



U.S. DEPARTMENT OF
ENERGY



BERKELEY LAB



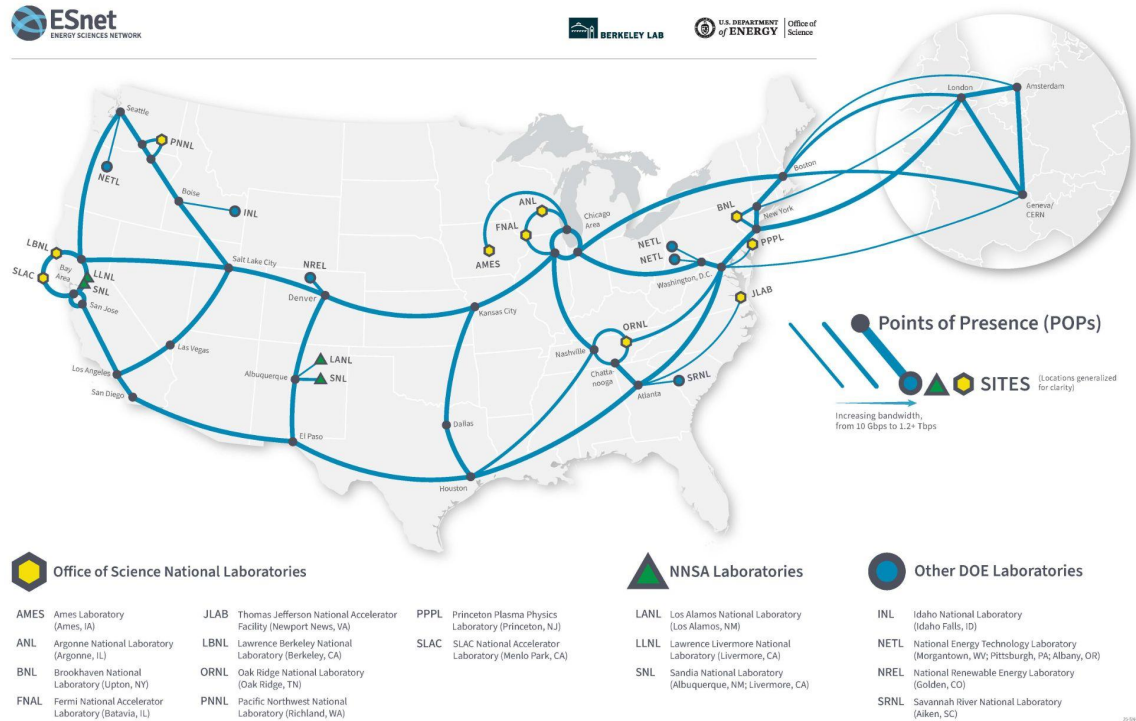
ESnet Provider Update

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ESnet is the DOE'S data circulatory system...

- ESnet supports the DOE scientific research ecosystem.
- Interconnects all national labs and user facilities
- Provides reliable, high-performance connectivity to global research collaborations, the Cloud, and the larger Internet.



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

>30,000
science
users

ASCR High End Computing (HEC) Argonne Leadership Computing Facility (ALCF)	Advanced Photon Source (APS)	Linac Coherent Light Source (LCLS)	BES X-Ray Light Sources Stanford Synchrotron Radiation Light Source (SSRL)	Advanced Light Source (ALS)	National Synchrotron Light Source II (NSLS-II)
Oak Ridge Leadership Computing Facility (OLCF)	Center for Functional Nanomaterials (CFN)	Center for Integrated Nanotechnologies (CINT)	BES Nanoscale Science Research Centers (NSRCs) The Molecular Foundry (TMF)	Center for Nanophase Materials Sciences (CNMS)	Center for Nanoscale Materials (CNM)
National Energy Research Scientific Computing Center (NERSC)	BES Neutron Scattering Facilities Spallation Neutron Source (SNS)	High Flux Isotope Reactor (HFIR)	BER Joint Genome Institute (JGI)	Environmental Molecular Sciences Laboratory (EMSL)	Atmospheric Radiation Measurement (ARM) user facility
ASCR High Performance Scientific Network Energy Sciences Network (ESnet)	FES National Spherical Torus Experiment - Upgrade (NSTX-U)	DIII-D National Fusion Facility (DIII-D)	HEP Facility for Advanced Accelerator Experimental Tests (FACET)	Fermilab Accelerator Complex	Accelerator Test Facility (ATF)
Argonne Tandem Linac Accelerator System (ATLAS)	Continuous Electron Beam Accelerator Facility (CEBAF)	Facility for Rare Isotope Beams (FRIB)	NP RHIC	PHENIX Relativistic Heavy Ion Collider (RHIC)	

The Strategic Balancing Act: 3+1 Competing Priorities

American Science Cloud (AmSC)



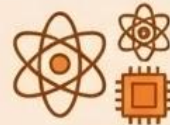
- Make DOE successful in its mission.
- **Tension:** Slowing down ESnet ops for critical projects.
- ~16 FTEs working on various aspects.
- Future funding may add ~8-16 FTE.
- Adding innovations like EJFAT.

