



U.S. DEPARTMENT
of ENERGY



BERKELEY LAB



ESnet
ENERGY SCIENCES NETWORK

Seamless WAN, Happy Users

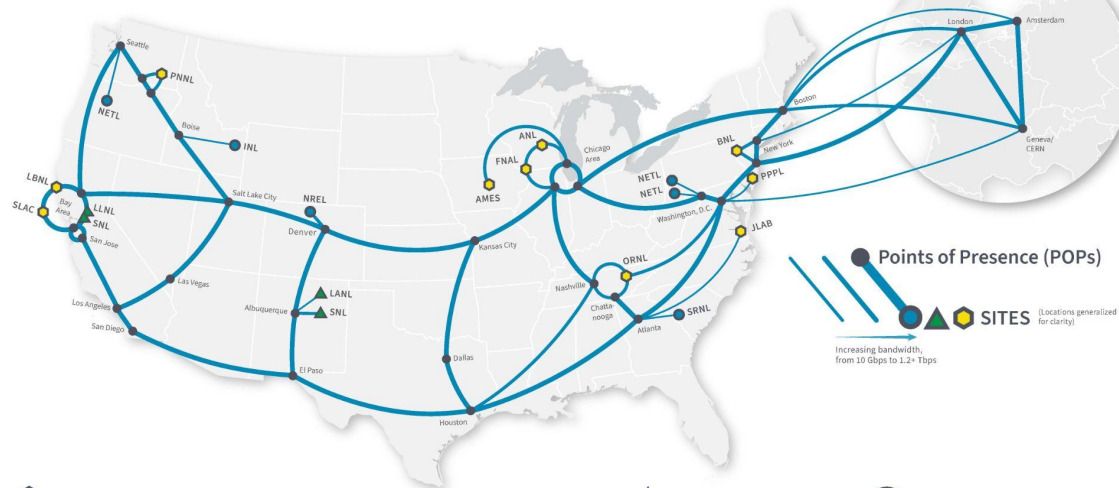


Justas Balcas
ESnet
Software Engineer

6GRP/eScience 25
Chicago, Illinois
2025-09-15

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.



Office of Science National Laboratories

AMES Ames Laboratory (Ames, IA)	JLAB Thomas Jefferson National Accelerator Facility (Newport News, VA)	PPPL Princeton Plasma Physics Laboratory (Princeton, NJ)
ANL Argonne National Laboratory (Argonne, IL)	LBNL Lawrence Berkeley National Laboratory (Berkeley, CA)	SLAC SLAC National Accelerator Laboratory (Menlo Park, CA)
BNL Brookhaven National Laboratory (Upton, NY)	ORNL Oak Ridge National Laboratory (Oak Ridge, TN)	
FNAL Fermi National Accelerator Laboratory (Batavia, IL)	PNNL Pacific Northwest National Laboratory (Richland, WA)	



NNSA Laboratories

LANL Los Alamos National Laboratory (Los Alamos, NM)
LLNL Lawrence Livermore National Laboratory (Livermore, CA)
SNL Sandia National Laboratory (Albuquerque, NM; Livermore, CA)



Other DOE Laboratories

INL Idaho National Laboratory (Idaho Falls, ID)
NETL National Energy Technology Laboratory (Morgantown, WV; Pittsburgh, PA; Albany, OR)
NREL National Renewable Energy Laboratory (Golden, CO)
SRNL Savannah River National Laboratory (Aiken, SC)

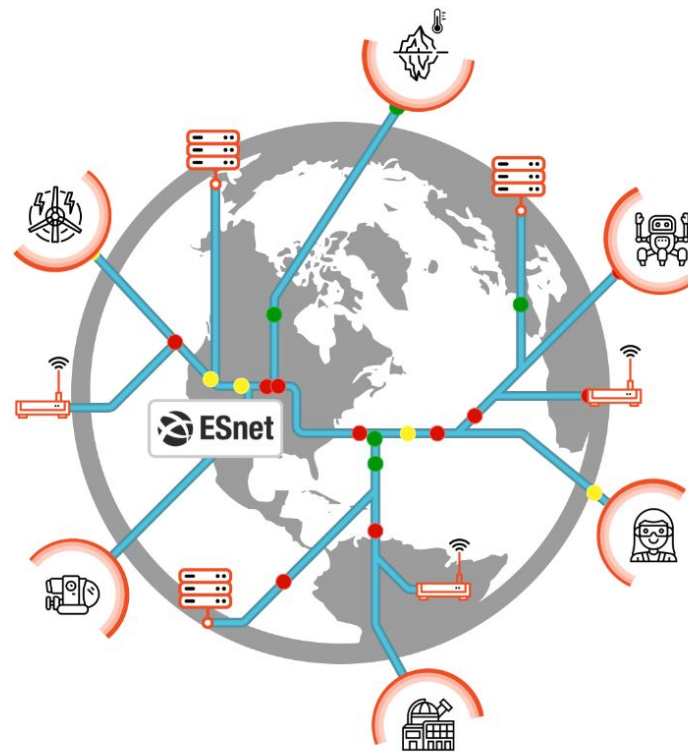
...and the stage for a global science laboratory.

ESnet's Vision

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

ESnet's Mission

Networking that accelerates science.



ESnet by the Numbers

ESnet Connects



17

National laboratories



28

DOE user facilities (including ESnet)



277

R&E, commercial, and other networks (in 5 countries including U.S.)



31K

Organizations around the world



99.99%

Site uptime*



4.88

Overall user satisfaction rating (out of 5), 2024

ESnet Comprises



15K Miles

of dedicated fiber-optic cable*



78

Router sites*



278

Amplifier sites*



48

U.S. sites connected at 400 Gbps or higher

Capabilities



400 Gbps to 1.2 Tbps

Network backbone**



57 Tbps

Aggregate capacity**



2.7 Tbps

Trans-Atlantic capacity**



1.8 Exabytes

Transited ESnet in 2024

**ESnet is measured and expected to provide 99.9% site uptime. The network regularly exceeds that standard, providing near 100% uptime to almost all connected sites.*

***From the 2024 ESnet Site Coordinators Committee survey*

The ESnet Team

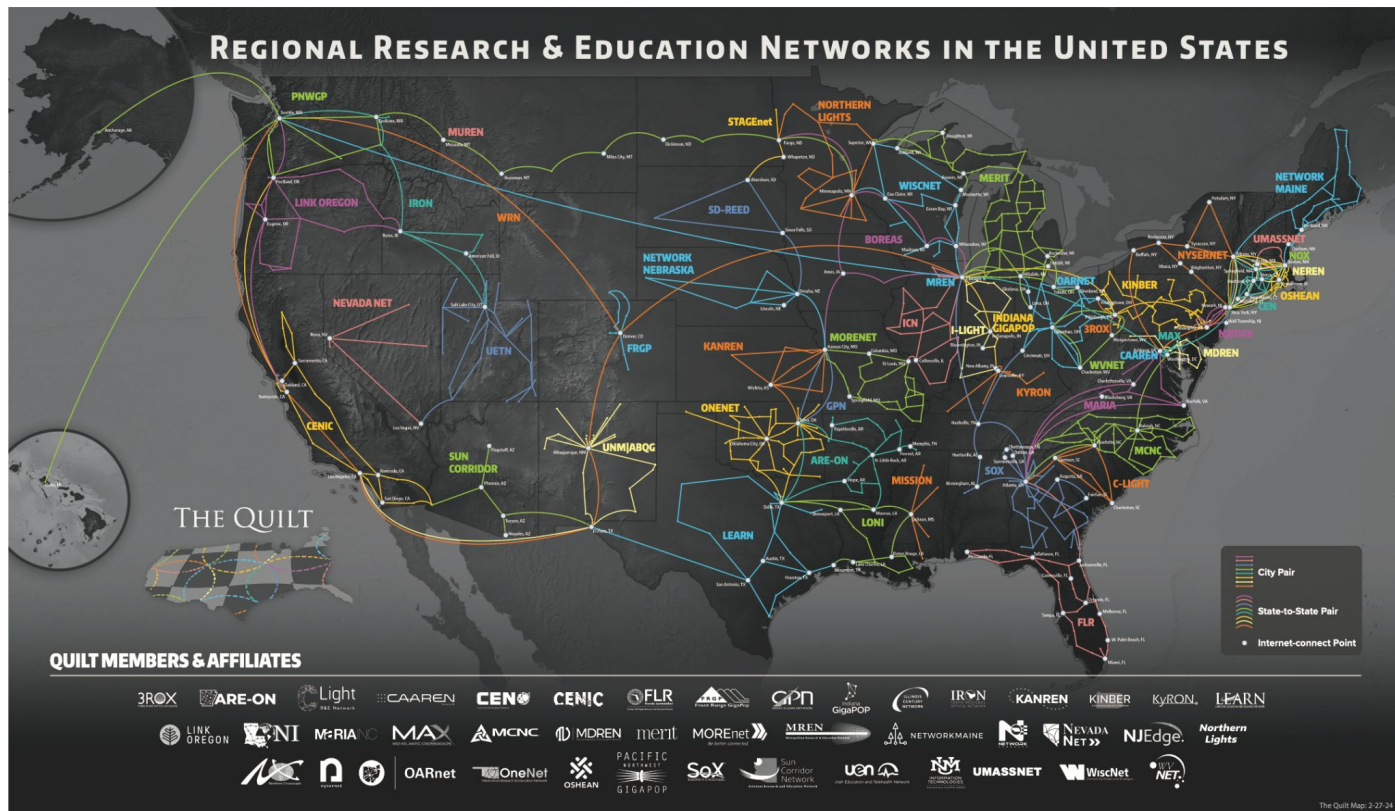
 **142**
Staff and subcontractors

 **22**
States

**As of June 2025*



We are Part of a Larger Community





**Connecting the Dots Before the
Elephants Trip Over Them**

Our Philosophy



- **Understand Science Needs:** Anticipate where science is going
 - We listen to our users through requirement reviews, public forums, and daily interactions.

