

StarLight Software Defined Exchange (SDX) And The Global Research Platform

Joe Mambretti, Director, (j-mambretti@northwestern.edu)

International Center for Advanced Internet Research (www.icaire.org)

Northwestern University

Director, Metropolitan Research and Education Network (www.mren.org)

**Director, StarLight International/National Communications Exchange Facility
(www.startap.net/starlight),**

PI: StarLight SDX, Co-PI Chameleon, PI-iGENI, PI-OMNINet

Global Research Platform Workshop

Co-Located With IEEE International Conference On eScience

Chicago, Illinois

September 15-16, 2025



The GRP: A Platform For Global Science



GLOBAL RESEARCH PLATFORM

*A Next Generation, Software Defined,
Globally Distributed, Multi-Domain
Computational Science Environment*

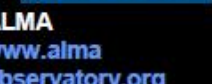
Selected Applications/Instruments



Open Storage Network
www.openstorage.network.org
OSIRIS
www.osiris.org



XSEDE
www.xsede.org
Blue Waters
bluewaters.ncsa.illinois.edu



Global Research Platform: Global Lambda Integrated Facility

Available Advanced Network Resources



Next Generation eScience Ecosystem

Visualization courtesy of Bob Patterson, NCSA; data compilation by Maxine Brown, UIC.



www.glif.is

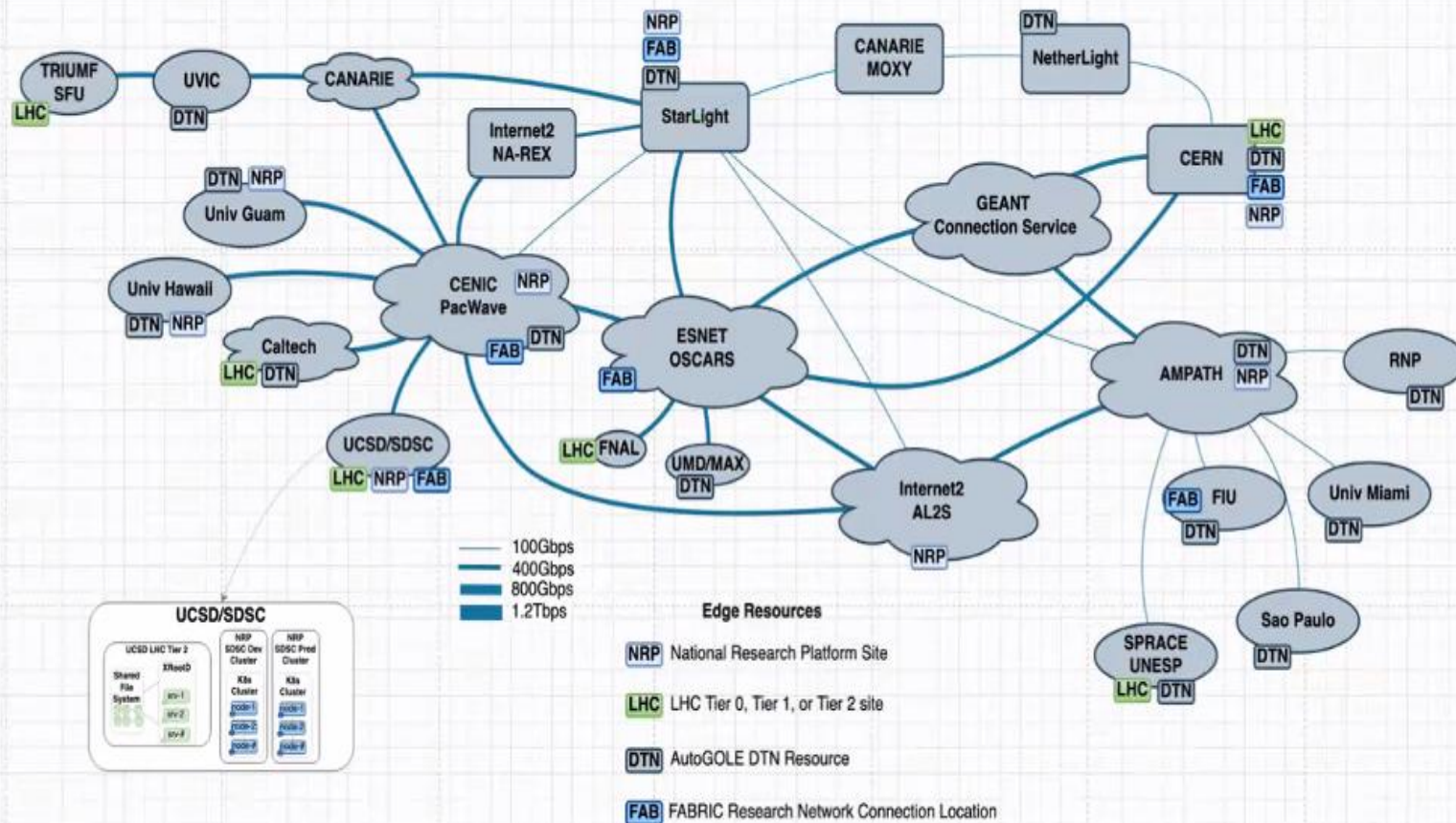
STARLIGHTSM

"The global advancement of science by realizing a multiresource infrastructure through international collaboration."



