

StarLight, the GRP, and SC23

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

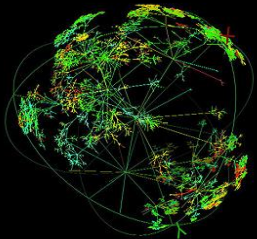
Joint Engineering Taskforce

IEEE/ACM International Conference on

High Performance Computing, Networking, Storage, and Analytics

Denver, Colorado

November 14, 2023



Large Scale Science Ecosystems

- **Science Domains Create Cyberinfrastructure Ecosystems, Some Distributed World Wide, Some Devoted To Domains, Some Shared Among Domains**
- **GRP Provides Opportunities For Information Sharing: Cyberinfrastructure Architecture, Implementation, Technologies and Operations Among Projects (Especially Useful For Cross Disciplinary Research)**
- **Projection/Definition of Future, Specialized Requirements, Architecture, Services, Techniques, Technologies, Processes Described In Cyberinfrastructure “Blueprints”**
- **Cambrian Explosion Of Requirements and Innovations**
- **Techniques and Technologies Emerge from Multiple Sources (Academic, Commercial, Government Labs, Utilitarian Imperatives, e.g., Commercial Clouds)**
- **Macro-Trend: “Software Eating The World” - Software Defined Everything**
- ***Multiple Software Building Blocks For Data-Intensive Science (Modules/Components) Are Emerging***

Global Collaborative Research Communities

- **Science Is Global**
- **Open Information Sharing, A Cornerstone of The Science Process**
- **Concepts, Experiments, Instruments, Methods, Techniques, Data, Technologies And Results Are Openly Communicated and Shared Among Collaborative Science Communities World-Wide**
- **The Global Research Platform Is An International Collaborative Partnership Creating A Distributed Environment for International Data Intensive Science**
- **The GRP Facilitates High Performance Data Gathering, Analytics, Transport (100 Gbps-Tbps E2E), Computing, And Storage**
- **www.theglobalresearchplatform.net**



Selected Applications



GENI
www.geni.net



Open Storage Network
www.openstorage.network.org



GLEON
www.gleon.org



USGS EROS
www.usgs.gov/centers/eros



NEON
www.neonscience.org



PRAGMA
www.pragma-grid.net



CENTRA
www.globalcentra.org



OSG
www.openscience.grid.org



GRP
the global research platform.net/



PRP
pacificresearchplatform.org



CHASE-CI
www.calit2.net/newsroom/article.php?id=2910



SAGE2
sage2.sagecommons.org



Polar Geospatial Center
www.pgc.umn.edu



IceCube
icecube.wisc.edu



Chameleon
www.chameleoncloud.org



Jetstream
www.jetstream-cloud.org



Genomic Science Program
genomicscience.energy.gov



LSST
www.lsst.org



Pierre Auger Observatory
www.auger.org



Belle II
www.belle2.org



LBNF/DUNE/ProtoDUNE
lbnf.fnal.gov



ISS
www.nasa.gov/station



SKA
www.skatelescope.org



XENON
xenon.astro.columbia.edu



NOVA
novaexperiment.fnal.gov



Virgo
www.virgo-gw.eu



LIGO
www.ligo.caltech.edu



SDSS
www.sdss.org



ALMA
www.almaobservatory.org



LHC
home.cern.ch/science/accelerators/large-hadron-collider



LHCONE
twiki.cern.ch/twiki/bin/view/LHCONE/WebHome



LHCOPN
twiki.cern.ch/twiki/bin/view/LHCOPN/WebHome



IVOA
www.ivoa.net

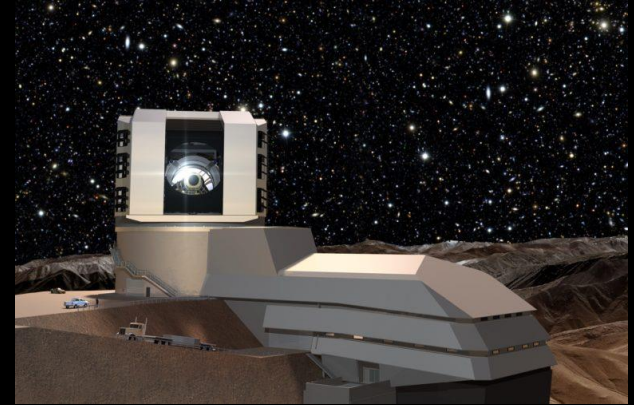
Instruments: Exebytes Of Data



High Luminosity LHC



SKA Australia Telescope Facility



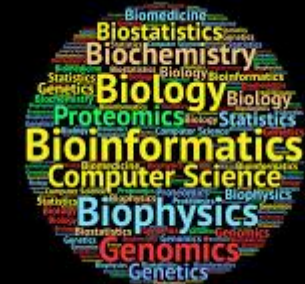
Vera Rubin Observatory



KSTAR Korea Superconducting Tokamak



Next Gen Advanced Photon Source



Bioinformatics/Genomics

The GRP: A Platform For Global Science



GLOBAL RESEARCH PLATFORM

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

Global Research Platform: Global Lambda Integrated Facility Available Advanced Network Resources



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



www.glif.is

STARLIGHTSM

Annual Global Research Platform Workshop – Co-Located With IEEE International Conference On eScience Oct 9-10

'23 eScience

October 9-13, 2023

Limassol, Cyprus

IEEE eScience 2023 brings together leading interdisciplinary research communities, developers and users of eScience applications and enabling IT technologies. The objective of the eScience Conference is to promote and encourage all aspects of eScience and its associated technologies, applications, algorithms and tools with a strong focus on practical solutions and challenges. eScience 2023 interprets eScience in its broadest meaning that enables and improves innovation in data- and compute-intensive research across all domain sciences ranging from traditional areas in physics and earth sciences to more recent fields such as social sciences, arts and humanities, and artificial intelligence for a wide variety of target architectures including