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- **Collaborate:** Work with our users to build what they need
 - We develop foundational network services, add-on software services, and domain specific solutions.
 - With our partners we rapidly prototype new concepts.

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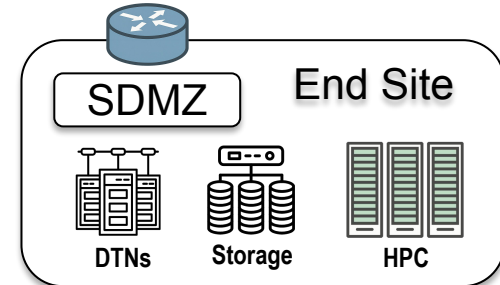
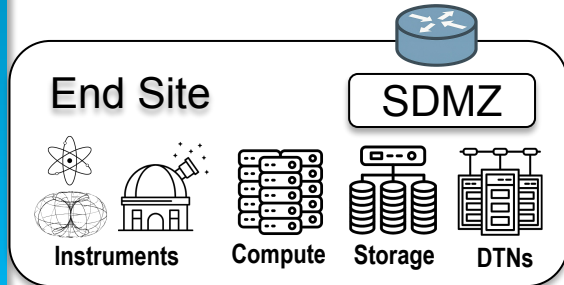


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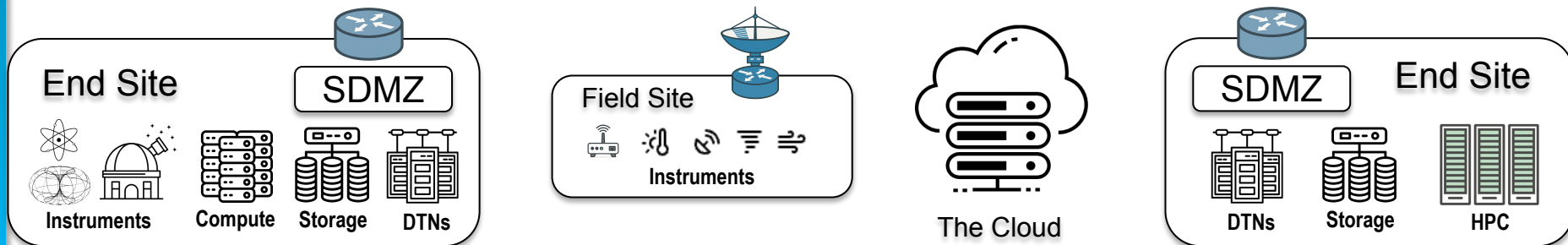


- **Co-design:** Consult, design, test, and support
 - Deliver capabilities within the network that can be programmatically consumed by your scientific workflows.
 - Provide solutions to control resources not only within ESnet, but wherever resources are consumed.