AutoGOLE Open R&E Exchanges

STARLIGHTSM



NRP
Connections

P4 Testbed Site/End System Data

ESnet6



ESnet



U.S. DEPARTMENT OF
ENERGY

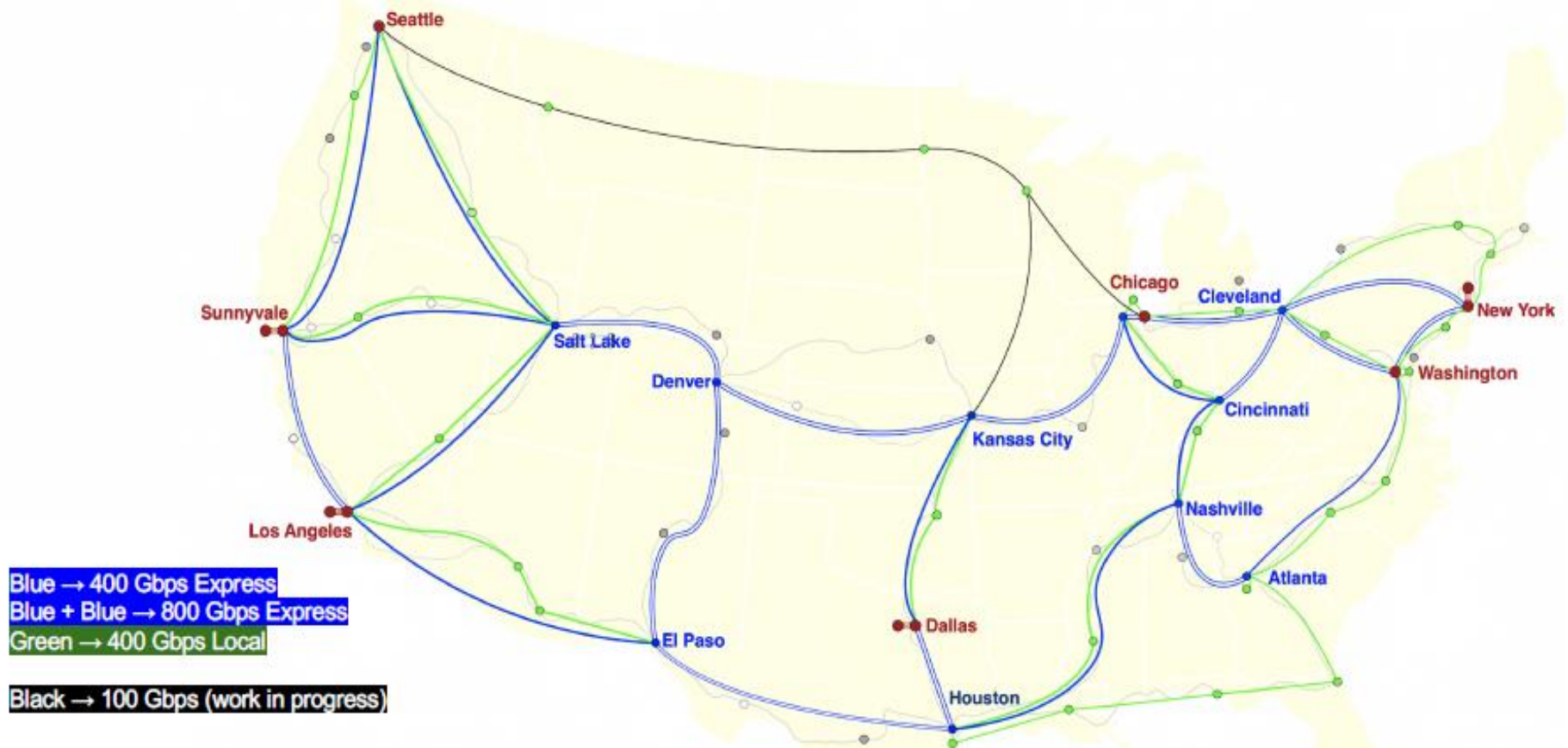
Office of
Science

STARLIGHTSM

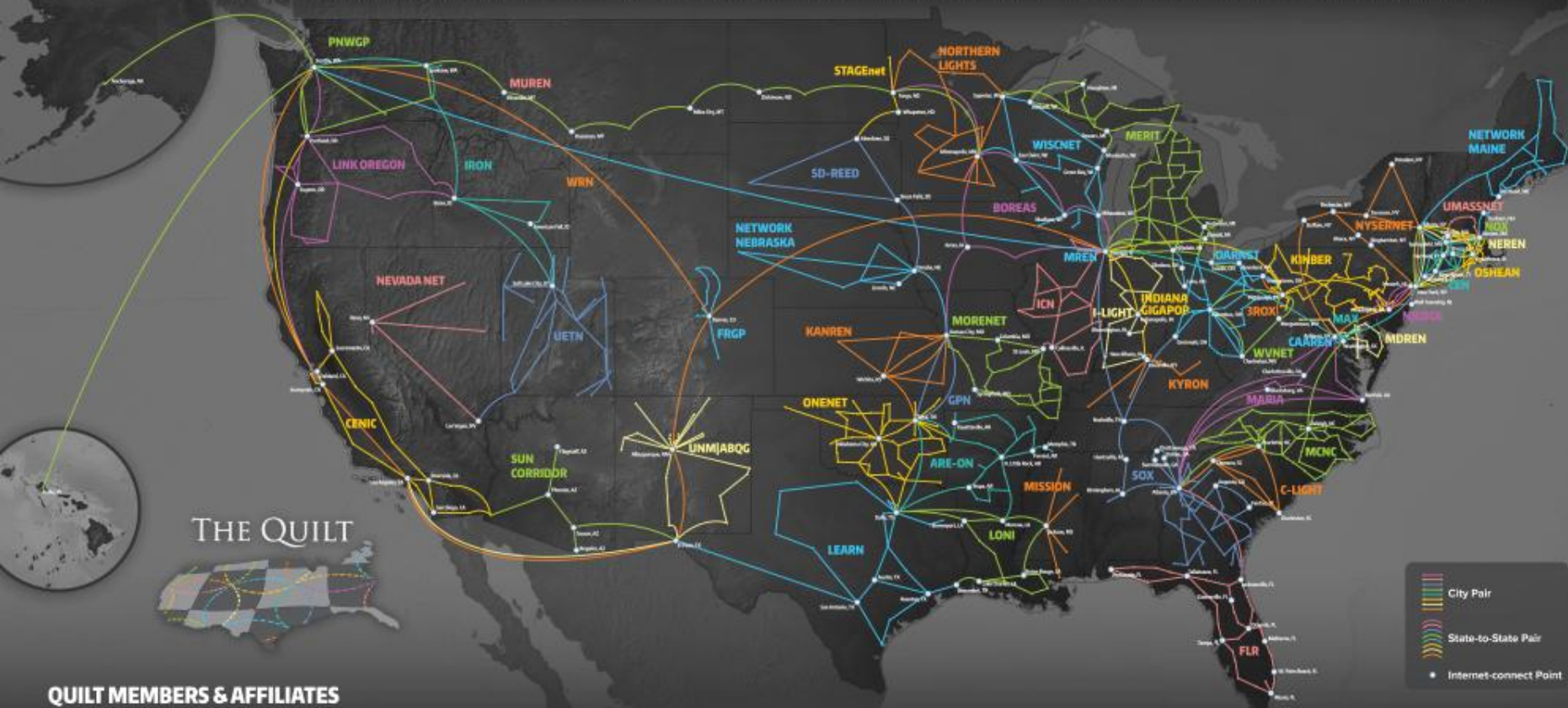
Internet2 Backbone Topology

Backbone Topology - Capacity and Traffic Management

Chris Wilkinson, Director of Planning and Architecture



REGIONAL RESEARCH & EDUCATION NETWORKS IN THE UNITED STATES



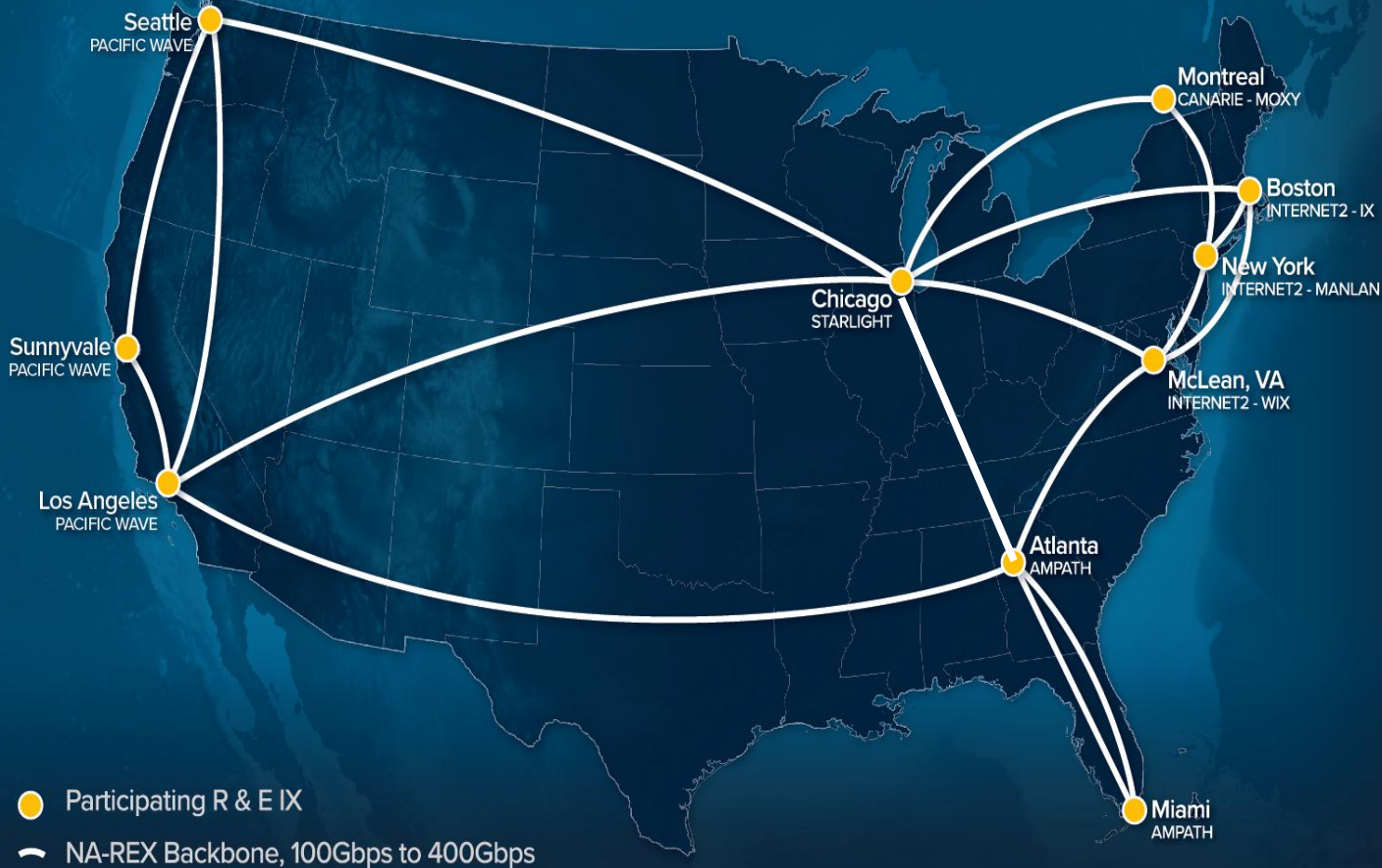
QUILT MEMBERS & AFFILIATES



The Quilt Map 2-27-24

STARLIGHTSM

NA-REX North America Research & Education Exchange Collaboration



StarLight – “By Researchers For Researchers”

StarLight: Experimental Optical Infrastructure/Proving Ground For Next Gen Network Services
Optimized for High Performance Data Intensive Science
Multiple 100 Gbps
(110+ Paths)
StarWave
100 G Exchange
World's Most Advanced Exchange
Multiple First of a Kind
Services and Capabilities

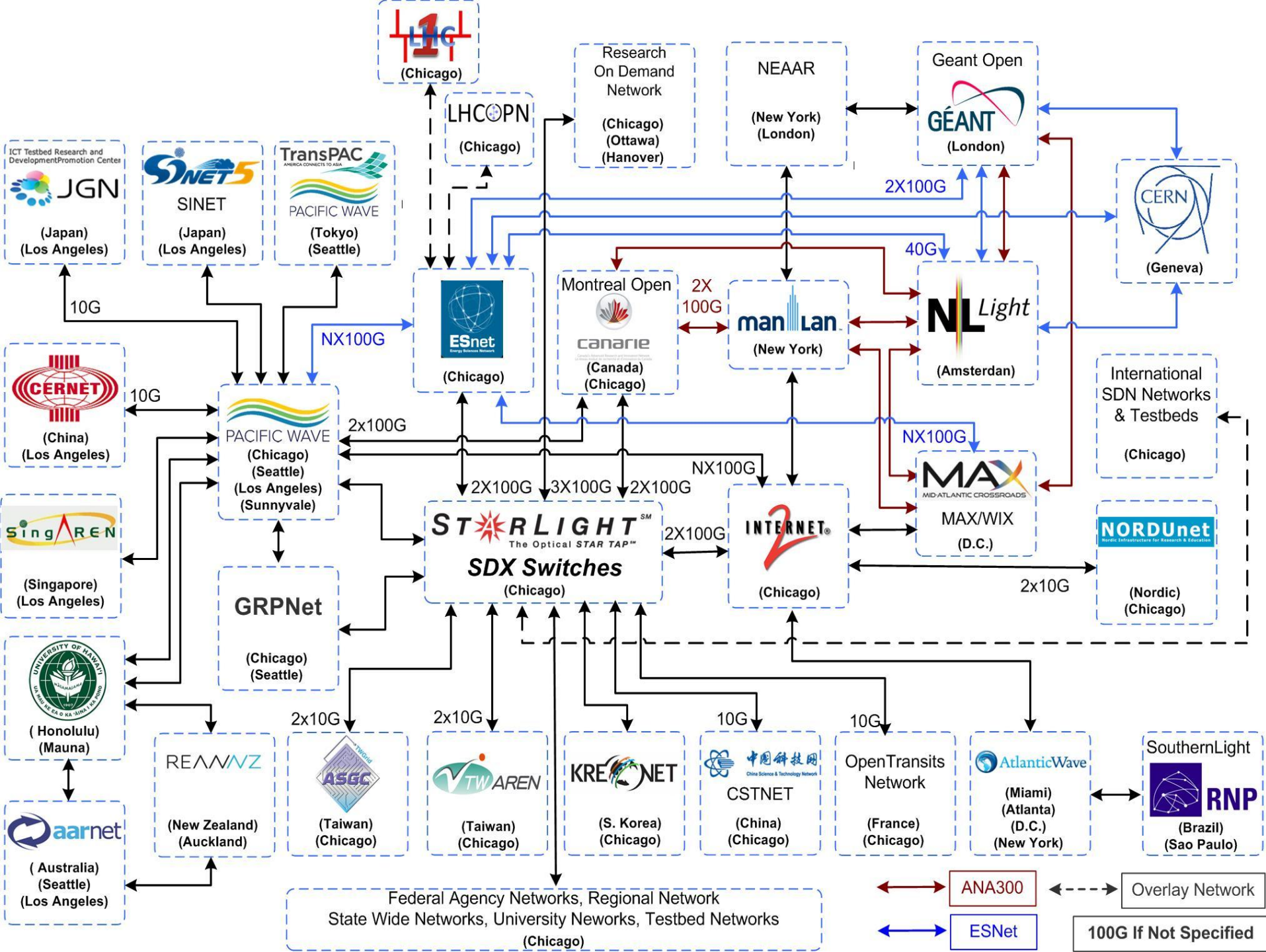


View from StarLight



Abbott Hall, Northwestern University's Chicago Campus

Currently: 26+ 400 Gbps Paths Prototyping 800 Gbps **StarLight** SM



International Federated Testbeds As Instruments for Computer Science/Network Science

- **The StarLight Communications Exchange Facility Supports ~ 28 Network Research Testbeds (Instruments For Computer Science/Networking Research)**
- **StarLight Supports Two Software Defined Exchanges (SDXs)**
- **An NSF IRNC SDX & A Network Research**
- **A Research SDX Supports National and International Federated Testbeds**

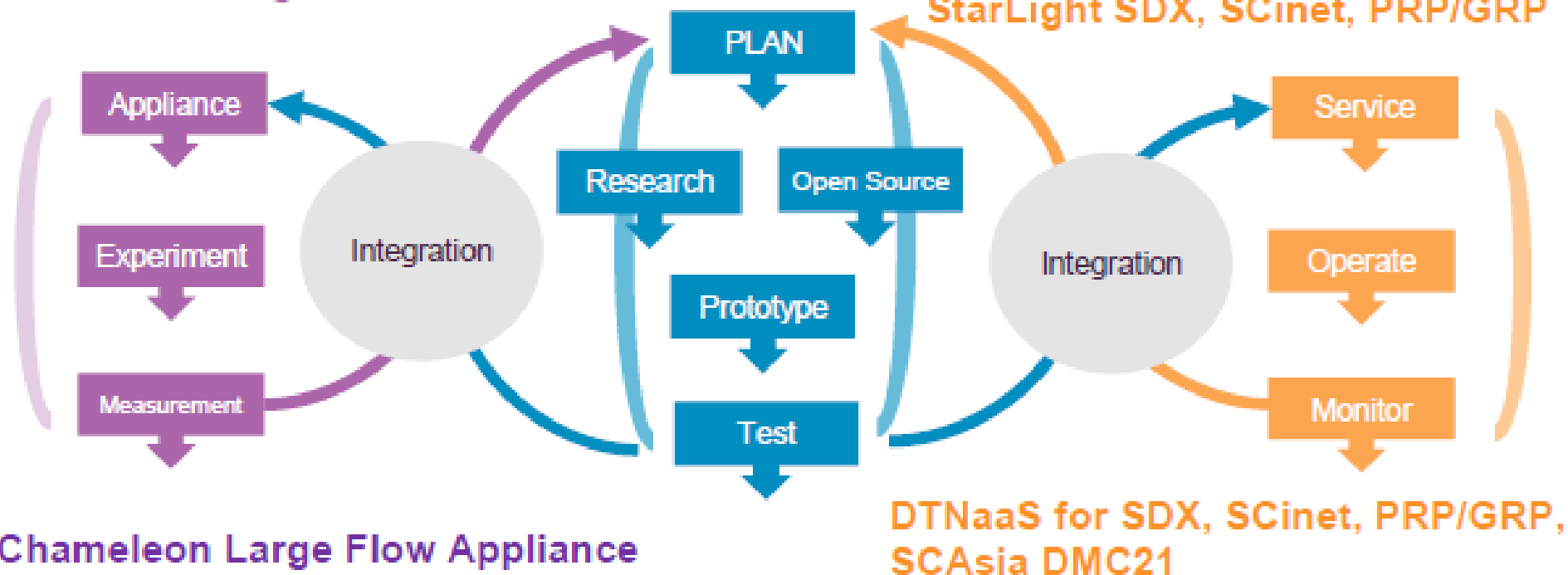


StarLight Software Defined Exchange

StarLight Software Defined Exchange (SDX) CD/CI/CD Innovation Workflow

StarLight Testbeds

StarLight SDX, SCinet, PRP/GRP



iCAIR

STARLIGHTSMSDX

Source: Jim Chen

STARLIGHTSM

SCinet National WAN Testbed

- **As In Previous Years, iCAIR Supports SCinet In Designing and Implementing a National WAN Testbed**
- **A Key Focus Is 400, 800, and 1.2 Tbps Path Services and Interconnections, Including Direct Connections To Edge Nodes, Primarily High Performance DTNs**
- **The SC25 National WAN Testbed Is Being Designed and Implemented To Support Demonstrations and Experiments Of Innovations Related To Data Intensive Science**



Example SC25 SCinet Network Research Exhibitions

- **Global Research Platform (GRP)**
 - SDX 1.2 Tbps WAN Infrastructure
 - SDX E2E 1.2 Tbps WAN Services
 - SDX E2E 400 Gbps 800 Gbps WAN Services
 - 400 Gbps DTNs & Smart NICs
 - Orchestration With Packet Marking (SciTags) at 1.2 Tbps
 - Coherent Optics Over WANs
 - Real Time FPGA Based Network Measurements
 - NA REX Continental Backbone For Data Intensive Science
 - SDX International Testbed Integration
 - StarLight SDX for Petascale Science
 - DTN-as-a-Service For Data Intensive Science With Scitags
 - NASA Goddard Space Flight Center HP WAN Transport Services (800 G Dsk-Dsk)
- **Resilient Distributed Processing & Rapid Data Transfer**
- AutoGOLE/SENSE E2E Orchestration Net Services And Workflow Integration
- Open Science Grid Demonstrations
- National Research Platform Demonstrations
- Chameleon FABRIC/FAB Integration
- SciStream Multi Site Data Streaming Orchestration
- Distributed Pipelines Over WANs For On-Line Data Analysis



Tbps WAN Services For Data Intensive Science

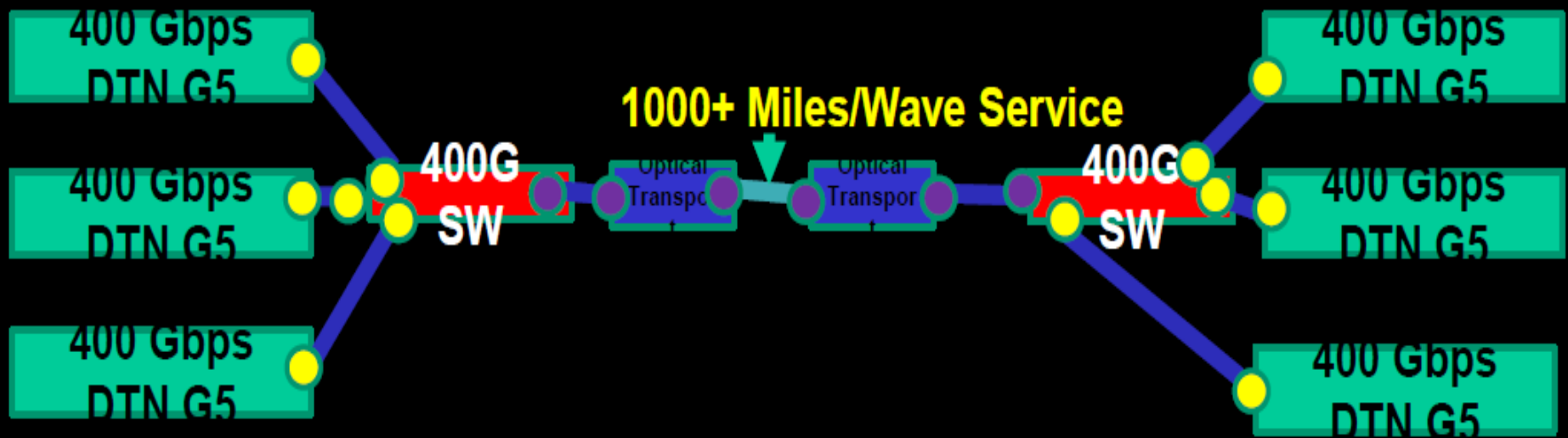
- NRE Demonstrations Leverage Experimental Research In the Optimal Design, Configuration, Components, and Integration Of DTNs
- Technologies: Software Defined Networking (SDN), 400 Gbps Smart NICs, NVMe over Fabric, RDMA, Techniques For Kernel Bypass Using Zero-Copy for Memory and Disk Copy (To Avoid Bottlenecks in Large Scale Data Transfers Over 1.2 Tbps WANs), GPU Acceleration, P4 And Optimal Affinity Bindings for NUMA Architecture for Higher Resource Utilization
- Demonstrations Also Showcase Middleware Required to Orchestrate infrastructure Resources for Reliable, Optimized High-Performance WAN Data Transfers.
- Demonstrations Showcase Measurement Techniques for Real-Time monitoring, benchmarking and evaluation including an AI Toolset.
- WAN Service Investigations Include Examining Implications for Production Operations.



