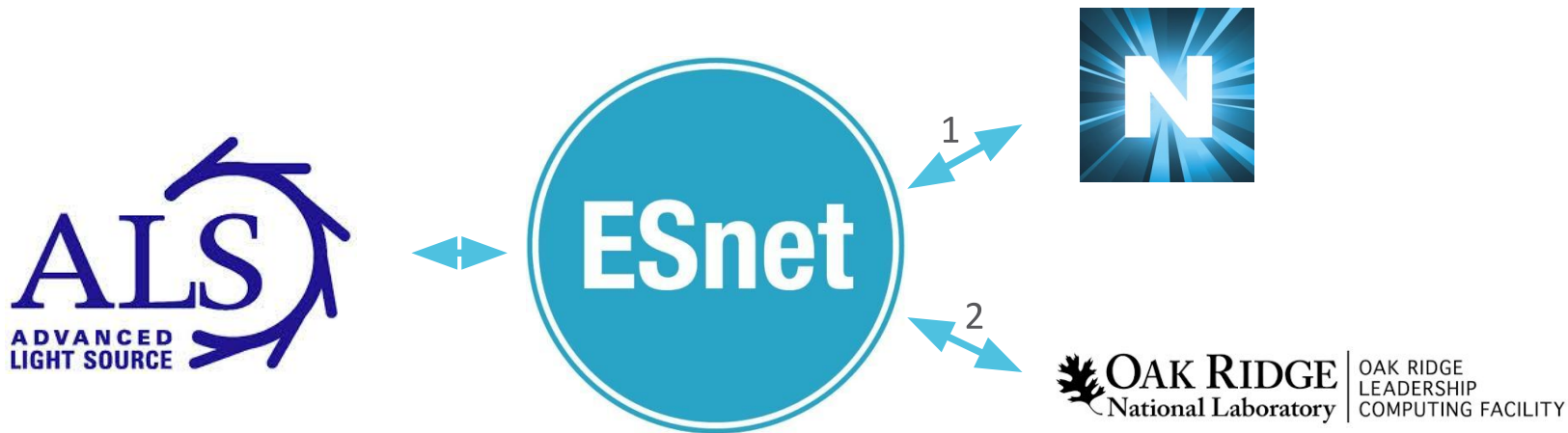**Figure 1. SENOS End-to-End Orchestration**

Named-Data Networking collaboration with NSF funded Colorado State CC* project continues to engage DOE science initiatives

- An **NSF-funded Future Internet Architecture** in which clients express intent for data objects to the network

- Collaborating with Colorado State University, PI Christos Papadopoulos, to investigate applicability for climate data sets.
  - Mentoring the project and providing focus: enabling high-speed data transfer, data management and caching strategies for large scientific data sets.

- CSU collaborators and ESnet invited to presented NDN results at three conferences, CHEP 2015, NDN Comm 2015 and ACM Conference on Information Centric Networks
  - ESnet invited talks to give talks at ACM and NDNComm

- ESnet is hosting a large part of an NDN testbed and dedicated 10G to NDN research.
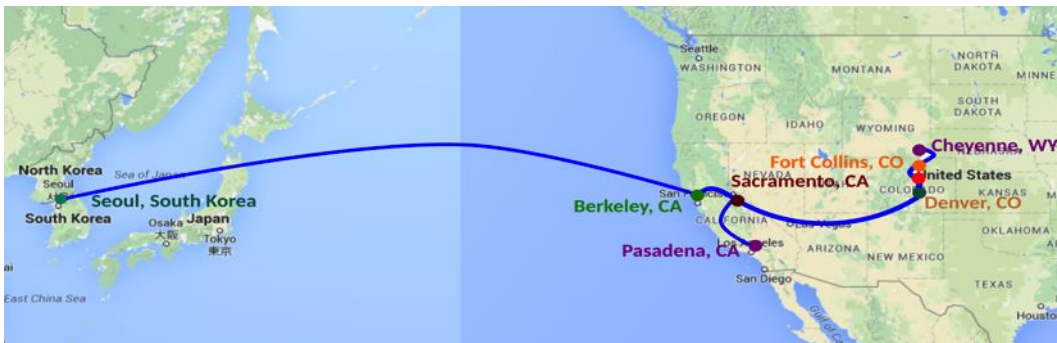
Superfacility: our global science complex can become more than the sum of its parts.