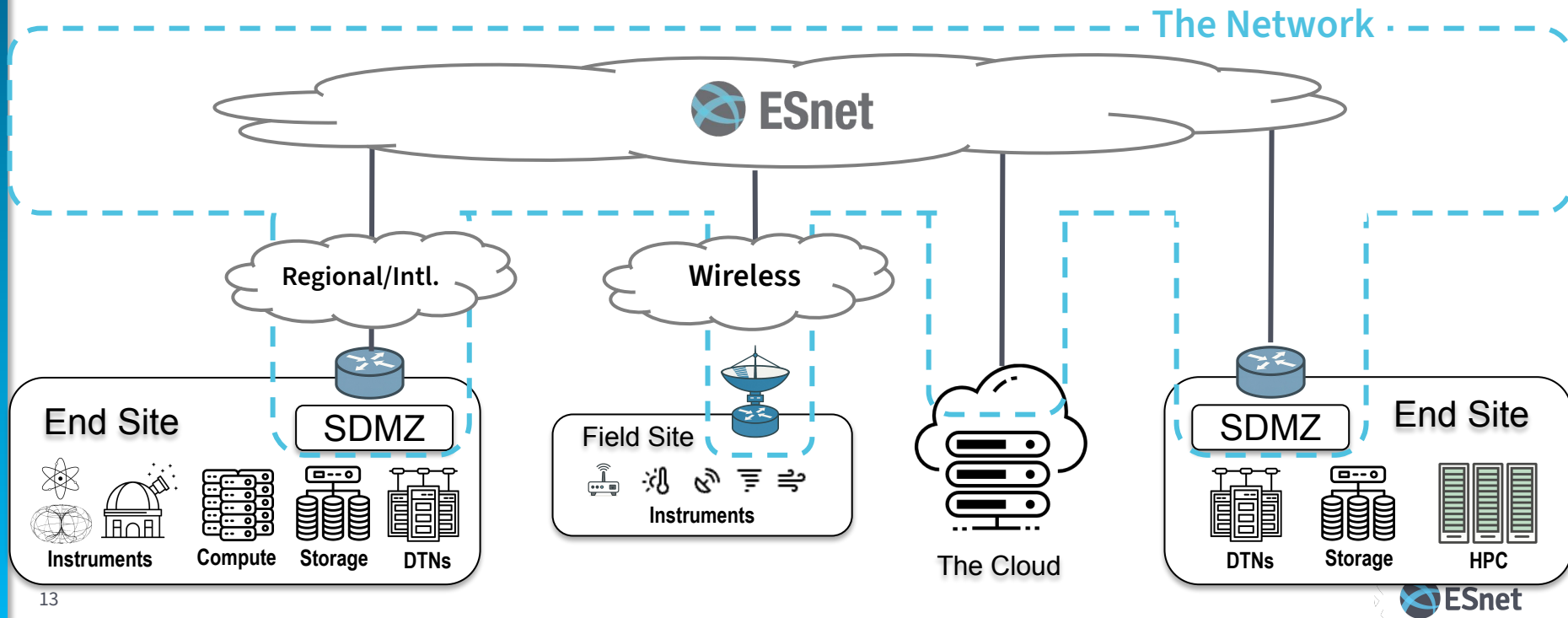
The Evolving Research Infrastructure



The Evolving Research Infrastructure



The Evolving Research Infrastructure



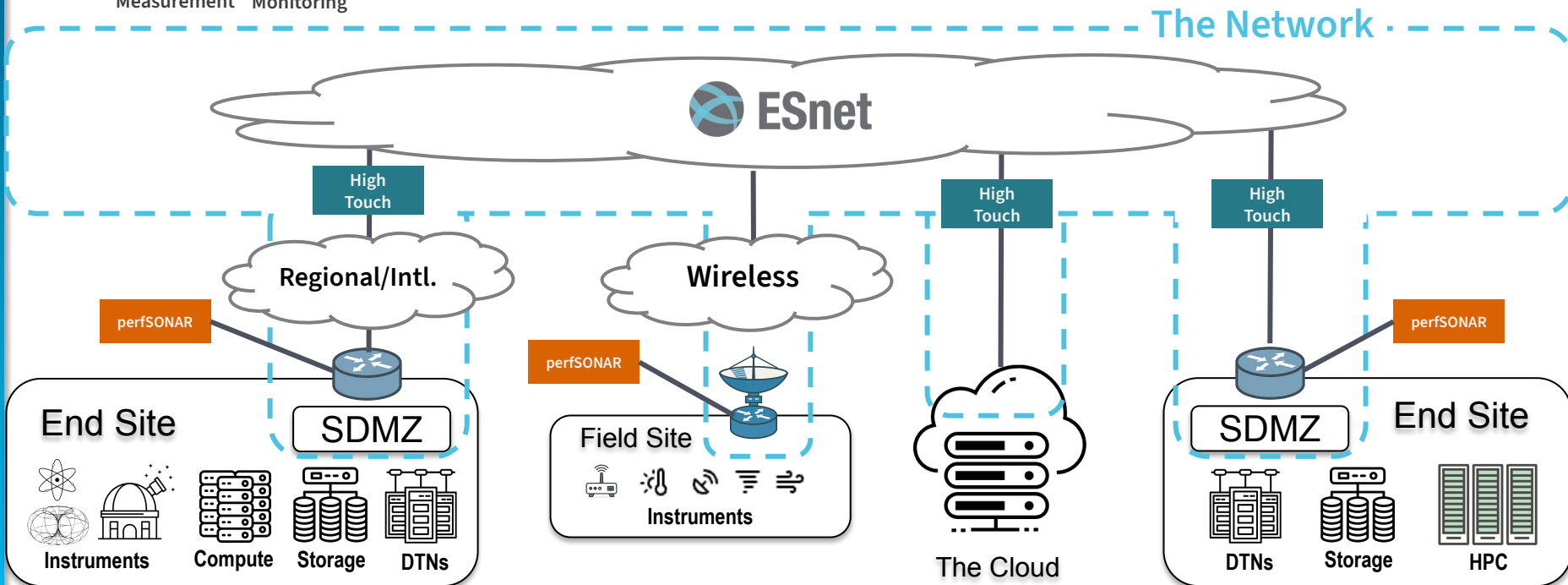
The Evolving Research Infrastructure



Measurement



Monitoring



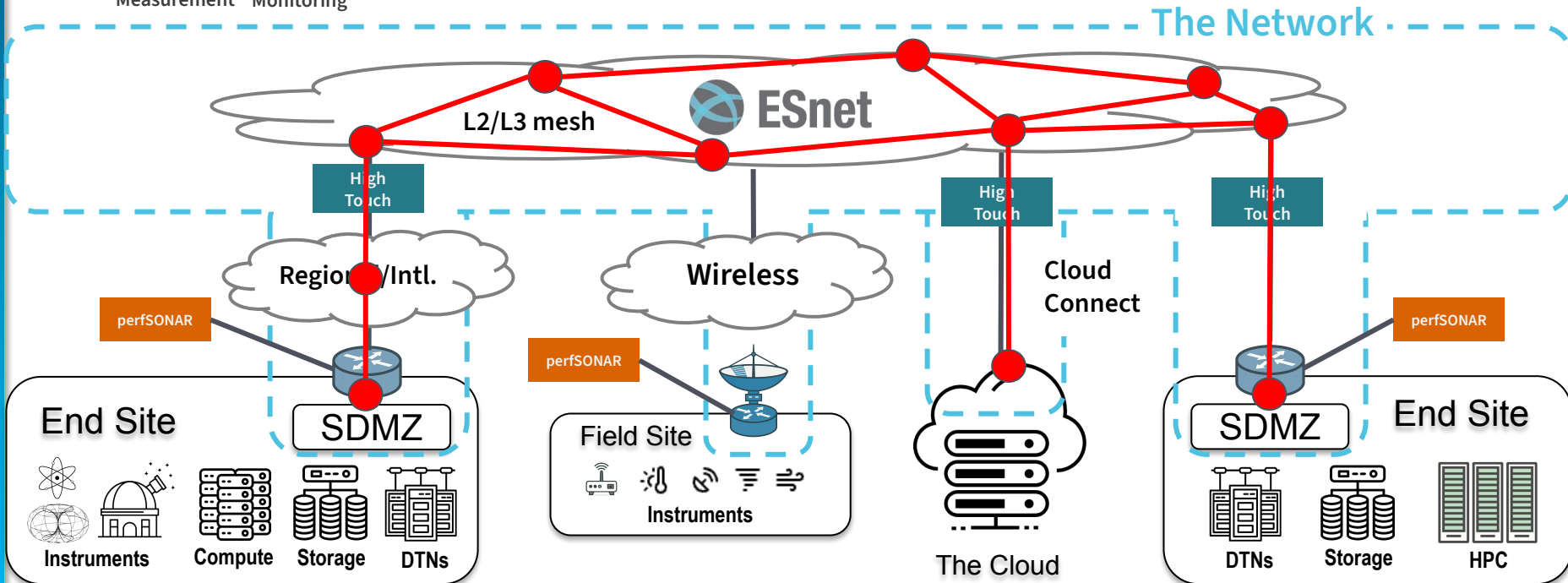
The Evolving Research Infrastructure



