The Story of ESnet6

Inder Monga
Executive Director
ESnet

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ESnet6 Project Honored with DOE Project Assessment Award

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ESnet Overview

ESnet6

ESnet6 Project

Lessons Learned

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Mission network

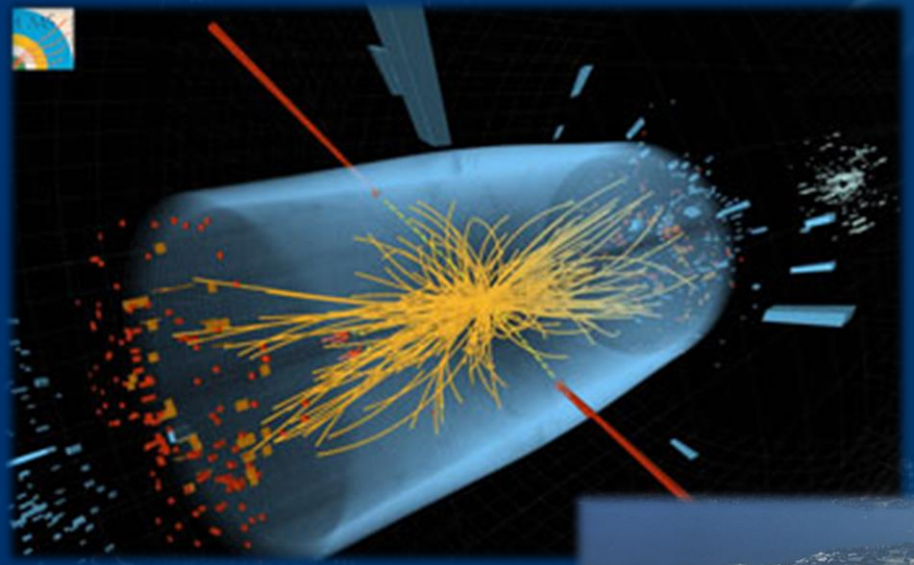
Scientific progress will be **completely unconstrained** by the physical location of instruments, people, computational resources, or data.

Vision:

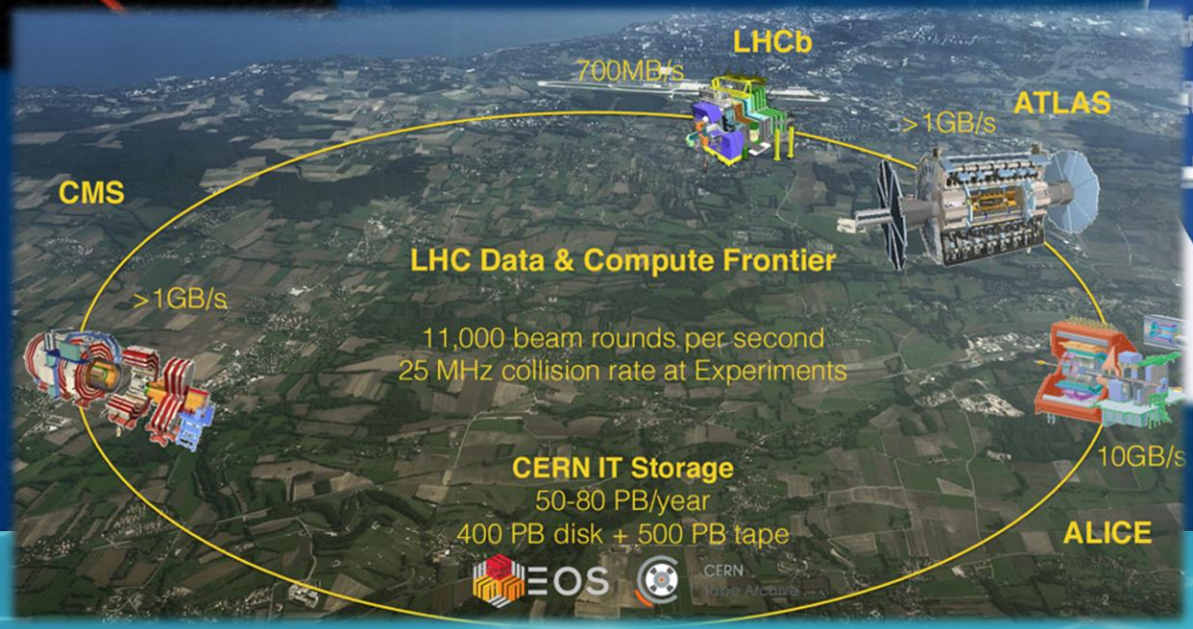
Accelerate Scientific Discovery

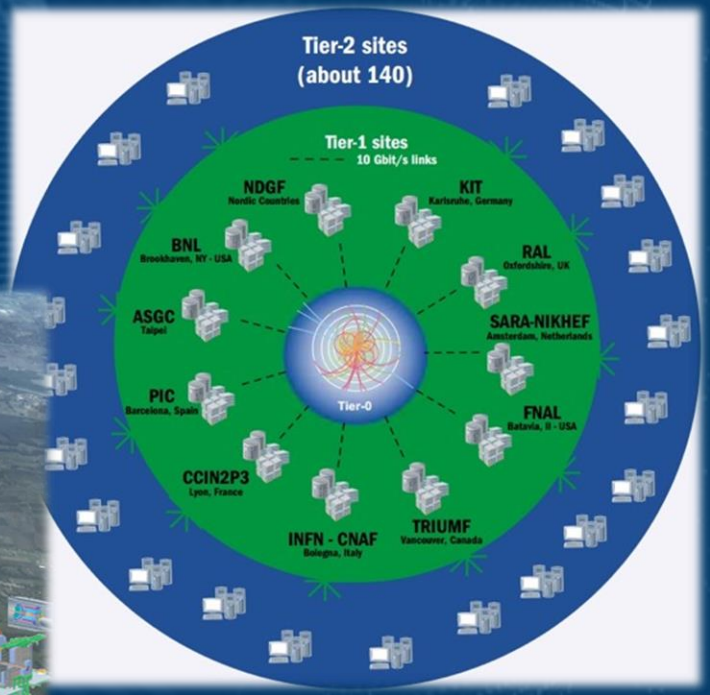
Science is a conversation…

High Energy physicists worldwide discover the nature of matter by analyzing data from CERN thus helping create new materials and quantum technologies to solve tomorrow's critical energy problems



2012 Nobel prize
for the discovery of the Higgs Boson





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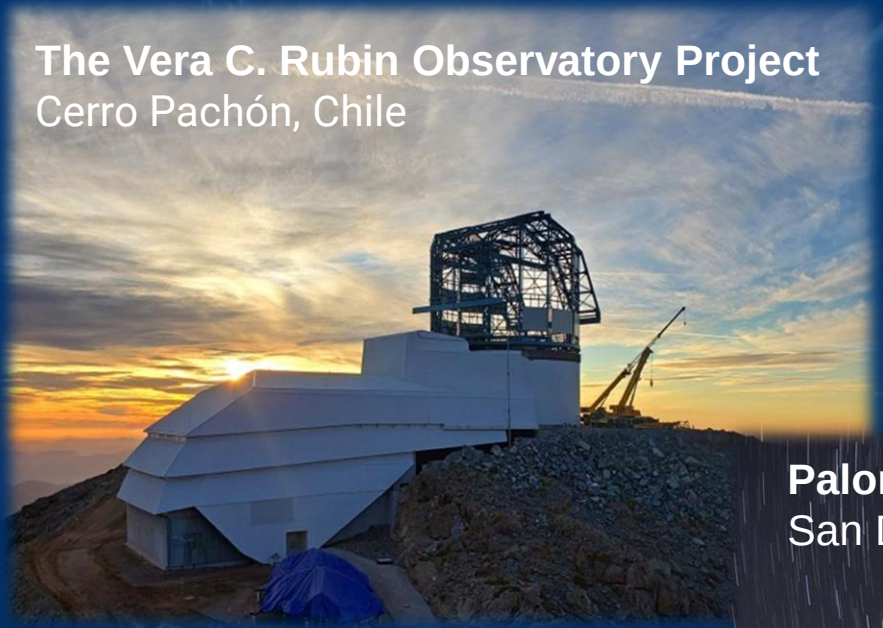
…a critical conversation

Climate and Life scientists worldwide analyze the data collected by sensors and simulations to prevent disaster and improve the quality of life