1.2 Tbps WAN Service Prototype for Data Intensive Science

StarLight International/National
Communications Exchange Facility, Chicago, IL

Joint Big Data Testbed
McLean, Va



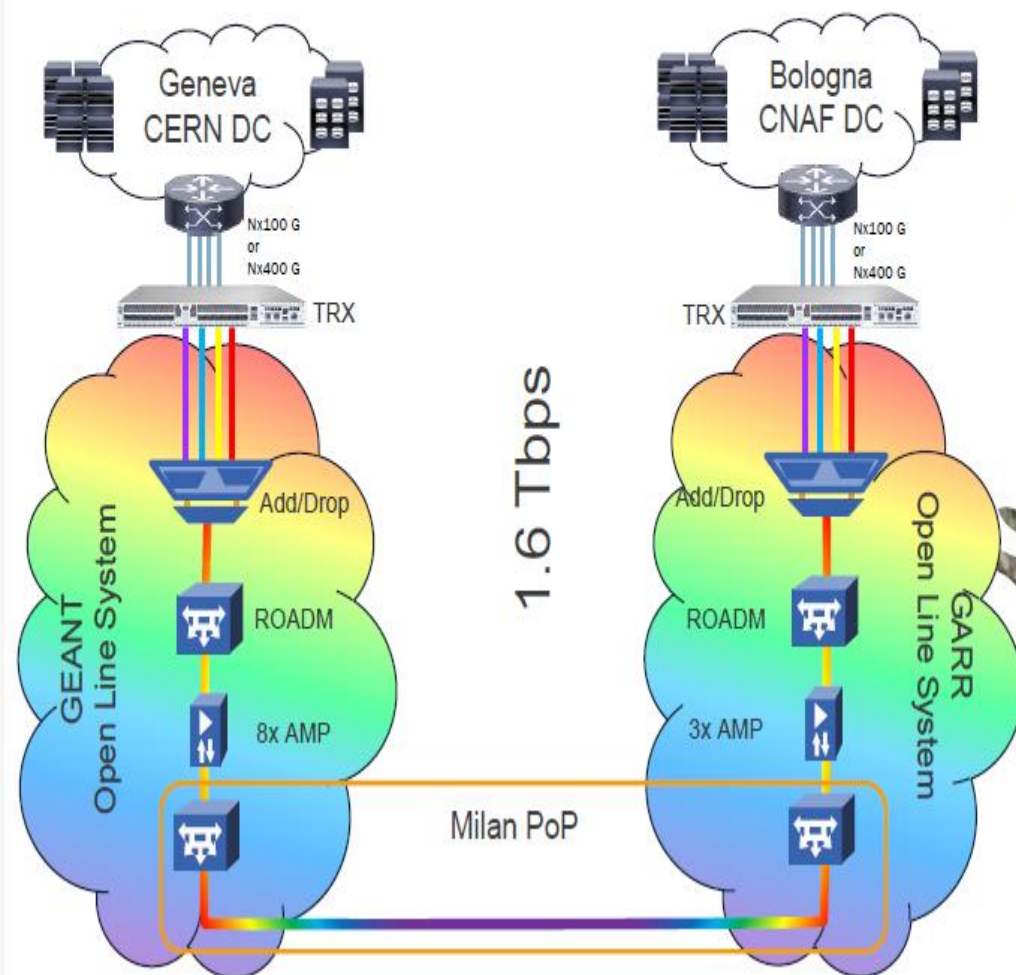
NB: G5=>G6
CX7>CX8

● LR4 Transceiver + Smart NIC, e.g., CX7

● Transceivers/OSFPs

CERN - CNAF DCI

As presented last year we have a pilot link based on multidomain Spectrum sharing Connection.
We managed to activate a 4x100Gbps to be used as LHCOPN link for INFN-T1 during the Data Challenge 2024

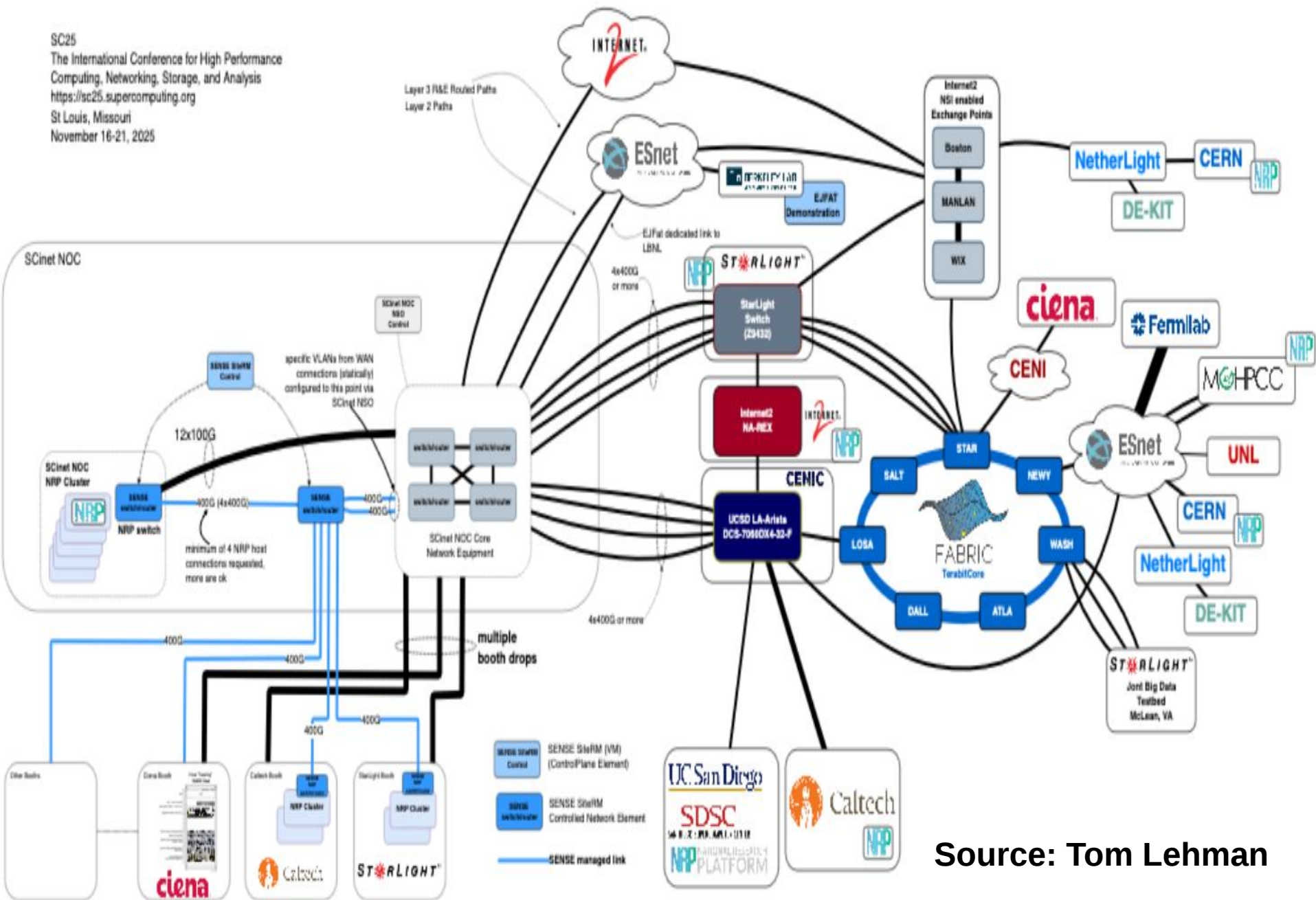


CERN, Esplanade des Particules, Meyrin, Svizzera

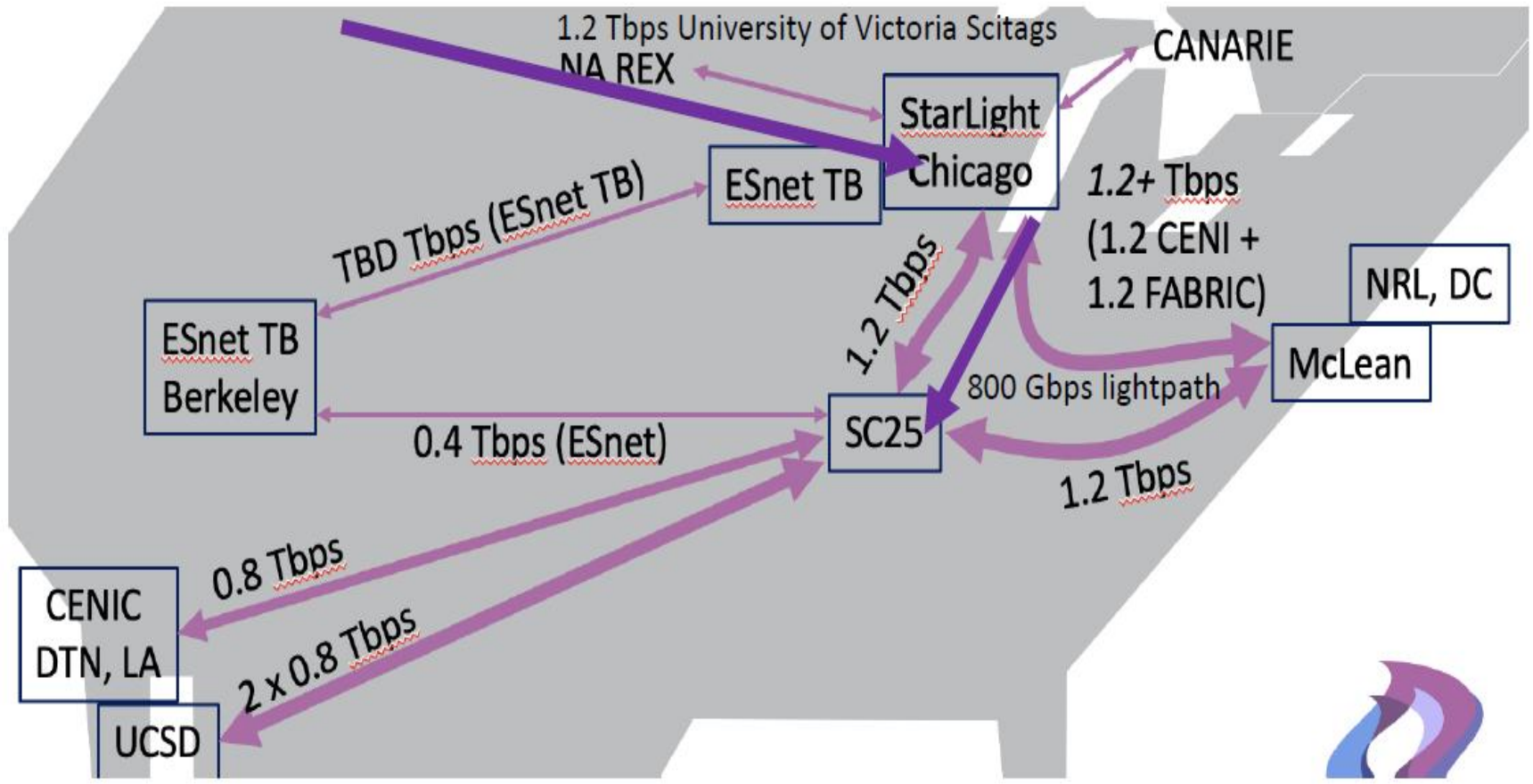
INFN CNAF, Viale Carlo Bertini Pichat, Bologna, BO