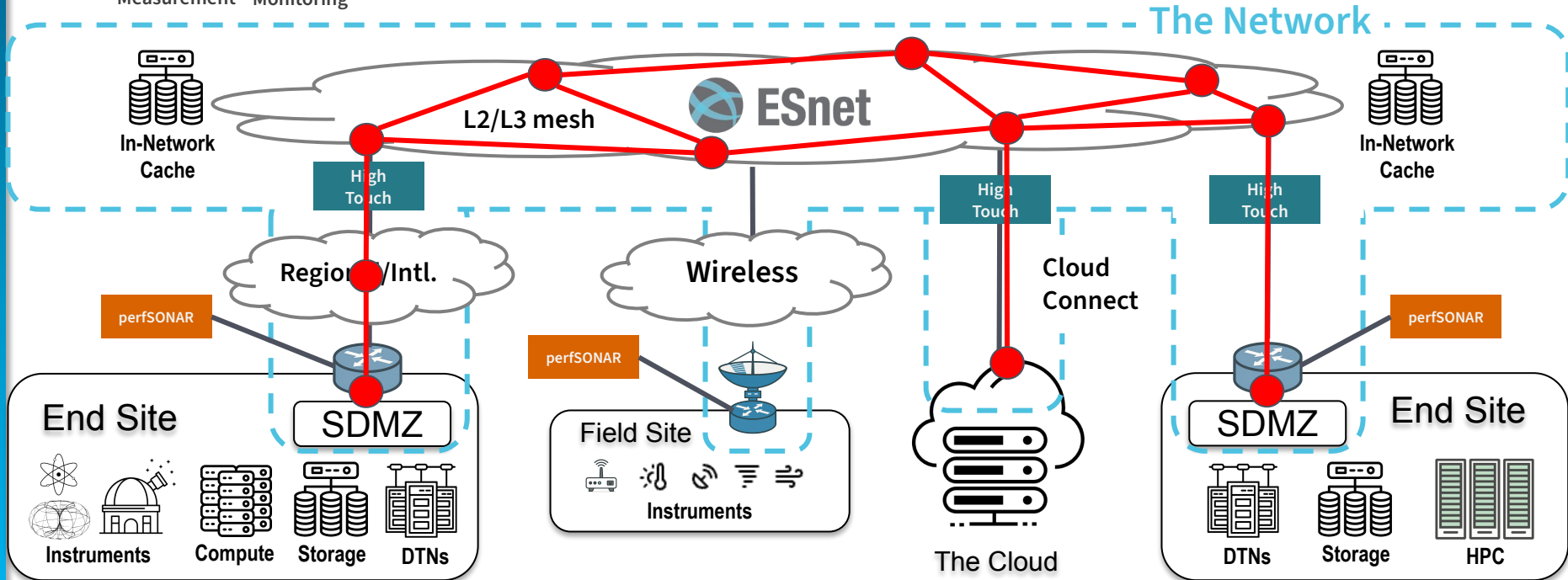
Measurement



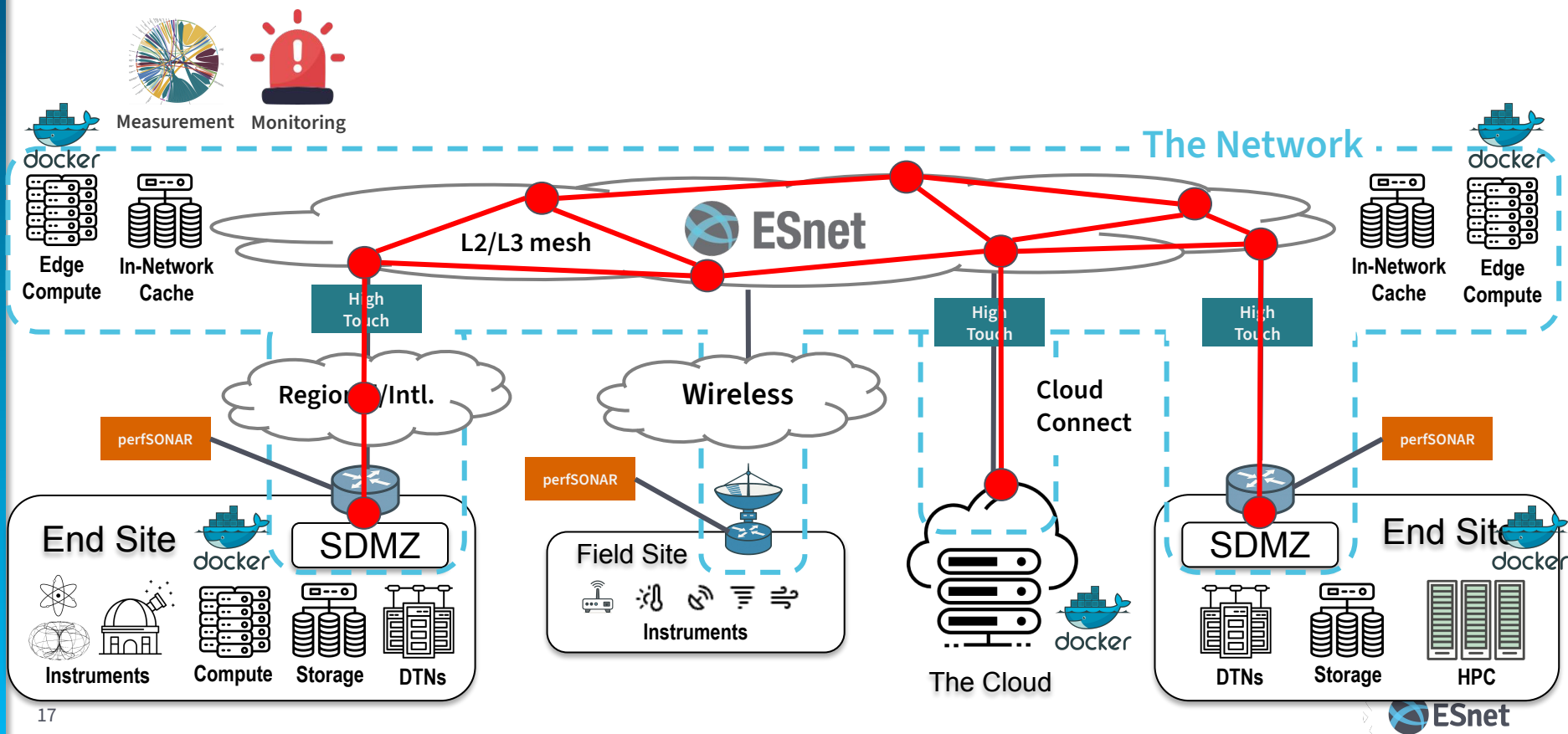
Monitoring



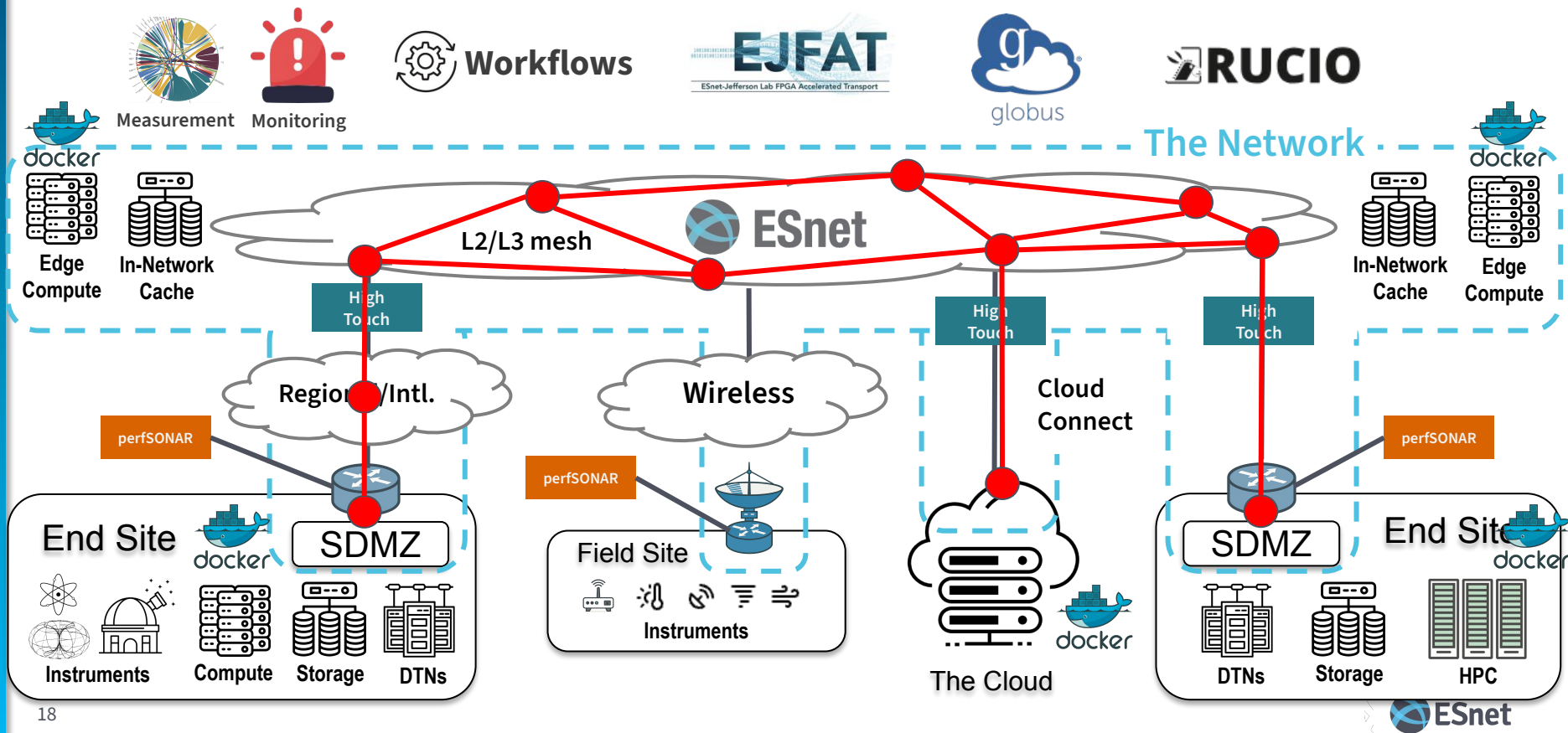
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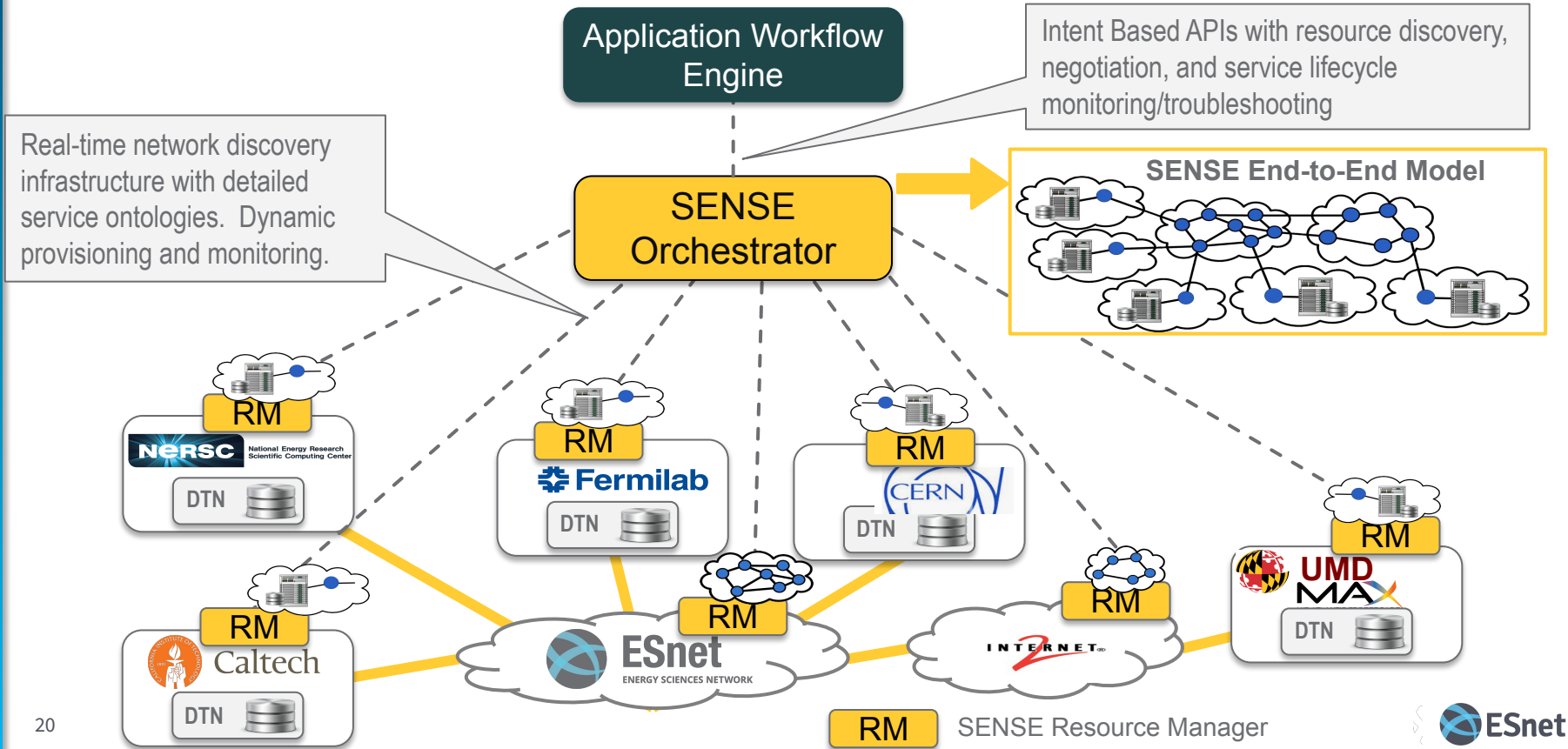
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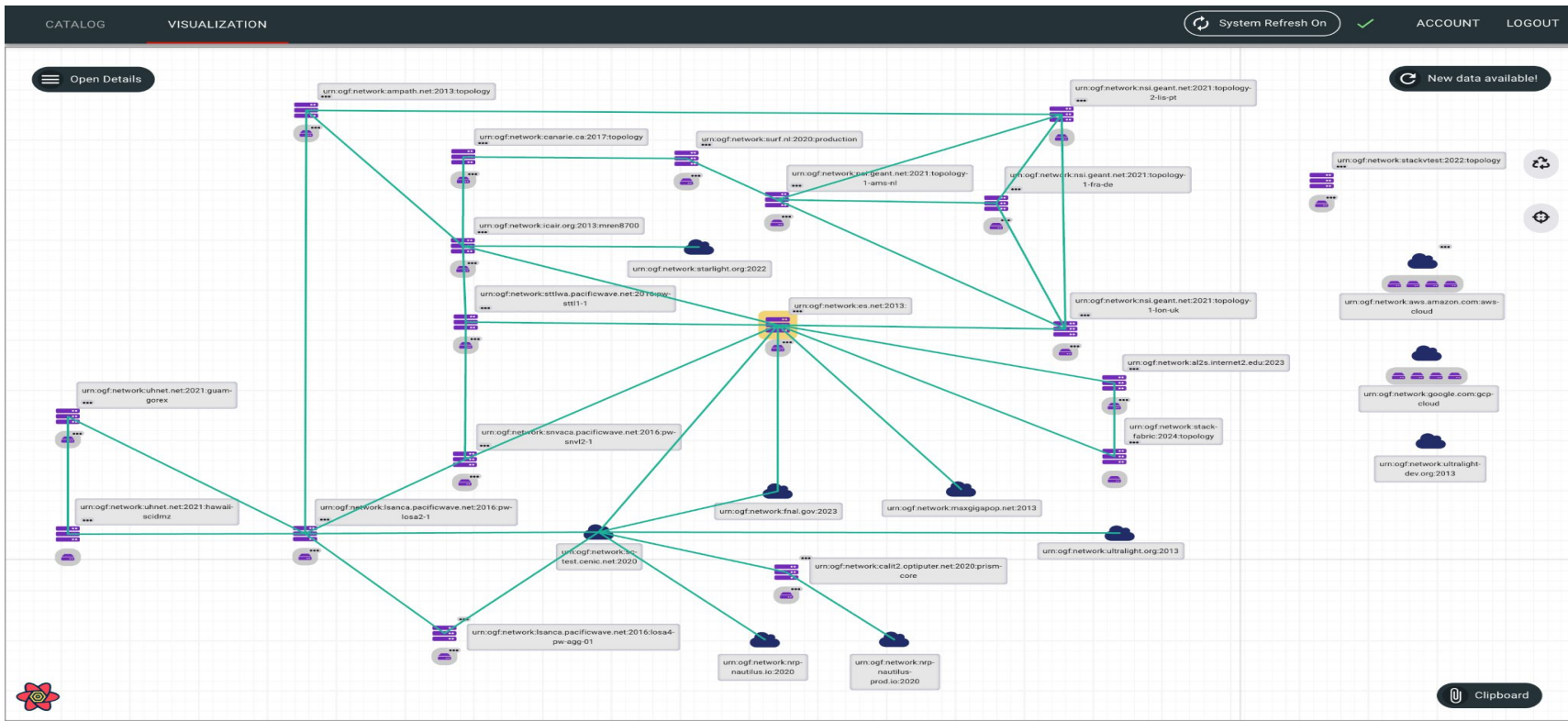


