The ESnet6 Project

Kate Mace
ESnet6 Project Director
ESnet Network Engineering Group Lead
Lawrence Berkeley National Laboratory

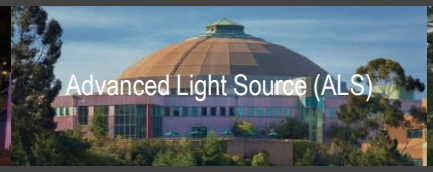
ESnet

The ESnet User Facility:
Data-circulatory system for all 28 SC facilities

ASCR High End Computing (HEC)

ASCR High Performance Scientific Network

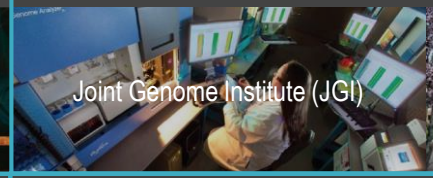
BES X-Ray Light Sources



BES Nanoscale Science Research Centers (NSRCs)

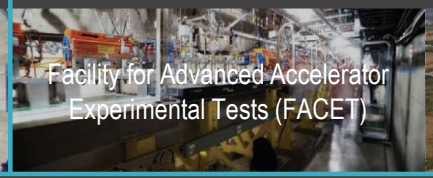
BES Neutron Scattering Facilities

BER

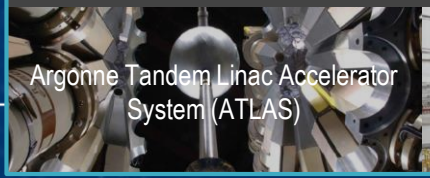


FES

HEP



NP



U.S. DEPARTMENT OF ENERGY
Office of Science

ESnet

Mission network

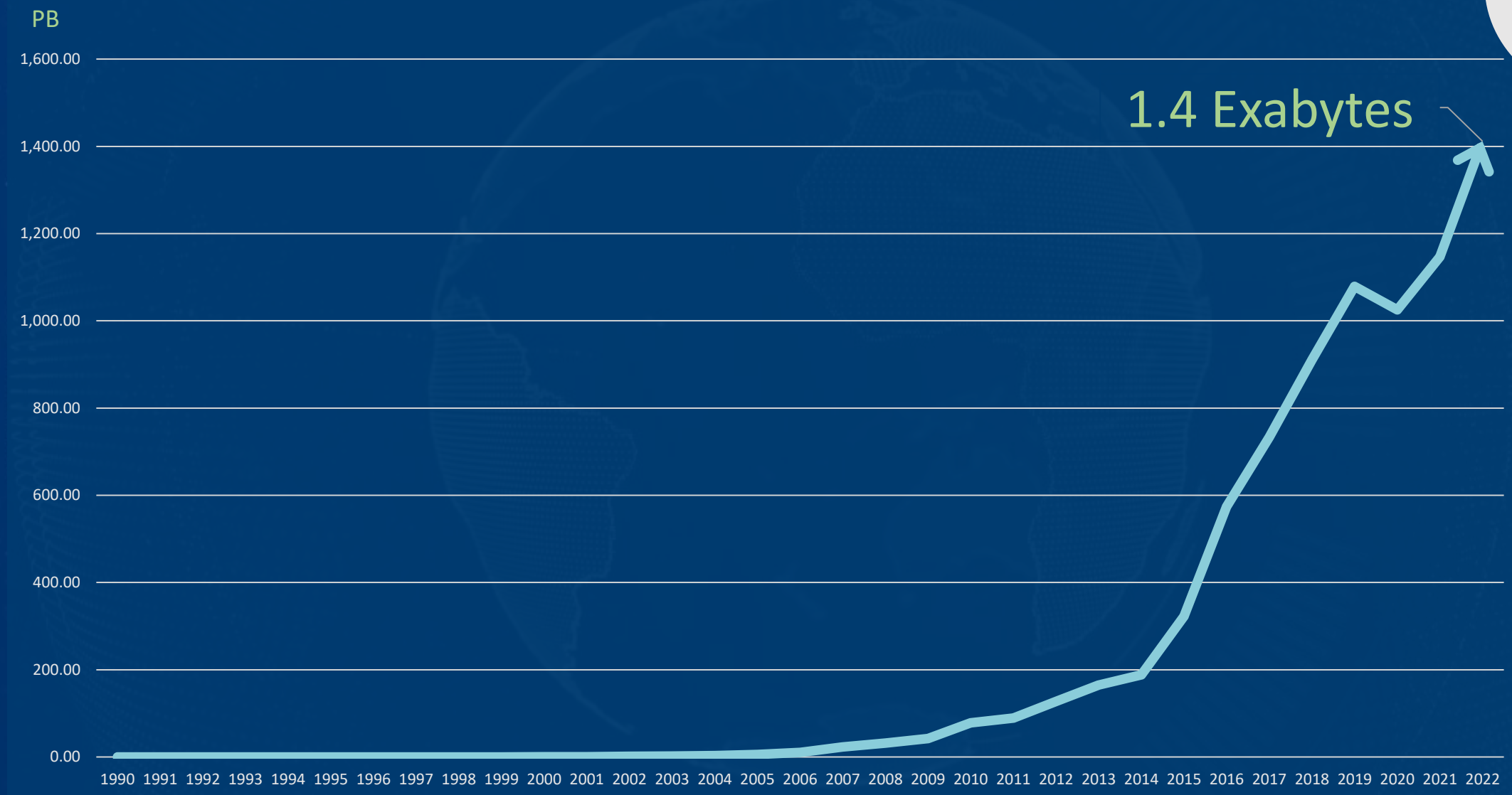
Scientific progress will be **completely unconstrained** by the physical location of instruments, people, computational resources, or data.

Vision:

Accelerate Scientific Discovery

Network traffic growing exponentially 60% yearly since 1990

>1.4 Exabytes in 2022 alone



ESnet

The Project Scope and Timeline

ESnet6 Project Scope

Manage Exponential Data Growth

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

Increase resiliency and reliability

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

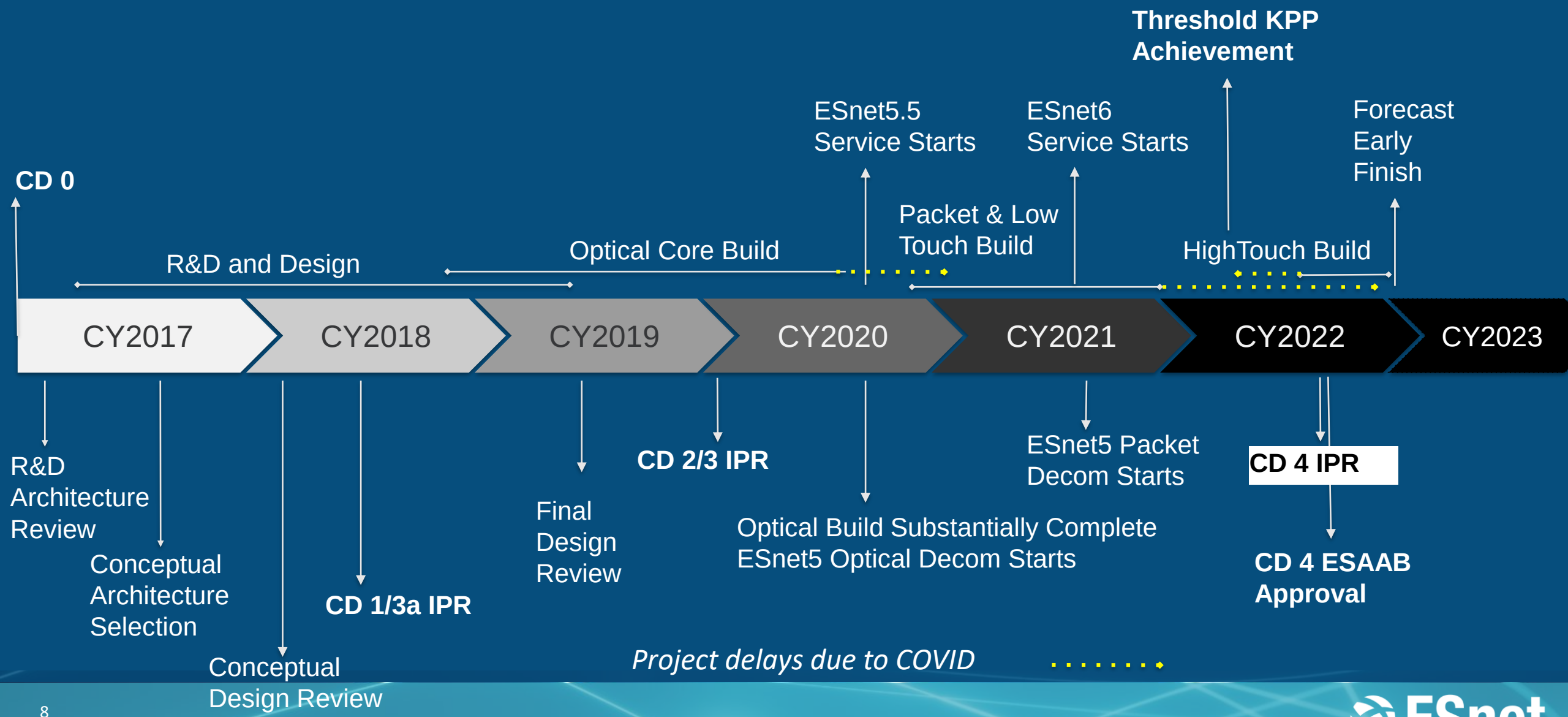
Lay foundation to handle future science workflows

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

ESnet6 KPPs

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	O1a. Installed and commissioned new optical equipment to support wave transmission on at least 52 fiber segments
	T1b. Deployed and commissioned 15.5 Tbps of network capacity on the backbone	O1b. Deployed and commissioned at least 20.6 Tbps of network capacity on the backbone
	T1c. Installed and commissioned new routing equipment at the Network Backbone Hub Locations	O1c. Installed and commissioned new routing equipment at the Network Backbone Hub Locations and Connected Sites
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	O2a. Deployed automated provisioning of two or more network services
	T2b. and one security service	O2b. and two or more security services
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	O3. Deployed one or more services using a programmable data plane (i.e., high-touch services), among more than two sites