Important Dates

~~February 10, 2023~~ **Friday, February 24, 2023**
Workshop Submissions

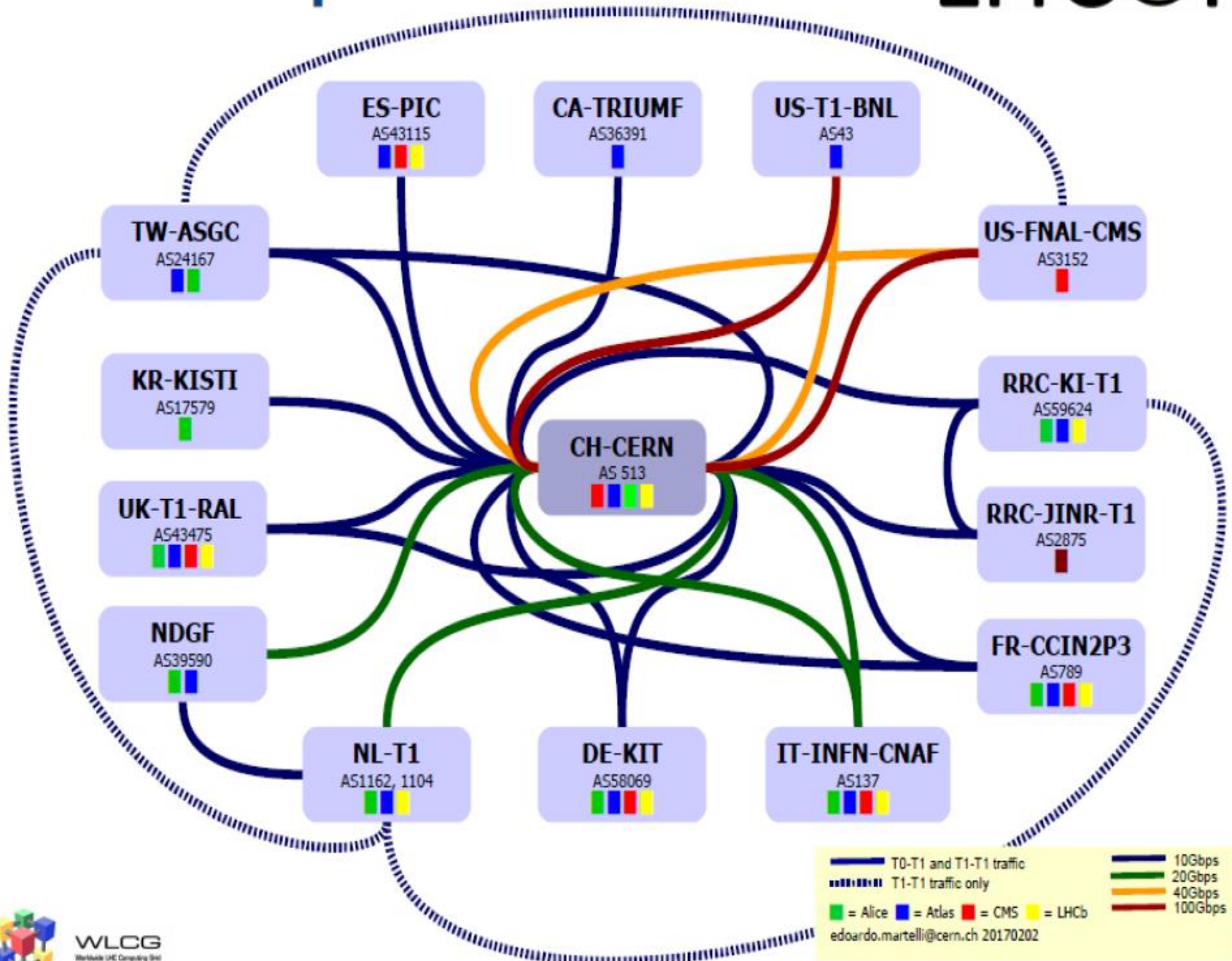
~~February 24, 2023~~ **Friday, March 10, 2023**
Workshop Acceptance Notification

Friday, May 26, 2023
Paper Submissions

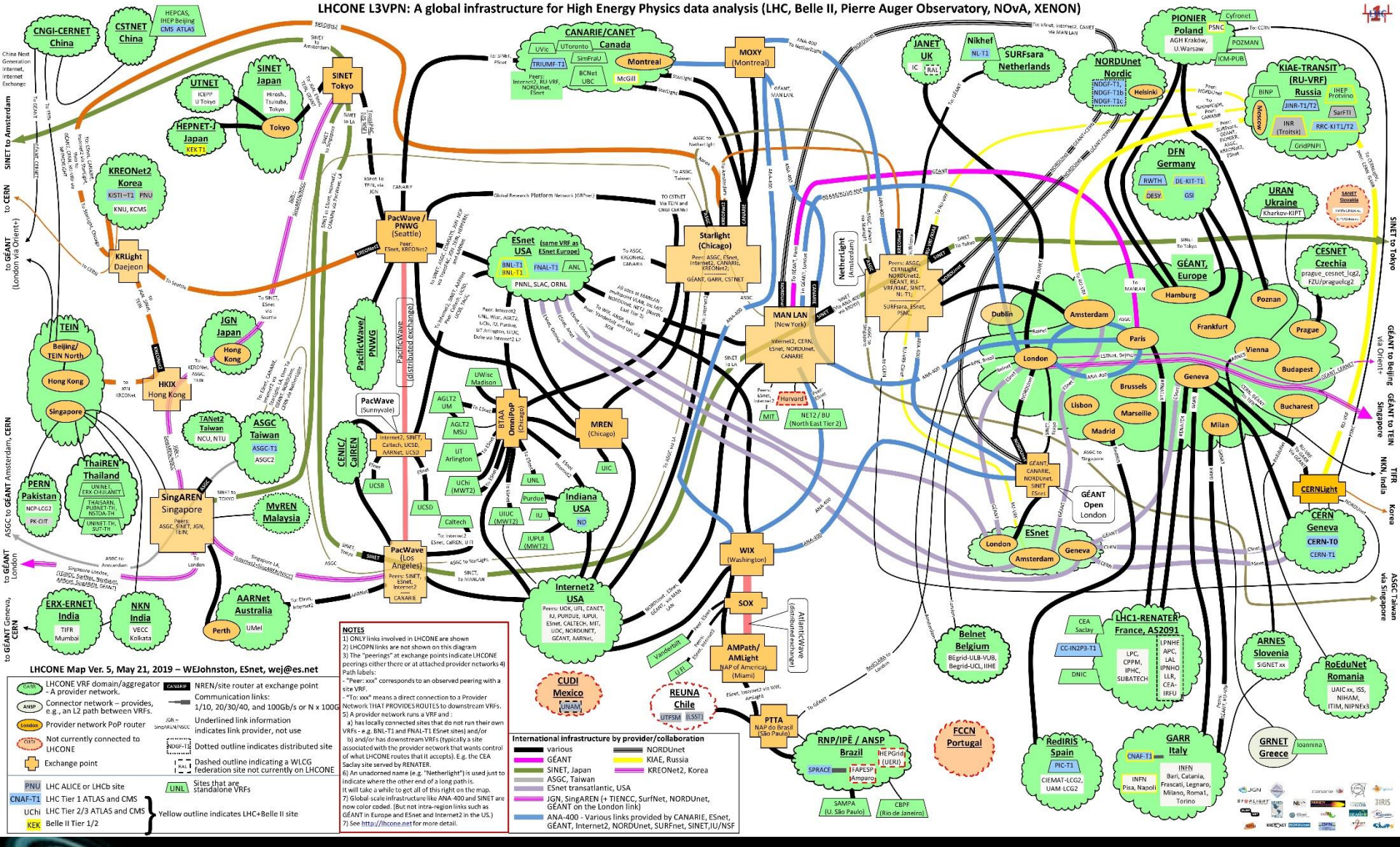
Friday, June 30, 2023
Notification of Paper Acceptance