Breaking Barriers, Linking Everything

The API-Driven SENSE Architecture



AutoGOLE Testbed - Real Time Topology Model



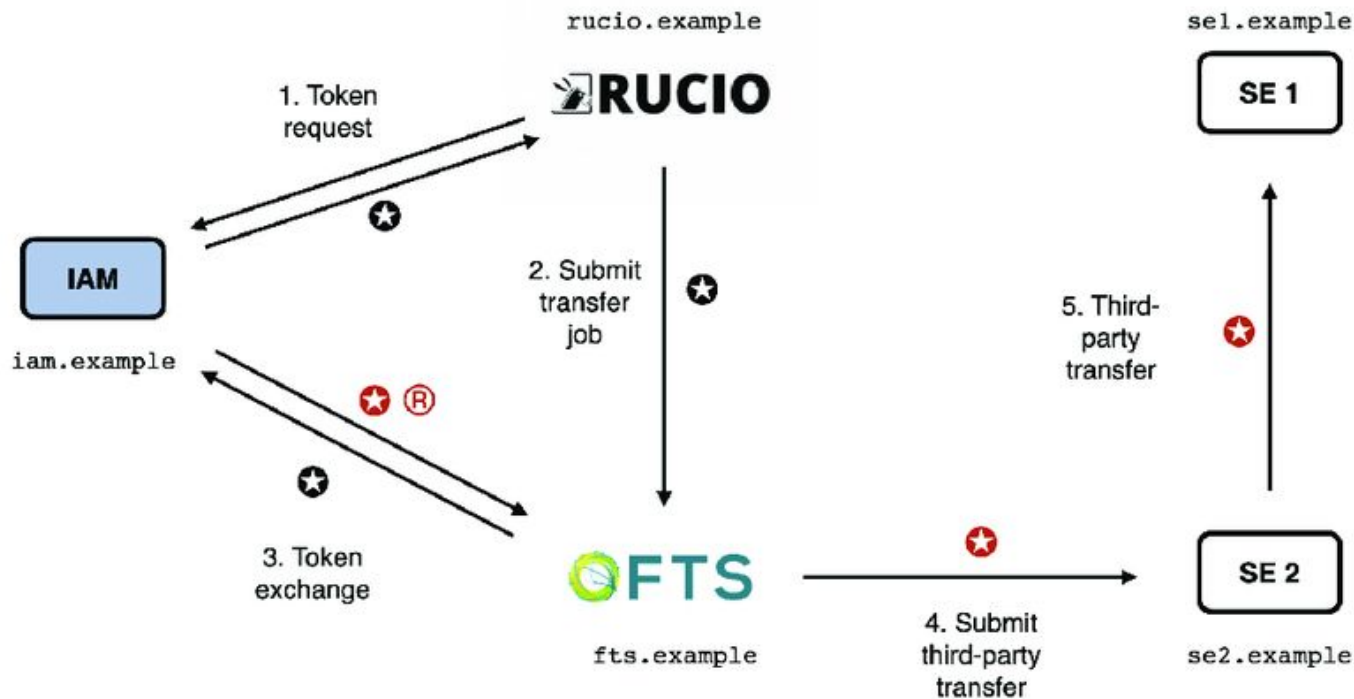
Supported Services by SENSE

- Layer 2 (end-to-end)
- Layer 3 BGP
- Layer 2 Multi-point (many-to-many)
- Layer 3 BGP Multipath
- QoS (on Hosts - traffic shaping/traffic police)
- QoS (on Network devices - limited support)
- Public Cloud Access
- Realtime per service monitoring and status verification
- Automatic recovery, monitoring:
 - reboot, vlan removal, port down - noticed, alerted, auto-recovered if possible.

<https://app.swaggerhub.com/apis/xi-yang/SENSE-RM-API/1.0.0>

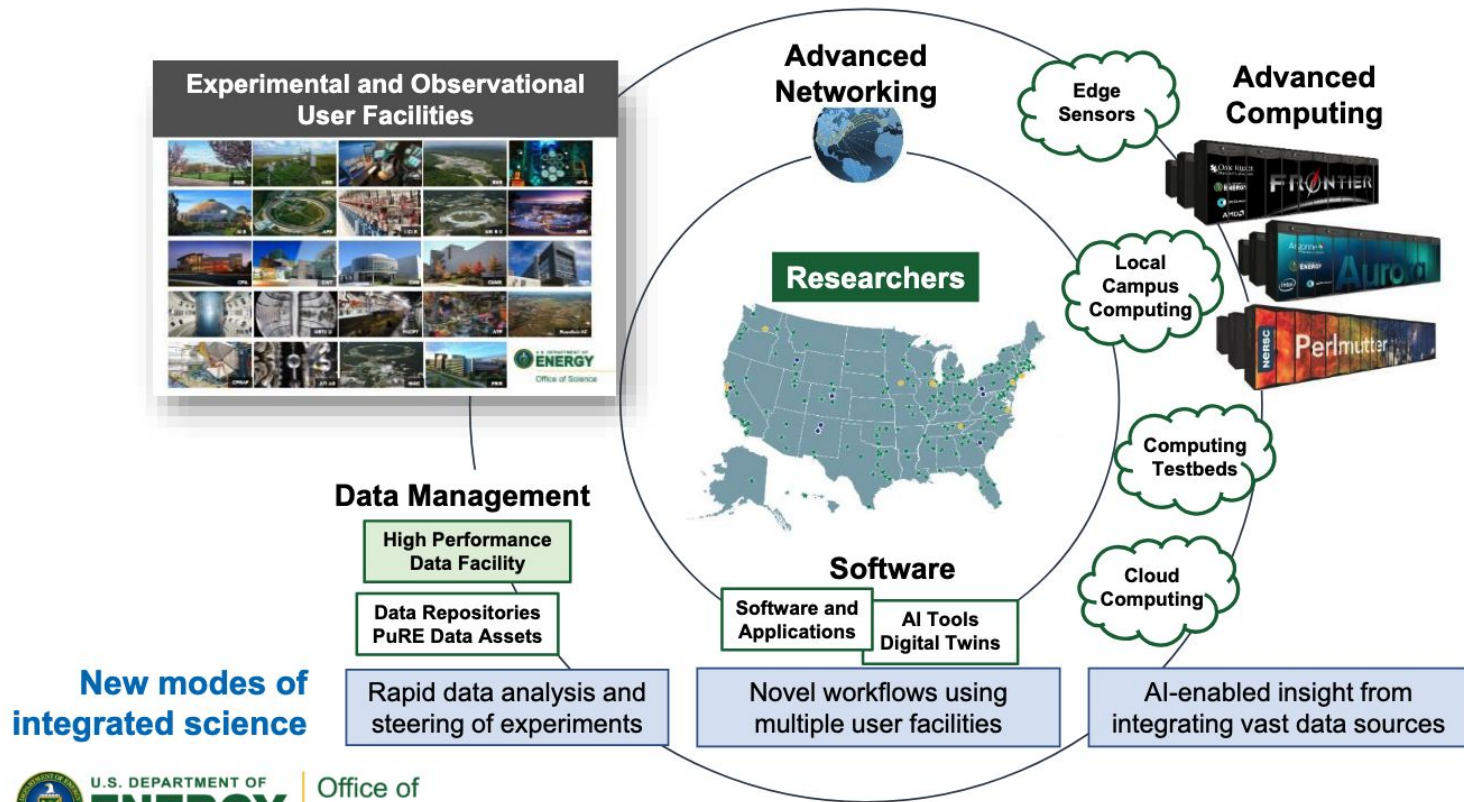
GET	/models	Pull MRML model(s) from the RM	📄 ↶ Ⓞ ▼
POST	/deltas	Propagate MRML model delta to the RM (push phase I)	📄 ↶ Ⓞ ▼
PUT	/deltas/{id}/actions/commit	Commit a propagated delta to the RM (push phase II)	📄 ↶ Ⓞ ▼
GET	/deltas/{id}	Get delta status from the RM	📄 ↶ Ⓞ ▼