Real-time analysis of 'slot-die' technique for printing organic photovoltaics, using ALS + NERSC (SPOT Suite for reduction, remeshing, analysis) + OLCF (HipGISAXS running on Titan w/ 8000 GPUs).
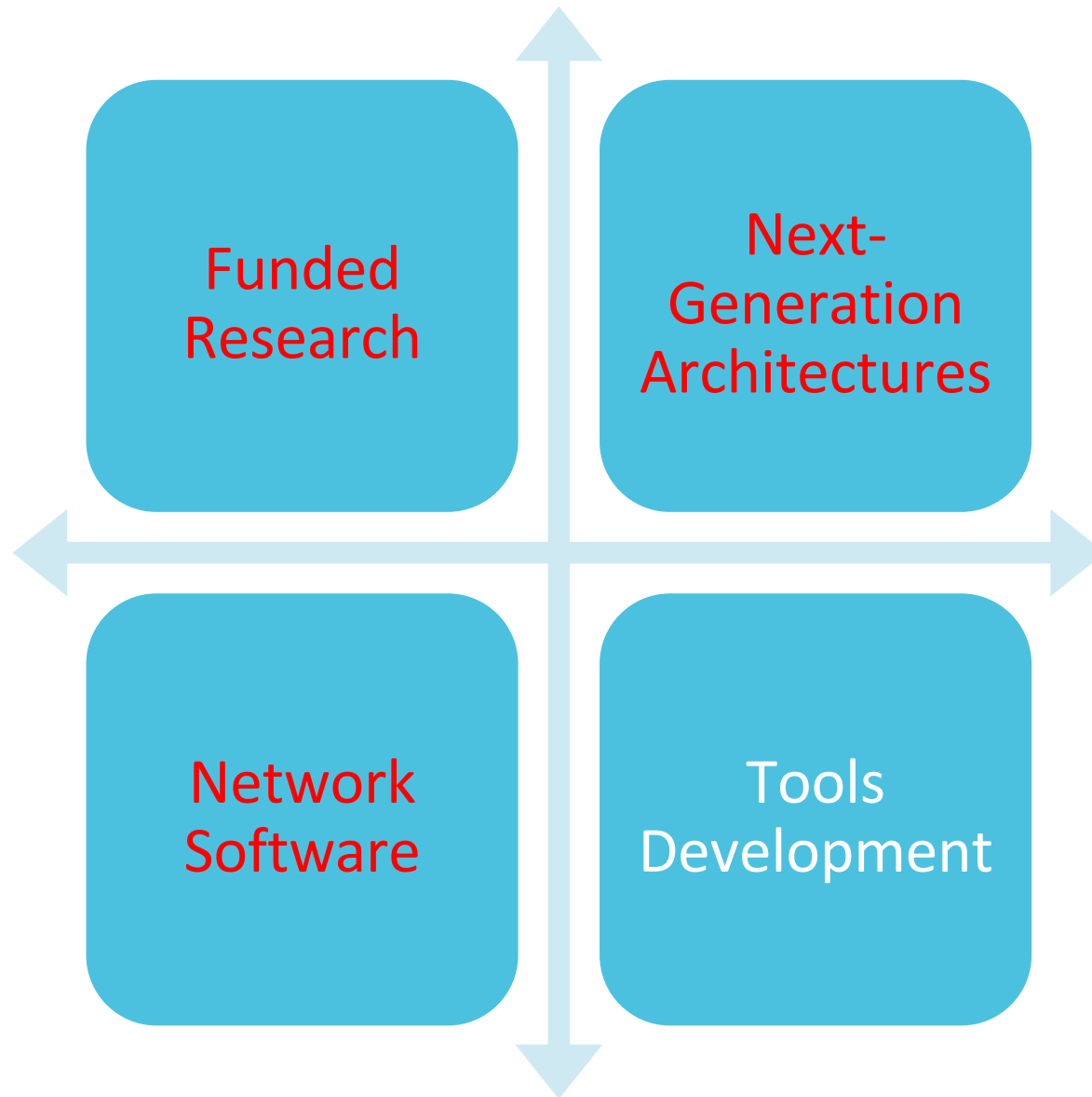

http://www.es.net/news-and-publications/esnet-news/2015/esnet-paves-way-for-hpc-superfacility-real-time-beamline-experiments/

Results presented at March 2015 meeting of American Physical Society by Alex Hexemer.

Additional DOE contributions: **GLOBUS** (ANL), **CAMERA** (Berkeley Lab)

ESnet Research and Software Development Portfolio

# New Portal Feature: Monthly Traffic Volume

- Portal version of monthly stats

- Same data, new visualization

- Provides summary view
  - Percent change vs. last month
  - Percent change vs. same month last year

- Explore contribution of OSCARS or LHCONE

- Explore contribution of interfaces that match a pattern

https://my.es.net/network/traffic-volume/
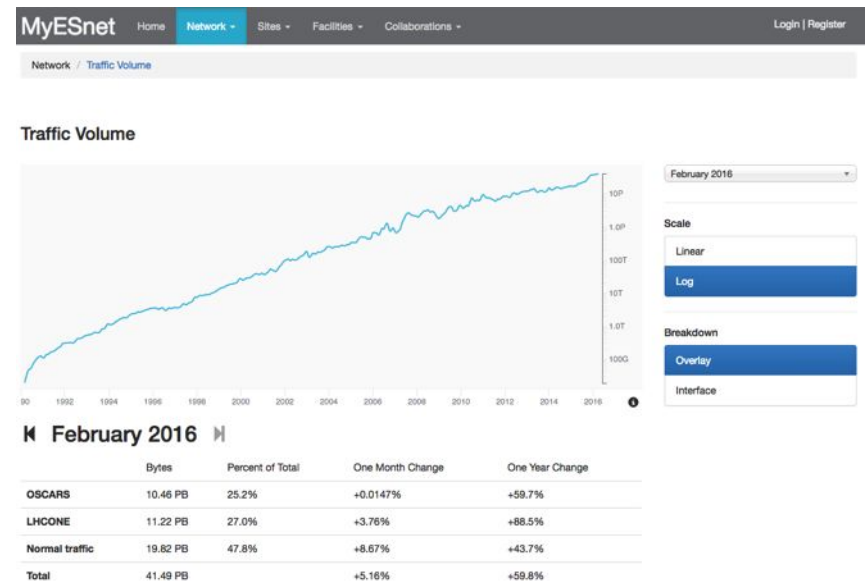
ESnet