ESnet7 (Facility Refresh)



- Critical network refresh.
- ESnet6 mission need was in 2016.
- Upgrade finished 2022, equipment from 2019-2021.
- Typical life: Servers 3-5y, Routers 7-10y, Optical 10-12y.
- By project end, all gear will be end of life.
- Zero runway to wait for ESnet8.

Genesis Mission: Strategic Quantum investment



- Strategic Imperative.
- **Tension:** Focus heavily shifting toward Distributed Quantum Computing.
- Focus on Distributed Quantum Computing and Quantum Data Center enablement.

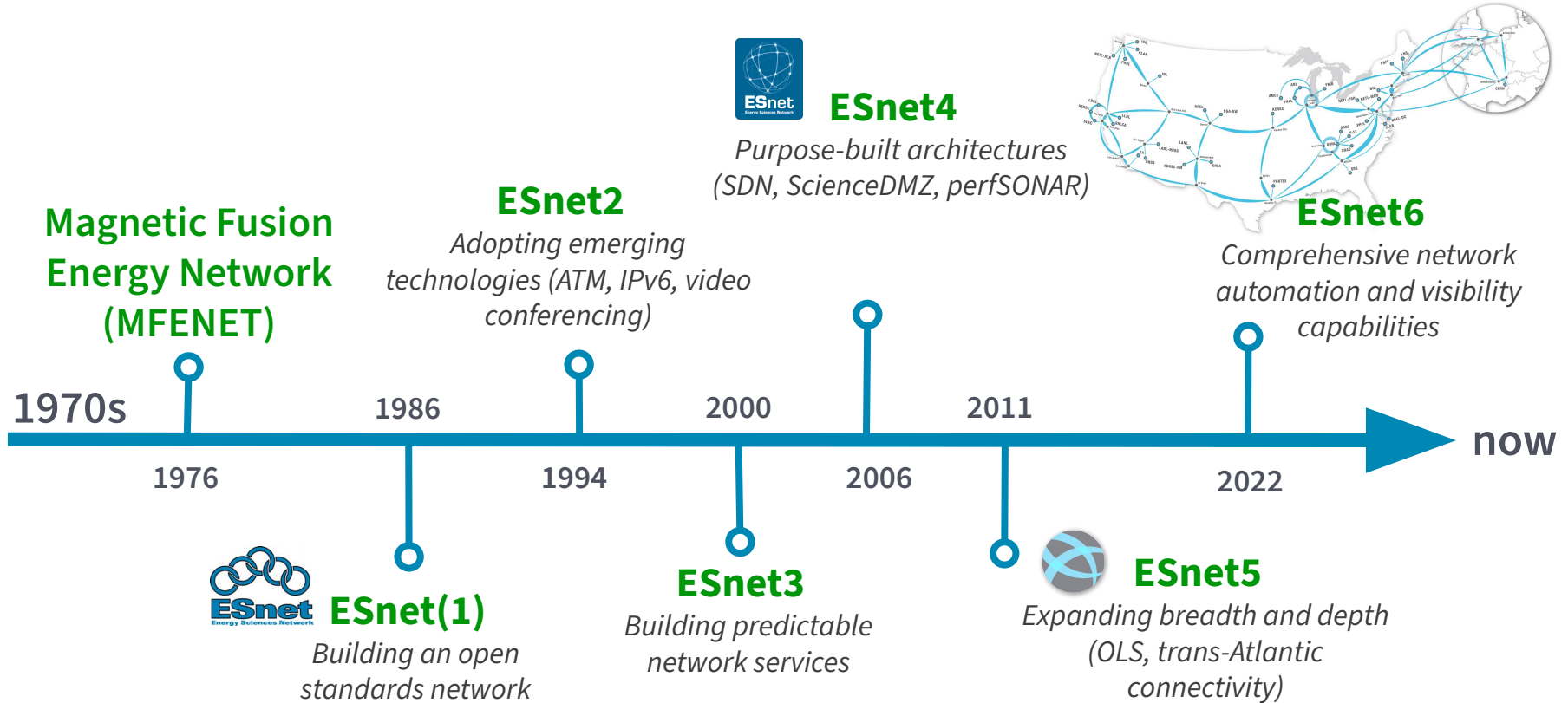


ESnet Operations: Critical to maintain current network

ESnet 7

- Next evolution of the ESnet network
- This is part of how ESnet gets its funding for larger network changes and hardware refreshes
- Have to use DOE project management planning process to start design and get approved
- Includes defining need and oversight through life of project
- Will be largely shaped by American Science Cloud and Genesis efforts