Scientific Data Management (LHC, CMS, ATLAS)



DOE's Integrated Research Infrastructure (IRI) Vision:

To empower researchers to meld DOE's world-class research tools, infrastructure, and user facilities seamlessly and securely in novel ways to radically accelerate discovery and innovation



U.S. DEPARTMENT OF
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Office of
Science

What will future automated IRI look like? Here is but one example...

Compute Reservations via API

Q: How do we provide real-time compute *without* lowering utilization?

A: Policy-driven compute reservations, requested via API from EOD workflows.

*Paradigm
buster!*

One brief moment in the life of the Superfacility API . . .



User
Workflow
Manager

GIVE ME ALL OF THE GPU NODES NEXT WEDNESDAY.

REQUEST DENIED DUE TO GLUTTONY.

MY APOLOGIES. INSTEAD GIVE ME 10 GPU NODES
NEXT WEDNESDAY AT 2:00 FOR 4 HOURS.

YOUR RESERVATION IS 8D7A392D. YOU MAY SUBMIT
JOBS INTO IT UNTIL NEXT WEDNESDAY AT 5:59.

THANK YOU AND HAVE A NICE HUMAN-DAY.



Superfacility
API



Linac Coherent Light Source at SLAC

4



NERSC at LBNL

+ Data transport reservations via API

ESnet6



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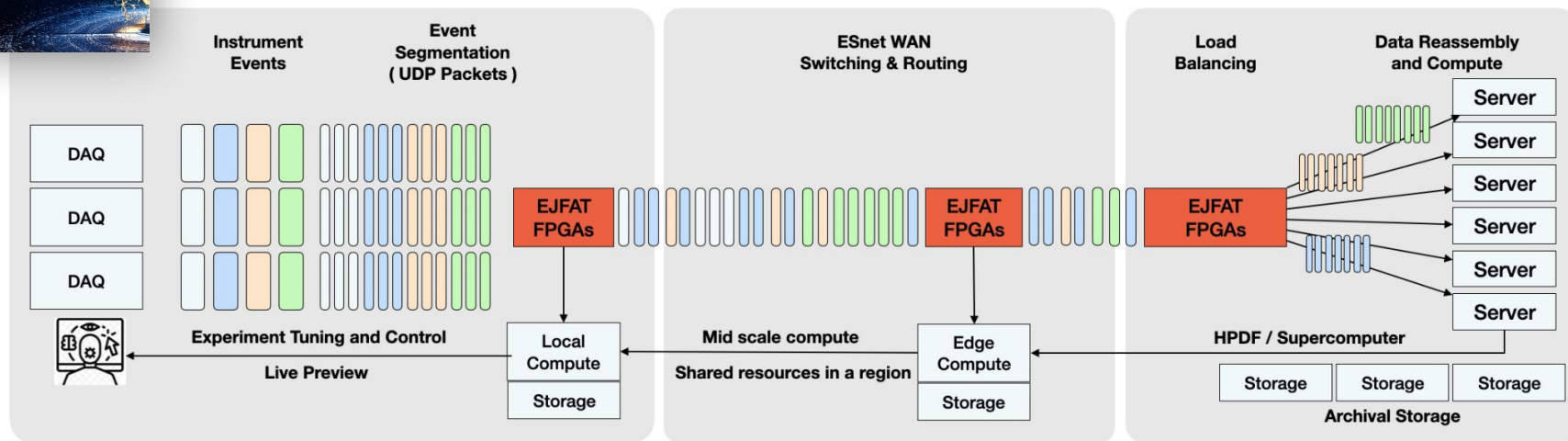
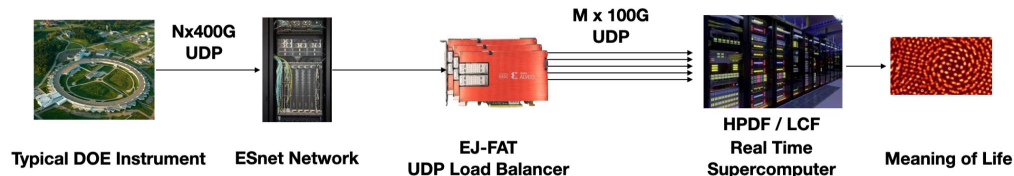
Example from Cory Snaveley, NERSC
EOD = experimental and observational data users

EJFAT: An IRI / HPDF Streaming Load Balancer



IRI Blueprint identifies the need for **real time streaming** and compute

HPDF takes on the challenge and ESnet jointly develop the hardware and software to stream from **any instrument to any LCF**



Significance and Impact :

- High performance (Terabit scale) streaming into supercomputers
- Secure and IT operations friendly interconnection of different national labs
- Reliable and high fidelity data processing and storage for better science

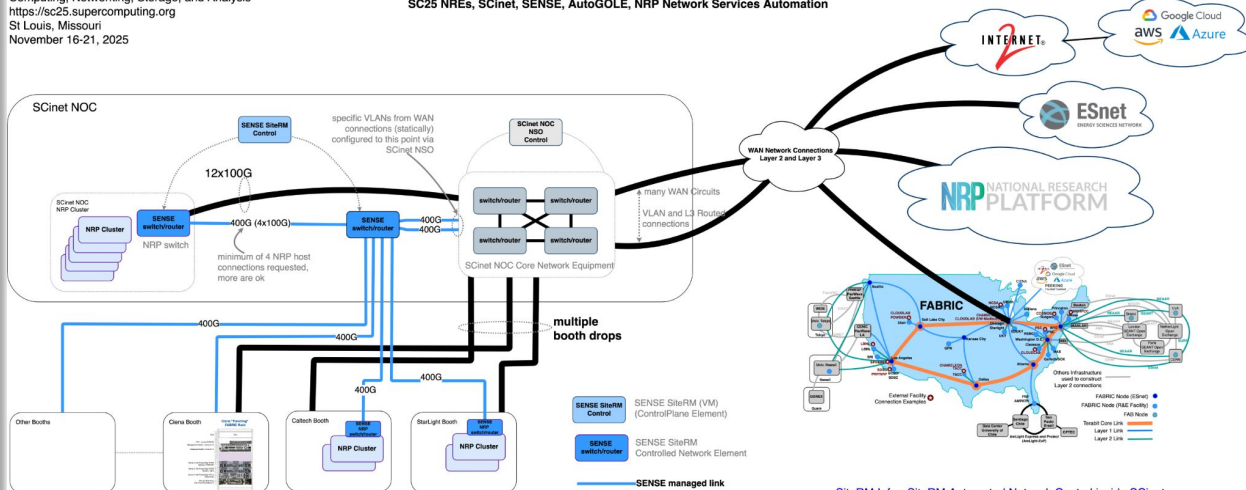
Collaborators:

ESnet , Jefferson Lab , NERSC , LBNL , ORNL = IRI

IRI Compute Job Portability (NRE 116)

SC25
The International Conference for High Performance
Computing, Networking, Storage, and Analysis
<https://sc25.supercomputing.org>
St Louis, Missouri
November 16-21, 2025

SC25 NREs, SCinet, SENSE, AutoGOLE, NRP Network Services Automation



[SiteRM Info - SiteRM Automated Network Control inside SCinet](#)

[SENSE SiteRM Documentation](#)

[2025-11-16-sc25 information](#) (google folder)

Enable tightly integrated workflows across experimental facilities, HPC systems, and high-speed networks.

Establish unified interfaces and APIs for allocations, data and job movement, scheduling.

Support data-intensive and time-sensitive applications, like experiment steering and real-time analytics, together with EJFAT.

Foster modularity and portability, allowing seamless transitions of data and computation jobs across different facilities.