New Portal Feature: LHCONE

- Provide a place for all ESnet connected LHCONE participants to see traffic

- Flow data provides insight on how traffic is flowing over the VPRN
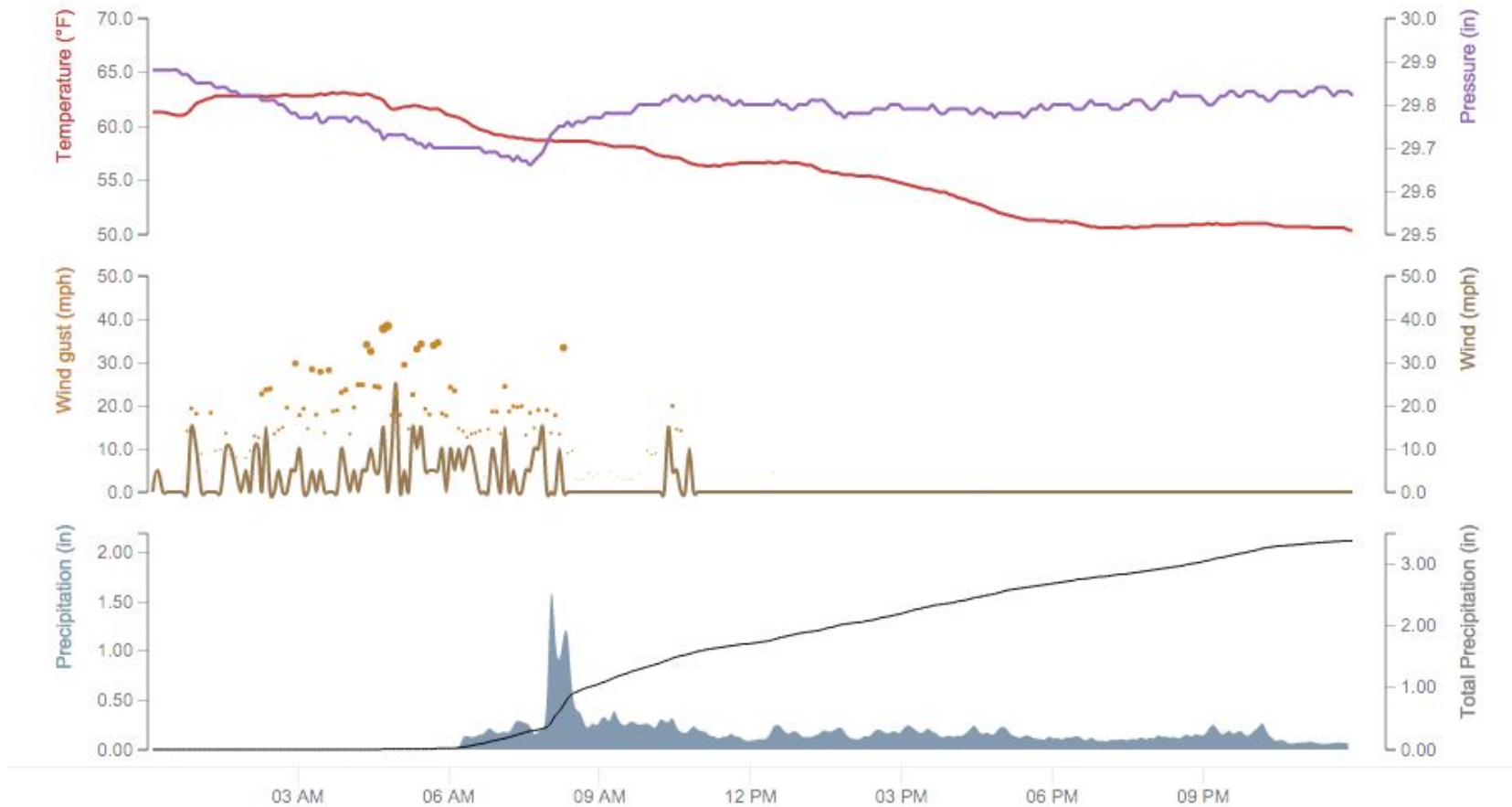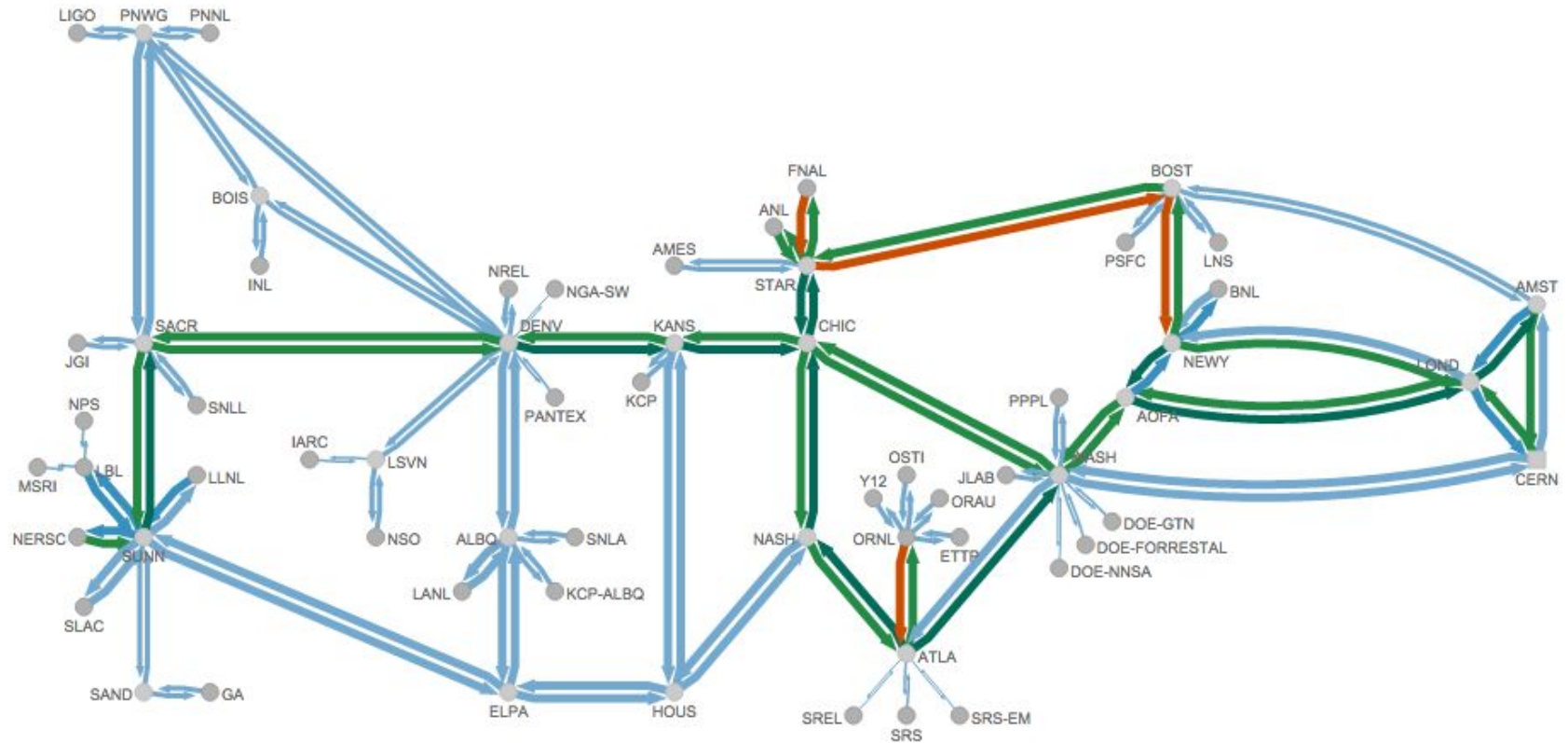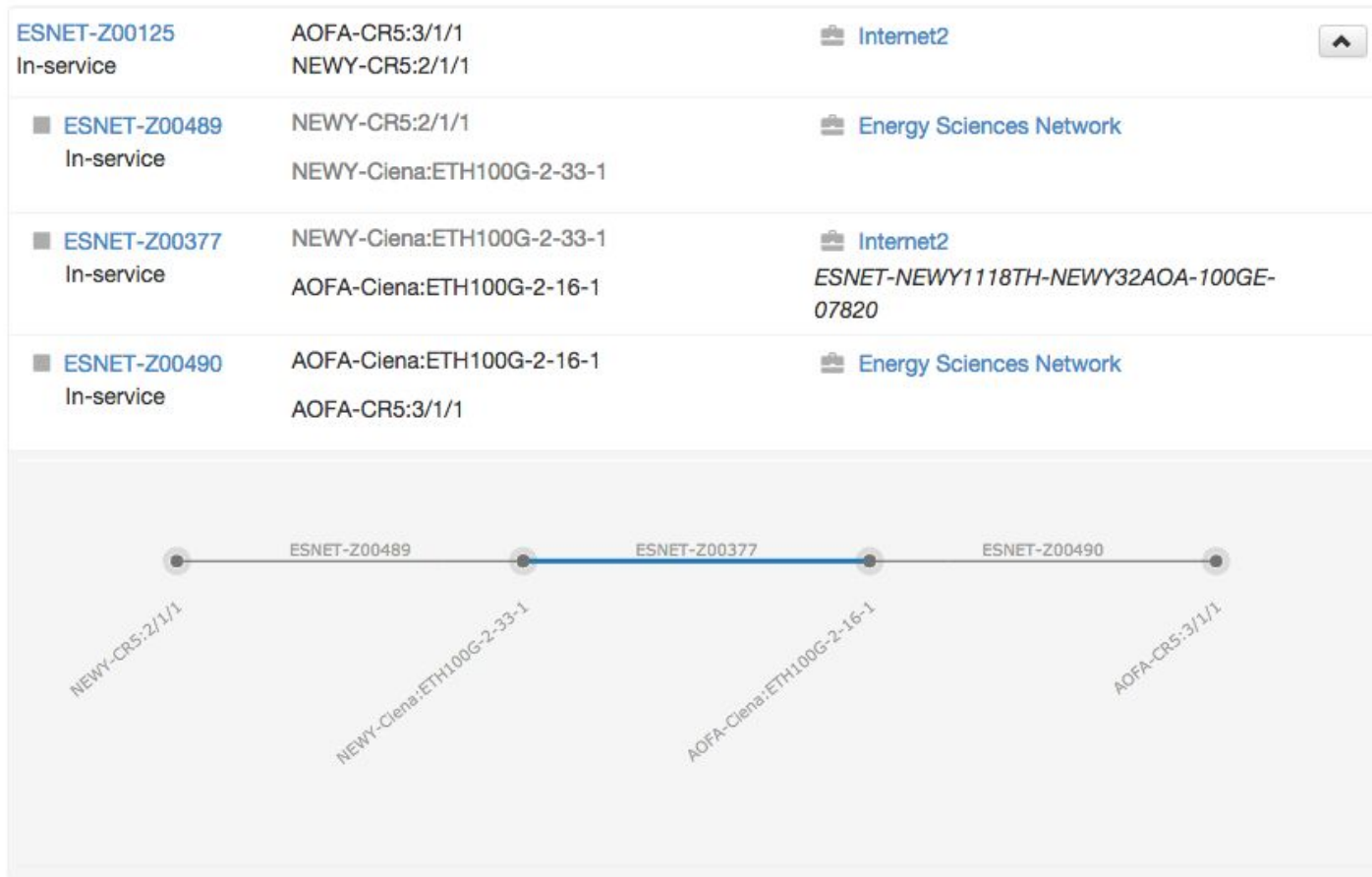
- Showcases traffic from Universities onto ESnet