The evolution of ESnet's innovative infrastructure



Science requirements drive design and upgrades

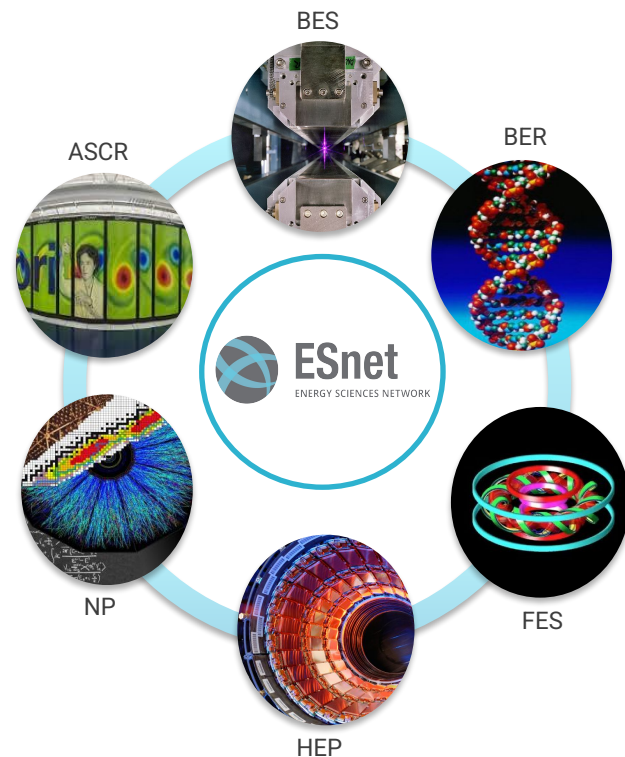
ESnet's Requirements Review program builds knowledge, understanding, and collaboration with DOE/SC programs and facilities allowing the larger ecosystem to learn from each other.

We capture:

- Major science experiments and facilities, both in operation and planned.
- The process of science used for knowledge discovery
- The volume of data produced now, and anticipated in the future, and where the data must be shared, computed and/or stored.
- The current technology capabilities (network, computation, storage, and software stack) plus planned upgrades, additions or improvements.

This dialogue provides the foundation for ESnet services and strategy.

ESnet's Requirements Review reports have become a strategically essential set of documents for the Office of Science.



Scientific Case Studies (14 Total, about 350pg)

- Cosmological Simulation Research
- Dark Energy Science Collaboration (DESC)
- Dark Energy Spectroscopic Instrument (DESI)
- The Vera C. Rubin Observatory (Rubin Observatory) & the Legacy Survey of Space and Time (LSST)
- Cosmic Microwave Background - Stage 4 (CMB-S4)
- Alpha Magnetic Spectrometer (AMS) Experiment
- Muon Experimentation at Fermilab
 - Muon G minus two ($g-2$)
 - Muon-to-electron-conversion experiment (Mu2e)
- Belle II Experiment
- Neutrino Experiments at Fermilab
 - Short-Baseline Neutrino Program (SBN)
 - The Deep Underground Neutrino Experiment (DUNE)
- Super Cryogenic Dark Matter Search (Super CDMS)
- Large Hadron Collider (LHC) Experimentation and Operation
 - ATLAS (A Toroidal LHC ApparatuS) Experiment
 - Compact Muon Solenoid (CMS) Experiment
 - LHC Operations
 - High Luminosity (HL) Era of the LHC

Requirement Review Network Findings

- **Data volume Increases:**
 - Across the board - PB era is now common for the large experiments. Small have graduated to TB scale
 - Frequency of production increasing, along with fidelity
- **Ability to support multi-facility workflows:**
 - Sensor, Computation, Storage, and People may all be in different locations - regularly.
 - Focus in DOE space: Integrated Research Infrastructure (<https://iri.science>)
 - Ability to execute 'near real-time' workflows is now routine (thanks R&E Networking Community!)
 - This is the only way we will scale - but requires significant coordination and cooperation
- **Cloud use:**
 - A significant number of workflows are now 'cloud-ready' and can burst there if the costs allow it
 - Some experiments have built successful hybrid model (Rubin): cloud 'front end' to support the users, backed against DOE-based storage and production/analysis computation.