NRP, SCinet, SENSE (NRE: 119, 120, 121, 122)

Live High-Precision Per-Packet Kubernetes Data Telemetry from NRP to StarLight via ESnet SENSE

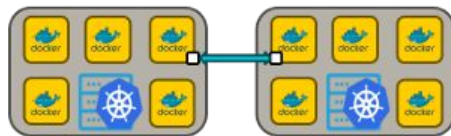
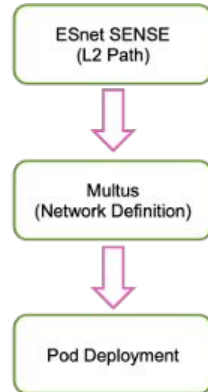
The National Research Platform and SCinet: Enabling Live, Multi-Institutional Scientific AI/ML and HPC Workflows

Real-Time In-Network Machine Learning and P4 Testbed Deployment on FPGA SmartNICs, DPUs, and Switches

Agentic AI with Qualcomm Cloud AI 100 Ultra Cards for HPC Cluster Management and Resource Provisioning

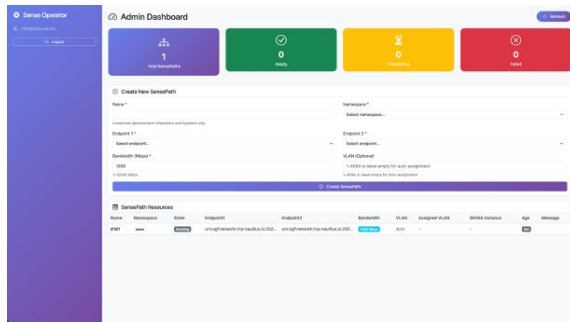
K8s SENSE Operator for NRP NRE: 119, 120, 121, 122

