U.S. DEPARTMENT OF ENERGY

BERKELEY LAB

ESnet

ESnet Data and AI Workshop 2025 Readout

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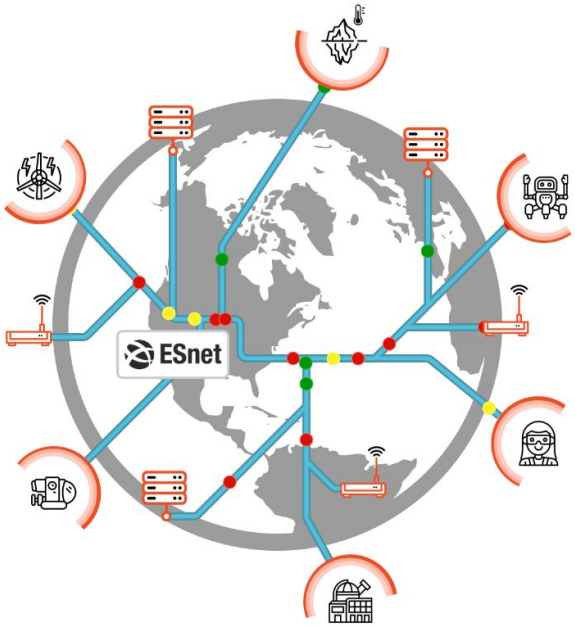
CTO
ESnet

SIG AI @ TNC25
Brighton, UK
Jun 9, 2025

Background and Motivation



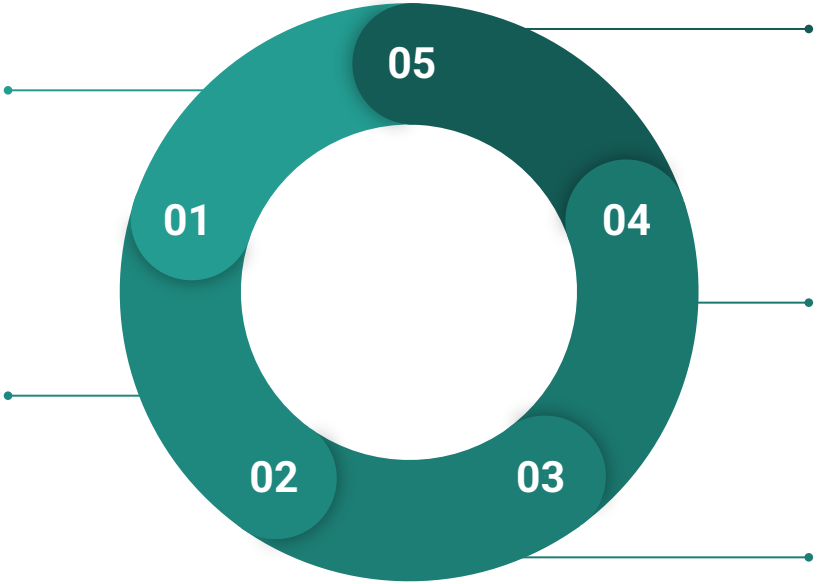
ESnet's Vision
Scientific progress will be completely unconstrained by the physical location of instruments, people, computational resources, or data.

ESnet

ESnet7: Build new capabilities and services on ESnet6 foundation to deliver on science needs, including ASCR strategy on IRI, HPDF, and AI for Science

Capacity with Resiliency
Scale the capacity of the network cost-effectively while increasing resiliency

Network-Application Service Composability
Automation and orchestration-related capabilities for intelligent decision-making and custom workflow services



Advanced Wireless
Transform field and small sensor-driven science by deploying private 5G and LEO connectivity for near real-time data collection and processing.

In-Network Storage and Compute
In-network pre-processing, caching, and data transfer assists for science workflows

Artificial Intelligence for IT Operations (AIOps)
Data and analytics-driven systems operations leveraging AI/ML models

Preliminary work in all areas is informing potential ESnet7 components and reducing risk.