The image features a blue background with a complex, white circuit-like pattern of lines and nodes. The lines are of varying thickness and form a dense, interconnected network. Small white circles are placed at various points along these lines, resembling nodes or data points. The overall aesthetic is clean, modern, and technical.

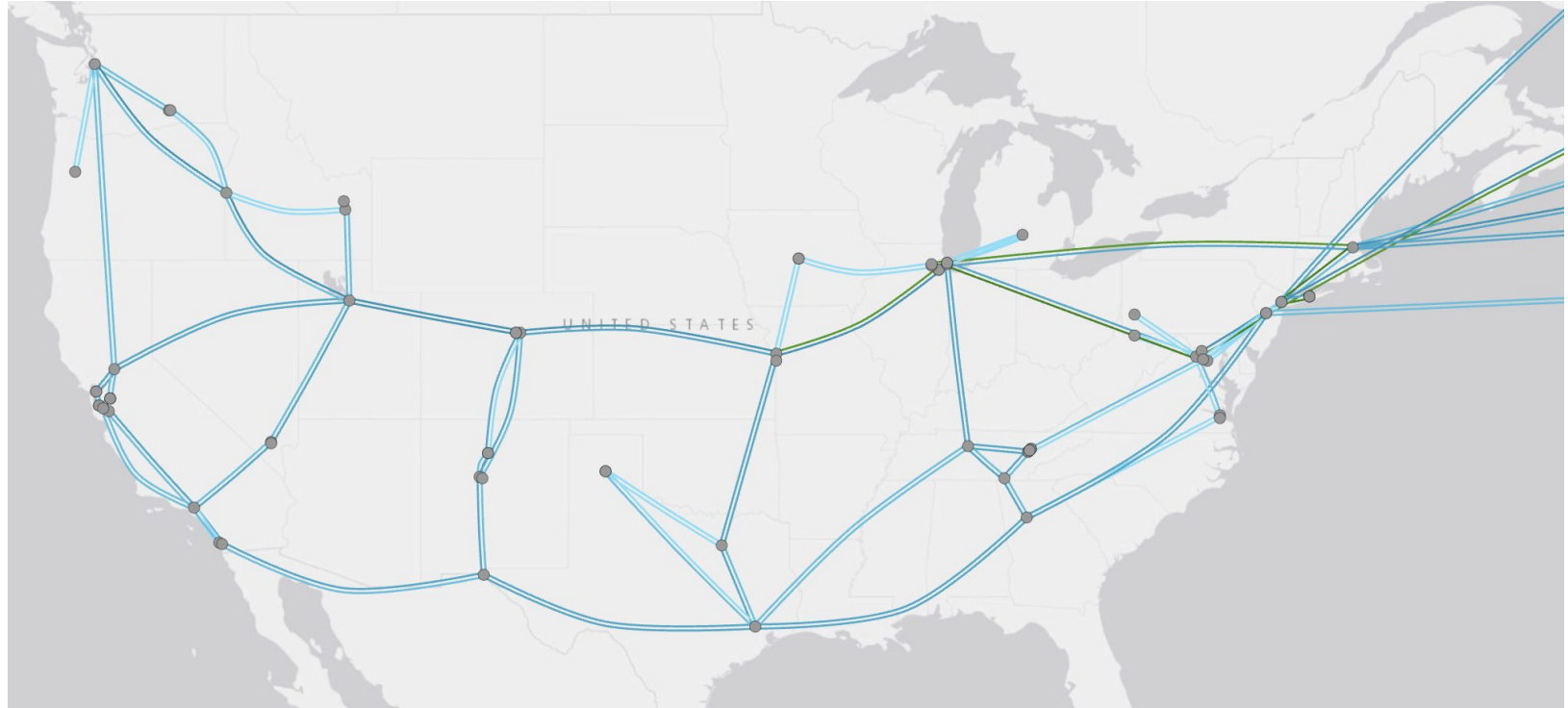
Network Engineering Updates

ESnet Network by the Numbers

- Individual core backbone links: 1.2Tb - 1.6Tb
- Aggregate backbone capacity: 84.5Tb
- Aggregate peering capacity: 14Tb
- Including 1.8Tb cloud interconnect capacity
- 7 out of 10 SC Labs connected at 400G or greater
- Including recent addition SLAC
- Aggregate Site connectivity: 24Tb

Core Backbone upgraded to 1.2T

- Entire core backbone network is at least 1.2T (3x400G)
- Upgraded to 4x400G in city areas - Chicago, New York
- Needed to accommodate large TA deployment