https://my.es.net/collaborations/lhcone/
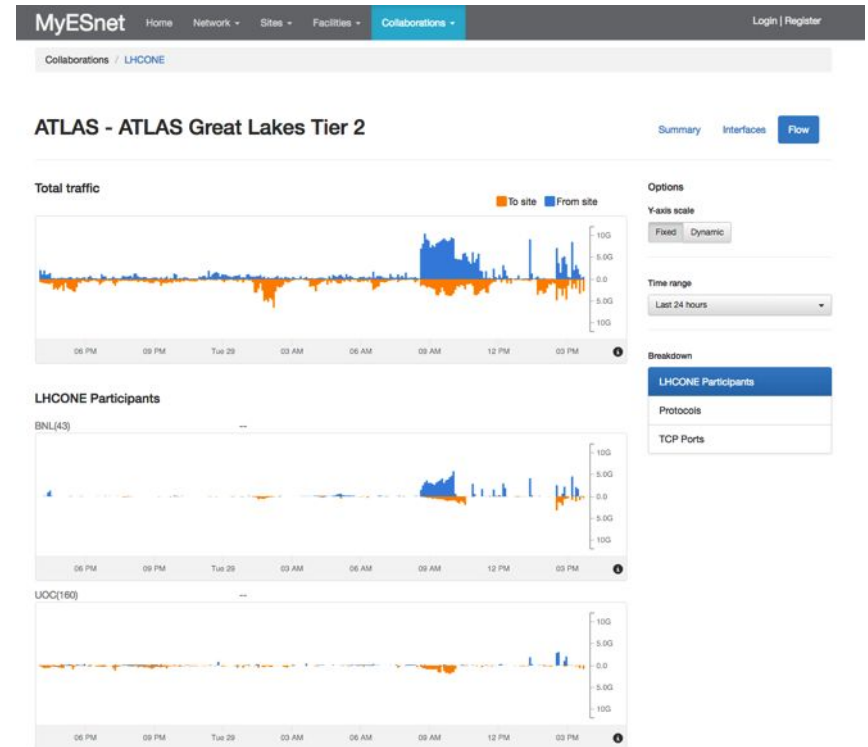
Time Series Charts