ESnet6 Project: Six years from concept to done

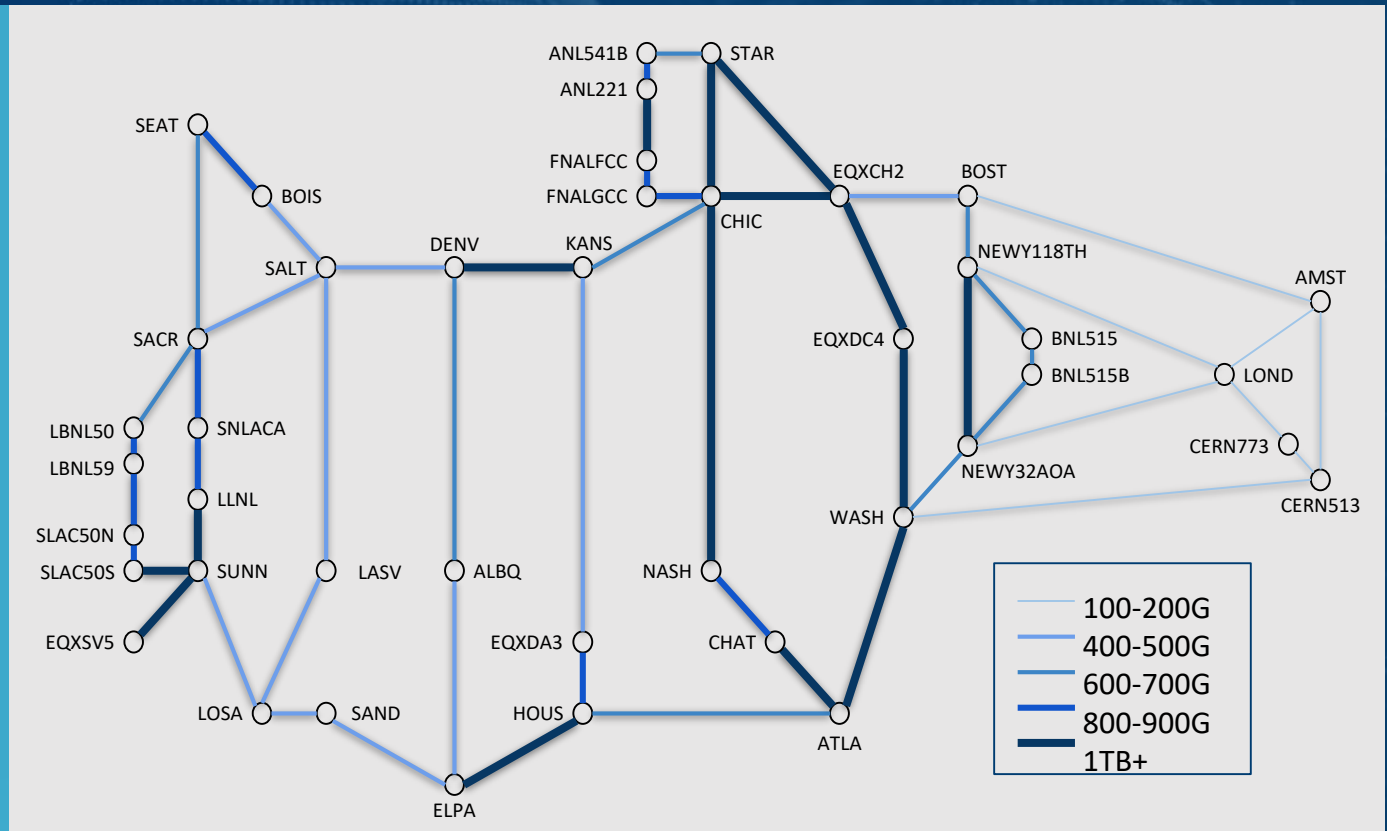


ESnet

ESnet6 lays 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

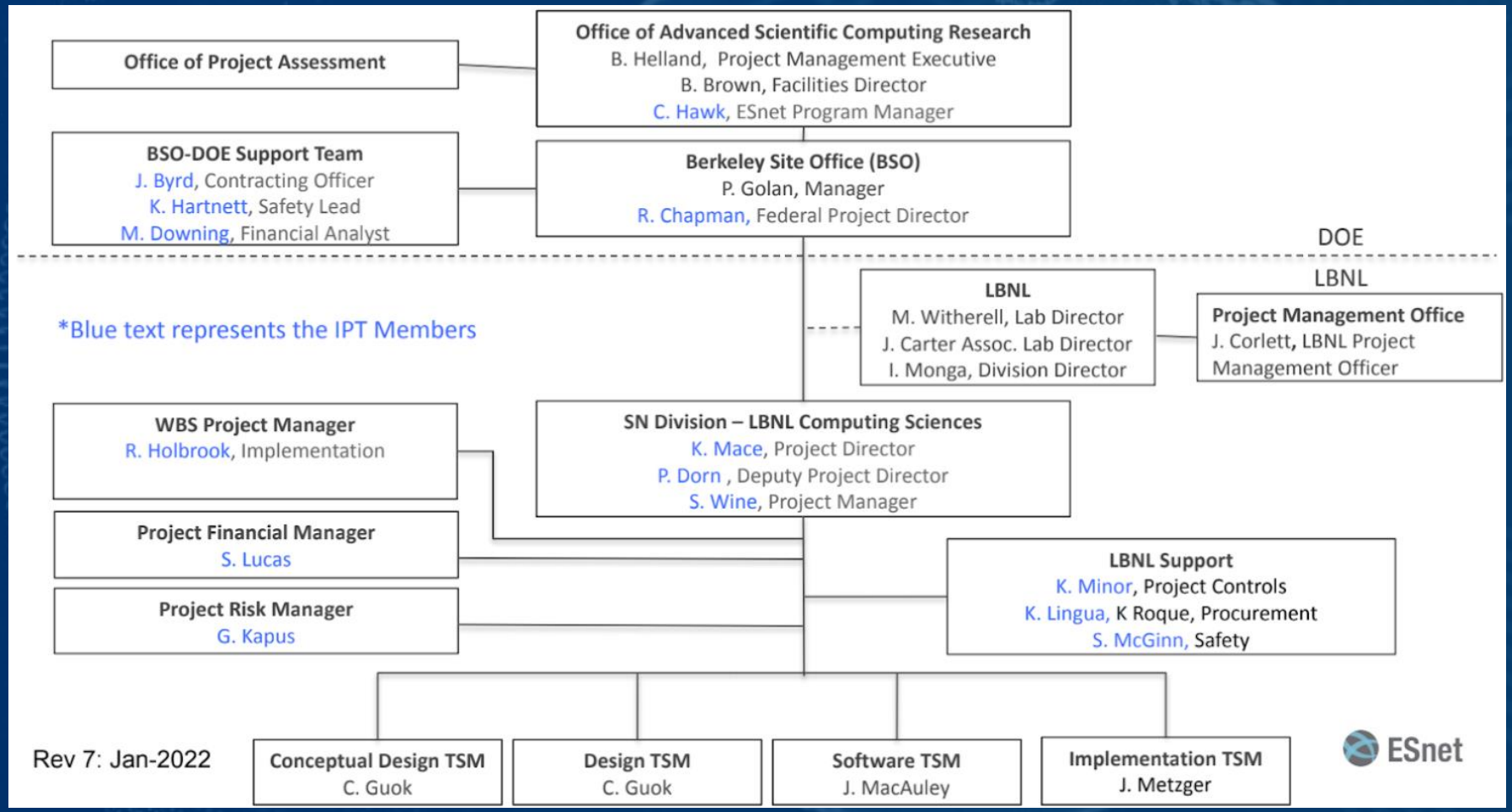
- **15,000 miles** of fiber across the continental US
- **300 leased colocation spaces** installed with ESnet optical equipment
- **> 46.1 Tbps** aggregate capacity deployed
- **400Gbps - 1 Tbps** services available
- New fiber spans acquired to **increase reliability and reduce latency**