Data from ARM user facility

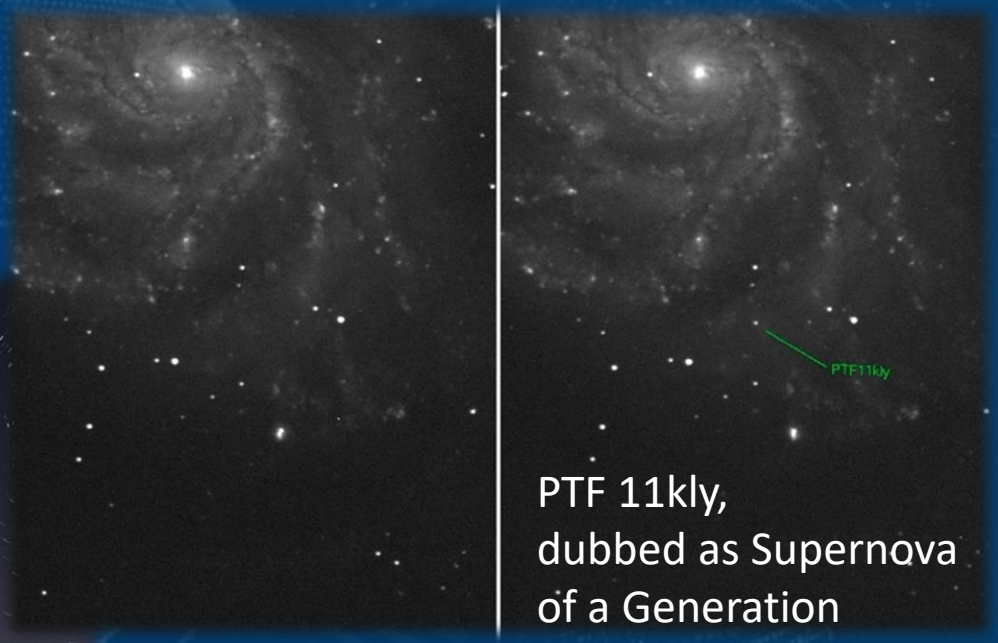
…a global conversation

ESnet collaborates with research networks worldwide to create a global observatory helping develop a deeper understanding how our universe was formed and our place in it



The Vera C. Rubin Observatory Project
Cerro Pachón, Chile

Palomar Observatory,
San Diego County, California, USA



PTF 11kly,
dubbed as Supernova of a Generation

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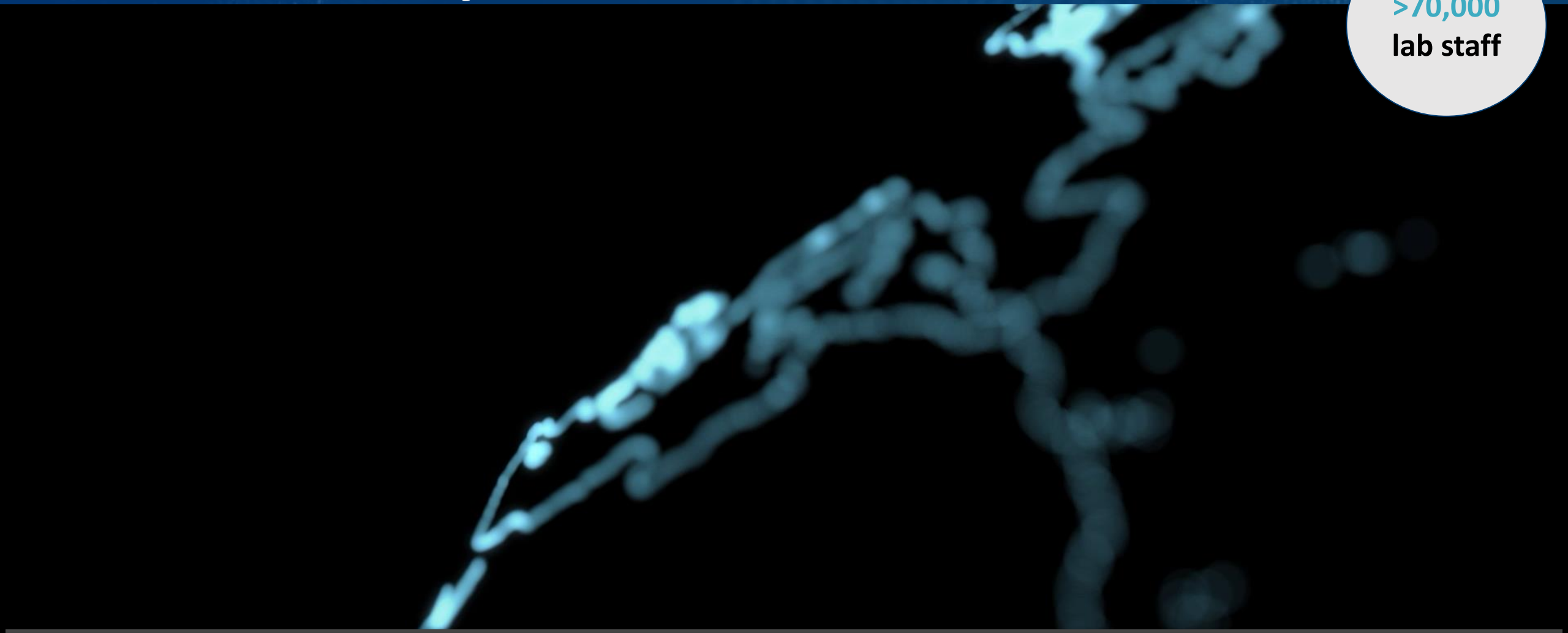
Serves connectivity needs of all DOE National Labs



>70,000
lab staff

The Department of Energy's 17 National Laboratories are powerhouses of science and technology whose researchers tackle some of the world's toughest challenges.

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The ESnet user facility:
Data-circulatory system for all 28 SC facilities*

>30,000 science users

ASCR High End Computing (HEC)

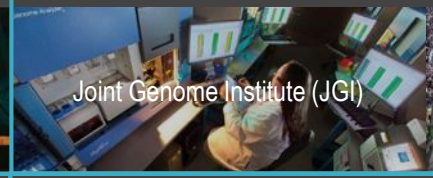
ASCR High Performance Scientific Network

BES X-Ray Light Sources

BES Nanoscale Science Research Centers (NSRCs)

BES Neutron Scattering Facilities

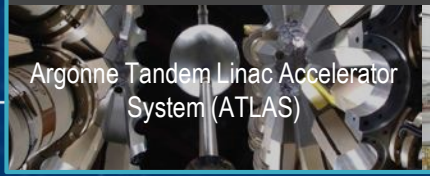
BER

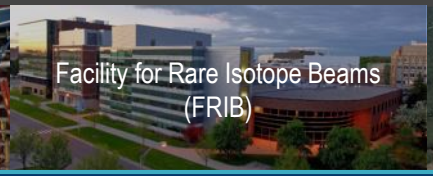


FES

HEP

NP





U.S. DEPARTMENT OF ENERGY
Office of Science

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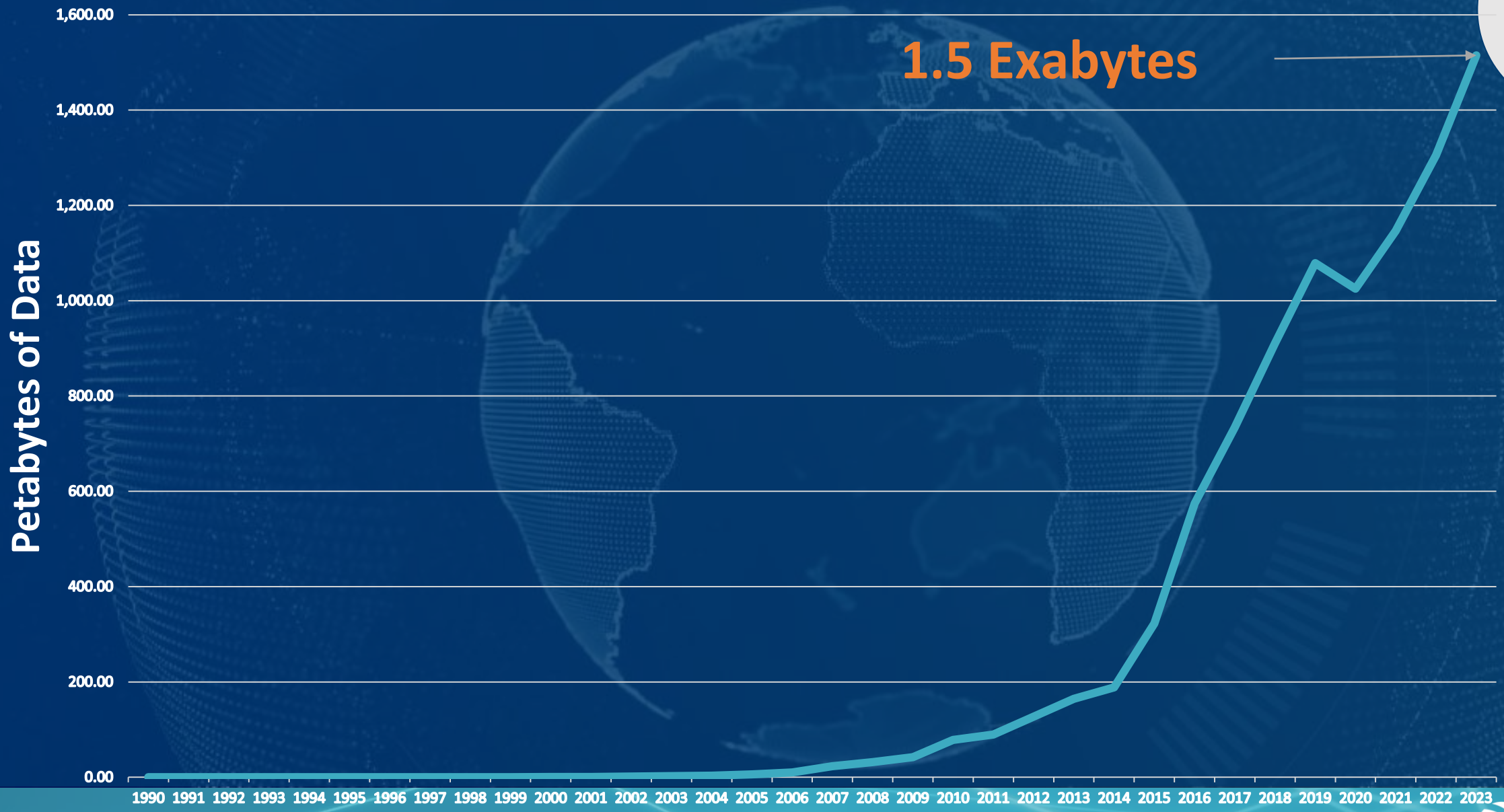
Network traffic growing exponentially 60% yearly since 1990