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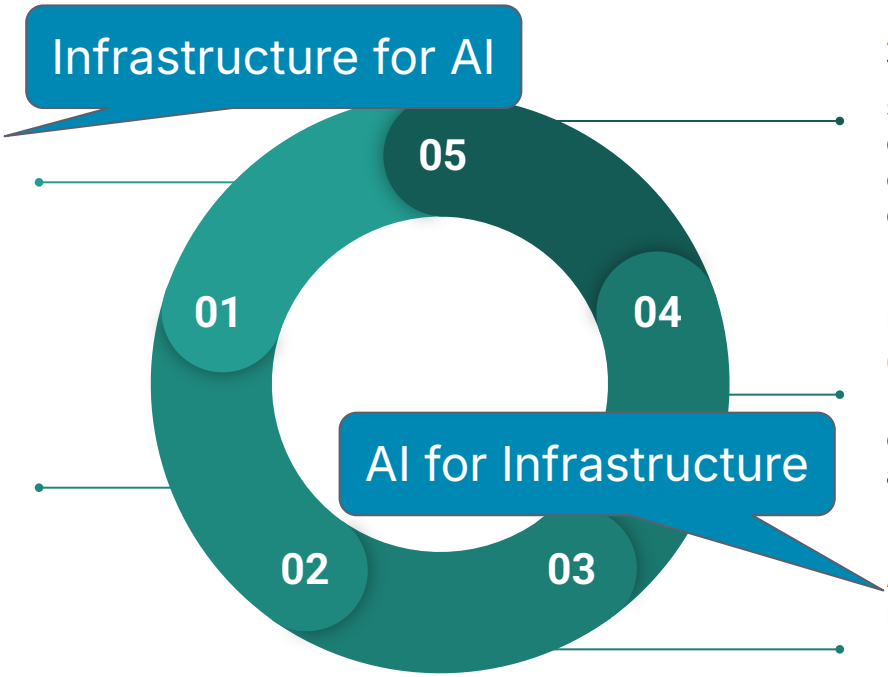

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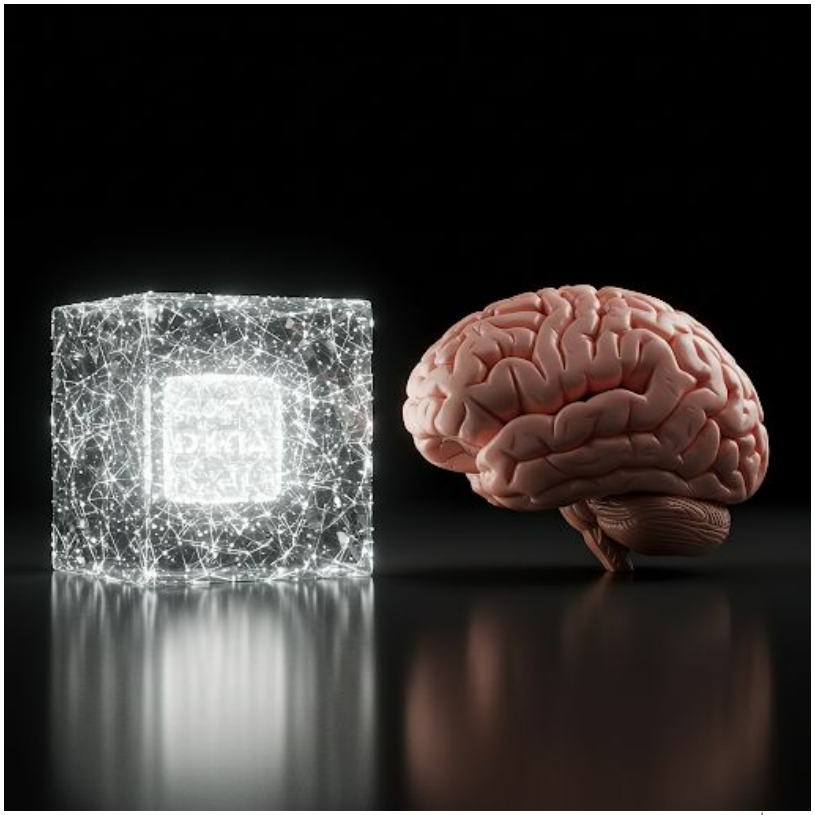
ESnet Data and AI Workshop



Gemini

"Render an image of a data block sitting next to a brain"

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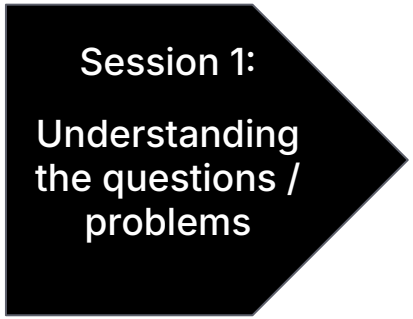
Workshop Objective and Structure

The objective of the Data and AI workshop is to identify challenges within ESnet that can be addressed through data-driven methods. This will help define ESnet's data analysis requirements and shape its AI strategy, guiding data stewardship efforts, and the direction of AI research and AIOps exploration for ESnet7.