ESnet

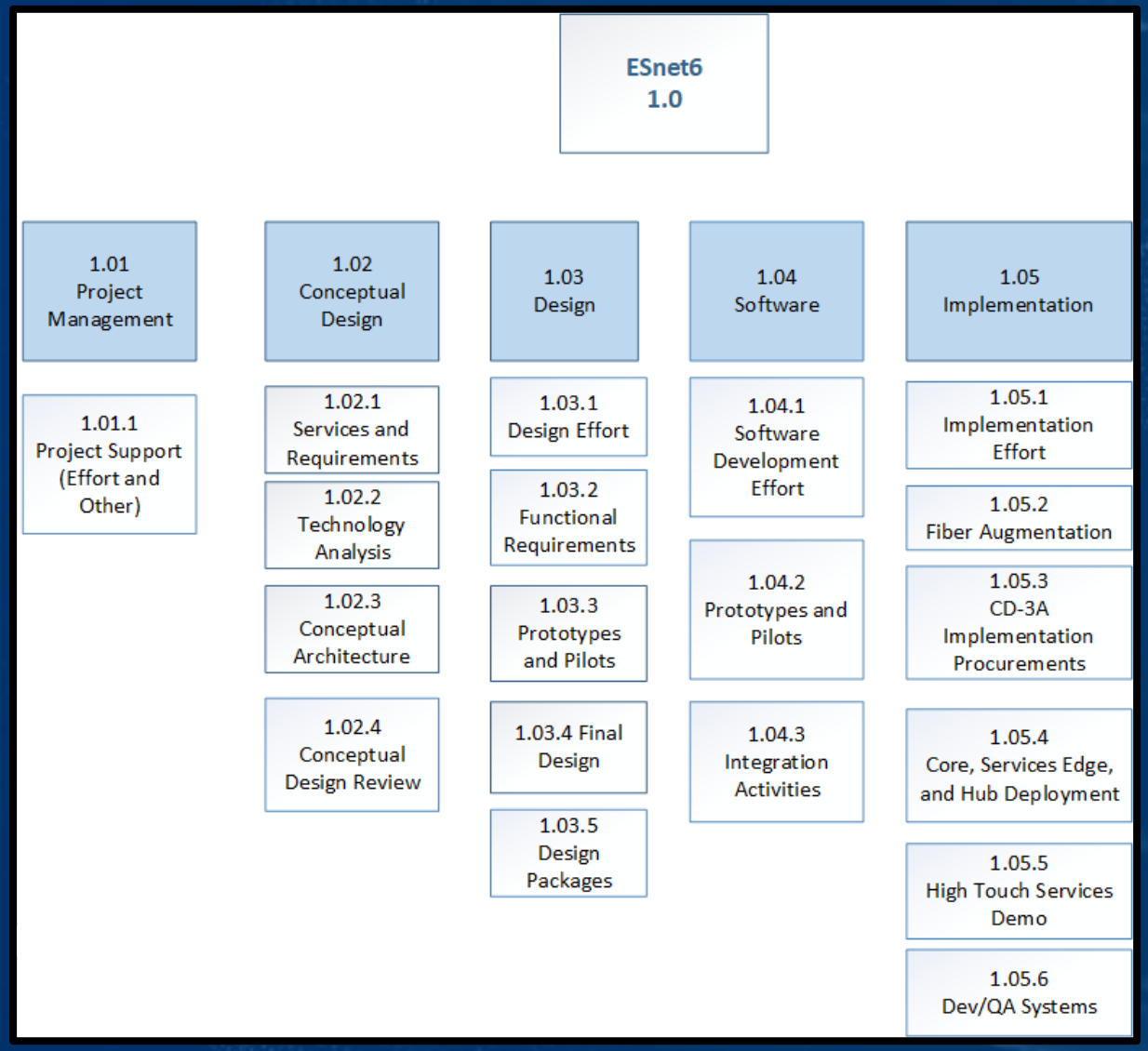
Performance Management Approach

Integrated Project Team (IPT)



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

ESnet



ESnet6 WBS: Work Breakdown Structure

- ESnet6 WBS followed standard networking project phases, based on:
  - Prior ESnet backbone upgrades
  - Industry standards
- WBS was mapped into charge accounts
- WBS 1.04 and 1.05 comprised the majority of the project acquisitions, implementation/integration work, and level of effort.

ESnet

Performance Management Approach

- ESnet6 successfully utilized an approved performance management approach which was tailored specifically for ESnet6. The approach was like what is being used for other HPC projects and has proven effective in managing the projects appropriately.

- This is consistent with DOE O413.3B
  - Change 4 directed that “Non-construction activities, which are programmatic elements of HPC activities including research and development, leases, and software development is tracked with level of effort activities and milestone achievement and EVM compliance should be eliminated.”

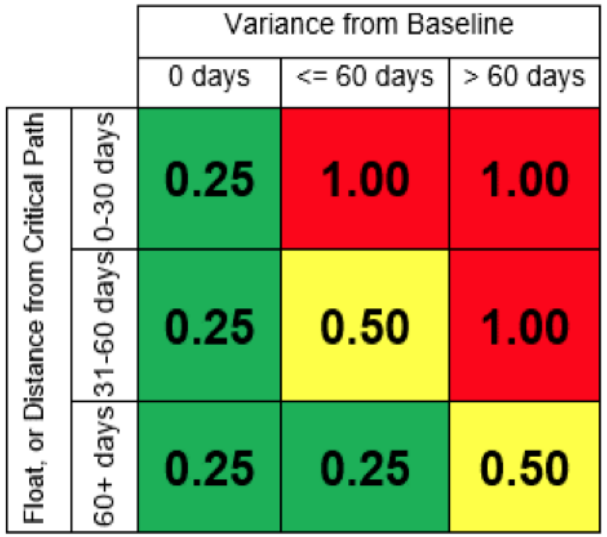
Schedule Management

- P6 Master Schedule & WBS was structured to support a phased implementation.
- Master Schedule included cost milestones which provided alignment to the project budget in the LBNL Financial Management System (FMS).
- Monthly updates included:
  - Master Schedule status updates in P6 (% complete and expected finish dates)
  - Cost milestone achievement and outlook updates in P6 for timing of costs and EAC
  - FMS financial execution file updated - actual/expected dollar values and timing of costs
- Monthly reports provided variance analysis, critical path review, milestone progress and outlook, and Milestone Execution Index (MEI) performance rating.

Milestone Execution Index (MEI) Description

- Cumulative monthly Level 4 (L4) Milestone Performance rating: Planned vs. Achieved to date
- Every month, each L4 Milestone assigned a weight and “Stoplight” rating
- Weight & Rating are based on milestone health + criticality:
  - Variance from Baseline
  - Distance from Critical Path
- Identifies critical schedule areas and highlights potential issues in the forecast
- Variance Analysis Report created when MEI threshold is met:
  - Threshold MEI < 0.85
  - Any delay to a L1 or L2 milestone
- Variance analysis report: root cause, schedule impact & mitigation or corrective actions

Milestone Index Ratings



Milestone	Red Stoplight 🔴	Yellow Stoplight 🟡
Milestone on or within 30 days of critical path	Any delay outside of planned reporting period	N/A
Milestone 31-60 days from critical path	Any delay greater than or equal to 60 days	Any delay outside of planned reporting period
Milestone 60+ days off critical path	N/A	Any delay greater than or equal to 60 days
Milestones achieved/forecasted earlier than the baseline reporting period are tracked with a grey Stoplight ⚫		

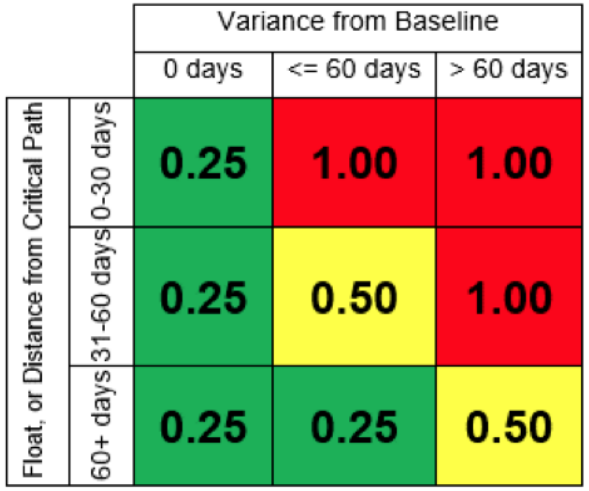
- Every month, each L4 Milestone was assigned a color rating based on the Milestone Index Rating chart
- Specific criteria used for rating assignment
  - Distance from Critical Path or Total Float
  - Variance from the Baseline

Monthly Milestone Report

- All level 4 milestones were listed in a monthly milestone report with the latest schedule data as well as the Milestone Status Stoplight.
- Each month the project team reviews the milestones, analyzing the yellow and red milestones for the cause of delay.
- The report shows all milestones, completed and forecast, so that the team can see projections for upcoming milestones. The milestone row is highlighted light green upon completion.
- For a more focused view, a current report was posted monthly which provides a 6 month window: two months past, current period and three months forecast.