LHCOPN map



LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NoVA, XENON)



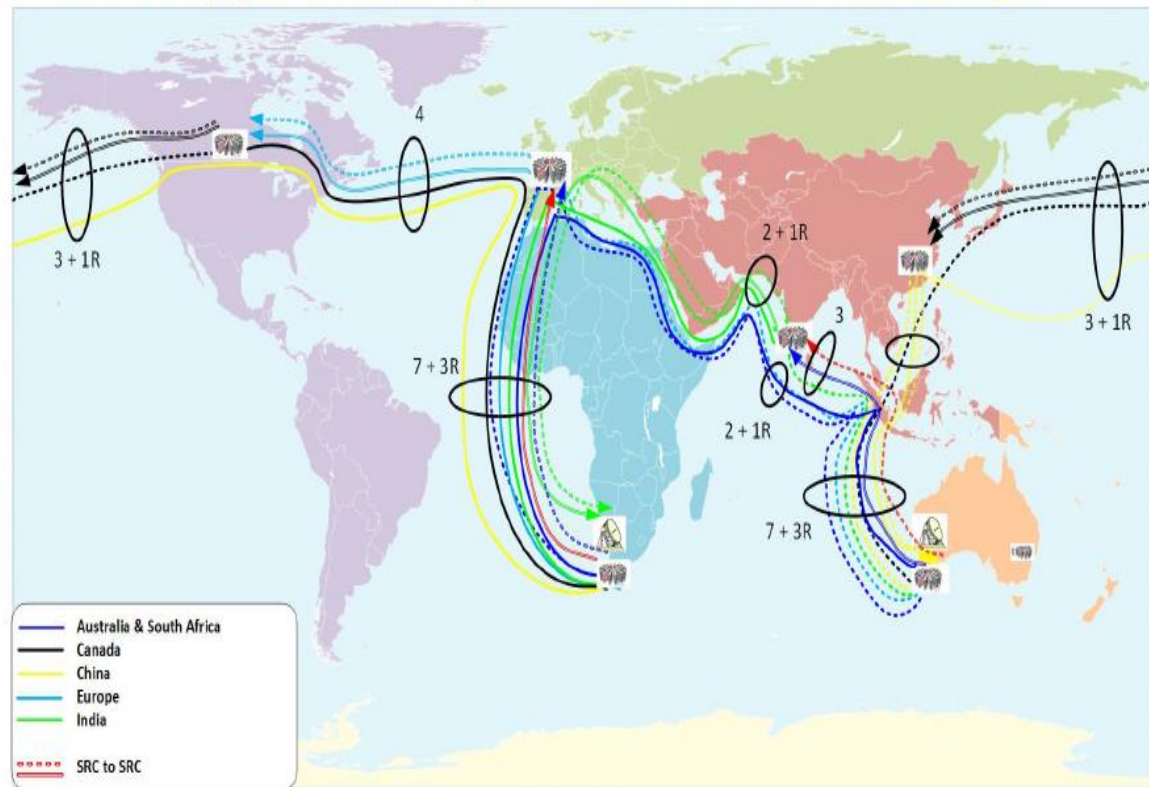
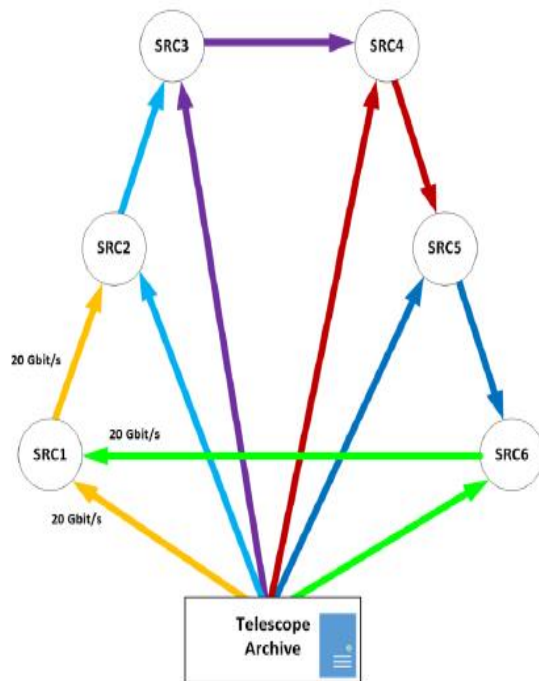
Non-LHC Scientific Communities Using LHCONE

- **Belle II Experiment, Particle Physics Experiment Designed To Study Properties of B Mesons (Heavy Particles Containing a Bottom Quark)**
- **Pierre Auger Observatory, Studying Ultra-High Energy Cosmic Rays, the Most energetic and Rarest Particles in The Universe**
- **LIGO and Virgo (In August 2027 This Collaboration Measured a Gravitational Wave Originating From a Binary Neutron Star Merger.)**
- **NOvA Experiment: Designed To Answer Fundamental Questions In Neutrino Physics**
- **XEON Dark Matter Project: Global Collaboration Investigating Fundamental Properties of Dark Matter, Largest Component of the Universe**
- **DUNE/ProtoDUNE – Deep Underground Neutrino Experiment**