>1.5 Exabytes past 12 months

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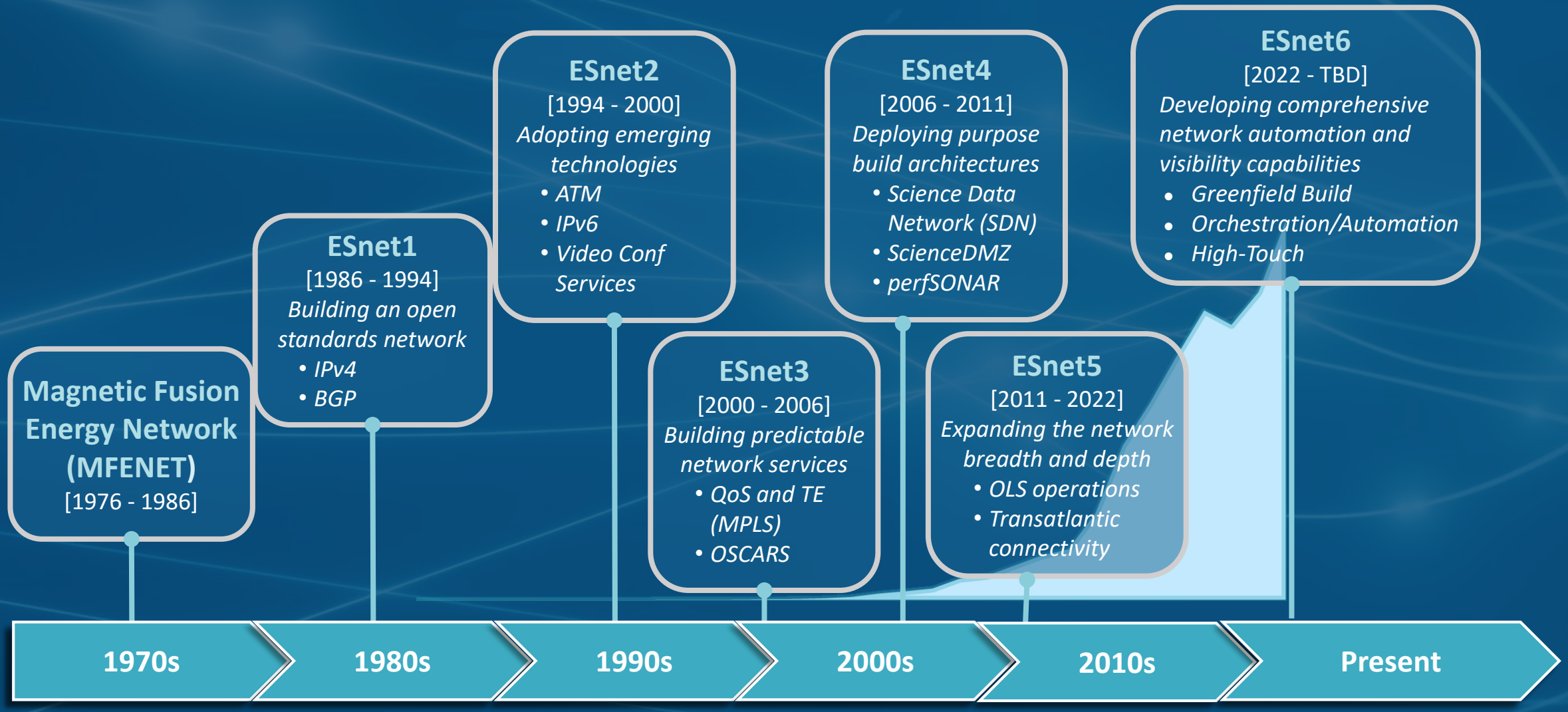
Evolution of the ESnet over the past 30+ years



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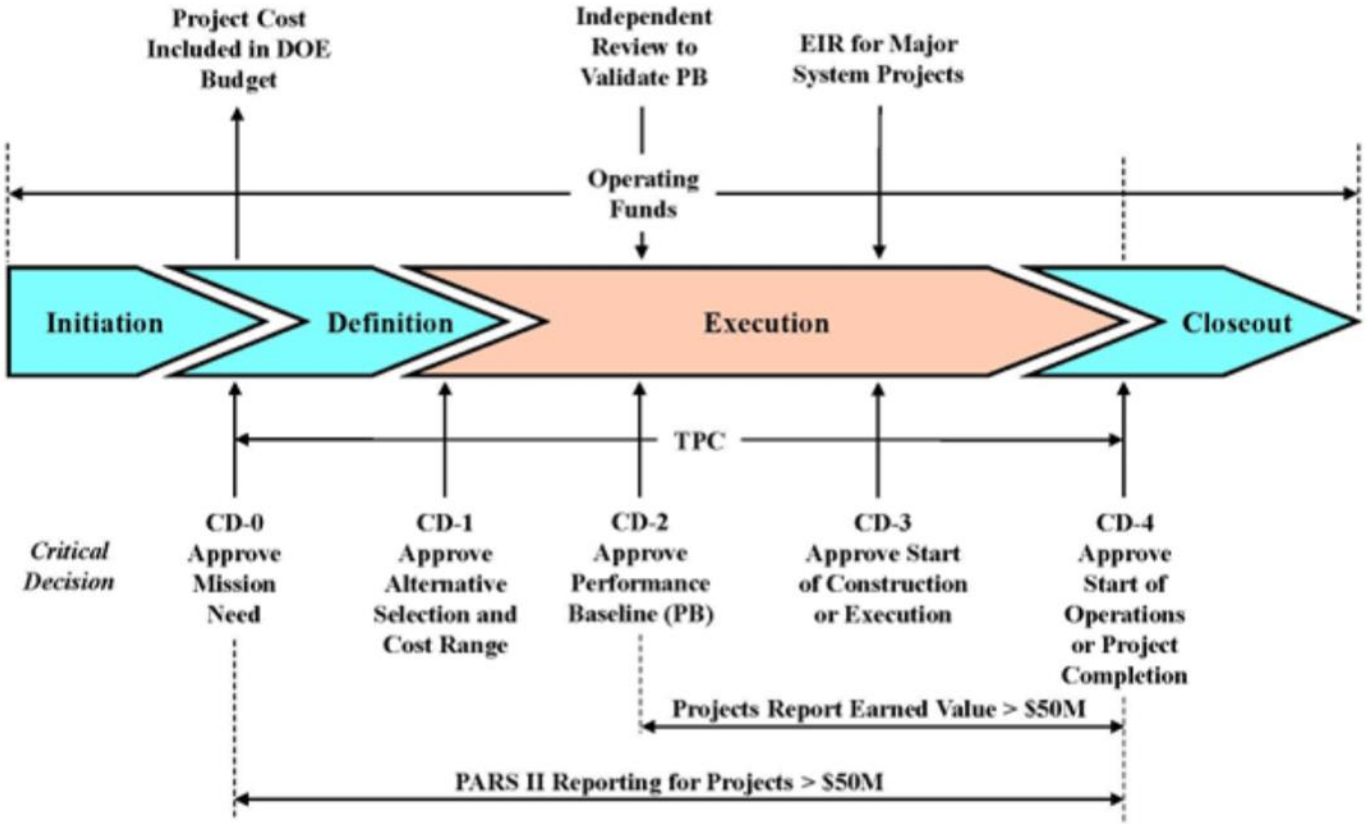
ESnet6: the project

DOE ORDER 413.3 B: PROGRAM AND PROJECT MANAGEMENT FOR THE ACQUISITION OF CAPITAL ASSETS



- CD-0, Approve Mission Need
- CD-1, Approve Alternative Selection and Cost Range
- CD-2, Approve Performance Baseline
- CD-3, Approve Start of Construction/Execution
- CD-4, Approve Start of Operations or Project Completion.