Global Milestone Levels	WBS Path	Activity ID	Activity Name	Baseline Milestone Date	Forecast /Actual Milestone Date	Variance	Total Float	Milestone Status
IMPLEMENTATION								
Core, Services Edge, Hub Deployment								
MS04	1.05.04.01.03	E6_154130_040	AWARD: Routers - Europe Brownfield	11-Dec-20	10-Dec-20 A	2	117	
MS04	1.05.04.01.06.01	E6_154161_090	AWARD: Chicago: ANL Diverse Egress	22-May-20	11-Dec-20 A	-140	197	
MS04	1.05.04.01.04	E6_154140_190	AWARD: Routers - Professional Services	15-Oct-20	16-Feb-21	-77	297	
MS04	1.05.04.01.01	E6_154110_2742	ACCEPT: Routers - Domestic Greenfield (Large Routers Order) Equipment	4-Jan-21	26-Feb-21	-37	372	
MS04	1.05.04.01.05	E6_154150_175	AWARD: Master Agreement, Procurement and Installation Services - Transponders - Phase 2 (Vendor 1)	6-Oct-20	1-Mar-21	-93	133	

Milestone Index Weights



Float, or Distance from Critical Path	Variance from Baseline: 0 days	Variance from Baseline: <= 60 days	Variance from Baseline: > 60 days
0-30 days	0.25	1.00	1.00
31-60 days	0.25	0.50	1.00
60+ days	0.25	0.25	0.50

- Similar to the stoplight colors, every month, each L4 Milestone is assigned a weighting based on the Milestone Index Rating chart
- The same criteria apply as before (variance and distance from critical path)

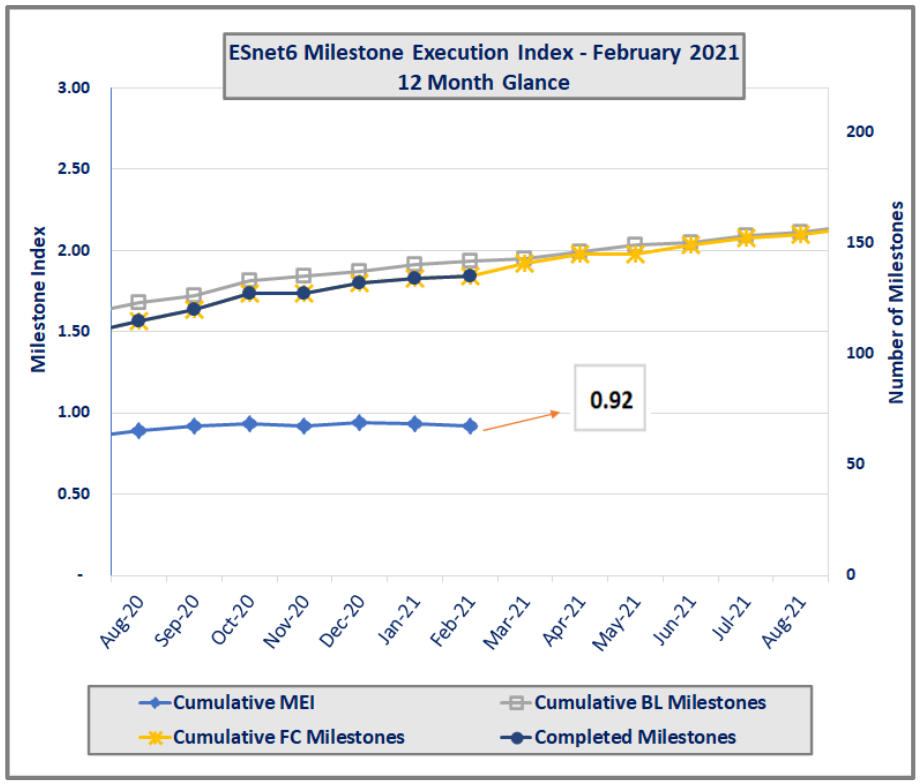
Milestone	**Red Stoplight = 1.00 weight**	**Yellow Stoplight = 0.5 weight**
Milestone on or within 30 days of critical path	Any delay outside of planned reporting period	N/A
Milestone 31-60 days from critical path	Any delay greater than or equal to 60 days	Any delay outside of planned reporting period
Milestone 60+ days off critical path	N/A	Any delay greater than or equal to 60 days

Green (on-time) and Grey (ahead) milestones are both given a **0.25 weight**

Milestone Execution Index

- Once each milestone has been assigned a weight, the cumulative to date sum of all the baseline weights are added together, as well as the cumulative to date total of all the completed milestones.
- The MEI is then calculated as:

$$\text{Cumulative Index} = \frac{\text{Cumulative Sum of Ratings of Milestones Completed}}{\text{Cumulative Sum of Ratings of Milestones Planned}}$$



For example, for February 2021:

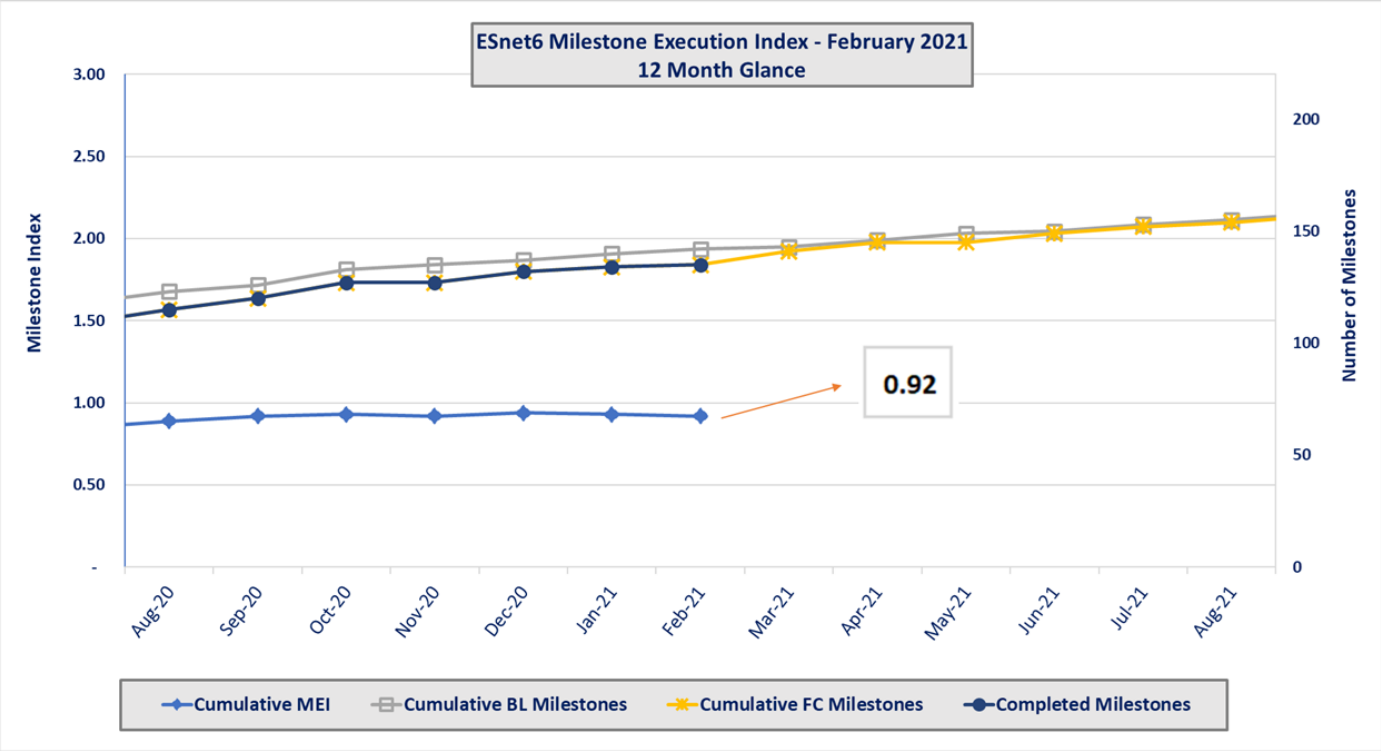
- the cumulative sum of the BL weights = 41.50
- the cumulative sum of the FC wights = 38.25
- MEI: 38.25 / 41.50 = 0.92

Cumulative MEI Rating Indicators

1.0 = On Plan
> 1.0 = Ahead of Plan
< 1.0 = Behind Plan

ESnet

MEI Status (February 2021)



L4 Milestone Performance = 0.92

- 142 planned (75%), 135 achieved (71%)
- 7 milestones behind
- Outlook - 90 day average MEI rating = 0.98

MEI Indicates that the ESnet6 Project Schedule was slightly behind but overall performing well

ESnet

Milestone Report (February 28, 2021)

Global MS Levels	WBS Path	Activity ID	Activity Name	Baseline Milestone Date	Forecast /Actual MS Date	Variance	Total Float	MS Status
PROJECT MANAGEMENT								
Project Reviews								
MS04	1.01.01.04	E6_111400_060	Documents Due Annual Review 2021	19-Apr-21	19-Apr-21	0	48	
SOFTWARE								
Software Integration Activities								
MS04	1.04.02.02.07	E6_142270_900	COMP: Software - Low-Touch-Integration	23-Dec-20	23-Dec-20 A	0	235	
MS04	1.04.02.03.01	E6_142310_080	COMP: Complete PCS Acceptance	30-Apr-21	30-Apr-21	0	120	
IMPLEMENTATION								
CD-3A - Implementation Procurements								
MS04	1.05.03.03.06	E6_153360_175	ACCEPT: Automation Framework Software (AFS) Procurements (Year 2 FY2021)	6-Nov-20	23-Dec-20 A	-31	187	
MS04	1.05.03.03.01.03	E6_153313_100	ACCEPT: Phase 5 - Equip/Install/Testing/QA - OLS & Transponders Phase 1 (In Service)	1-May-20	30-Mar-21	-223	196	
MS04	1.05.03.03.01.03	E6_153313_110	COMP: Equip/Install/Testing/QA - OLS & Transponder Phase 1 (all 5 segments in service)	1-May-20	30-Mar-21	-223	196	
MS04	1.05.03.04	E6_153400_100	COMP: OLS Optical System Implementation & Commissioning (ESnet 5.5)	28-Jul-20	1-Apr-21	-165	194	
Core, Services Edge, Hub Deployment								
MS04	1.05.04.01.01	E6_154110_262	ACCEPT: Routers - Lab	6-Oct-20	01-Dec-20 A	-38	137	
MS04	1.05.04.01.03	E6_154130_040	AWARD: Routers - Europe Brownfield	11-Dec-20	10-Dec-20 A	2	117	
MS04	1.05.04.01.06.01	E6_154161_090	AWARD: Chicago: ANL Diverse Egress	22-May-20	11-Dec-20 A	-140	197	
MS04	1.05.04.01.01	E6_154110_2742	ACCEPT: Routers - Domestic Greenfield (Large Routers Order) Equipment	4-Jan-21	15-Mar-21	-48	361	
MS04	1.05.04.01.04	E6_154140_190	AWARD: Routers - Professional Services	15-Oct-20	19-Mar-21	-100	274	
MS04	1.05.04.01.05	E6_154150_175	AWARD: Master Agreement, Proc&Install Services - Transponders - Phase 2 (Vendor 1)	6-Oct-20	19-Mar-21	-107	119	
MS04	1.05.04.01.08	E6_154180_100	AWARD: Router Implementation Updates FY21	2-Apr-21	2-Apr-21	0	176	
MS04	1.05.04.01.06.01	E6_154161_270	AWARD: ANL Optical Equipment & Install	17-May-21	10-Jun-21	-17	197	
MS04	1.05.04.01.04	E6_154140_090	ACCEPT: Routers - Domestic Brownfield	4-Jan-21	21-Jun-21	-117	117	
MS04	1.05.04.01.01	E6_154110_300	ACCEPT: Routers - Domestic Greenfield (Large Routers Order) Installation	28-May-21	16-Jul-21	-33	242	
High Touch Services Demo								
MS04	1.05.05.02.01	E6_155210_020	START: High Touch Server & FPGA - Procurement	5-Jan-21	05-Jan-21 A	0	85	
MS04	1.05.05.02.02	E6_155220_050	AWARD: Prototypes and Pilots Equipment - FY21	9-Feb-21	11-Jan-21 A	20	20	
MS04	1.05.05.02.02	E6_155220_070	ACCEPT: Prototypes and Pilots Equipment - FY21	24-Mar-21	24-Mar-21	0	20	
MS04	1.05.05.02.01	E6_155210_075	COMP: RFP Release - High Touch Server & FPGA	26-May-21	1-Jun-21	-3	82	
Dev/QA Systems								
MS04	1.05.06.05	E6_156500_100	COMP: Dev/QA: Routers	9-Feb-21	09-Feb-21 A	0	380	