- **SENSE Path Provisioning**
 - Establish L2 path between Nautilus nodes using ESnet SENSE.
 - SENSE dynamically configures VLAN interfaces across multi-domain networks.
 - Once configured, SENSE creates and activates VLAN network interfaces on the nodes involved in the experiment.
- **Multus Network Definition**
 - Multus CNI enables pods to have multiple network interfaces beyond the default.
 - A NetworkAttachmentDefinition (NAD) is created for the VLAN interfaces provisioned by SENSE.
 - Specifies the VLAN network (e.g., vlan-10).
 - Connects the pods to the configured L2 path.



```
nautilus@node-2-7:~$ ifconfig vlan.3112
vlan.3112: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 9000
    inet6 fc00:0:100:142f::1 prefixlen 64 scopeid 0x0<global>
    inet6 fe80::966d:a6ff:fea6:6641 prefixlen 64 scopeid 0x20<link>
    ether 94:6d:a6:a6:66:41 txqueuelen 1000 (Ethernet)
    RX packets 1780 bytes 148720 (148.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1788 bytes 180840 (180.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

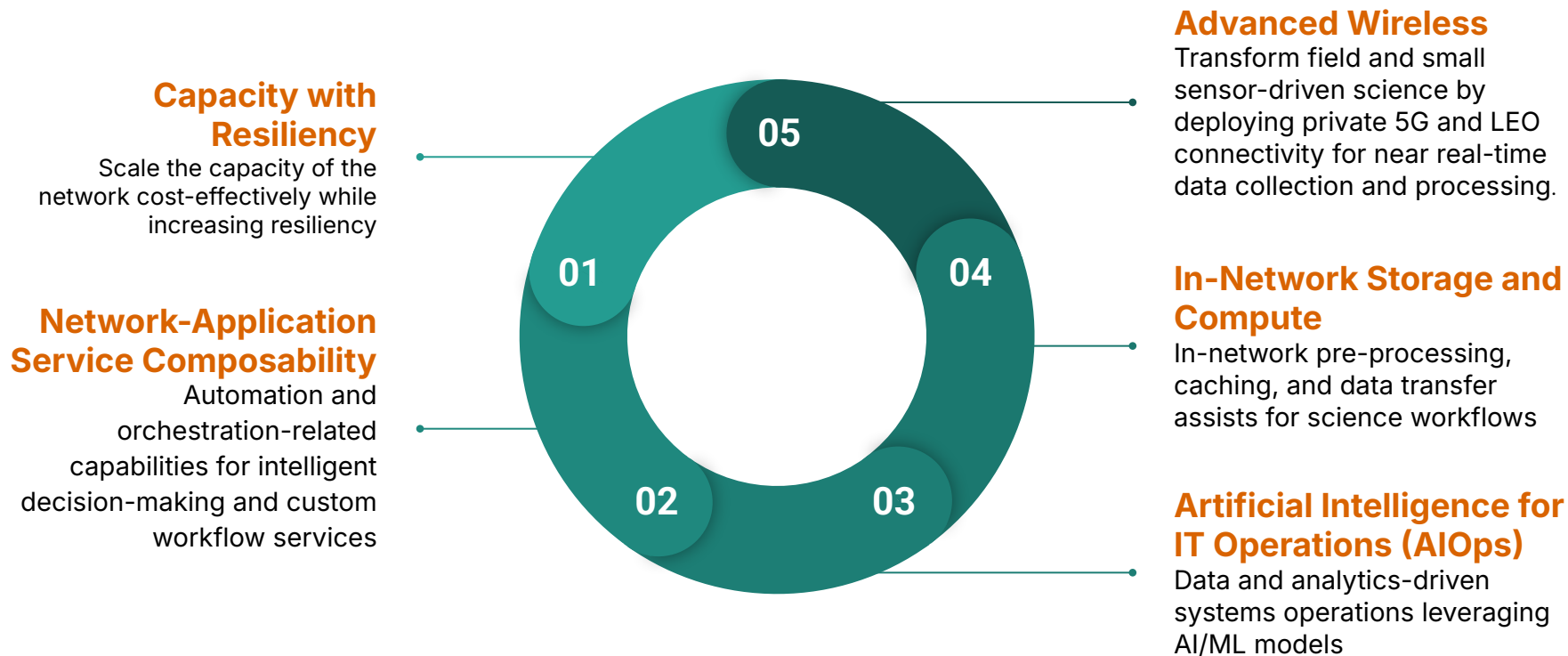
This is on the Node (Host Server)



The background of the image is a complex, abstract network of light blue lines and dots, resembling a web or a molecular structure. The lines are thin and connect various points, creating a dense, interconnected pattern. The dots are small and dark, serving as nodes in the network. The overall color scheme is light blue and white, giving it a clean, technological feel.

**Building Tomorrow's Network
Today!**

ESnet 7 is to Build New Capabilities and Services in Support ASCR Strategy on IRI, HPDF, and AI for Science



In-Network Storage and Compute

Squid was completely empty.

x6 faster!

Varnish was under regular production load.

Transactions:	101391 hits
Availability:	100.00 %
Elapsed time:	235.63 secs
Data transferred:	7059.98 MB
Response time:	0.05 secs
Transaction rate:	430.30 trans/sec
Throughput:	29.96 MB/sec
Concurrency:	22.02
Successful transactions:	93525
Failed transactions:	0
Longest transaction:	3.37
Shortest transaction:	0.03

Transactions:	101391 hits
Availability:	100.00 %
Elapsed time:	42.66 secs
Data transferred:	6894.09 MB
Response time:	0.01 secs
Transaction rate:	2376.72 trans/sec
Throughput:	161.61 MB/sec
Concurrency:	16.04
Successful transactions:	96796
Failed transactions:	0
Longest transaction:	4.01
Shortest transaction:	0.00

Testing it - Frontier

Harder to test (but will be done).

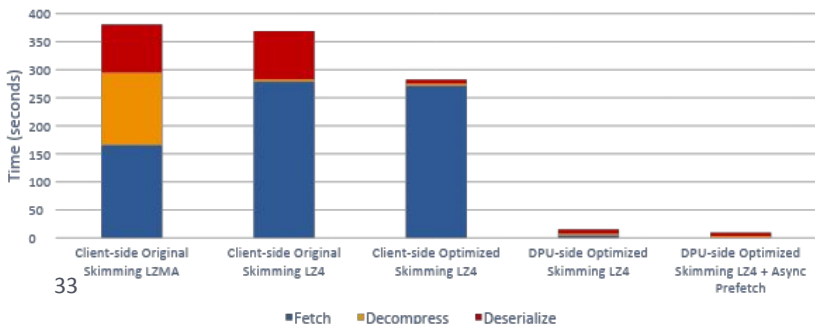
Squid was completely empty.

Hard to believe need a recheck.

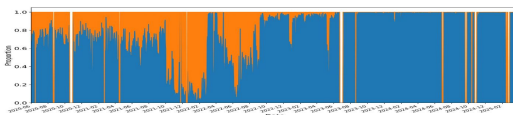
Varnish was under regular production load.

Transactions:	177595 hits
Availability:	99.96 %
Elapsed time:	1612.89 secs
Data transferred:	1232.78 MB
Response time:	0.26 secs
Transaction rate:	110.11 trans/sec
Throughput:	0.76 MB/sec
Concurrency:	28.34
Successful transactions:	177595
Failed transactions:	75
Longest transaction:	24.38
Shortest transaction:	0.21

Transactions:	177602 hits
Availability:	99.96 %
Elapsed time:	37.07 secs
Data transferred:	1232.79 MB
Response time:	0.00 secs
Transaction rate:	4790.99 trans/sec
Throughput:	33.26 MB/sec
Concurrency:	16.55
Successful transactions:	177602
Failed transactions:	68
Longest transaction:	4.97
Shortest transaction:	0.00

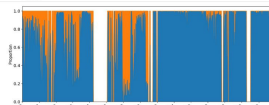


Ratio of Data Volume of Cache hits and misses

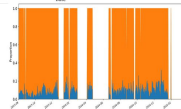


SoCal Cache from June 2020 to Mar. 2025, with 34.79 million data access records for 37.3PB of traffic volume for cache hits and 11.9PB of traffic volume for cache misses. 75.7% of the total traffic has been saved from the cache of 2PB. From Aug. 2022 to Mar. 2025, 96.9% of the total traffic was saved.

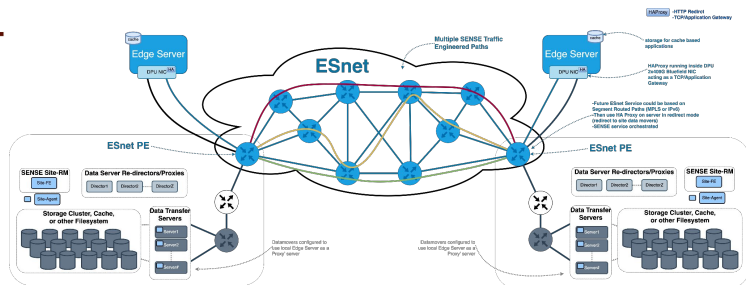
Cache misses
Cache hits



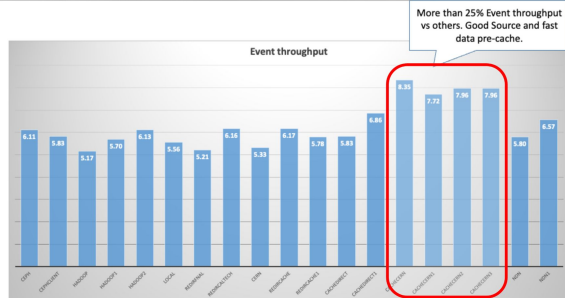
Chicago Cache from Oct. 2022 to Mar. 2025, with 11.86 million data access records for 16.45PB of traffic volume for cache hits and 15.48PB of traffic volume for cache misses. 51.5% of the total traffic has been saved from the cache of 340TB.



Boston Cache from Aug. 2023 to Mar. 2025, with 39.33 million data access records for 9.54PB of traffic volume for cache hits and 121.87PB of traffic volume for cache misses. 7.26% of the total traffic has been saved from the cache of 150TB.

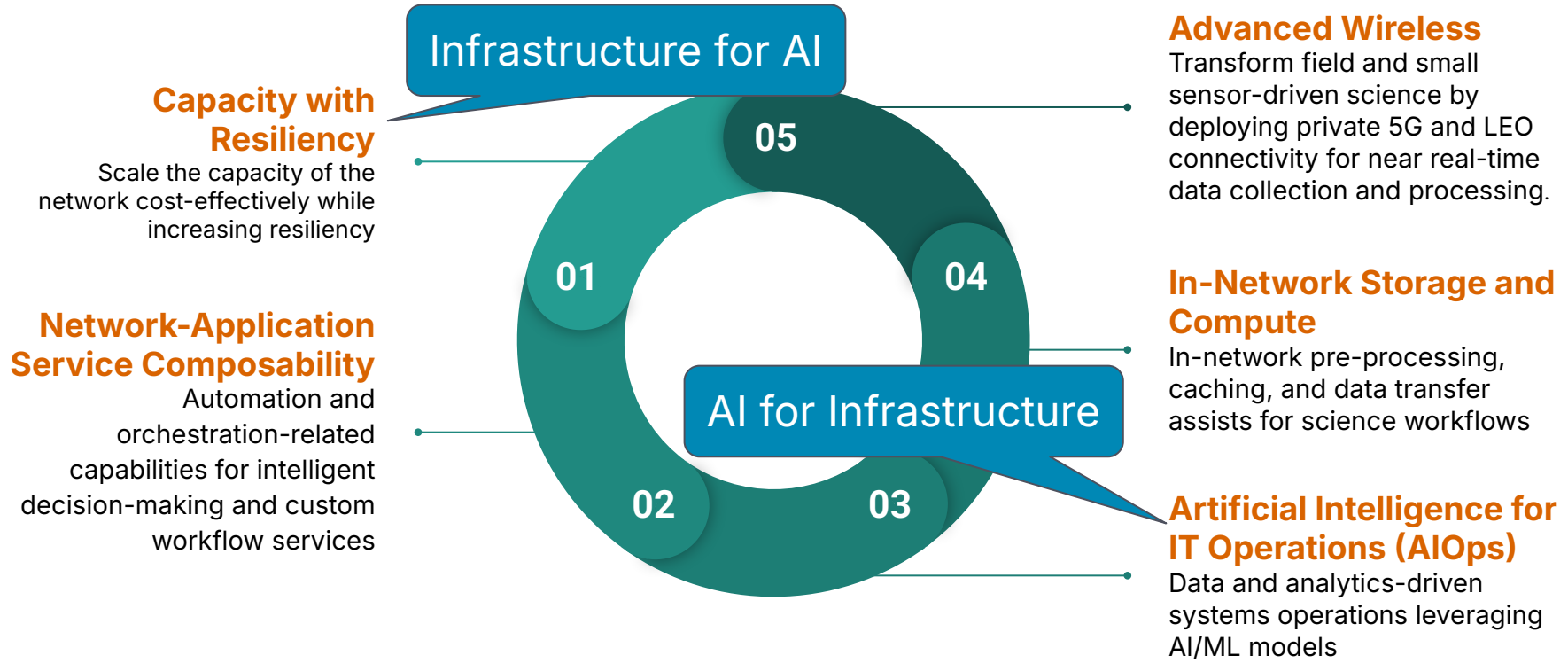


Gains in CPU Efficiency



More than 25% Event throughput vs others. Good Source and fast data pre-cache.

ESnet 7 is to Build New Capabilities and Services in Support ASCR Strategy on IRI, HPDF, and AI for Science



AI Working Group was formed in 2024 to collect information for the business case of AIOps

AI WG Organized a Workshop in Feb 2025 to Produce ~30 Work Packages



WP1 Alerting

WP2 Rule Correlation

WP3 Data Quality

WP4 Lifecycle

WP5 Data Catalog

WP6 Service Usage

WP7 Business Ops

WP8 Outage Notification
Parsing

WP9 Ticket Resolution

WP10 Alarm Correlation

WP11 Hardware Failure
Prediction

WP12 External Configuration
Anomaly Detection

WP13 Capturing Configuration
Intent

WP14 Fast Contract Lookup

WP15 Consistent Data
Management

WP16 All Data Query

WP17 Automating Site
Deployment

WP18 Automating
Configuration

WP19 AI Sandbox

WP20 Generating RFP /
Contracts

WP21 Unified Document
Search

WP22 Ticket Summarization

WP23 Federated
Authentication

WP24 Rewriting Legacy Perl
Software

WP25 NLP Interface to
Systems

WP26 Information
Architecture

WP27 Requirement
Management

WP28 Mission Support
Management

WP29 Dataset Unified Query

Workshop report complete in June 2025: <https://doi.org/10.2172/2571672>



American Science Cloud

H.R.1 - One Big Beautiful Bill Act

Subtitle D - Energy

SEC. 50404. TRANSFORMATIONAL ARTIFICIAL INTELLIGENCE MODELS.

(a) Definitions.--In this section:

(1) American science cloud.--The term ``American science cloud'' means a system of United States government, academic, and private sector programs and infrastructures utilizing cloud computing technologies to facilitate and support scientific research, data sharing, and computational analysis across various disciplines while ensuring compliance with applicable legal, regulatory, and privacy standards.

(2) Artificial intelligence.--The term ``artificial intelligence'' has the meaning given the term in section 5002 of the National Artificial Intelligence Initiative Act of 2020 (15 U.S.C. 9401).

American Science Cloud, cont.



U.S. DEPARTMENT
of **ENERGY**

Office of
Science

Advanced Scientific Computing Research (ASCR)

THE AMERICAN SCIENCE CLOUD (AmSC)

DOE National Laboratory Program Announcement Number:
LAB 25-3555

Announcement Type: Initial

“The DOE SC program in Advanced Scientific Computing Research (ASCR) hereby announces its interest in receiving proposals from eligible DOE National Laboratories to establish an integrated team to lead the development and deployment of AmSC. AmSC will serve as the enabling software and hardware infrastructure for DOE’s AI data and model development efforts in furtherance of SC’s mission and in fulfillment of Section 50404 of the OBBB Act.” - pg. 1, para. 1, ln. 2-3

Funding Details

- Expected total available funding \$40m
- Expected number of awards 1-10
- Expected dollar amount of individual awards \$1m - \$40m
- Expected award project period 1-2 years

Anticipated Timeline for Notice of Selection for Award Negotiation

- Award selection completed by Sep 30, 2025
- Awards will be made in FY2025
- Begin work by October 20, 2025

Announcement Issue Date:	August 22, 2025
Submission Deadline for Proposals:	September 15, 2025, at 5 PM ET

Comments and Questions

Working across providers and science domains is inspiring... and step by step, the network grows smarter, faster, and works in perfect harmony