The workshop has 5 sessions, each building on the output of the previous session.



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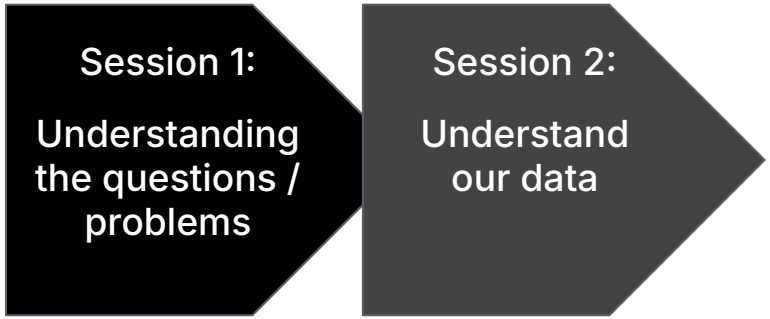

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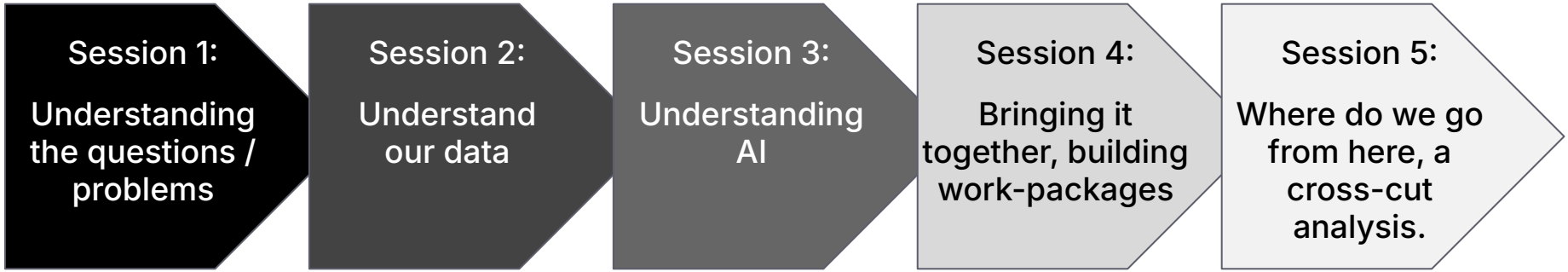

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Workshop Outcomes - Work-packages [28]

- 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

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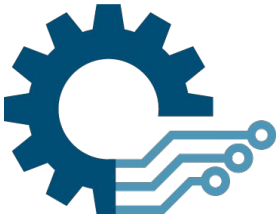
Cross-cut analysis - 4 practice areas

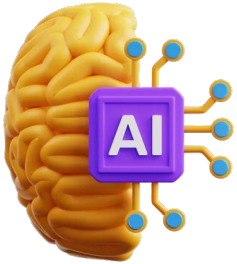


Data Management

Data collection, curation, storage, access, etc

Traditional Analysis Methods

Traditional methods such as statistical analysis, etc.



AI Methods

Natural language parsing, large language models, machine learning, etc.

User eXperience

Interactivity, look and feel, etc

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Data Management Recommendations

1. Enhance data discovery and insight with NLP, enterprise search, AI, and ML, leveraging improved metadata and topology-aware analysis.
2. Establish a consistent information architecture with API-driven access, uniform access control, and a comprehensive data catalog to support zero-trust architecture and operational innovation.
3. Develop an integrated view of production services with seamless access to technical and business data, and a detailed operational service model.
4. Establish a standardized data flow to unify and normalize operational data, ensuring high-quality data for AI analysis through automated checks and metadata management.
5. Bridge key information gaps by tracking underutilized resources, gathering essential data, and establishing a unified security analysis framework.
6. Collaborate with the R&E networking community to develop end-to-end awareness and monitoring of cyberinfrastructure beyond ESnet's boundaries.