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..and we are deconstructing the older plane and transferring the passengers to the new one in parallel

First DOE 413.3B project for the team

- First time upgrading a fully operational facility, with no planned service downtime to the users
- First greenfield design and build of the entire network by ESnet team
- Full integration of components by the ESnet team, including the building the optical layer for the first time
- Hired, onboarded and trained new people onto the project, doubled the size of the organization
- ~10x increase in coordination, communication and reporting due to the Pandemic

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CD-0

Mission Need

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CD-0: Mission need was critical in framing the scope of the project and deriving the Key Performance Parameters (KPPs)

Manage Exponential Data Growth

- Cost-effective design
- 5 - 7 years operation
- Just-in-time capacity

KPP 1

Increase resiliency and reliability

- Scientific progress impeded by lack of network availability
- Protect against malicious behavior

KPP 1 and 2

Lay foundation to handle future science workflows

- Enable custom science workflows and services
- Allow integration of new technologies

KPP 3

Projecting the future
and
having a 12+ year vision
for science and its intersection with networking was critical in writing this mission need

Mission Need Statement for the ESnet6 Project

Submitted by:

Vince Dattoria, Program Manager
Office of Advanced Scientific Computing Research
Office of Science, DOE
Date: 10/18/16

Barbara Helland, ASCR Facilities Director
Office of Advanced Scientific Computing Research
Office of Science, DOE
Date: 10/17/16

J. S. Binkley, Associate Director
Office of Advanced Scientific Computing Research
Office of Science, DOE
Date: 10/17/16

Concurrence:

Stephen Meador, Director
Office of Project Assessment, Office of Science, DOE
Date: 10/21/16

Patricia M. Dehmer
Deputy Director for Science Programs
Date: 11/3/2016

Approval:

C. A. Murray, Director, Office of Science
Date: 11/3/2016

CD-1 / 3A

Design and Long-lead

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Conceptual Design and Alternatives Analysis – preparing for CD-1

5.4 Conclusion and submission

The committee greatly appreciated the efforts of the ESnet team
the engagement in the lively discussions during the sessions. Th
by the professional manner, quality and the open mind with wh
conceptual design with the committee.

Submitted:

Prof.dr.ir. C.T.A.M. de Laat
CDR Review Chair
February 14, 2018

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Project Management Reviews were done with seasoned 413.3B folks, and not just with technical leaders of the community

Not all reviews were a success, but the critical feedback was important to course-adjust and understand unknown unknowns

Executive Summary

The Lawrence Berkeley National Laboratory (LBNL) Project Management Office organized and conducted a Director's Assist Review on April 24-26, 2018 of the Energy Sciences Network (ESnet6) Project in advance of the Department of Energy (DOE) Independent Project Review (IPR) for approval of the Alternative Selection and Cost Range (CD-1) and the approval of Long Lead Procurement (CD-3a). The following are the 20 Recommendations put forward by the review committee:

Practice makes perfect: The practice reviews made us pass CD-1/3a with flying colors

A Department of Energy/Office of Science (DOE/SC) review of the Energy Sciences Network (ESnet) ESnet6 project was conducted at Lawrence Berkeley National Laboratory (LBNL) on June 26-28, 2018. The review was conducted at the request of Barbara Helland, Associate Director of Science for the Office of Advanced Scientific Computing Research (ASCR). The review was chaired by Kin Chao, Office of Project Assessment (OPA), Office of Science. The purpose of the review was to evaluate the overall project readiness for Critical Decision (CD) 1/3a, Approve Alternative Selection and Cost Range and Approve Long Lead Procurement. The Committee found that the project is ready for CD-1/3a approval after the Committee's recommendations have been appropriately addressed.

Approval:

Based on the information presented above, Critical Decision-1/3A, Approve Alternative Selection, Cost Range and Long Lead Procurements for the ESnet6 Project, is approved.

JSBinkley 8/3/18

J. Stephen Binkley, Project Management Executive
Deputy Director for Science Programs
Office of Science

Date

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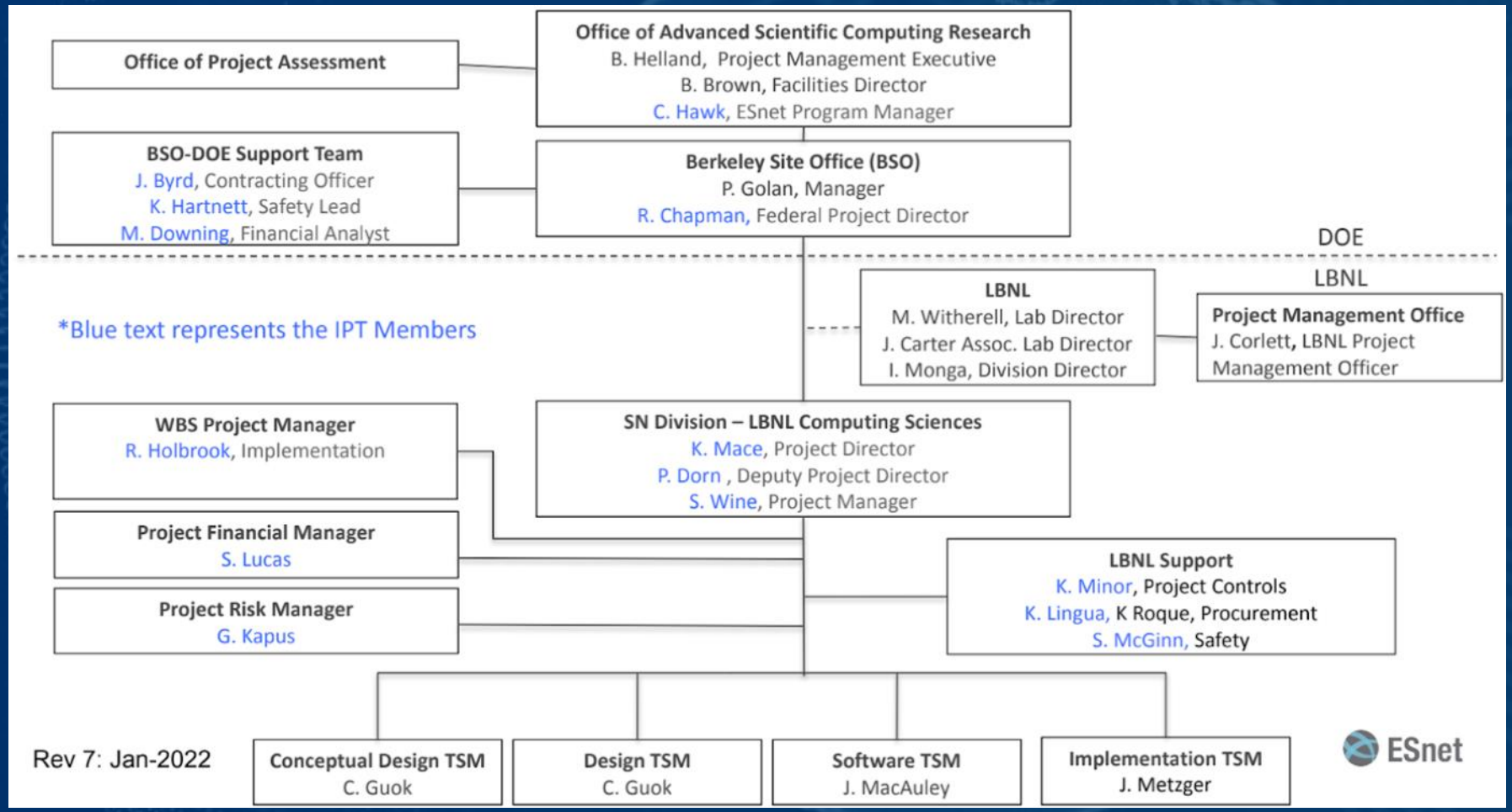
Lessons Learned from CD 1 / 3A

- Tailoring is key
  - Each project is different, and adapting the management framework to meet the uniqueness of the project, within the reasonable bounds, is key to success
- Innovative thinking is as important for project execution as much as the technical design
  - We requested 40+ M dollars, based on just a conceptual design, to build the optical infrastructure as a long-lead procurement
  - Allowed us to ramp staff, phase and transition the implementation and avoid supply chain issues during the pandemic

Summary of Tailoring for ESnet6

- Milestone Execution Index (MEI) instead of using Earned-Value Management (EVM)
  - Cumulative monthly Level 4 (L4) Milestone Performance rating: Planned vs. Achieved to date
  - Identifies critical schedule areas and highlights potential issues in the forecast
- Labor used level of effort (LoE) and was provided as a percentage of an FTE based on appropriate resources to complete the work in each WBS.
  - No standing army, and resources were managing upgrades as well as current network
- Estimate at Completion (EAC) costs were updated monthly through our re-forecasting process. This included status updates and refreshing costs according to the re-forecasted dates.
  - Operational funding for the project vs line-item construction meant LBL financial management system more accurately represented costs, burdens and allowed us to manage the program
- Project Acceptance Memos (PAMs) helped us transition completed pieces of the new infrastructure into operations rather than waiting for the entire system to be operational before transition
  - Multiple phased transitions from ESnet5 to ESnet6 minimized risk and service outages
  - PAMs allowed the ESnet6 project to transform a 24x7x365 *continuously operating facility* via multiple incremental phases.