Global Data Flows if the SRC Re-distribute data – 2 Replicas

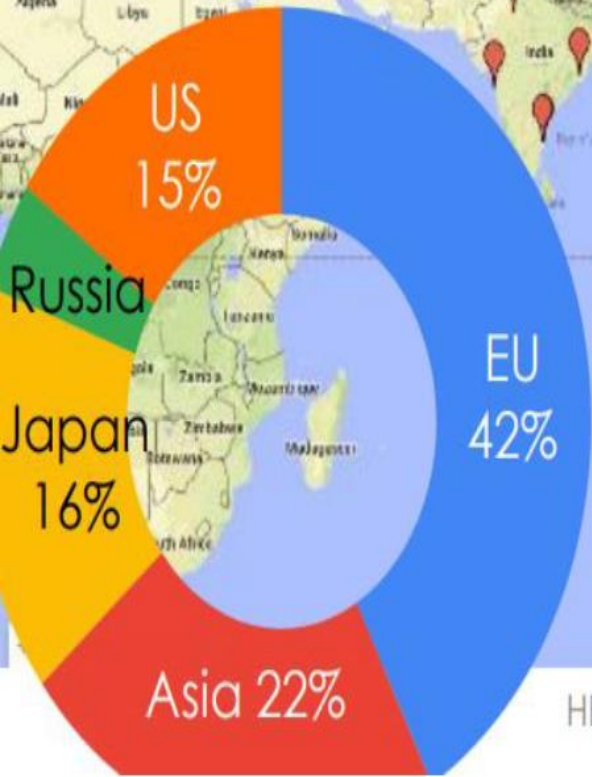
- Each SRC accepts its fraction of the Observatory Data Products and re-distributes to another SRC.
- SRC has 20 Gbit/s flow from the telescope & a second continuous 20 Gbit/s flow from another SRC.
- Each SRC sends out a 20 Gbit/s flow.
- Makes substantial use of the shared academic network which would imply charges to the SKA community.
- **Probable cost to SKA community Very approx. ~ 0.8 M USD/year not allowing for the extra BW from the telescopes**





Belle II Collaboration

A Global Collaboration
as wide as an LHC experiment



26 countries/regions
123 institutes
1,075 researchers

Global Scale Science Highlighted At Prior GRP Workshops

- **The Square Kilometer Array: Data Transport, Processing, Archiving and Access, Shaun Amy, Australia Telescope National Facility**
- **Large Synoptic Survey Telescope Distributed Computing and Networks, Jeff Kantor, LSST**
- **Korean Fusion Program: KSTAR, ITER and K-DEMO and International Collaborators, Si-Woo Yoon, National Fusion Research Institute**
- **Square Kilometer Array (SKA), Richard Hughes-Jones, GÉANT**
- **Vera C. Rubin Observatory, Large Synoptic Survey Telescope (LSST), Nate Lust, LSST/Rubin Observatory**
- **Belle II, Super B-Factory Experiment, Silvio Pardi, National Institute for Nuclear Physics, (INFN)**
- **Deep Underground Neutrino Experiment (DUNE) – Kenneth Herner, Fermi National, Accelerator Laboratory**
- **Distributed Computing Operations For HL-LHC With Operational Intelligence, Federica Legger, National Institute of Nuclear Physics (INFN)**
- **Next-Generation Cyberinfrastructures for LHC, High-Luminosity LHC and Data Intensive Sciences, Harvey Newman, Caltech**
- **KAUST Genomics Cloud, Alex Moura, KAUST**

Next Generation Research Platforms

- **Large Scale Highly Distributed Science DMZs**
- **Super Facilities**
- **National Research Platforms**
- **Continental Research Platforms**
- **Global Research Platforms**