400G to Major Sites

ESnet is moving site connections to 400G for all of the larger laboratory sites, including:

- Fermi National Laboratory
- Brookhaven National Laboratory
- Argonne National Laboratory
- National Energy Research Scientific Computing Center
- Pacific Northwest National Laboratory
- SLAC National Accelerator Laboratory
- Oak Ridge National Laboratory

SR-2se Upgrades

- Nokia 7750 SR-2s (large config) platform
 - Deployed circa 2021 during ESnet6
 - Supports max 24 ports 400GE
 - Not enough port density at some PoPs
- As-needed, replacing with SR-2se
 - Next-gen FP5 packet forwarding ASIC
 - 72 port 400GE
- Completed:
 - CHIC, EQXCH2, STAR
 - NEWY32AOA, NEWY32HUDSON
 - WASH, EQXLD8



Cloud Connectivity

ESnet provides cloud connectivity through two methods:

1. Public Peering

Direct peering with major cloud providers via internet exchanges (IX) and private network interconnections (PNI).

2. Cloud Connect

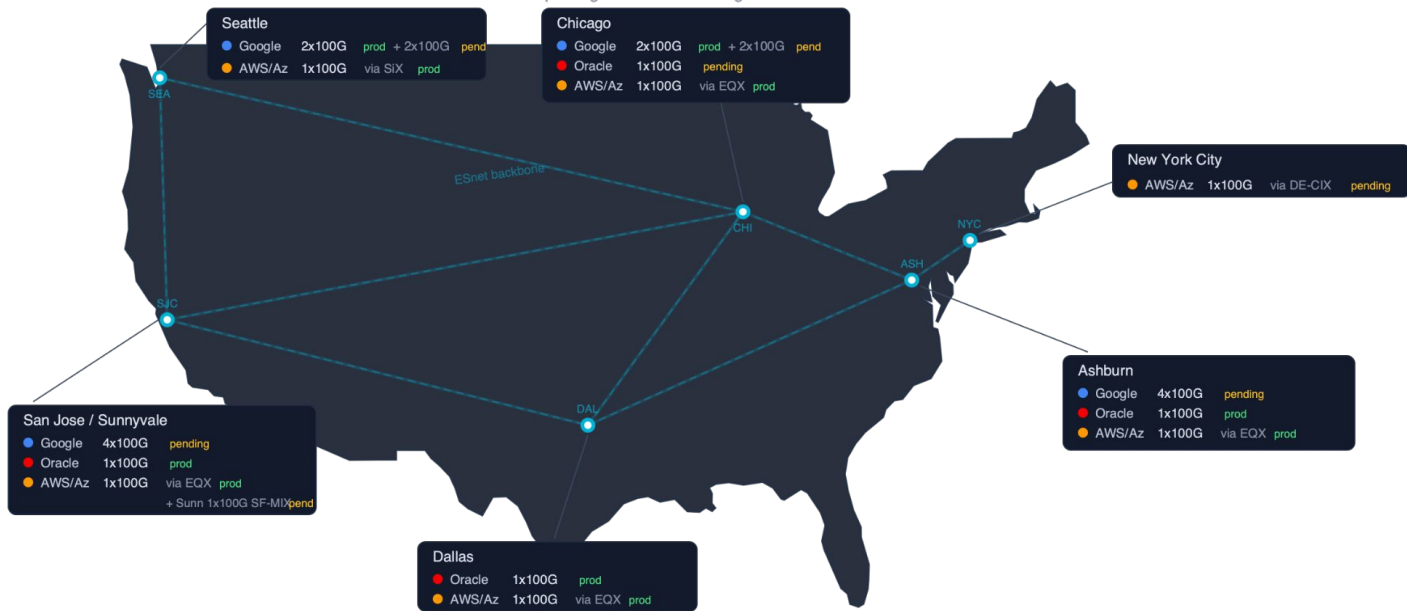
Private connections to Azure, AWS, and GCP for supported National Labs via high-availability OSCARS tunnels.