- The milestone report gave a 6 month window of level 4 (L4) milestones.
- In February 2021 there were 7 late milestones:
  - Accept OLS Phase 5
  - OLS (all 5 segments in service)
  - OLS System implementation & commissioning complete
  - Award master agreement for Transponders (phase 2)
  - Award router professional services
  - Accept Routers domestic greenfield
  - Accept Routers domestic brownfield

In March 2021, 6 of the 7 late milestones were achieved

ESnet

Tying Cost and Schedule

Cost Management

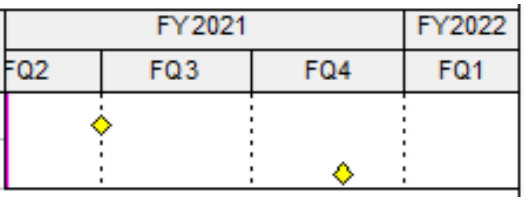
- Project costs were managed in the LBNL Financial Management System (FMS).
- The cost and obligation budgets were aligned with the schedule via ‘award’ and ‘paid’ milestones which were maintained in P6.
- Labor used level of effort (LoE) and was provided as a percentage of an FTE based on appropriate resources to complete the work in each WBS.
- 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.

Cost and Schedule Data Trace

Routers Domestic Greenfield (Cost)

Schedule

Activity ID	Activity Name	BL Project Start	BL Project Finish
E6_154110_2743	PAID: Routers - Domestic Greenfield (Large Routers Order) Equipment		31-Mar-21
E6_154110_305	PAID: Routers - Domestic Greenfield (Large Routers Order) Installation		24-Aug-21



Cost

Plan Line Description	06 - MAR	07 - APR	08 - MAY	09 - JUN	10 - JUL	11 - AUG	12 - SEP	2021 Total
Routers-Domestic Greenfield Equipment	8,141,858	-	-	-	-	-	-	8,141,858
Routers-Domestic Greenfield Install & Ma	-	-	-	-	-	917,036	-	917,036
	8,141,858	**-**	**-**	**-**	**-**	**917,036**	**-**	**9,058,894**

ESnet

Cost and Schedule Data Trace

OLS Transponders 2nd Buy (Cost)

Schedule

Activity ID	Activity Name	BL Project Start	BL Project Finish	FY2021	FY2022		
				FQ4	FQ1	FQ2	FQ3
E6_154150_225	PAID: Procurements - Transponders - Phase 2		01-Sep-21	◆			
E6_154150_255	PAID: Installation Services - Transponders - Phase 2		03-Feb-22			◆	

Cost

Plan Line Description	2022												2023				Grand Total
	12 - SEP	01 - OCT	02 - NOV	03 - DEC	04 - JAN	05 - FEB	06 - MAR	07 - APR	08 - MAY	09 - JUN	10 - JUL	11 - AUG	12 - SEP	01 - OCT	02 - NOV	03 - DEC	
⊟OLS Transponders 2nd Buy Install Service	-	-	-	-	-	250,280	-	-	-	-	-	-	-	-	-	-	250,280
⊟OLS Transponders 2nd Buy Procurement	3,710,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,710,900
	3,710,900	-	-	-	-	250,280	-	-	-	-	-	-	-	-	-	-	3,961,180

Transition to Operations and Project Closeout

Project Acceptance Memos (PAMs)

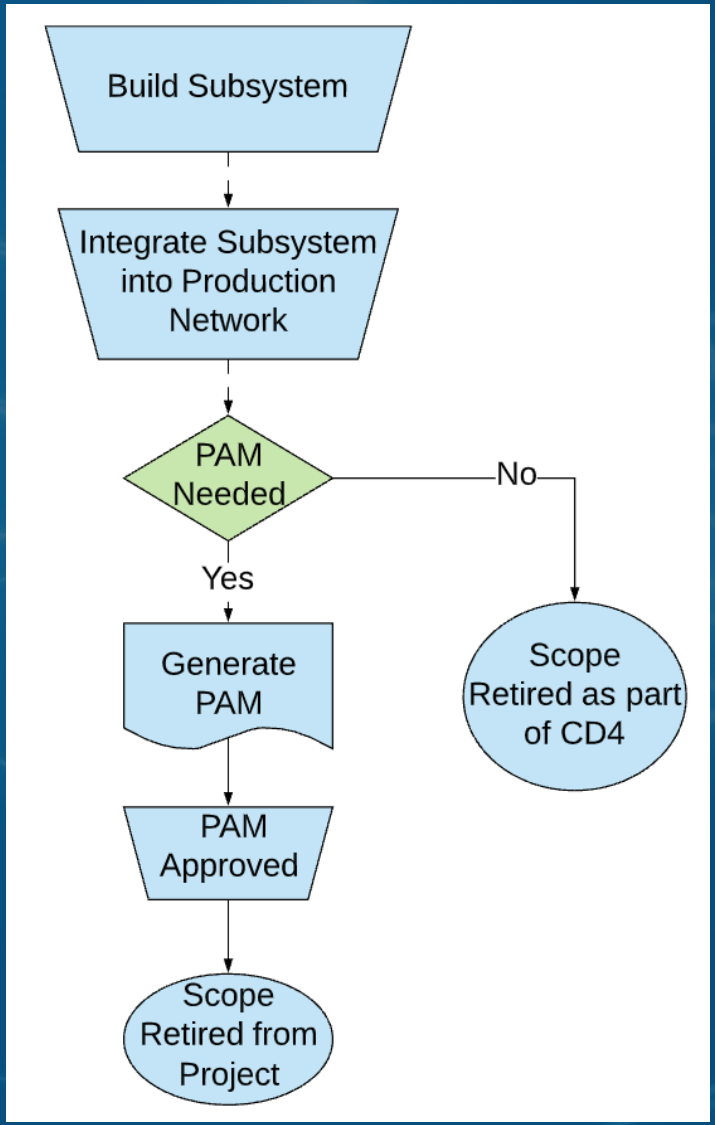
The ESnet High Performance Networking Facility remained fully operational during ESnet6 project execution.

- Phased Transition to Operations
- Multiple phased transitions from ESnet5 to ESnet6 minimized risk and service outages in a continuously operating facility
- CD-3a and throughout CD-3 scope:
  - At baseline: deployment & commissioning milestones were set for the multiple subsystems
  - Acceptance testing completed & documented
  - PAM issued: official notification that the subject equipment has been placed into operational status
  - Federal Project Director (FPD) approval of PAM: Subject equipment is considered operational; scope is retired from the project and assumed by the program.