Traditional Analysis Methods Recommendations

1. Prioritize statistical analysis work-packages in network operations, capacity planning, and predictive maintenance, focusing on areas with high data quality and significant operational impact.
2. Improve data quality and integration by standardizing data, enriching metadata, and automating collection processes to enable effective statistical analysis.
3. Leverage hybrid approaches combining statistical methods with NLP and AI/ML to maximize analytical effectiveness and unlock a comprehensive understanding of data.
4. Promote data stewardship and ownership across ESnet by assigning clear responsibility for data integrity, establishing protocols, and setting metadata standards to ensure reliable and accurate analysis.
5. Collaborate with stakeholders to validate statistical analysis approaches, ensuring insights are actionable, relevant, and align with business objectives.

AI Methods Recommendations

1. Invest in time series analysis for anomaly detection, providing insights through dashboards and programmable interfaces to improve observability, failure detection, and predictive modeling.

2. Prioritize automation areas with high ROI, exploring approaches like workflow engines, modular AI agents, and action-oriented automation for efficient and effective process automation.

3. Leverage NLP with domain-specific fine-tuning to enhance data integration, decision support, and document generation, improving network visibility and providing assistance for tasks like ticket resolution and configuration management.

4. Adopt predictive modeling to enhance incident management, optimize resource allocation, and automate processes, improving operational efficiency in managing the increasingly complex ESnet WAN.

5. Leverage AI tools to automate and enhance root cause analysis, reducing time to resolution and improving network resilience and stability.

6. Leverage AI to make data AI-ready by ensuring consistent formatting, efficient access, and enhanced quality assurance.

User eXperience Recommendations (1/3)

1. Design intuitive, transparent AI workflow management interfaces with layered UX elements, exposing intermediate steps and decision rationales, to ensure effective adoption and trust in AI-assisted operations.

2. Design a cohesive data management framework prioritizing quality, context, and hygiene, with intuitive tooling and seamless access, to facilitate collaboration between data owners and ML engineers.

3. Implement robust validation, edge case testing, and continuous monitoring to ensure safe and reliable AI behavior, with protocols for retraining and human-in-the-loop approval for high-risk actions.

4. Implement robust maintenance and monitoring frameworks with retraining protocols, triggered by performance thresholds or data shifts, to ensure sustained AI effectiveness and reliability.

5. Foster interdisciplinary collaboration and rigorous documentation through structured workflows, version-controlled repositories, and continuous knowledge exchange to ensure successful AI implementation.

User eXperience Recommendations (2/3)

6. Design Human-In-The-Loop (HITL) interfaces that ensure transparency, accountability, and user alignment, with clear suggestions, intuitive workflows, and accessible override options for manual review and model improvement.
7. Embed context-aware guidance into user interactions, providing adaptive help features, sample queries, and proactive suggestions to enhance user experience and AI response accuracy.
8. Embed rich, interpretable context into AI outputs, providing clear explanations, confidence levels, and risk indicators, to ensure actionable, trustworthy, and understandable results in operational environments.
9. Implement transparency and accountability measures for AI-generated content, including visual indicators, auditable history, and user controls, to ensure responsible and ethical AI deployment.
10. Integrate transparent data usage disclosure into user interfaces, with clear disclaimers, visual indicators, and context-aware warnings, to protect sensitive information and uphold ethical standards.

User eXperience Recommendations (3/3)

11. Embed intuitive feedback tools into user interfaces to capture structured feedback, facilitating supervised fine-tuning and transparency into how user input improves AI model accuracy and adaptability.
12. Tailor AI integration using immersive, assistive, or embedded UX design frameworks, based on task complexity and user engagement levels, to deliver AI features that align with user needs.
13. Evaluate AI-enabled work-packages to determine optimal interface granularity, mapping to user roles, task criticality, and environment constraints for effective AI integration.
14. Design user interfaces that avoid anthropomorphizing AI systems, using neutral language and visual elements, and provide clear disclaimers to foster trust and prevent misinterpretation of AI capabilities.

Thank you!

"If you're going to bring to bear on some really big problem, the same things that everyone else has been trying, you shouldn't expect to get better results than everyone else."

- Astro Teller (Google's Innovation Chief)

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Backup Slides

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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.)