Key Benefits:

- Discounted egress fees
- Formal bridge between on-prem and cloud environments
- Bandwidth up to 10Gbps (hosted) or 400Gbps (dedicated)
- MACsec encryption (dedicated only)

ESnet Cloud Peering Connections

Direct peering at Internet Exchange Points across the United States



Aggregate Capacity			Totals			PLANNED TOTAL		
Google Cloud	400G prod + 1,200G pending	4 locations	Production	1.2 Tbps	across 12 links	2.7 Tbps	27 x 100G links	6 cities + Sunnyvale
Oracle Cloud	300G prod + 100G pending	4 locations	Pending	1.5 Tbps	across 15 links			
AWS / Azure	500G prod + 200G pending	7 locations (via IXPs)						

LEGEND ● Google Cloud ● Oracle Cloud ● AWS / Azure ● prod= in production ● pend = pending / planned IXPs: SIX, EQX (Equinix), SF-MIX, DE-CIX

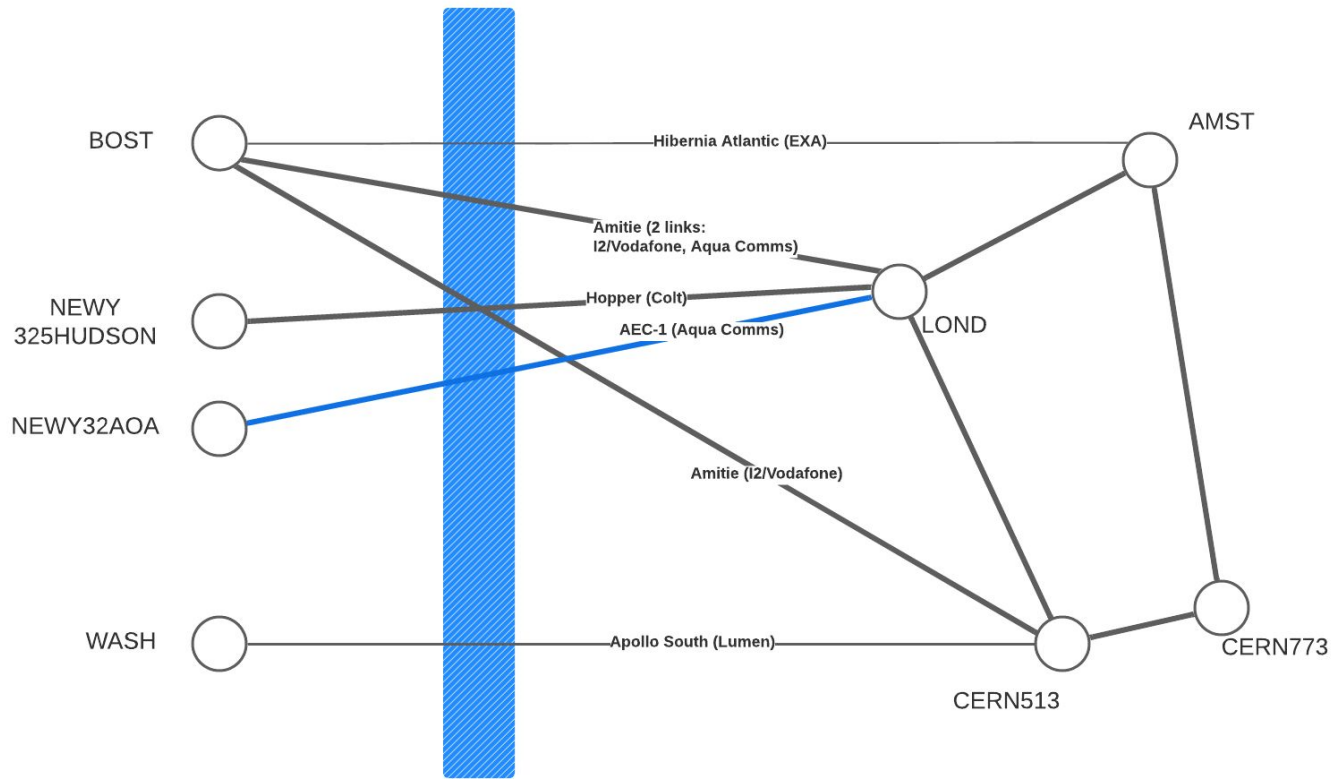
All links are 100 Gbps. AWS and Azure traffic is intertwined with commercial peering but cloud is the dominant force.