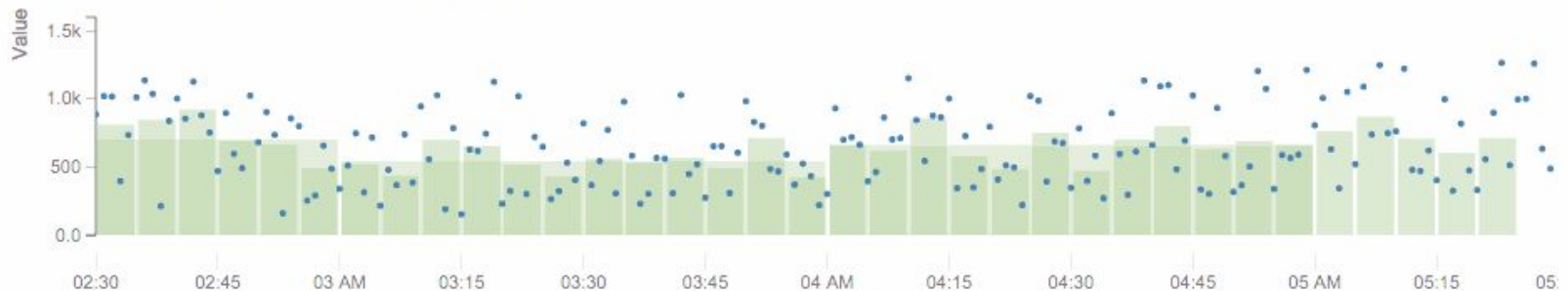# Time Series Charts

ESnet

Network Diagrams

ESnet

Network Diagrams

Pond: Time Series Operations

- We have lots of time series data: SNMP, netflow, log messages, etc

- Need a common abstraction and wire format for this data

- Provides common operations

Animation showing how Pond generates summary rollups

Open Source

Good news everyone, it's all open source!

- http://software.es.net/pond/
- http://software.es.net/react-timeseries-charts/
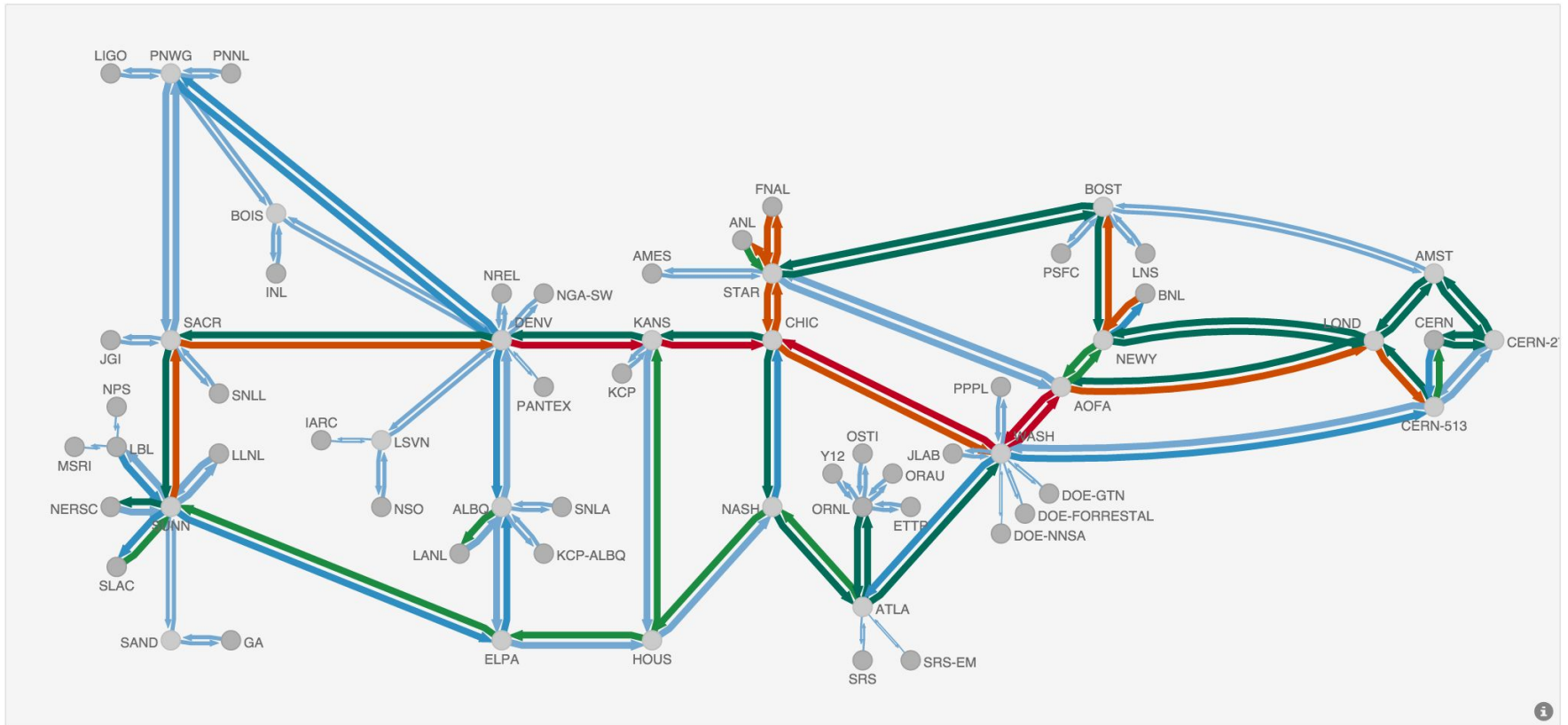- http://software.es.net/react-network-diagrams/