Also Ref LHC Data Challenge

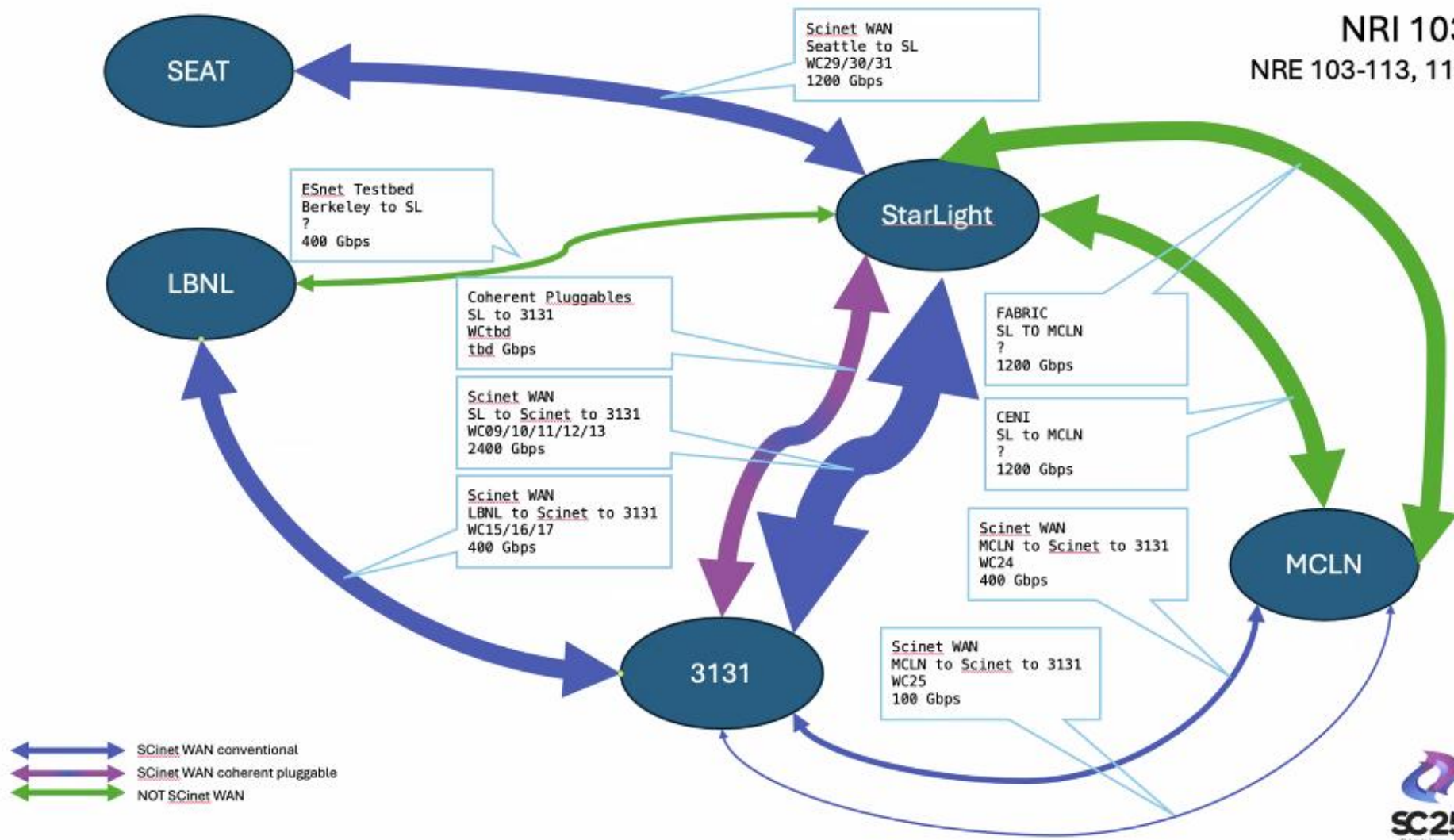
SC25
The International Conference for High Performance
Computing, Networking, Storage, and Analysis
<https://sc25.supercomputing.org>
St Louis, Missouri
November 16-21, 2025



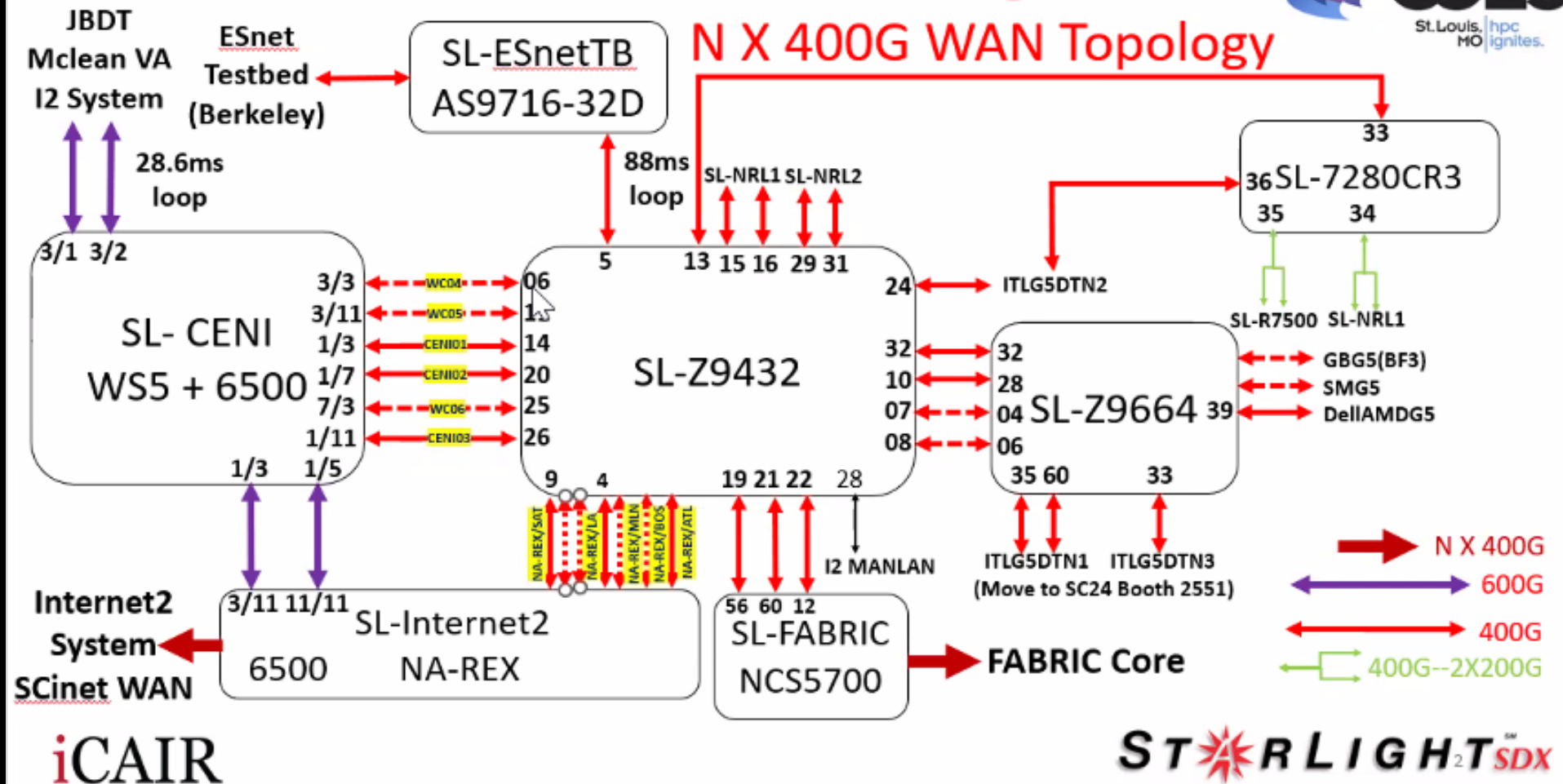
Source: Tom Lehman



NRI 103
NRE 103-113, 115



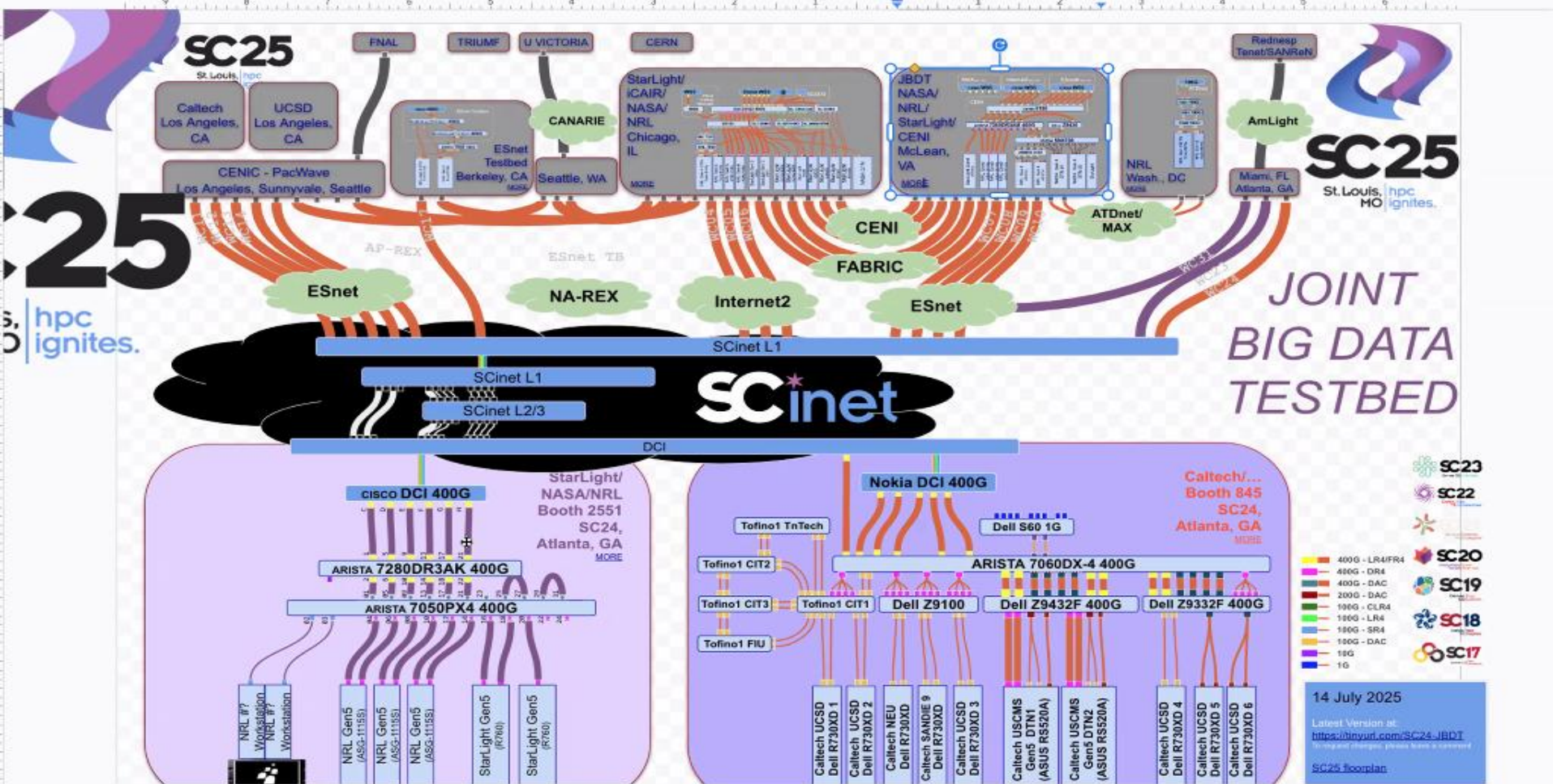
SC25 StarLight 08/27 N X 400G WAN Topology