Trans-Atlantic Update

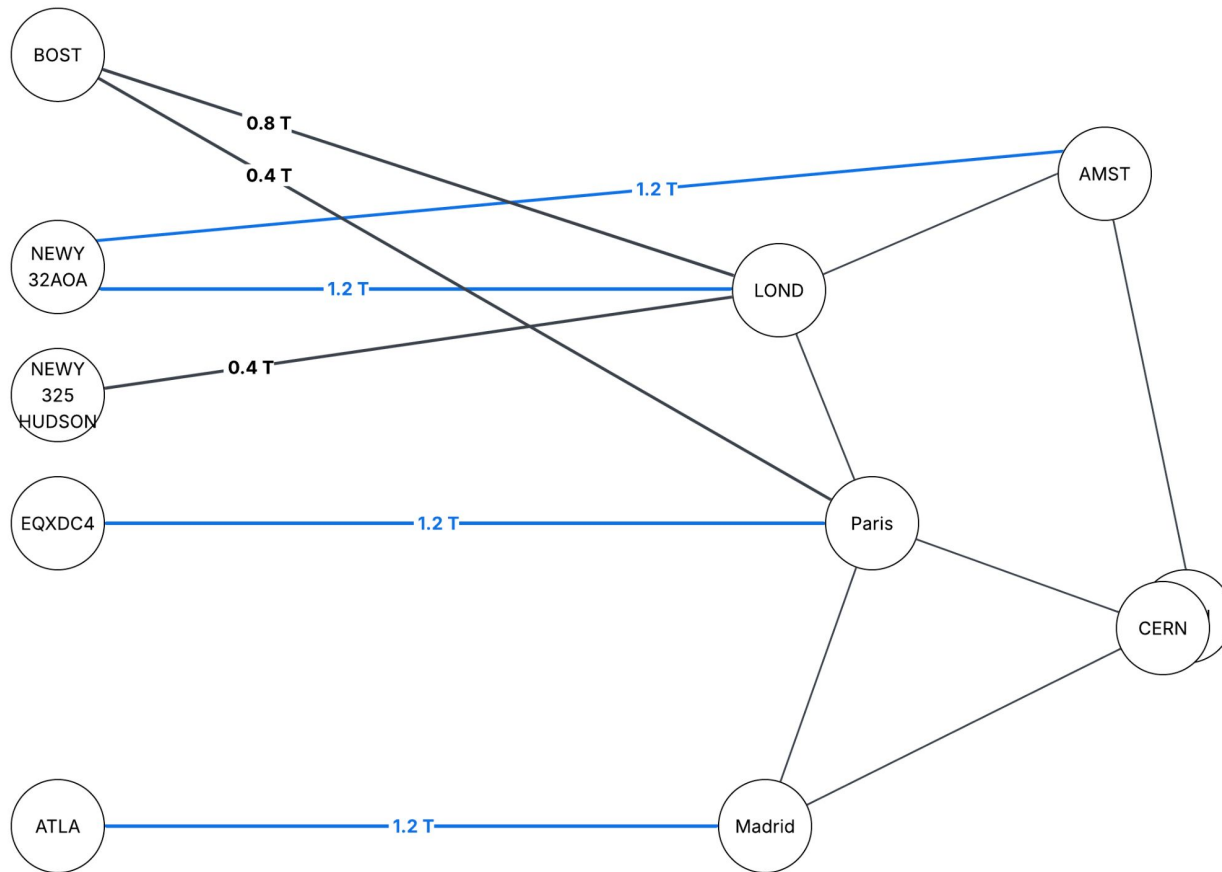
ESnet Trans-Atlantic Strategy

- Analysis from the science use cases in ESnet's 2020 HEP Requirements Review set multi-year plans into motion
- Components now coming into view
 - Procuring & lighting long-term use of spectrum
 - Diversity of cable routes
 - Partnerships between NRENs with Internet2 and GEANT
 - Upgrading some lit circuits to 400G
- ESnet is on track to meet and exceed the initial needs of the HL-LHC program by 2027 (3.2 Tbit/sec)
- Currently at 2.6 Tb capacity



- 100GE Lit capacity
- 400GE Lit capacity
- Spectrum capacity

Feb 2026 TA Connectivity Cable Details



Dec 2026 Target TA Capacity

- Primary long-term, bulk-spectrum capacity
- Ancillary capacity (resiliency, shorter-term, etc)