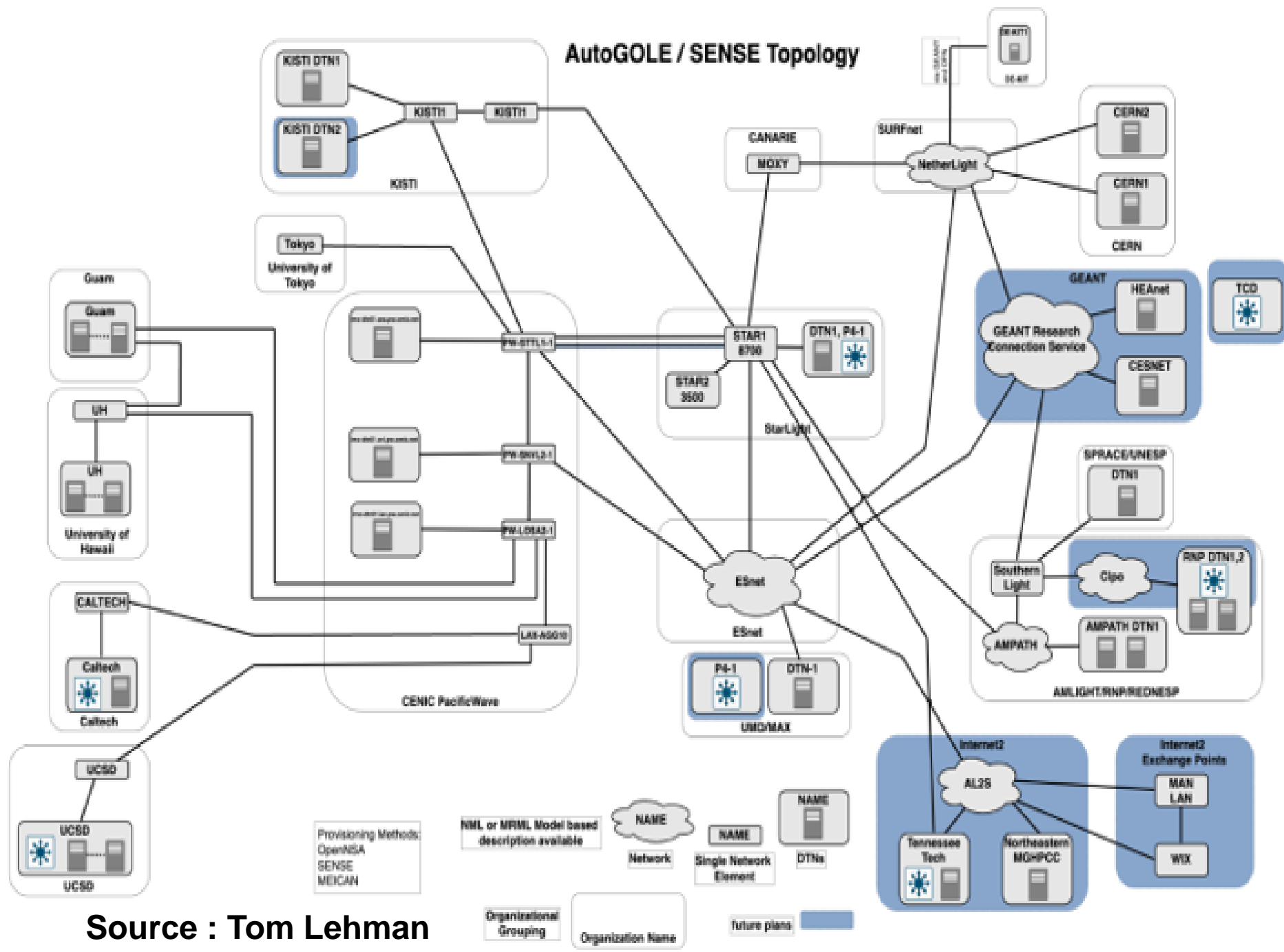


GRP Themes

- **Research Platforms**
- **Orchestration Among Multiple Domains**
- **Large-Scale High Capacity Data WAN Transport (Highlighted At SC23: 400 Gbps, 800 Gbps, 1.2 Tbps WAN Services For Data Intensive Science)**
- **High-Fidelity Data Flow Monitoring, Visualization, Analytics, Diagnostic Algorithms, Event Correlation AI/ML/DL**
- **International Testbeds for Data-Intensive Science**