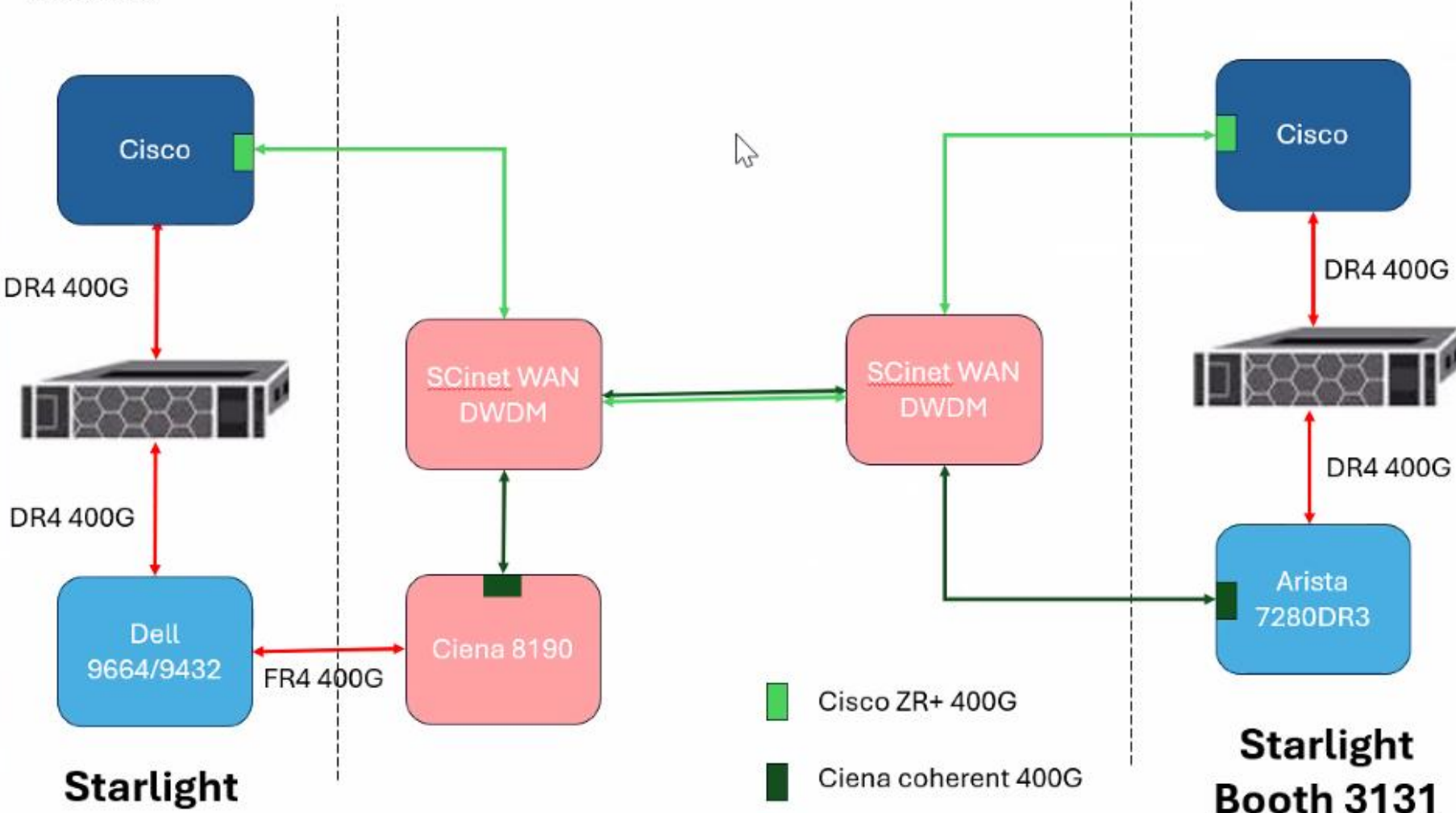
iCAIR

STARLIGHTSM SDX

STARLIGHTSM



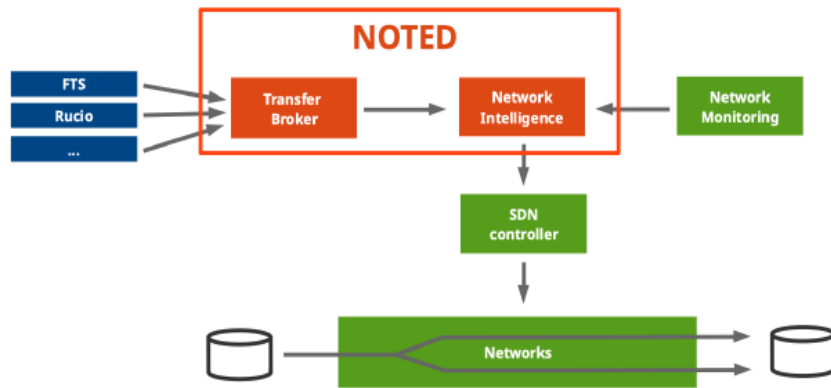
coherent optics
coherent optics



Network Optimized For the Transport Of Experimental Data (NOTED)



SKELETON AND ELEMENTS OF NOTED



FTS (File Transfer Service):

- Inspect and analyse data transfers to estimate if an action can be applied to optimise the network utilization → **get on-going** and **queued transfers**.

CRIC (Computing Resource Information Catalog):

- Enrichment to **get an overview** and knowledge of the **network topology** → get IPv4/IPv6 addresses, endpoints, rcsite and federation.

FLOWCHART AND DATASET STRUCTURE

- Input parameters: configuration given by the user
 - In noted/config/config.yaml → define a list of {src_rcsite, dst_rcsite}, maximum and minimum throughput threshold, SENSE/AutoGOLE VLANs UUID and user-defined email notification among others.
- Enrich NOTED with the topology of the network:
 - Query CRIC database → **get endpoints** that could be involved in the data transfers for the given {src_rcsite, dst_rcsite} pairs.
- Analyse on-going and upcoming data transfers:
 - Query FTS recursively → **get on-going** data transfers for each set of source and destination endpoints.
 - The total utilization of the network is the **sum** of on-going and upcoming **individual data transfers** for each source and destination endpoints for the given {src_rcsite, dst_rcsite} pairs.
- Network decision:
 - If NOTED interprets that the link **will be congested** → **provides a dynamic circuit** via SENSE/AutoGOLE.
 - If NOTED interprets that the link **will not be congested** anymore → **cancel the dynamic circuit** and the traffic is routed back.

scitags.org

Network Flow and Packet Marking for
Global Scientific Computing

View On
GitHub

Download
Tech. Spec

Join
scitags.org

Hosted on GitHub Pages — Theme by [orderedlist](#)

Scientific network tags (scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level.

It provides an open system using open source technologies that helps *Research and Education (R&E) providers* in understanding how their networks are being utilised while at the same time providing feedback to the *scientific community* on what network flows and patterns are critical for their computing.

Our approach is based on a network tagging mechanism that marks network packets and/or network flows using the science domain and activity fields. These tags can then be captured by the *R&E providers* and correlated with their existing netflow data to better understand existing network patterns, estimate network usage and track activities.

The initiative offers an **open collaboration on the research and development of the packet and flow marking prototypes** and works in close collaboration with the scientific storage and transfer providers to enable the marking capability. The project is currently in the prototyping phase and is open for participation from any science domain that require or anticipate to require high throughput computing as well as any interested *R&E providers*.

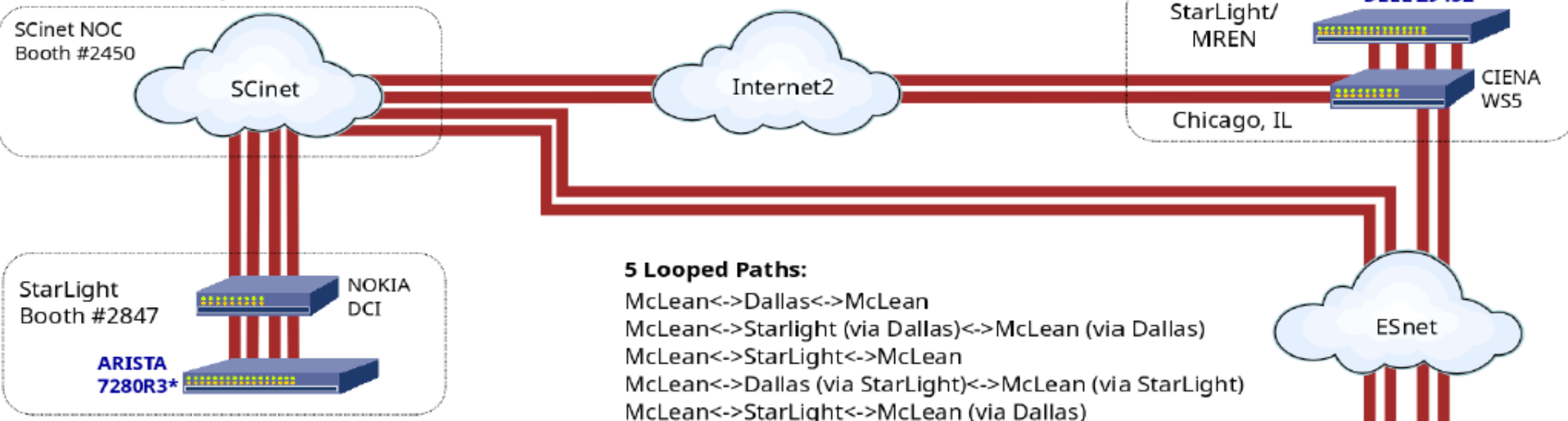
SC22

Joint Big Data Testbed

Demonstrations of 400 Gbps Disk-to-Disk WAN File Transfers using NVMe-oF/TCP

An SC22 Collaborative Initiative Among NASA and Several Partners

SC22 @ Dallas, TX



5 Looped Paths:

McLean<->Dallas<->McLean
 McLean<->Starlight (via Dallas)<->McLean (via Dallas)
 McLean<->StarLight<->McLean
 McLean<->Dallas (via StarLight)<->McLean (via StarLight)
 McLean<->StarLight<->McLean (via Dallas)

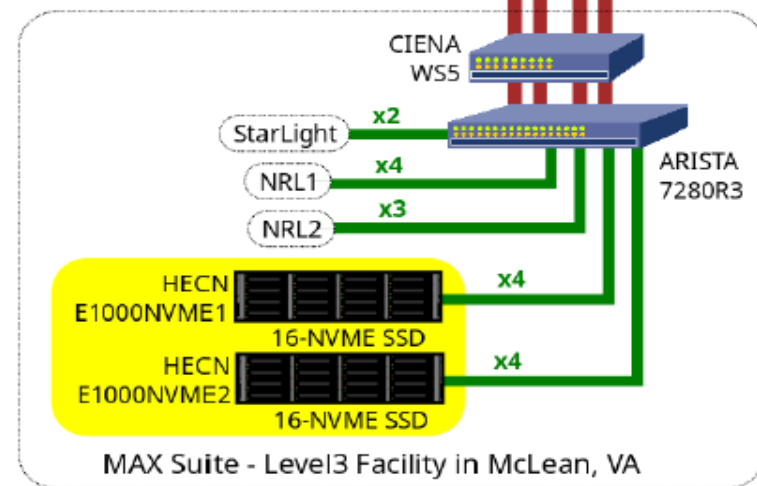
R&D Partners



Legend

400-GigE
 200-GigE
 NASA/GSFC-owned

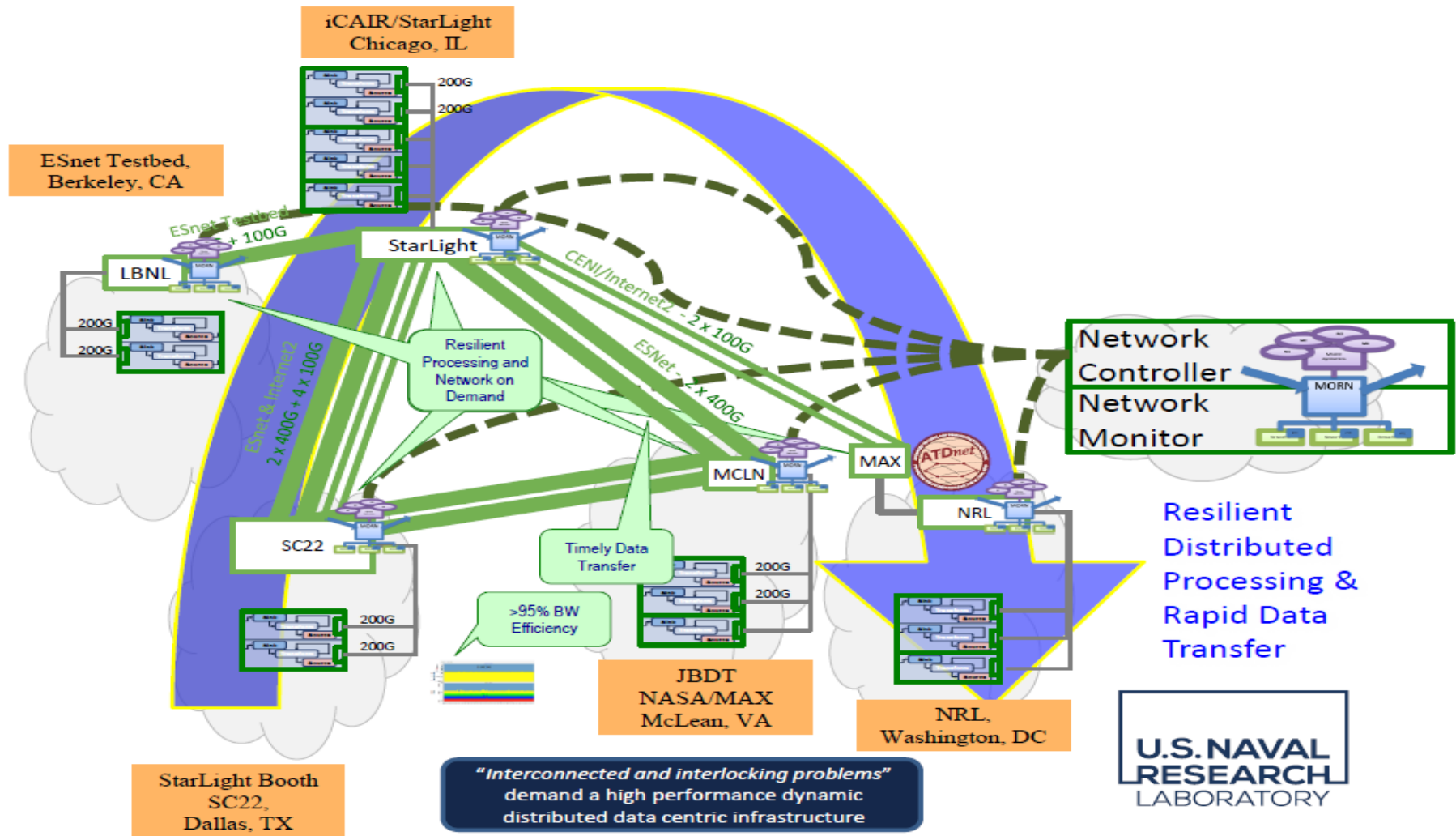
*IP Routed Loopback Point
 Back To MAX Suite - Level3
 McLean, VA



In memory of Paul Lang and Pat Gary

NASA/GSFC High End Computer Networking (HECN) Team
 Diagram by Bill Fink - 10/20/2022