A functional Integrated Project Team (IPT) was key to tailoring being discussed, understood and approved



IPT leveraged key expertise across DOE and LBNL to help discuss and resolve issues quickly and efficiently.

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CD-2 / 3

Implementation

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Detailed design review gave a chance for the technical team to shine

5 Conclusion and submission

The review committee greatly appreciated the wealth and clarity of information that was provided. We highly appreciated the open and candid discussions with the ESnet staff, including the thoughtful answers and quick responses to our questions. We recognize the excellent skills and passionate drive of the ESnet team that created and presented the reviewed design.

The ESnet6 Final Design Review Committee is of the opinion that the design and the phasing of the project are solid. The critical decision to not use a white box switch/router is the right approach. This decision better enables support for internet-scale routing tables and buffering needed on high-performance links. ESnet's selection of technologies for the packet core element for segment routing and path computation provides a switching substrate that will allow optimization in the use of resources and the delivery of innovative services. Any delay in funding or deployment of ESnet6 will affect the mission of ESnet and DOE as a whole, given the critical role the ESnet team and infrastructure play within the Department. In short, the final presented ESnet6 design is solid, flexible, scalable and ready to be implemented to fully support the Department of Energy science and national security missions.

CD 2/3 Review was finally a "breeze" as the project team was executing well…
…and we had now learnt how to prepare for reviews!

NO Review is ever a breeze, and takes months of preparation from any team.

While reviews are important, it is a huge overhead – we should add reviews very thoughtfully on a project.

Project Execution Plan for the ESnet6 Project

Submitted by:

Catherine Tonne — 2/20/2020
Catherine Tonne, ESnet6 Project Manager, LBNL — Date:

Kathryn P. Mace — 2/20/2020
Kathryn Mace, ESnet6 Project Director, LBNL — Date:

2/20/2020
Inder Monga, ESnet Director and
Scientific Networking Division Director, LBNL — Date:

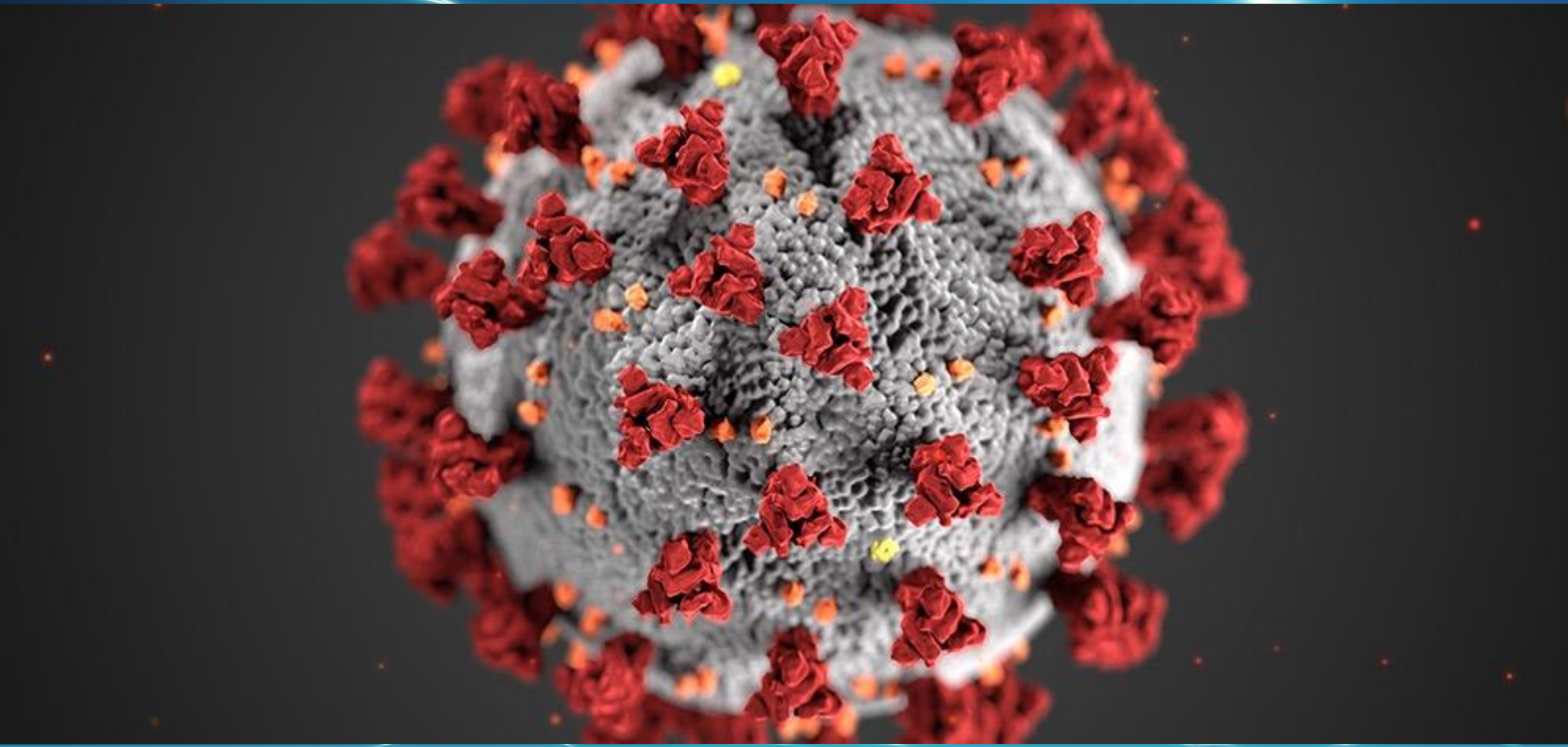
Jonathan Carter — 2/20/2020
Jonathan Carter, Associate Laboratory Director,
Computing Sciences, LBNL — Date:

Michael Witherell — 2/24/20
Michael Witherell, Laboratory Director, LBNL — Date:

R. Chapman — 2/25/2020
Rick Chapman, ESnet6 Federal Project Director,
Bay Area Site Office, DOE — Date:

2/25/2020
Paul Golan, Manager,
Bay Area Site Office, DOE — Date:

2/25/2020
Benjamin L. Brown,
ESnet Program Manager, Acting Facilities Division Director
Office of Advanced Scientific Computing Research,
Office of Science, DOE — Date:



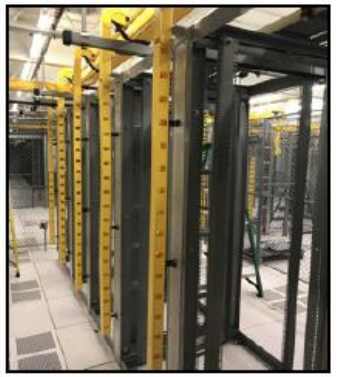
ESnet6 lit up 15,000 miles of fiber across the continental US, all of it was installed during the 2020 pandemic (pre-vaccine)

There are 309 ESnet6 equipment "colocation" installation sites:

- **37 optical switching sites**
- **272 optical in-line amplification sites**

"Colocation" or "co-lo" is telecom-speak for a shared commercial leased space for telecom equipment