AutoGOLE / SENSE Topology

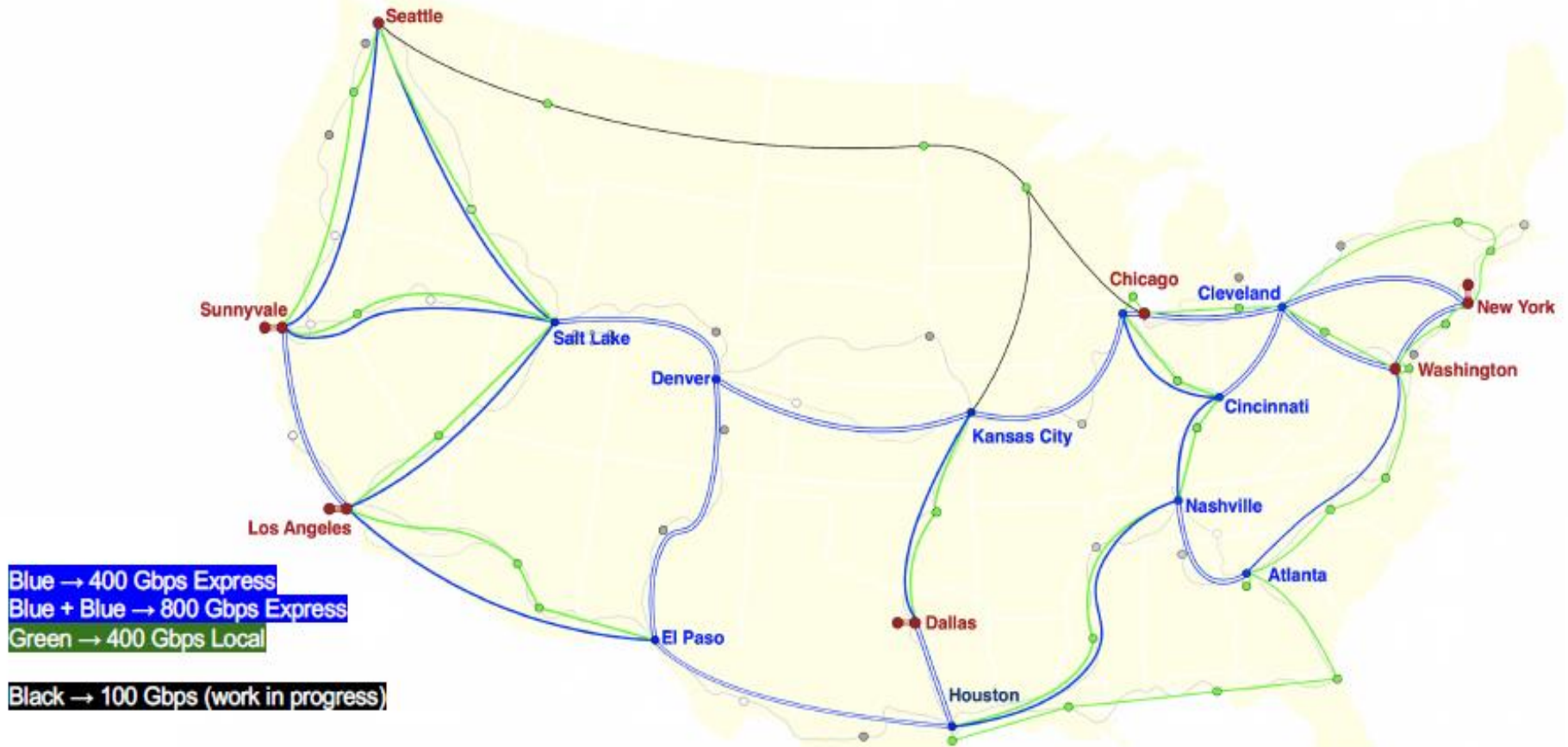


Source : Tom Lehman

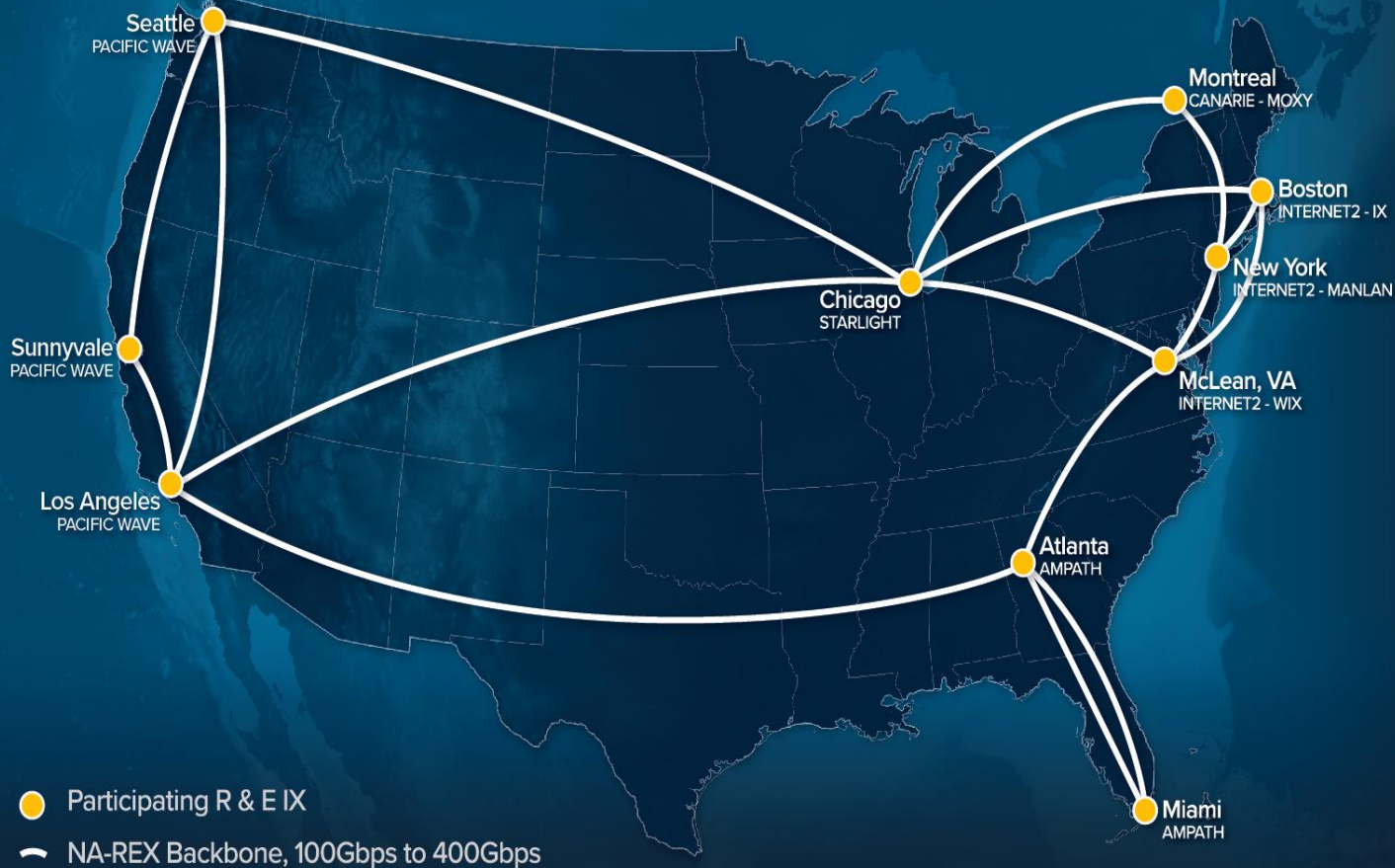
Internet2 Backbone Topology

Backbone Topology - Capacity and Traffic Management

Chris Wilkinson, Director of Planning and Architecture



NA-REX North America Research & Education Exchange Collaboration



November 2023

aponet ASIA PACIFIC OCEANIA NETWORK (APOnet)



- NII/SINET
- AARNet
- KREONet2/KISTI
- ARENA-PAC
- UoH
- Guam-SG consortium (ARENA-PAC, AARNET, Internet2, TransPAC)
- PacificWave
- PacificWave/TransPAC
- SingAREN/NSCC
- NICT/NSCC/SingAREN
- REANNZ

Logos of the network partners:

- aarnet
- ARENA-PAC
- INTERNET2
- NICT
- KISTI
- PACIFIC WAVE
- REANNZ
- SINETS
- SINGAREN
- UNIVERSITY OF HAWAII

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

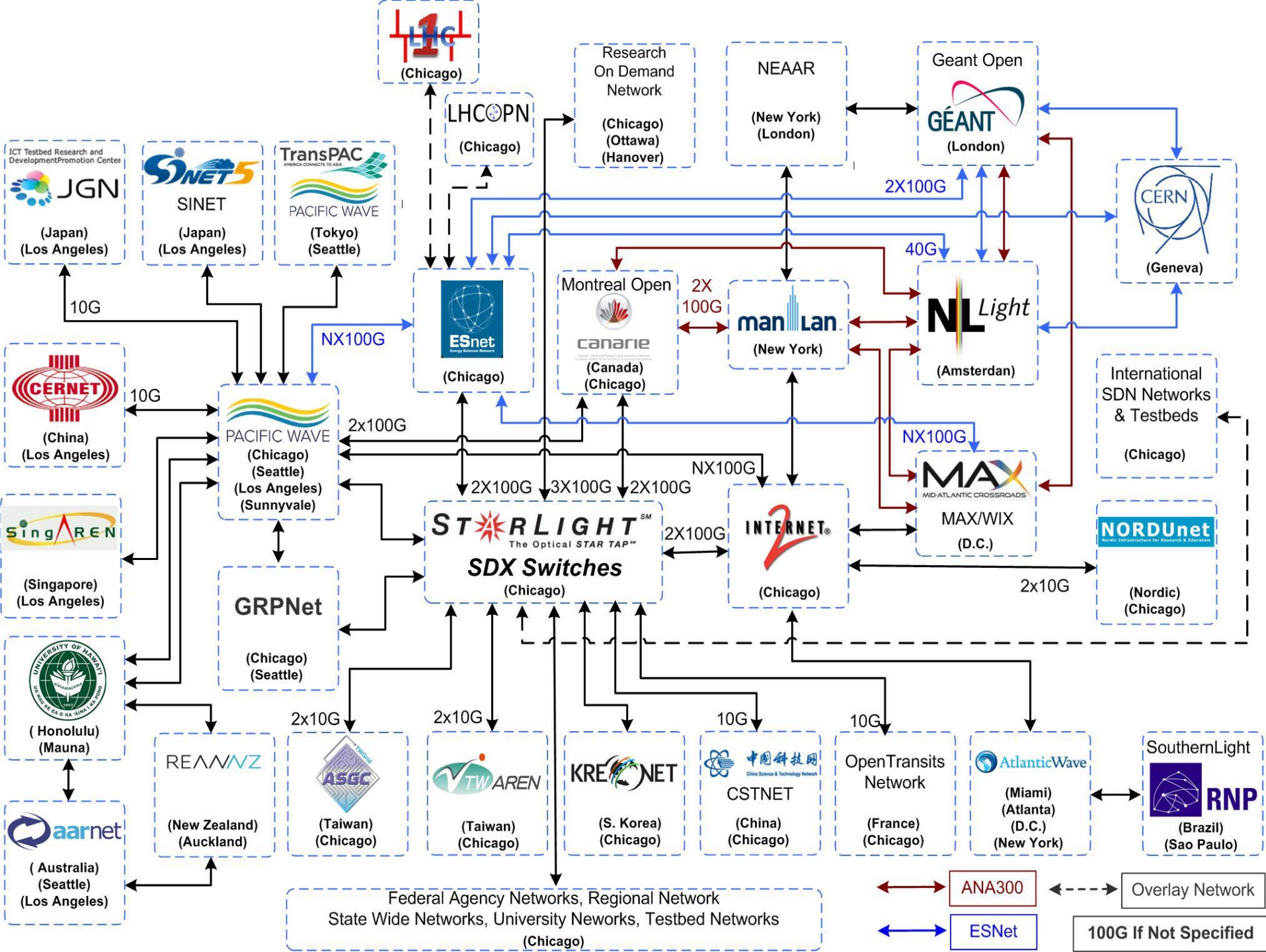


View from StarLight



Abbott Hall, Northwestern University's Chicago Campus

Currently: 20+ 400 Gbps Paths Prototyping 800 Gbps **STARLIGHT**SM



International Federated Testbeds As Instruments for Computer Science/Network Science

- **The StarLight Communications Exchange Facility Supports ~ 25 Network Research Testbeds (Instruments For Computer Science/Networking Research)**
- **StarLight Supports Two Software Defined Exchanges (SDXs), An NSF IRNC SDX & A Network Research GENI SDX (Global Environment for Network Innovations)**
- **The GENI SDX Supports National and International Federated Testbeds**