Resilient Distributed Processing & Rapid Data Transfer

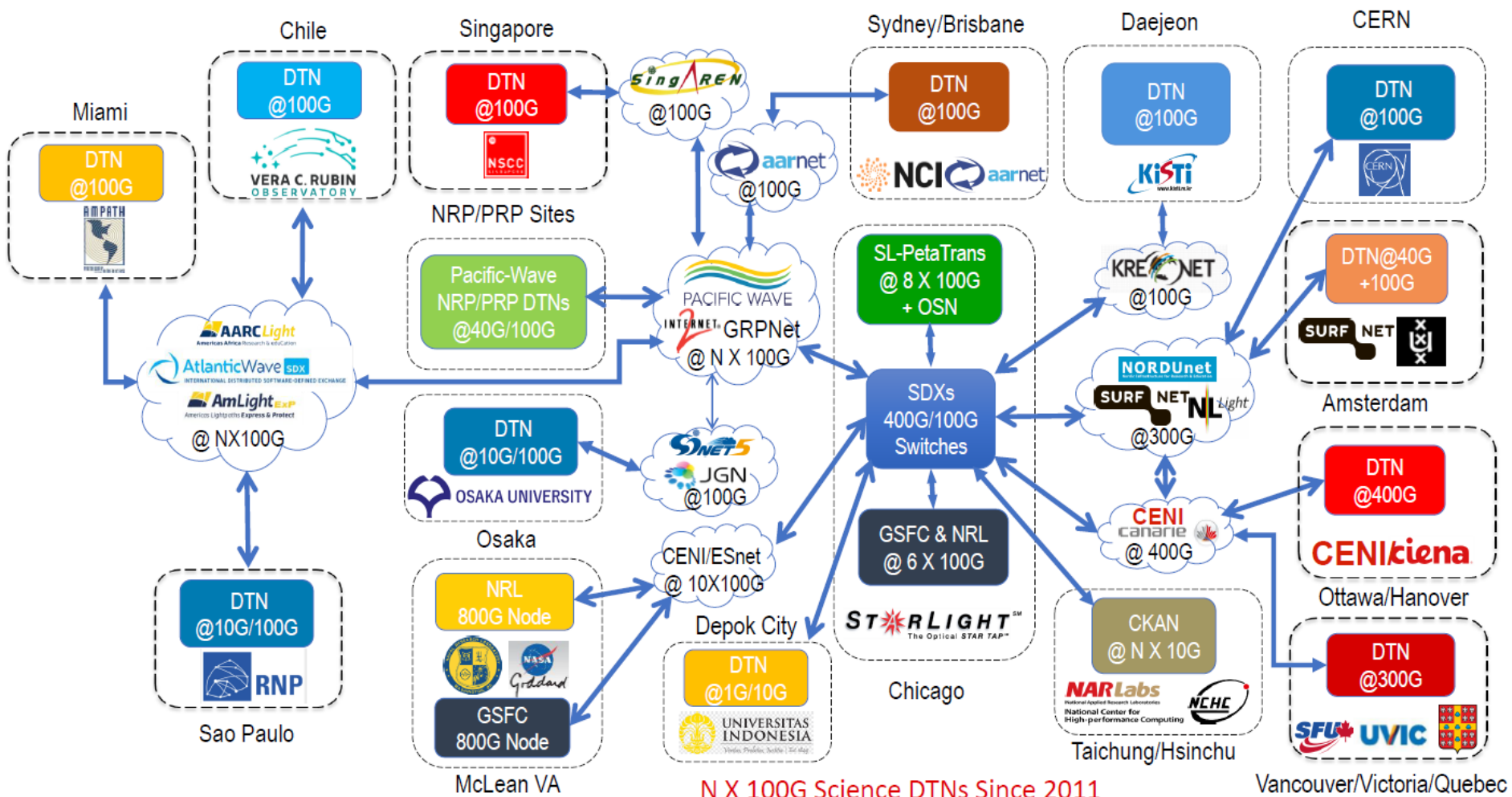


DISTRIBUTION A: Approved for Public Release

STARLIGHT

GRP DTNaaS For Petascale Science

GRP Service: DTNaaS for Petascale Sciences Data Movement



DTN-as-a-Service

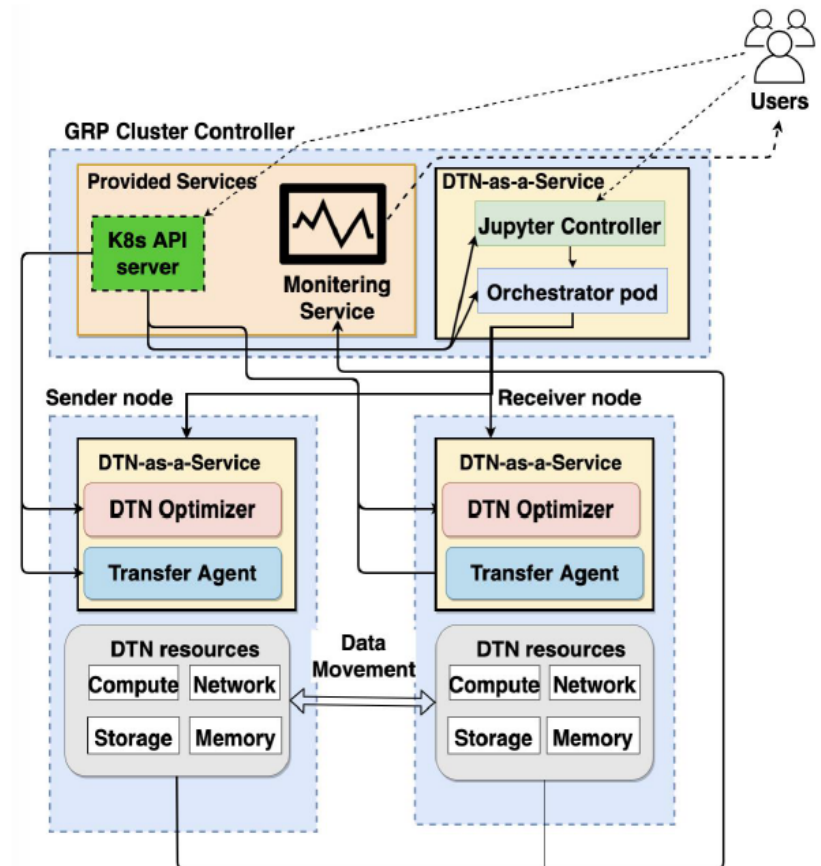
GRP Cluster with DTN-as-a-Service

DTN-as-a-Service(DTNaaS) provides a data movement workflow in GRP k8s cluster:

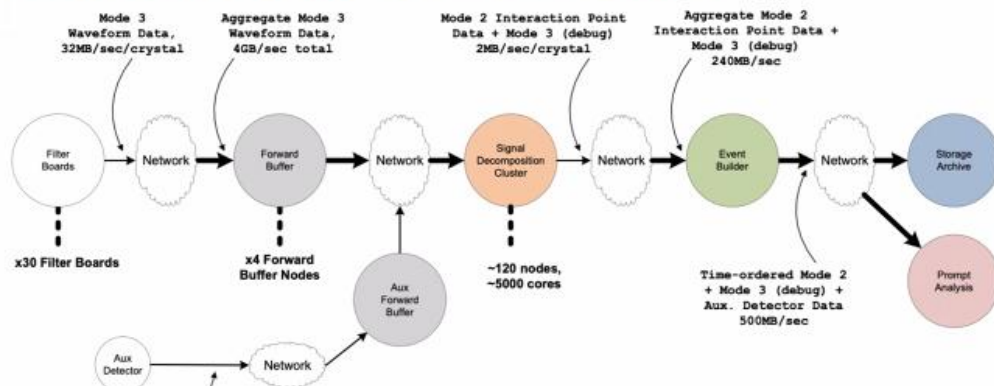
1. Deploy DTNaaS workloads via k8s API server
2. Use Jupyter to optimize and run transfers
3. Observe performance from monitoring service

GRP DTNaaS Components:

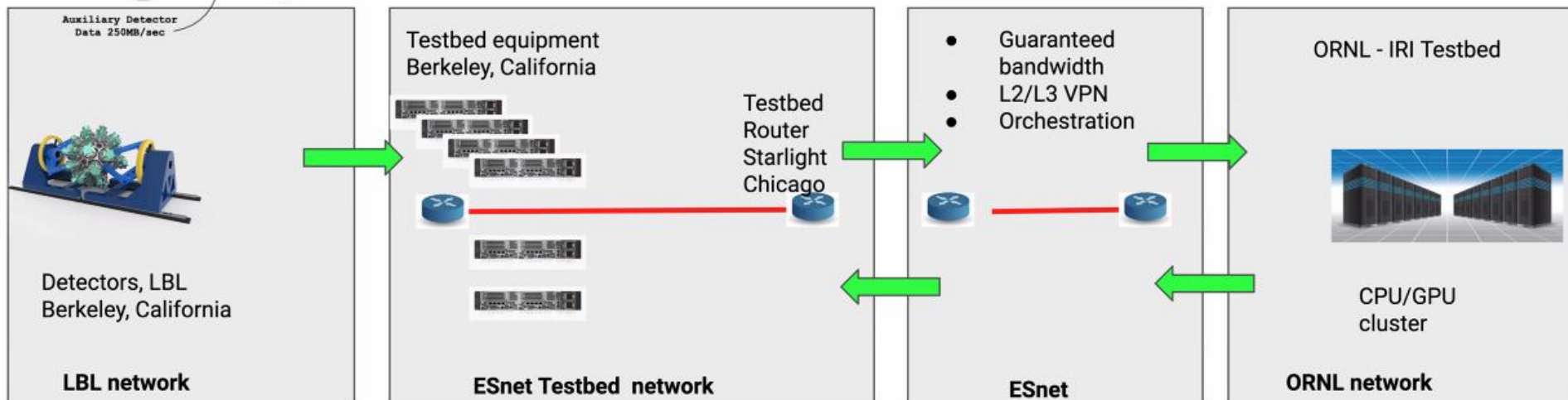
- Orchestrator: controller of DTNaaS to manage agent and optimizer pods via REST API.
- Transfer Agent: run transfer jobs
- DTN Optimizer: optimize the DTN resources for workflow
- Jupyter: web interface to run DTNaaS interactively