"co-lo" space



racks / power

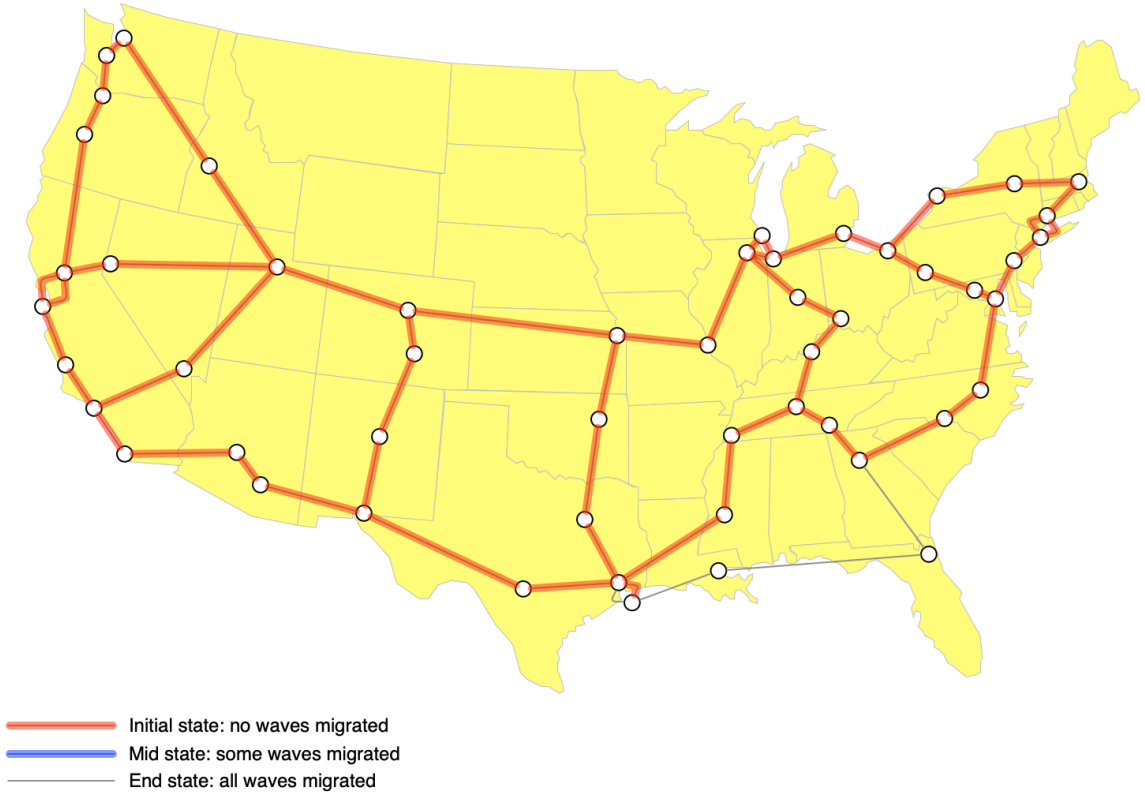
equipment

Safety planning was key - no COVID transmissions in installers or ESnet staff due to this install

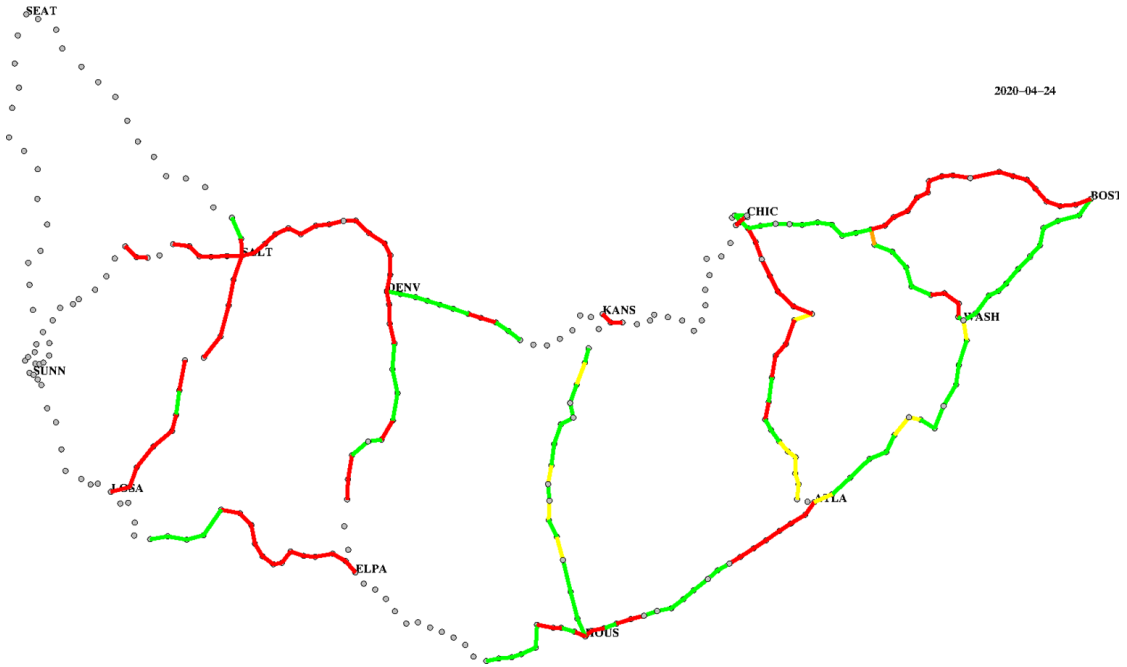
29

Service Transition and Decommissioning of ESnet5 Optical Network Happened in Parallel during that time

ESnet5 Optical Decommissioning



ESnet6 Optical Network Commissioning



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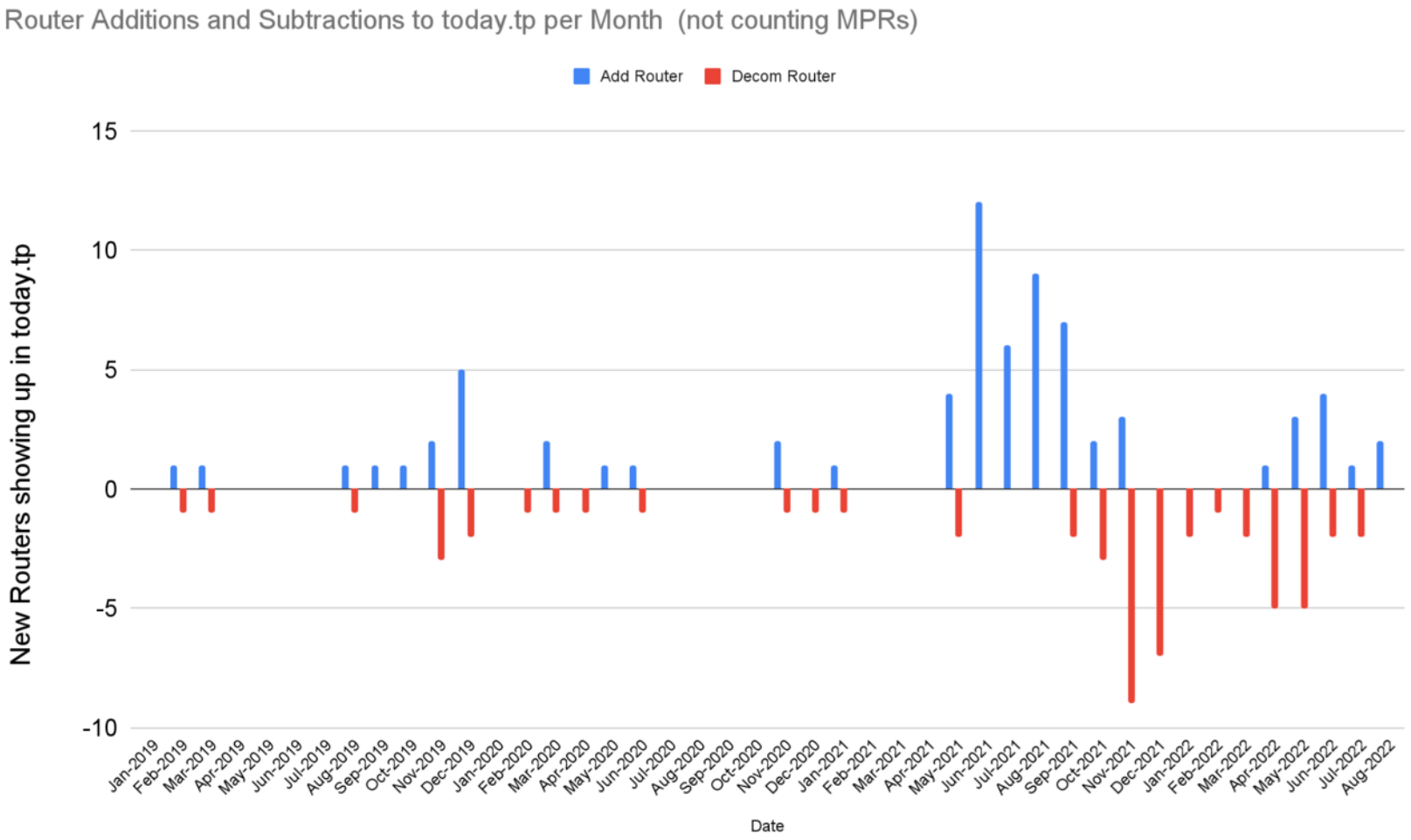
Transitioned to a new router platform with:

73 New Routers Deployed

53 Old Routers (ESnet5) Decommissioned



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CD-4

Closeout

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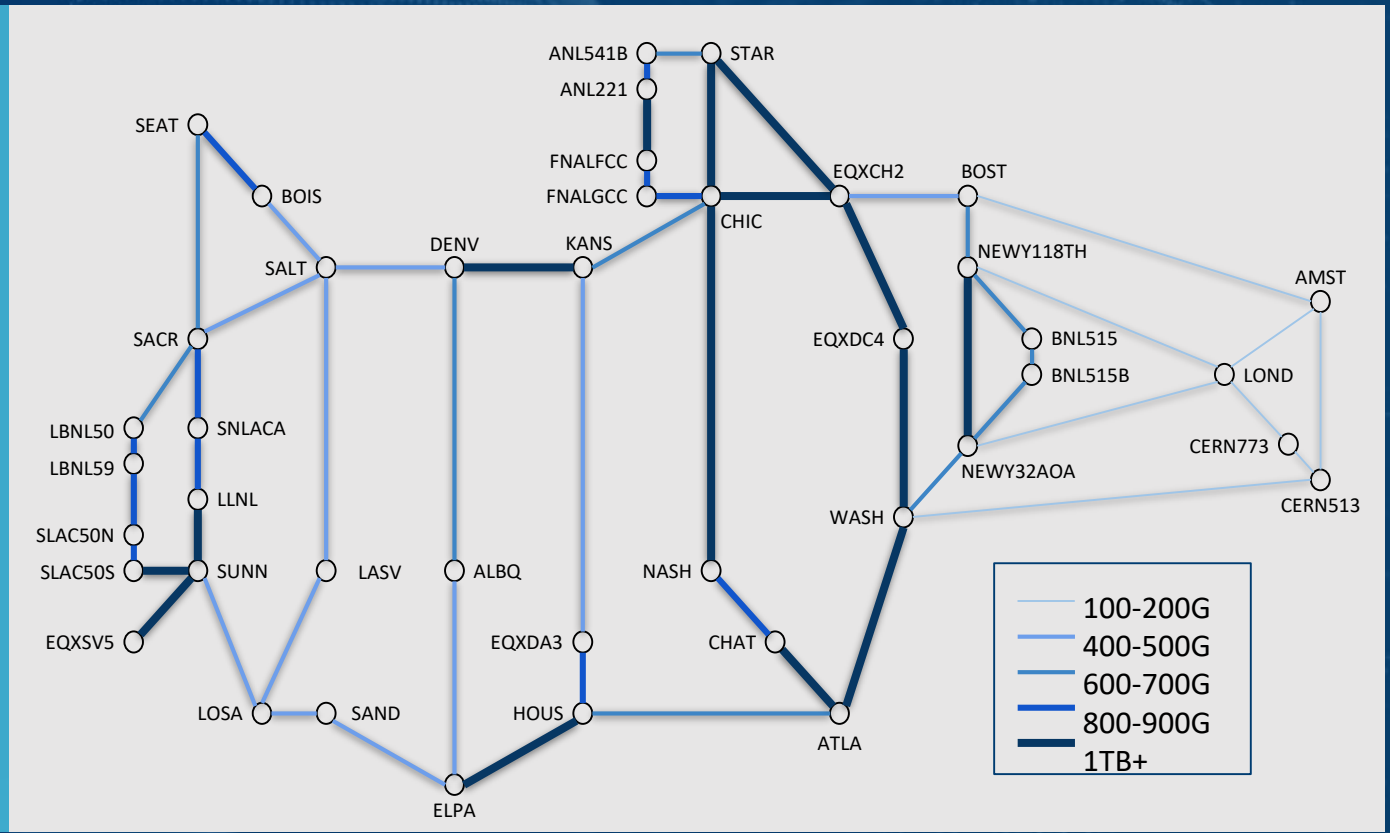
Met Threshold KPP's and almost all of Objective

Description	Threshold KPPs	Objective KPPs
1. **Network Backbone:** Deliver a new Tb-scale ESnet6 networking backbone with at least 2X the capability of ESnet5 that can deliver sufficient data movement capacity for the next 7-10 years	T1a. Installed and commissioned new optical equipment to support wave transmission on 40 fiber segments *Baseline: 7/2020* ***Actual : 3/2021***	O1a. Installed and commissioned new optical equipment to support wave transmission on at least 52 fiber segments *Baseline: 8/2021* ***Actual : 9/2021***
	T1b. Deployed and commissioned 15.5 Tbps of network capacity on the backbone *Baseline: 2/2022* ***Actual : 1/2022***	O1b. Deployed and commissioned at least 20.6 Tbps of network capacity on the backbone *Baseline: 4/2022* ***Actual: 5/2022***
	T1c. Installed and commissioned new routing equipment at the Network Backbone Hub Locations *Baseline: 9/2021* ***Actual: 2/2022***	O1c. Installed and commissioned new routing equipment at the Network Backbone Hub Locations and Connected Sites *Baseline: 11/2021* *Forecast: 12/2022*
2. **Automation:** Using an integrated network orchestration platform, commission automated provisioning and monitoring of network operations and security services	T2a. Deployed automated provisioning of one network service *Baseline: 11/2021* ***Actual: 10/2021***	O2a. Deployed automated provisioning of two or more network services *Baseline: 8/2021* ***Actual: 8/2021***
	T2b. and one security service *Baseline: 04/2022* ***Actual : 3/2022***	O2b. and two or more security services *Baseline: 1/2023* *Forecast: 1/2023*
3. **Programmable Network Flexibility:** Design and implement a highly programmable data plane for development and deployment of innovative science data services	T3. Demonstrated one service using a programmable data plane (i.e., high-touch service), at two sites *Baseline: 4/2022* ***Actual : 3/2022***	O3. Deployed one or more services using a programmable data plane (i.e., high-touch services), among more than two sites *Baseline 09/2022* *Forecast: 12/2022*

ESnet6 layed the foundation for future of data-intensive DOE science

Enough base capacity and ability to cost-effectively add more provides unconstrained access to data, no matter how big or distributed

- **15,000 miles** of fiber across the continental US
- **300 leased colocation spaces** installed with ESnet optical equipment
- **46.1 Tbps** aggregate capacity deployed
- **400Gbps - 1 Tbps** services available
- New fiber spans acquired to **increase reliability and reduce latency**

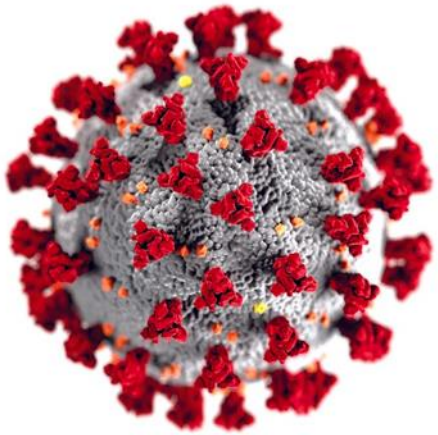


LUMEN Infinera ciena NOKIA ESnet

Lessons Learnt:
Formal Risk Management

Structured planning for problems like this

helped us manage problems like this!



- Expert training of all staff on formal risk management processes.
- Dedicated Risk Manager worked to identify, quantify, and develop mitigation strategies, and ensured we continuously updated and communicated about risks and issues throughout the project.
- All the early efforts paid huge dividends in the end.

Lessons Learnt:

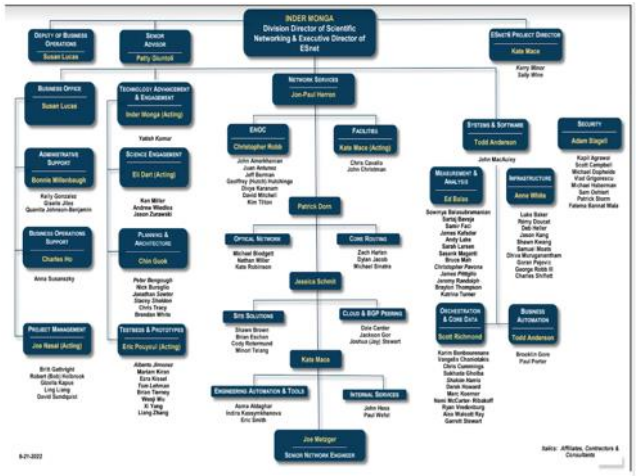
Team Growth!

Hiring and **onboarding** was critical to executing the project successfully!

We could never have completed it without our highly skilled, diverse, distributed team, with deep experience working and thriving in a virtual environment

2017
45 People

2022
120 People



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Lessons Learnt:
DOE 413.3B: A growth opportunity!

DOE Office of Science allows *tailoring* the 413.3b processes.