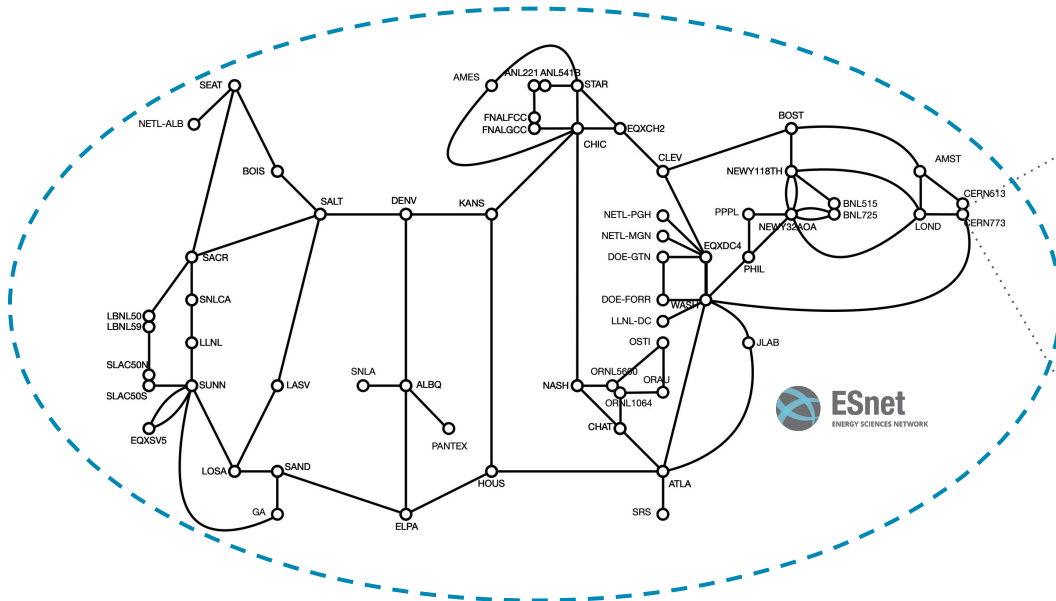
European Ring and new locations

- 3x400G lit circuits from GEANT currently between CERN-London-Amsterdam
- Adding new locations with hardware in Europe to accommodate new TA landing locations
- New location in Dublin with optical hardware installed
- Working on procuring space in Paris
- Future new location in Madrid
- Working with GEANT to find a solution to procure spectrum in lieu of lit circuits

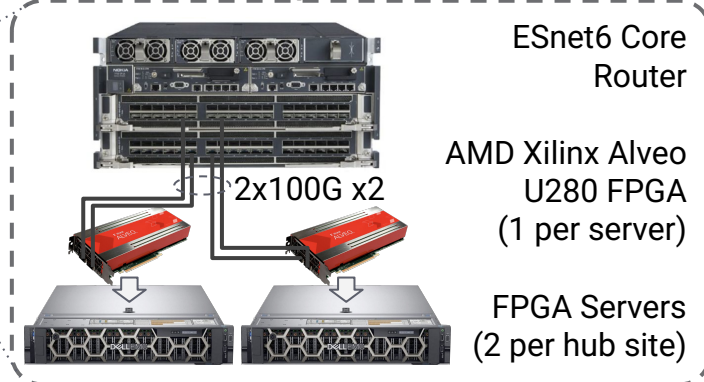


Measurement and Analysis (and AI)

ESnet6 High-Touch (HT) Platform Deployment



High-Touch Server Hardware Deployment



A combination of programmable hardware and software, placed throughout the network, to provide high-precision network measurements.

- O(40) deployment locations ("large router" sites)
- Focus: perimeter coverage*
- Router packet mirroring allows 100% packet inspection

ESnet High-Touch Telemetry Features

HT Flow Summaries (Unsampled)

- Provides big picture view of flows entering/exiting ESnet using unsampled packet headers
- Line rate hardware implemented meta analysis to augment flow summary information, e.g., packet size histogram, packet retransmission events*, packet loss events*.
- Integrated into ESnet's Stardust measurement system to leverage existing UX capabilities.
- Supports SQL queries against a relational database (Clickhouse) with a targeted capacity of ~1.5 trillion flows (30 days of network flows) for focused investigations

HT Full Network Captures (FUNCAP)

- Provides a network microscope function, enabling packet capture (first 128 bytes of each packet) of any flow entering/exiting ESnet
- Simple UI to automate deployment of packet capture filters along the ESnet High-Touch network perimeter
- Automated central collection, archiving, and packaging of packet capture information for user access

ESnet and AI

- ESnet deploying pilot project with LiteLLM
- LiteLLM is an open source AI gateway
- Users are granted access to four model groups:
 - esnet-anthropic — Claude models (Haiku, Sonnet, Opus) via Google Vertex AI
 - esnet-gemini — Google Gemini models via Vertex AI
 - esnet-3rdparty — Additional commercial and opensource models available through Vertex AI
 - cborg — On-prem models hosted by CBORG (LBNL)
- All requests to Anthropic and Gemini models are routed through Google Vertex AI — the same endpoint infrastructure used by LBNL's CBORG service. Data handling protections are equivalent to those in place for CBORG.
- LiteLLM will allow:
 - Monitor and control costs
 - track usage
 - API keys
 - Access control
 - Unified authentication and authorization
 - Security auditing

Claude skills + high-touch

- Wrote a skill file for both high touch and Rubin data flow
- Used Claude code via LiteLLM to analyze network diagram in conjunction with packet headers and network capture
- Claude created a summary of its findings



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Obrigado!

<https://my.es.net/>

<https://www.es.net/>

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