ESnet Comprises

15,000 Miles of dedicated fiber-optic cable*

78 Router sites*

278 Amplifier sites*

7 U.S. sites connected at 400 Gbps or higher**

Capabilities

400 Gbps to 1.2 Tbps Network backbone**

54.5 Tbps Aggregate capacity**

1.5 Tbps Trans-Atlantic capacity**

1.7 Exabytes Transited in ESnet in CY2023

99.99% Site uptime*

4.85 Overall user satisfaction rating (out of 5)**

**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 2023 ESnet Site Coordinators Committee survey*

**In U.S ** As of Oct. 15, 2024*

ESnet

ESnet's DNA includes integrating innovative ideas into operationally reliable infrastructure across the last 3 decades

Magnetic Fusion Energy Network (MFENET)
[1976 - 1986]

ESnet(1)
[1986 - 1994]
Building an open standards network
- *IPv4*
- *BGP*

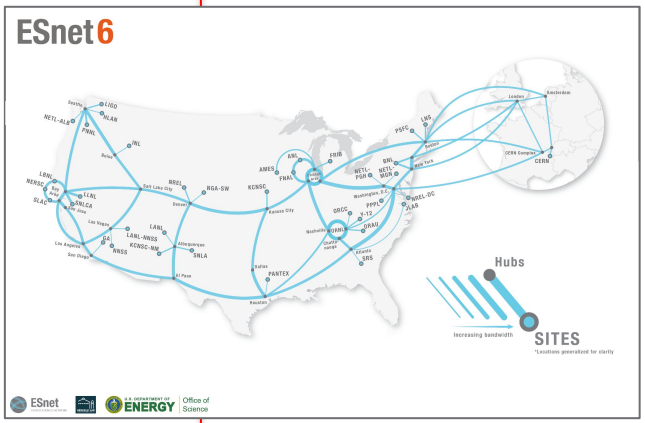
ESnet2
[1994 - 2000]
Adopting emerging technologies
- *ATM*
- *IPv6*
- *Video Conf Services*

ESnet3
[2000 - 2006]
Building predictable network services
- *QoS and TE (MPLS)*
- *OSCARS*

ESnet4
[2006 - 2011]
Deploying purpose build architectures
- *Science Data Network (SDN)*
- *ScienceDMZ*
- *perfSONAR*

ESnet5
[2011 - 2022]
Expanding the network breadth and depth
- *OLS operations*
- *Transatlantic connectivity*

ESnet6
[2022 - TBD]
Developing comprehensive network automation and visibility capabilities
- ***ESnet6 Orchestration/Automation***
- ***ESnet6 High-Touch***



1970s | 1980s | 1990s | 2000s | 2010s | Present

ESnet Energy Sciences Network

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ESnet's DNA includes integrating innovative ideas into operationally reliable infrastructure across the last 3 decades

- ESnet6 Orchestration/Automation stack provides the agility to take action when a decision is made.
- ESnet6 High-Touch, coupled with existing monitor tools, provides comprehensive information to make decisions.
- *Can AI be leveraged in the decision making process to surpass human-scale limitations?*

ESnet6
[2022 - TBD]
Developing comprehensive network automation and visibility capabilities
- ***ESnet6 Orchestration/Automation***
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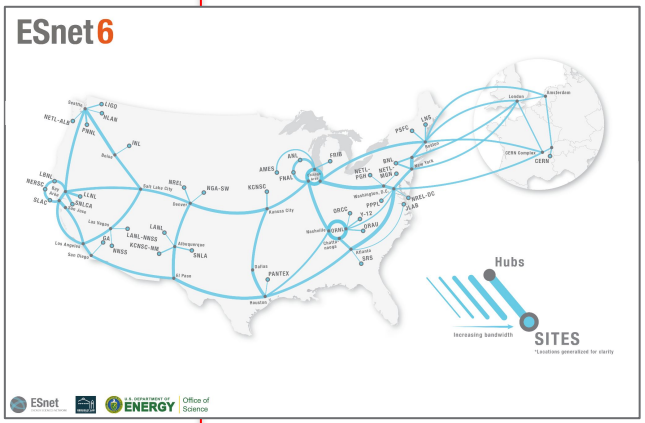

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ESnet Energy Sciences Network

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AI Generated Welcome Message

“Welcome to the ESnet Data and AI Workshop, where the boundaries of innovation and discovery are waiting to be pushed. Over the next few days, you'll be part of a dynamic community of experts, researchers, and practitioners passionate about harnessing the power of network data and artificial intelligence to drive meaningful impact. This workshop offers a unique opportunity to delve into the latest advancements and trends, explore the vast potential of these fields, and engage with renowned speakers, collaborate with fellow attendees, and learn from their experiences and insights, ultimately driving positive change and shaping the future of our world.”

- LBL CBorg Chat

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Attendees comprised of participants from every group across ESnet, including a handful from academia and industry

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