In hindsight, tailoring the 413.3b process saved the project:

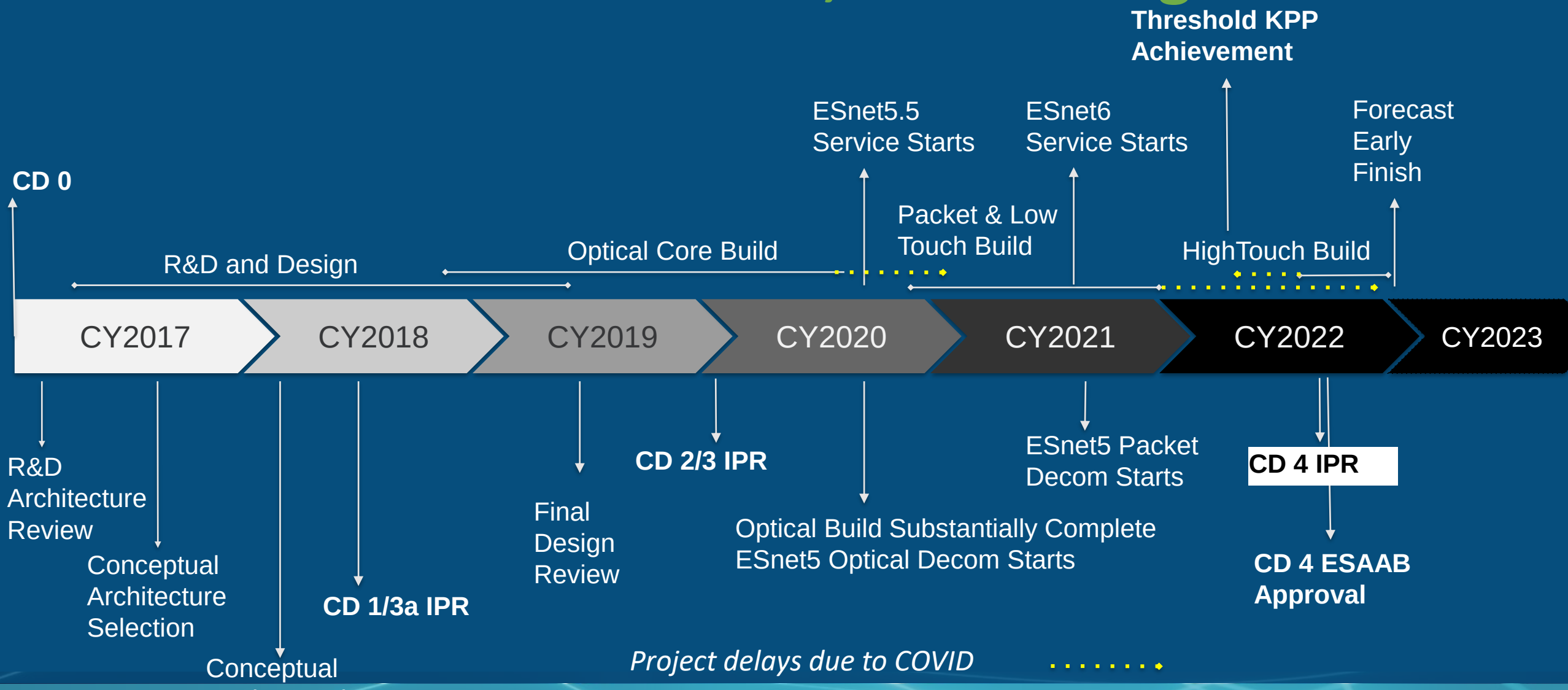
- Used Milestone Execution Index (MEI) metrics to measure and track progress, instead of Earned Value Management.
- Used Project Acceptance Memos (PAMs) to incrementally accept and retire scope from the project, and transition it to Program.

Working in this framework ensured that LBL Management, our Federal Project Director, Federal Program Manager, and other DOE leadership were 100% in sync with us and able to fully support us throughout the project.

Our entire organization now has a much better understanding of project management!

ESnet6 Project: Six years from concept to done

6 months ahead of schedule, under budget



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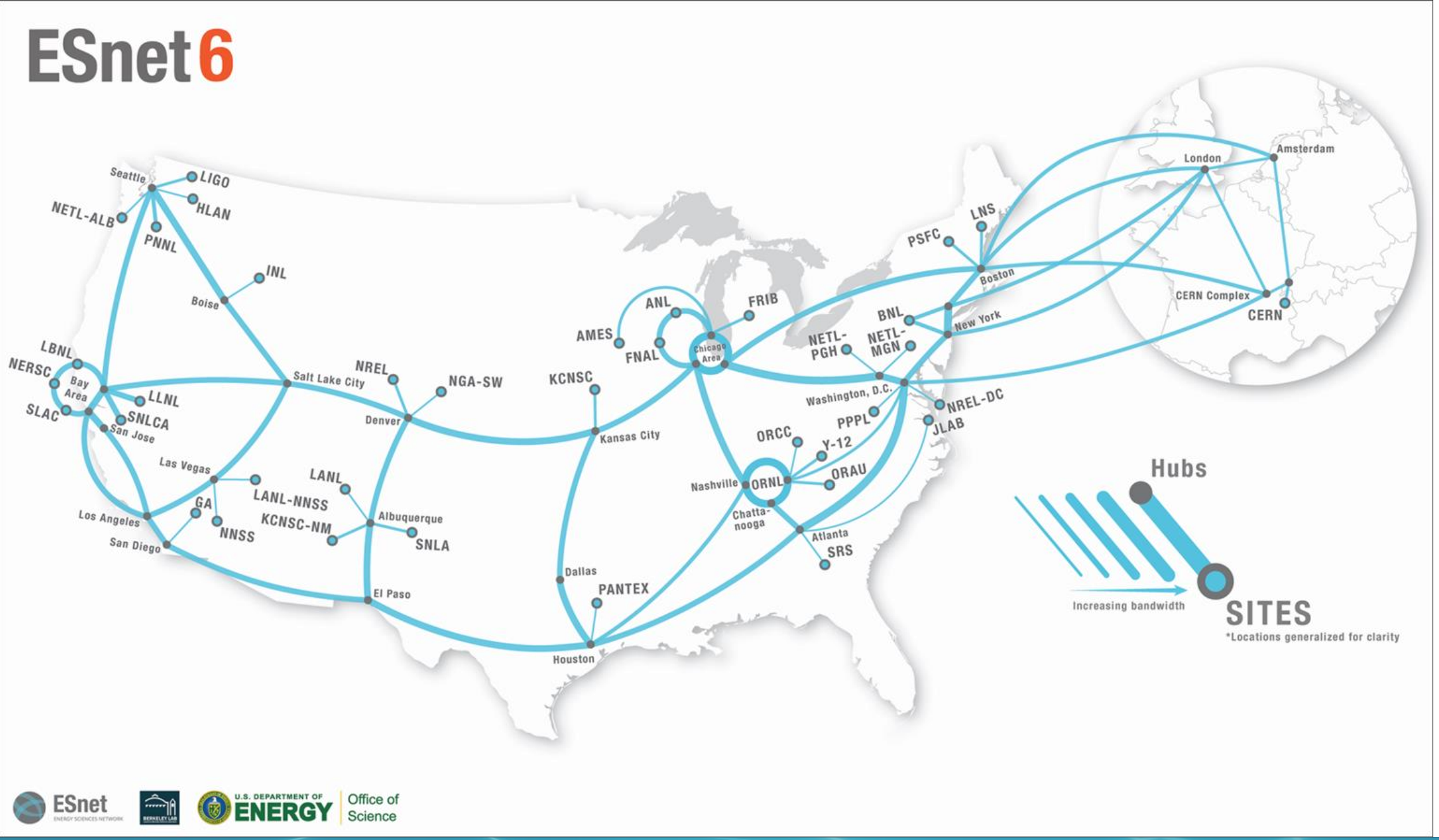
ESnet6
Seattle
LIGO
HLAN
NETL-ALB
PNNL
INL
Boise
LBNL
NERSC
Bay Area
SLAC
LLNL
SNLCA
San Jose
Salt Lake City
NREL
Denver
NGA-SW
Las Vegas
LANL
LANL-NNSS
GA
NNSS
KCNSC-NM
Albuquerque
SNLA
Los Angeles
San Diego
El Paso
KCNSC
Kansas City
Dallas
PANTEX
Houston
AMES
ANL
FNAL
FRIB
Chicago Area
NETL-PGH
NETL-MGN
BNL
New York
PSFC
LNS
Boston
Washington, D.C.
NREL-DC
JLAB
PPPL
ORCC
Y-12
ORAU
Nashville
ORNL
Chatta-nooga
Atlanta
SRS
London
Amsterdam
CERN Complex
CERN
Hubs
Increasing bandwidth
SITES
*Locations generalized for clarity
ESnet
ENERGY SCIENCES NETWORK
U.S. DEPARTMENT OF ENERGY
Office of Science

ESnet6 success as a project is due to the people that contributed

- 1st • First DOE 413.3 Project for the User Facility
- 1st First greenfield build of the entire network
- 1st First time for ESnet folks to design, build and manage Optical Infrastructure
- 1st Hiring and growing the team virtually more than 50%
- 1st Dealing with 10x increase in coordination and reporting due to Pandemic
- ✓ Nearly zero unplanned downtime and minimal planned downtime

Lab, Berkeley Site Office, Project Management Office, DOE Program Managers and Project Office,
Finance, Management, R&E partners, ESCC and many more

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Kate will share more details on Thursday at the Project Management Breakout – 3:45 pm

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Thank you!