Motivation
- Develop a common toolkit for visualizing networks
- Lower barrier to entry
- Allow people to use what we've built so they don't have to build their own
- Encourage others to share their visualizations
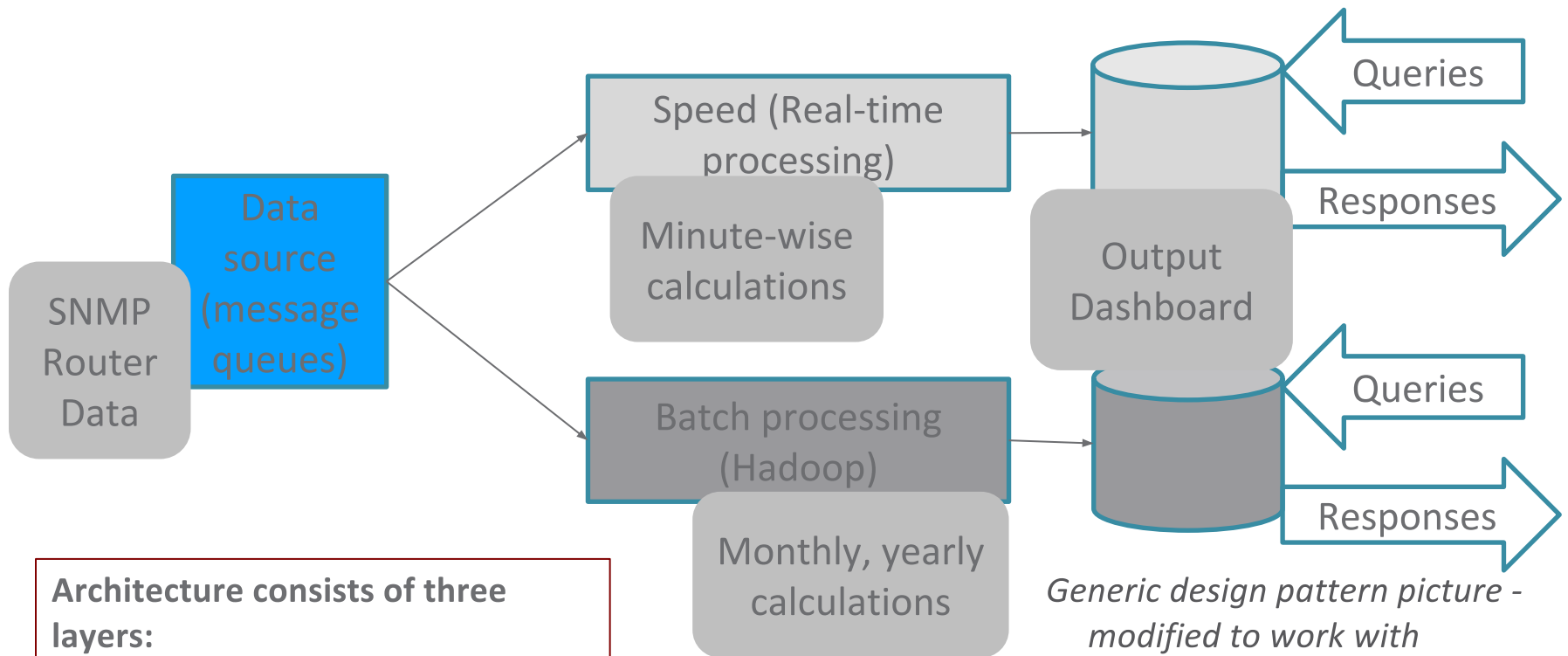- Give back to the community

Visualization of data is good, but not enough

Network Analytics

- Data being generated by the network every few seconds but not analysed or available for real-time analysis
  - The ability to ask questions of historical network data, and get answers
  - The answers updated with new data in near real-time
  - SNMP data, Flow data, Topology data, etc..
- Smart Cities, IoT, Smart Grid – have common problems