GRETA to DELERIA



Impact: scaling up
online processing using
user facilities

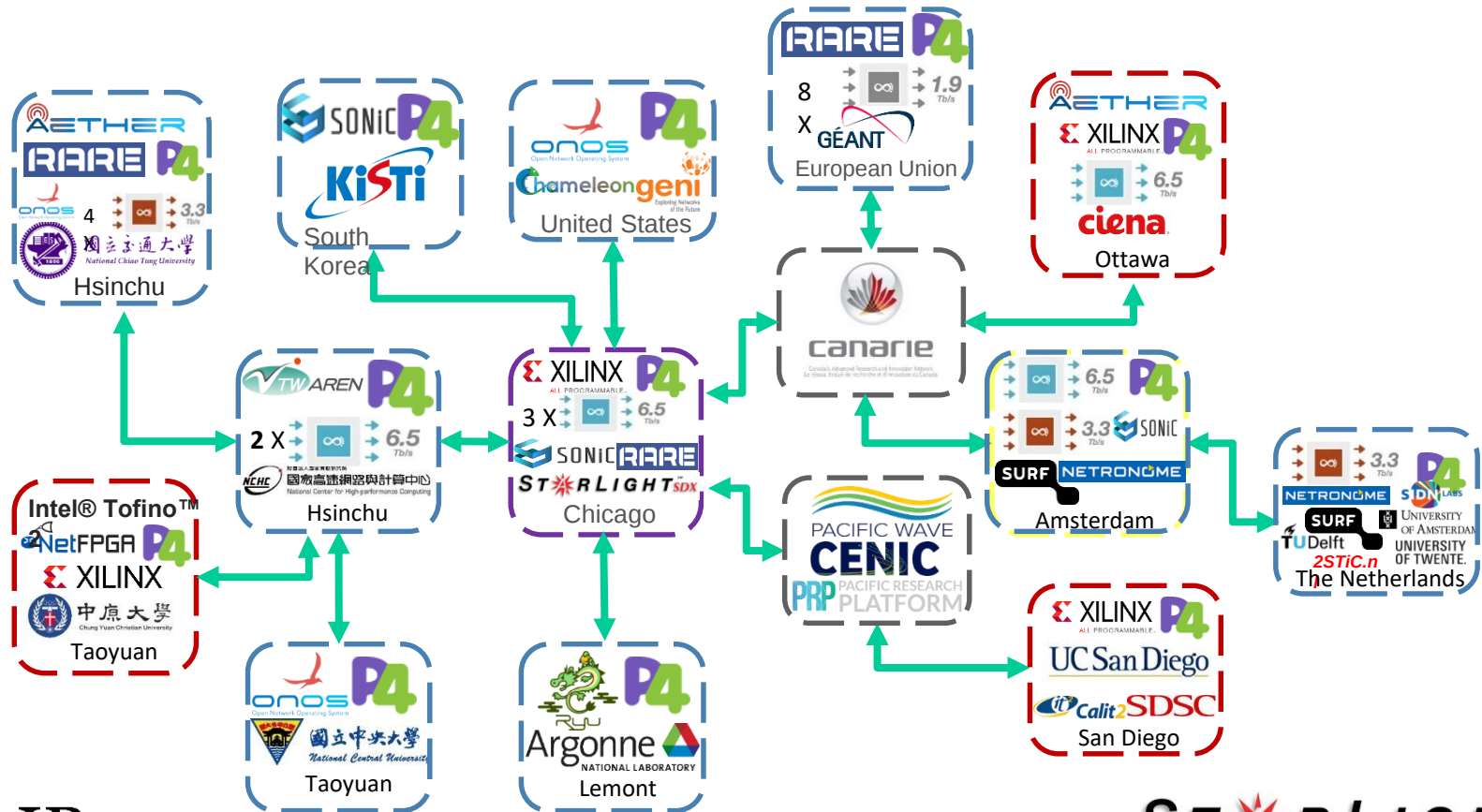


Source: ESnet Testbed

STARLIGHTSM

International P4 Testbed

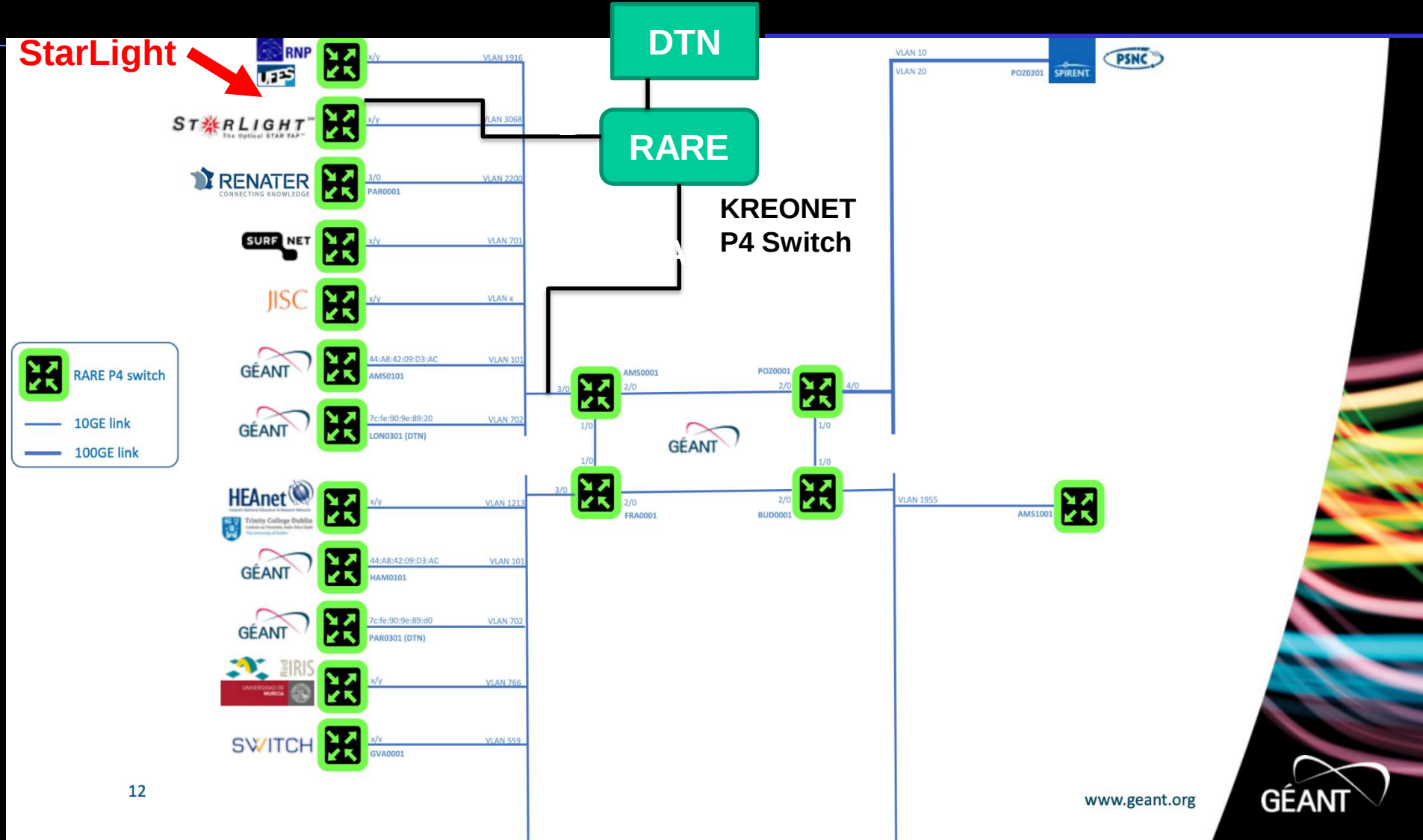
GRP Service: International P4 Experimental Networks (iP4EN)

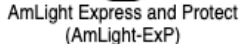


iCAIR

ST*RLIGHTSM SDX

Integration With GEANT P4 Testbed





STARLIGHTSM



www.chameleoncloud.org

CHAMELEON: A LARGE SCALE, RECONFIGURABLE EXPERIMENTAL INSTRUMENT FOR COMPUTER SCIENCE

Kate Keahey

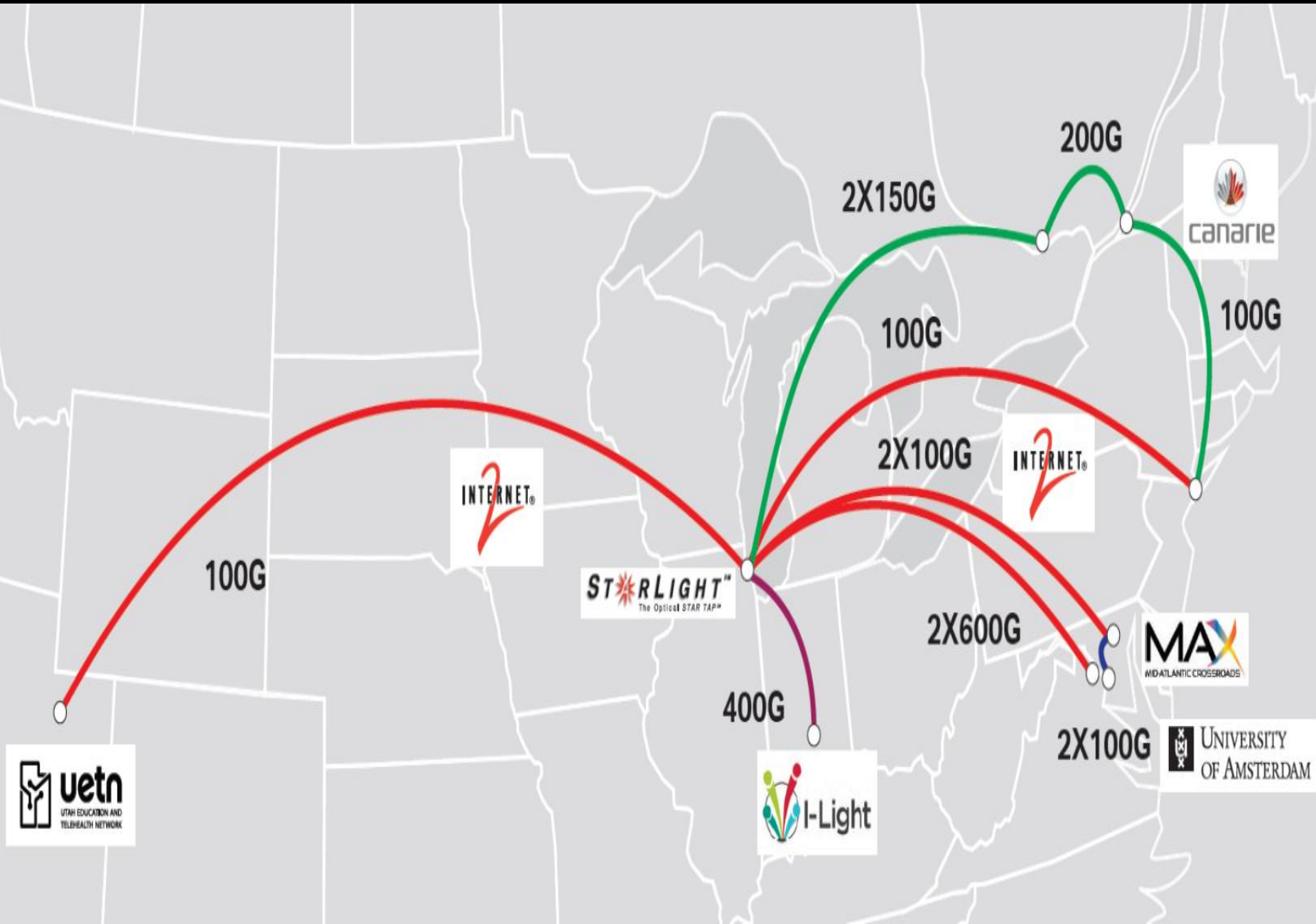
Joe Mambretti, Pierre Riteau, Paul Ruth, Dan Stanzione

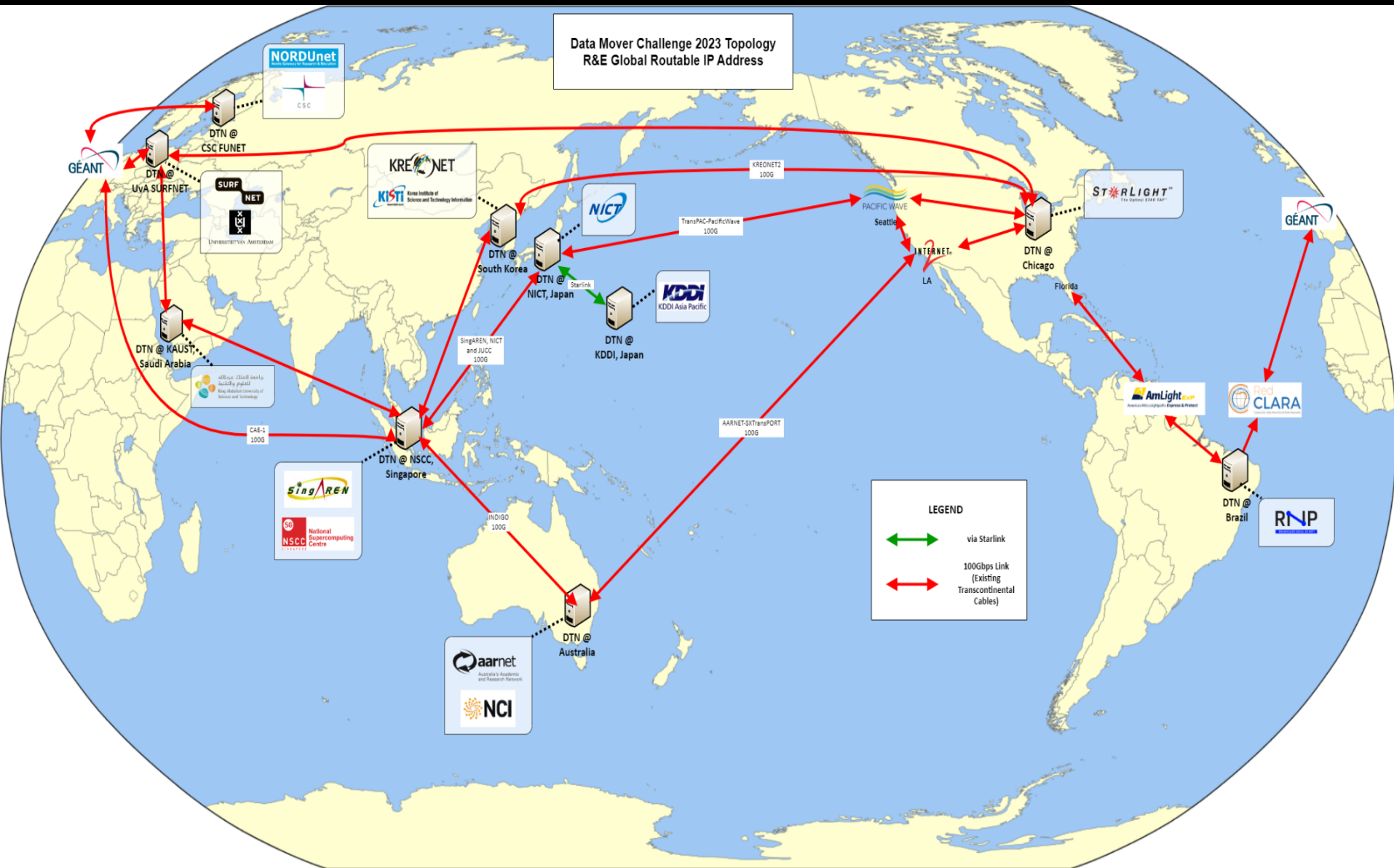
SEPTEMBER 28, 2017

1



Ciena CENI

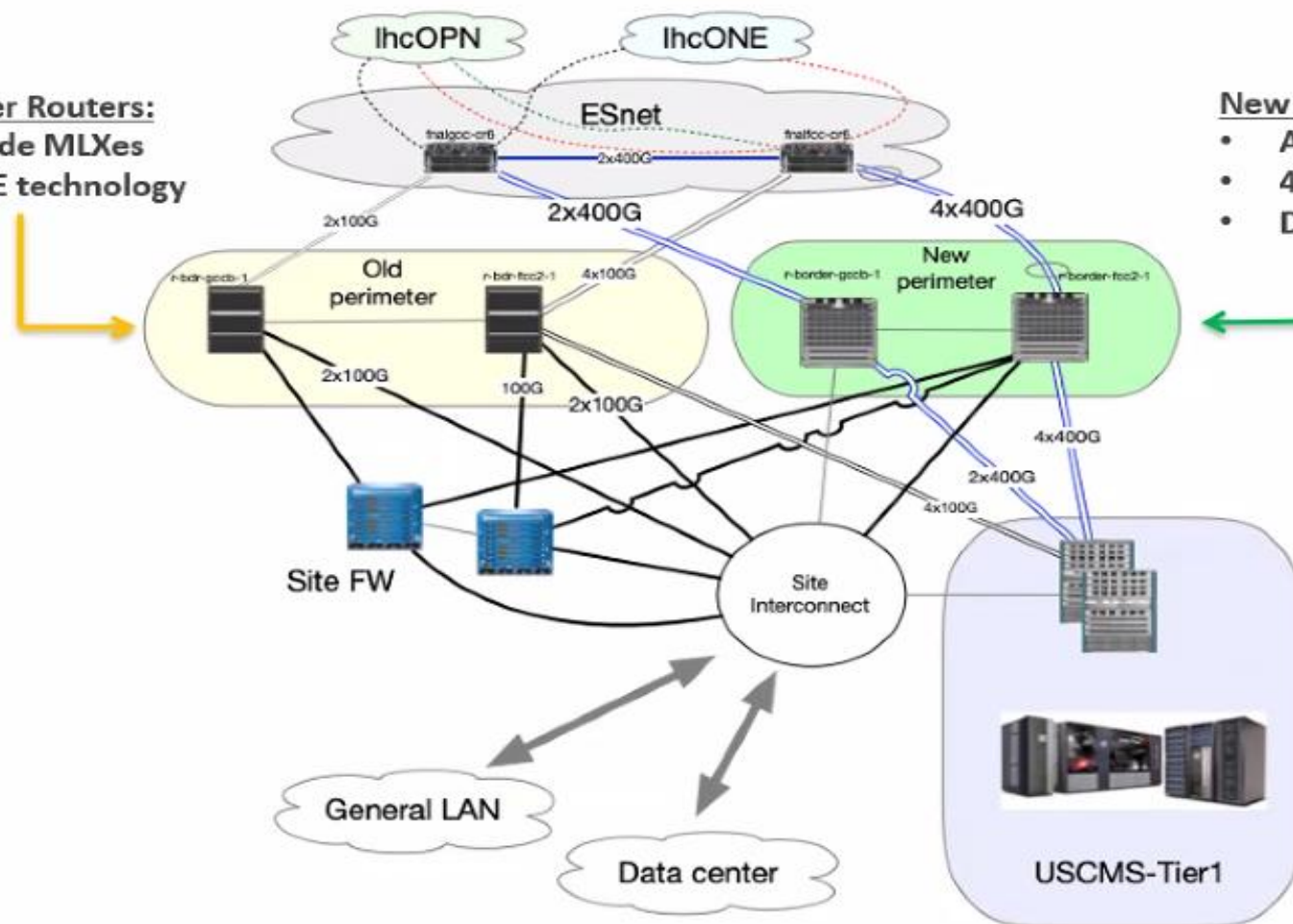




WAN Connectivity Transition! (to 2.4Tb/s...)