Project Acceptance Memos (PAMs)

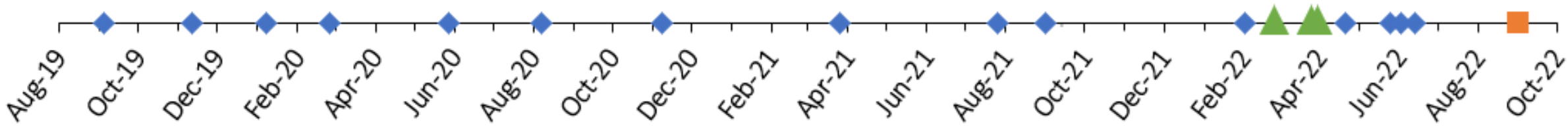
Why?

- PAMs follow the methodology behind *the life cycle replacement* approach, typical in industry-standard network upgrades (wide area and local area networks).
- PAMs allowed the ESnet6 project to transform a 24x7x365 *continuously operating facility* via multiple incremental phases.
- Retired project scope via PAMs allowed ESnet to *manage operational risks* and reduce total project + program expenses.
- Contractual obligations for colocation facilities and equipment maintenance are ongoing; PAMs provide a clear vehicle for cost transfers to the program with no interruption in services.



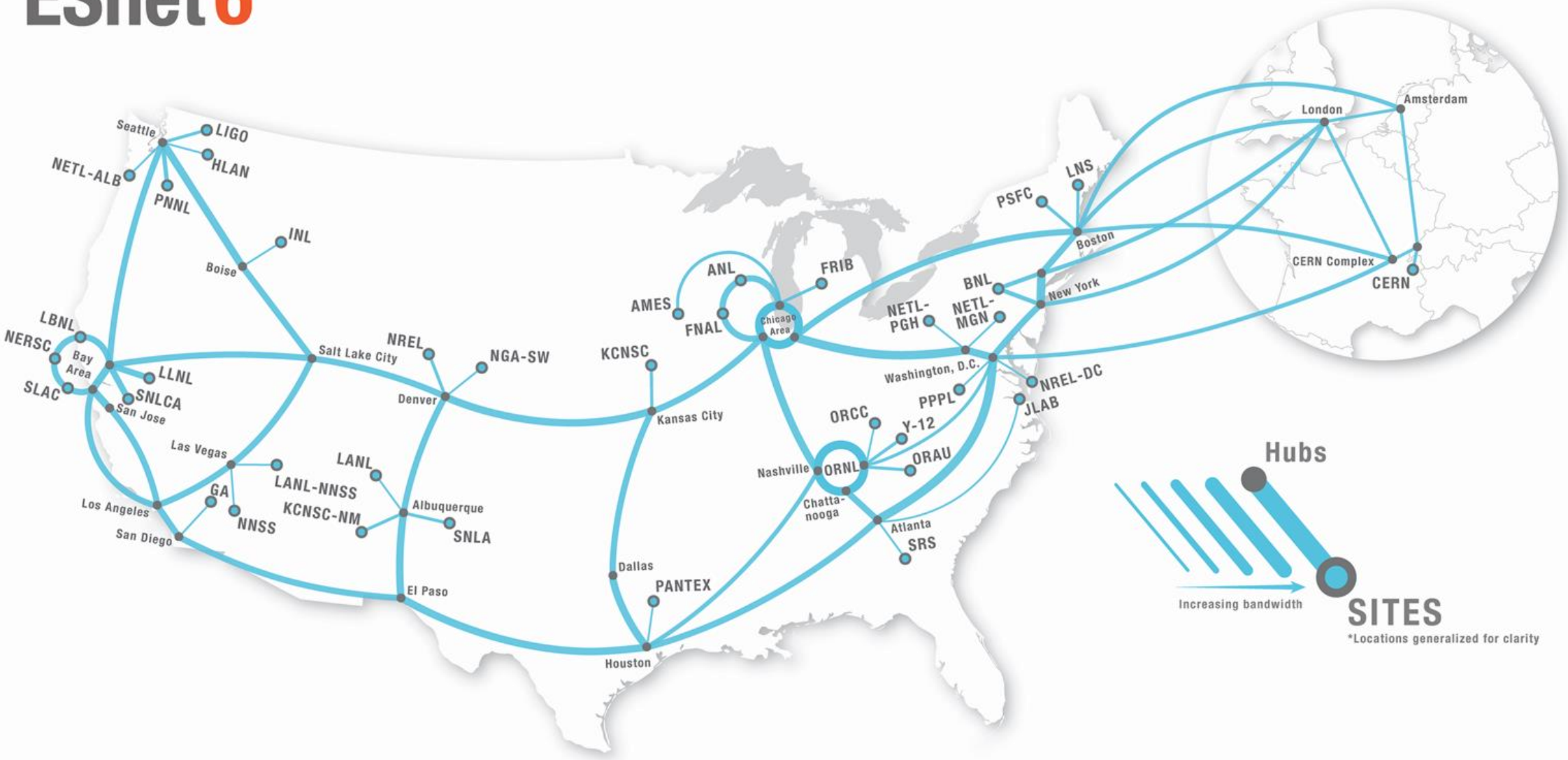
ESnet

Transition To Operations Timeline



- The project began transitioning scope to operations in September 2019 with the first PAM approval
- All Threshold KPPs were achieved in 2022
- CD-4 ESAAB Approval was achieved on July 29, 2022 at which time all scope was transitioned to operations

ESnet6



ESnet ENERGY SCIENCES NETWORK | BERKELEY LAB | U.S. DEPARTMENT OF ENERGY | Office of Science

ESnet


John Gann
Sukhada Gholba
Samuel Moats
Inder Monga
Eric Smith
Anne White
Dipak Ghosal
Robert Kobus
Michael Haberman
Nicholas Buraglio
Ling Liang
James Pittiglio
Garrett Stewart
Mariam Kiran
Basil Lalli
Sarah Larsen
James Kafader
Zach Harlan
Scott Campbell
Brian Eschen
Goran Pejovic
Alberto Jimenez
Susan Lucas
Nathan Miller
Jason Kang
Charles Ho
Luke Baker
Kate Mace
Sally Wine
Asma Samano
Patrick Storm
Tom Lehman
Patrick Dorn
Paul Wefel
Jackson Gor
Britt Gathright
Chris Cavallo
Chin Guok
Robert Holbrook
Evangelos Chaniotakis
Michael Sinatra
Christopher Cummings
Chris Robb
Ezra Kissel
Scott Richmond
Shawn Brown
Michael Blodgett
Cameron Jones
Paul Porter
Dylan Jacob
Gizella Kapus
Katrina Turner
Vlad Grigorescu
Bonnie Millenbaugh

Questions?