ESnet

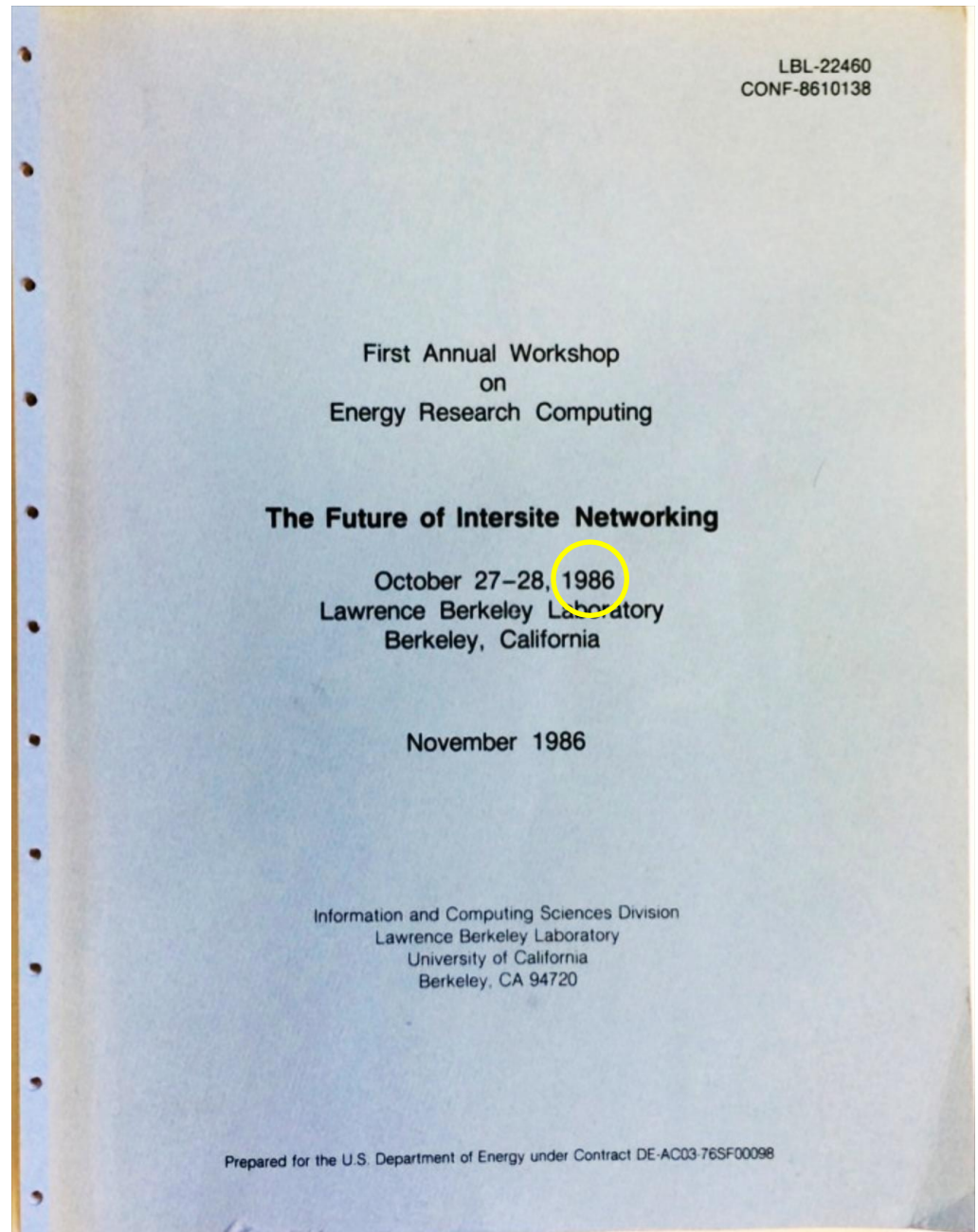# Leverage cloud computing tools to put together a *network analytics* pipeline

SNMP Router Data

Data source (message queues)

Speed (Real-time processing)

Minute-wise calculations

Batch processing (Hadoop)

Monthly, yearly calculations

Output Dashboard

Queries

Responses

Queries

Responses

Architecture consists of three layers:
- **Batch processing**
- **Speed or real time**
- **Layer to respond to queries**

Generic design pattern picture - modified to work with specific cloud computing technologies

ESnet

In 1986, physics community made two 'modest requests':

1. "What we can do on **LANs** today is indicative of what we wish to be able to do on **wide area networks**."

2. "Just as we expect a **computer** to perform as if we are the **only user**, we expect the **network** to give that same appearance."

In conclusion:

- Global science networks are not ISPs – rather, extensions of your discovery instruments.

- HEP's 'modest requests' from 1986 are in the process of being fulfilled.
  - 'discovery unconstrained by geography' is explicit vision of ESnet
  - and virtualization is a global initiative

- Design patterns, architectures, workflows and challenges from HEP science are now crossing over to domains.

ESnet

In conclusion:

- Global science networks are not ISPs – rather, extensions of your discovery instruments.

- HEP's 'modest requests' from 1986 are in the process of being fulfilled.
  - 'discovery unconstrained by geography' is explicit vision of ESnet
  - and virtualization is a global initiative

- Design patterns, architectures, workflows and challenges from HEP science are now crossing over to domains.

- HEP has been pushing the boundaries of networking for three decades.
  - please keep it up!

- It's time to make the next modest requests
  - we are taking orders for 2018.

ESnet

In conclusion, a reminder about our vision:

Scientific progress will be **completely unconstrained** by the physical location of instruments, people, computational resources, or data.

ESnet

Big Science Data in Motion = Elephant Flow!
IoT watching LOL Cats = Mice flow!

Science Data

Elephant Data vs. Mice Data Behavior