Old Border Routers:

- Brocade MLXes
- 100GE technology

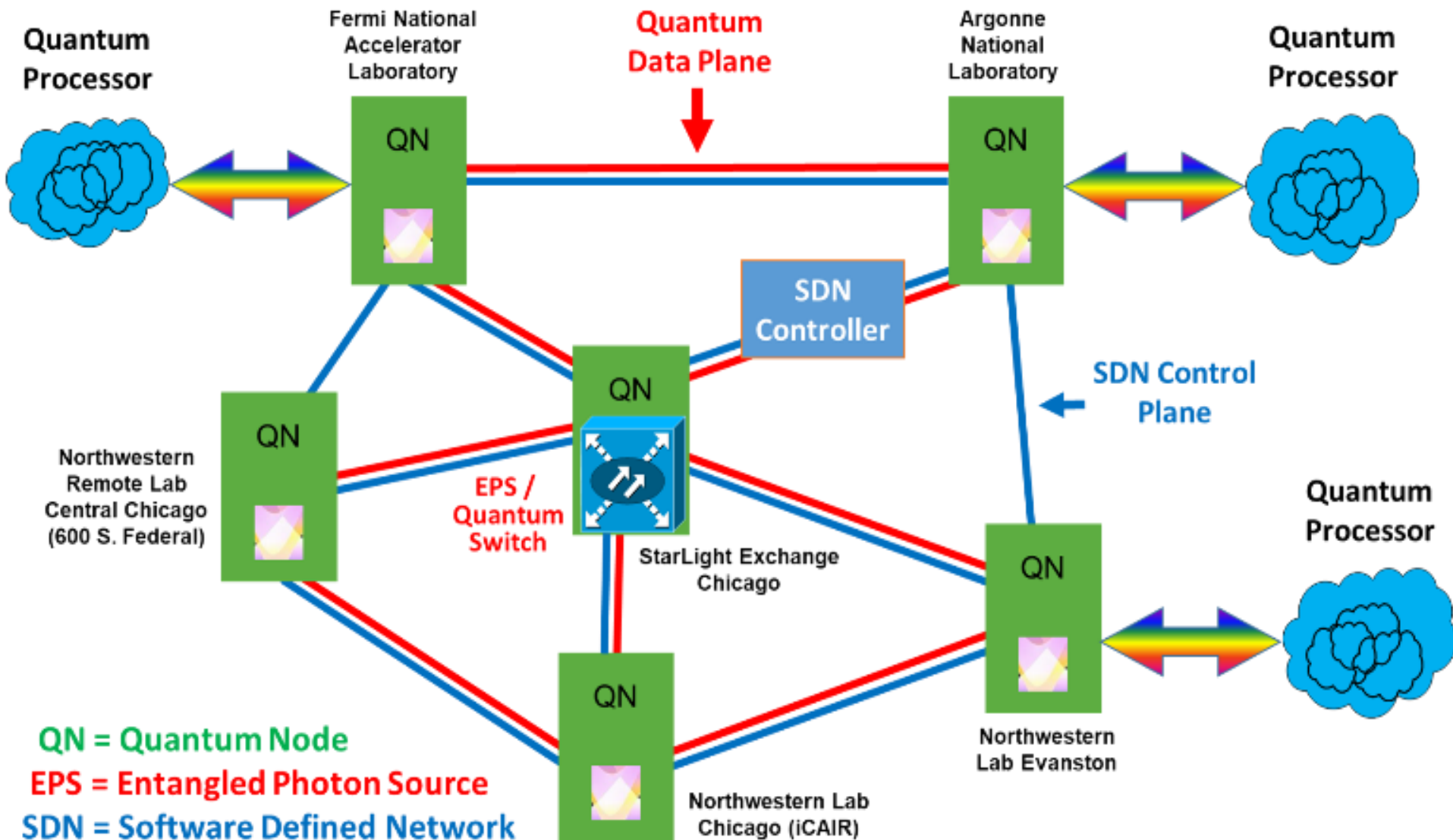


New Border Routers:

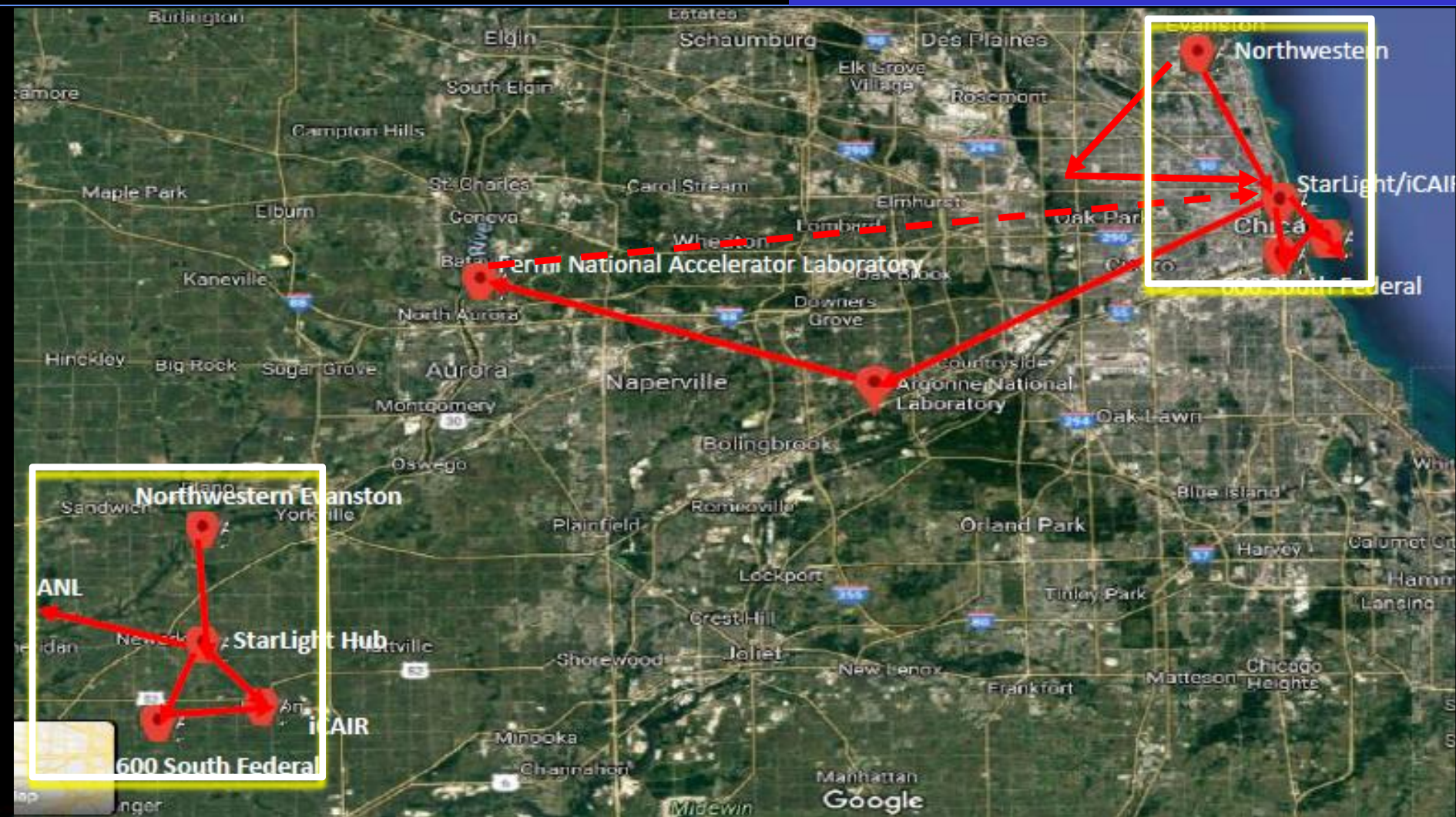
- Arista 7808R3s
- 400-800GE technology
- Deep buffers

Also: Large Scale Network Research Testbed On Site

Emerging Chicago Quantum Exchange Testbed



Energizing IEQnet Testbed Topology



ECOC Teleportation Paper

- *Quantum Teleportation Over Optical Fibers Carrying Conventional Classical Communications Traffic*
- Jordan M. Thomas, Gregory S. Kanter, Fei I. Yeh, Jim Hao Chen, Joe J. Mambretti, Scott J. Kohlert, Prem Kumar



OFC 2026 Los Angeles, CA

- **OFC 51 – Celebrating 51 Years Of Optical Networking and Communications**
- **Expected: Over 13,500 Registrants From 83+ Countries, Showcase of More Than 700 Exhibiting Global Companies**
- **Topics: 1.6 Terabit, AI, Coherent PON, Linear Coherent Pluggable Optics (LPO), Multicore Fiber, Data Center Technology, Quantum Networking, etc.**



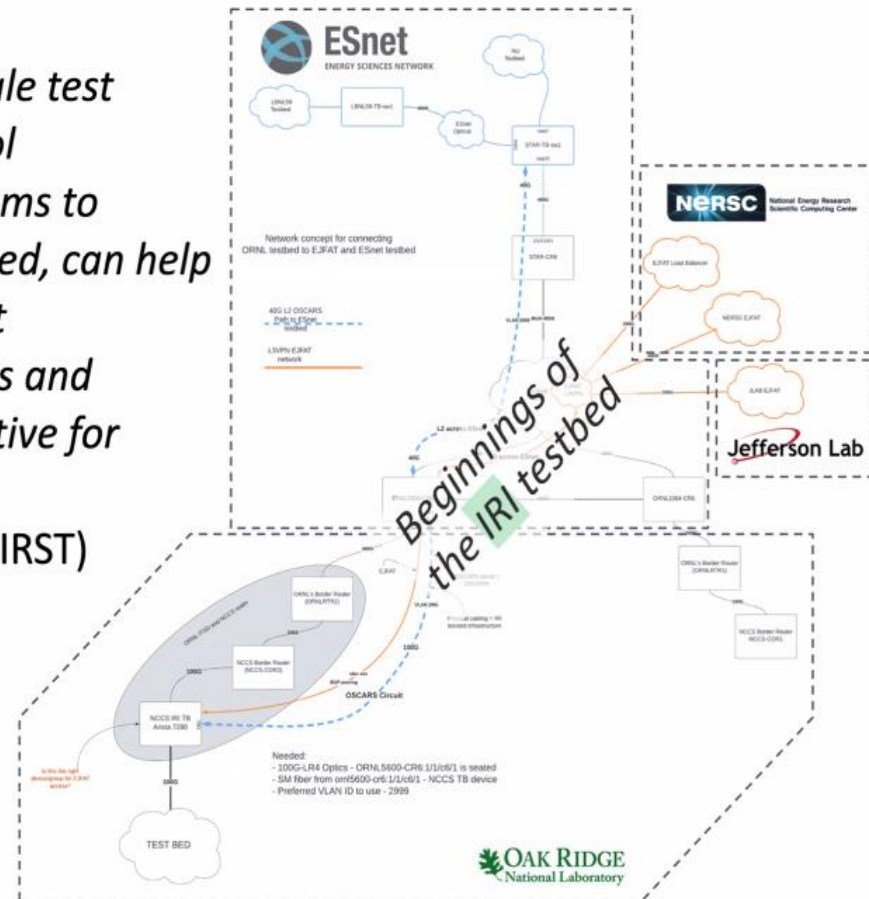
IRI Testbed - A shared playground for IRI developers and pilot applications will accelerate transition to operations

"A best practice in systems design is to create an at-scale test environment in which to build, assess, and improve tool functionality before transitioning technology and systems to production. Such a common test environment, or testbed, can help the broader complex move swiftly to realize an IRI built

on a collectively strong set of tools and functionality already shown effective for science."

- Federated IRI Science Testbed (FIRST) report

I. Monga, M. Shankar, C. Guok, "Federated IRI Science Testbed (FIRST): A Concept Note", December 2023, doi:10.2172/2205149, <<https://doi.org/10.2172/2205149>>



www.startap.net/starlight

Thanks to the NSF, DOE, NASA,
NIH, DARPA
Universities, National Labs,
International & Industrial
Partners,
and Other Supporters



STARLIGHTSM