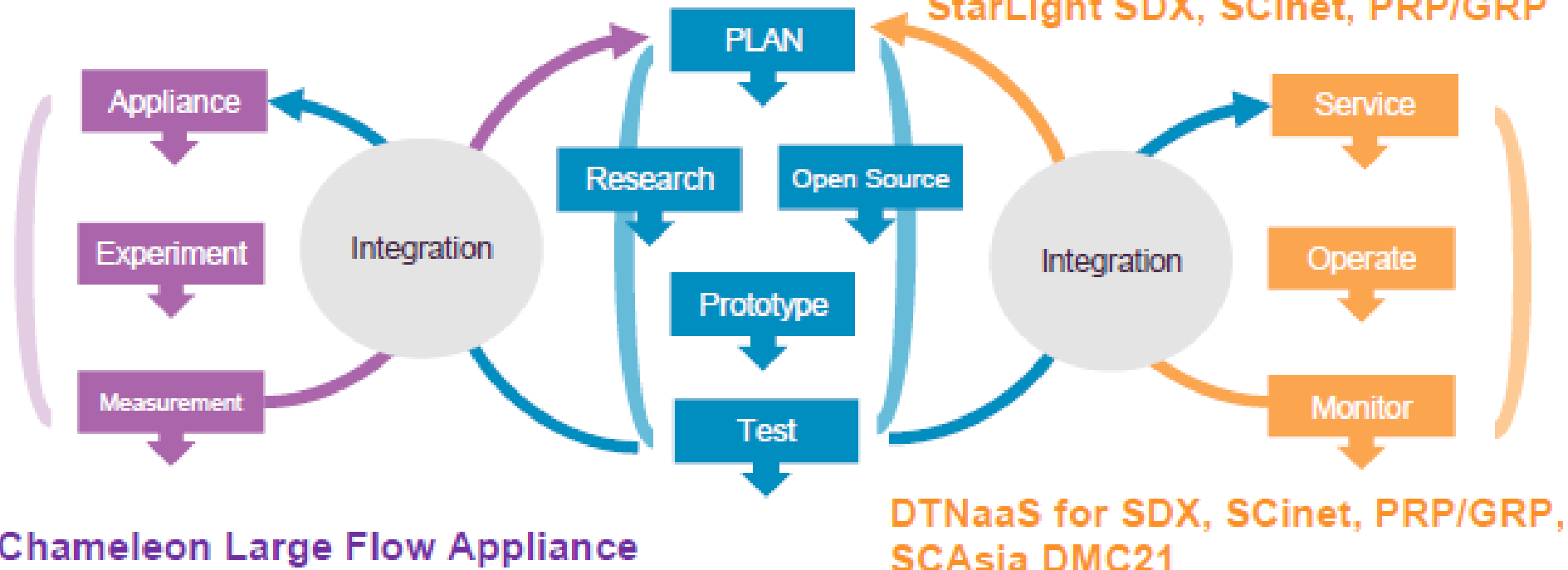


StarLight Software Defined Exchange

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

StarLight Testbeds

StarLight SDX, SCinet, PRP/GRP



iCAIR

STARLIGHTSM SDX

Source: Jim Chen

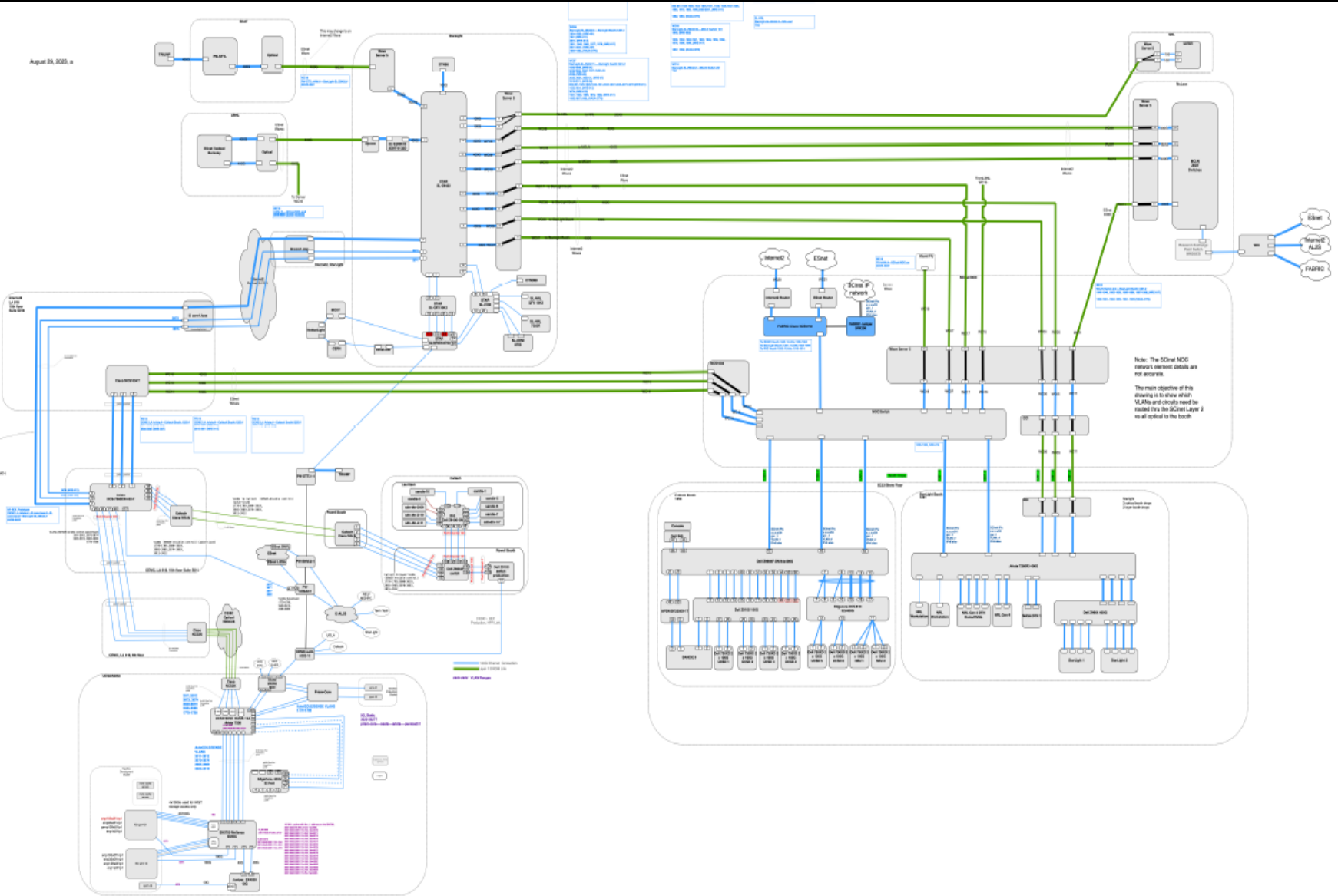
STARLIGHTSM

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 SC23 National WAN Testbed Is Being Designed and Implemented To Support Demonstrations and Experiments Of Innovations Related To Data Intensive Science**



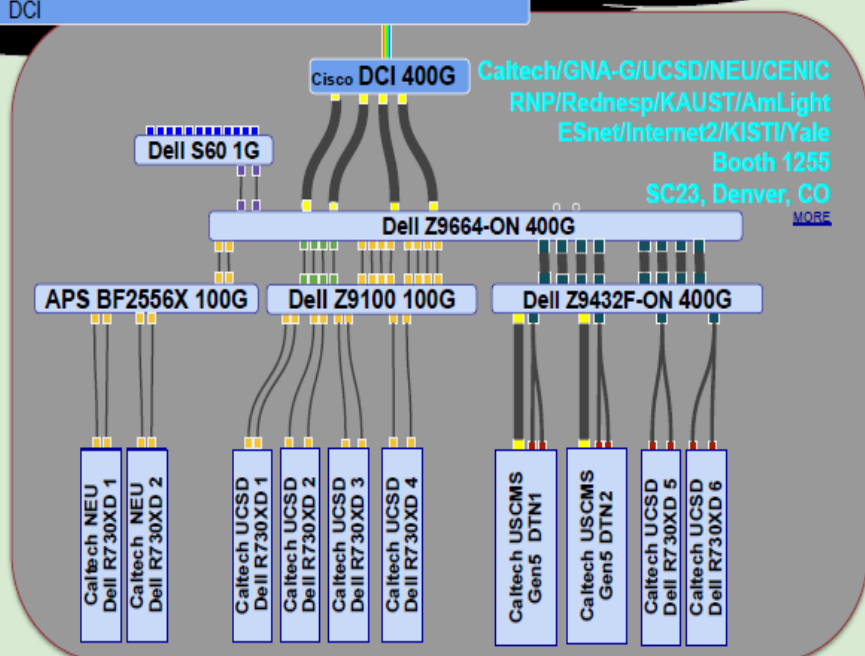
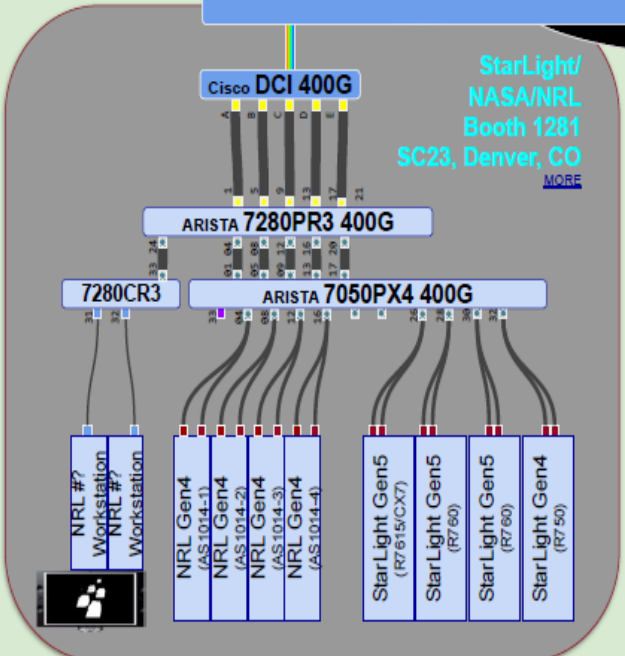
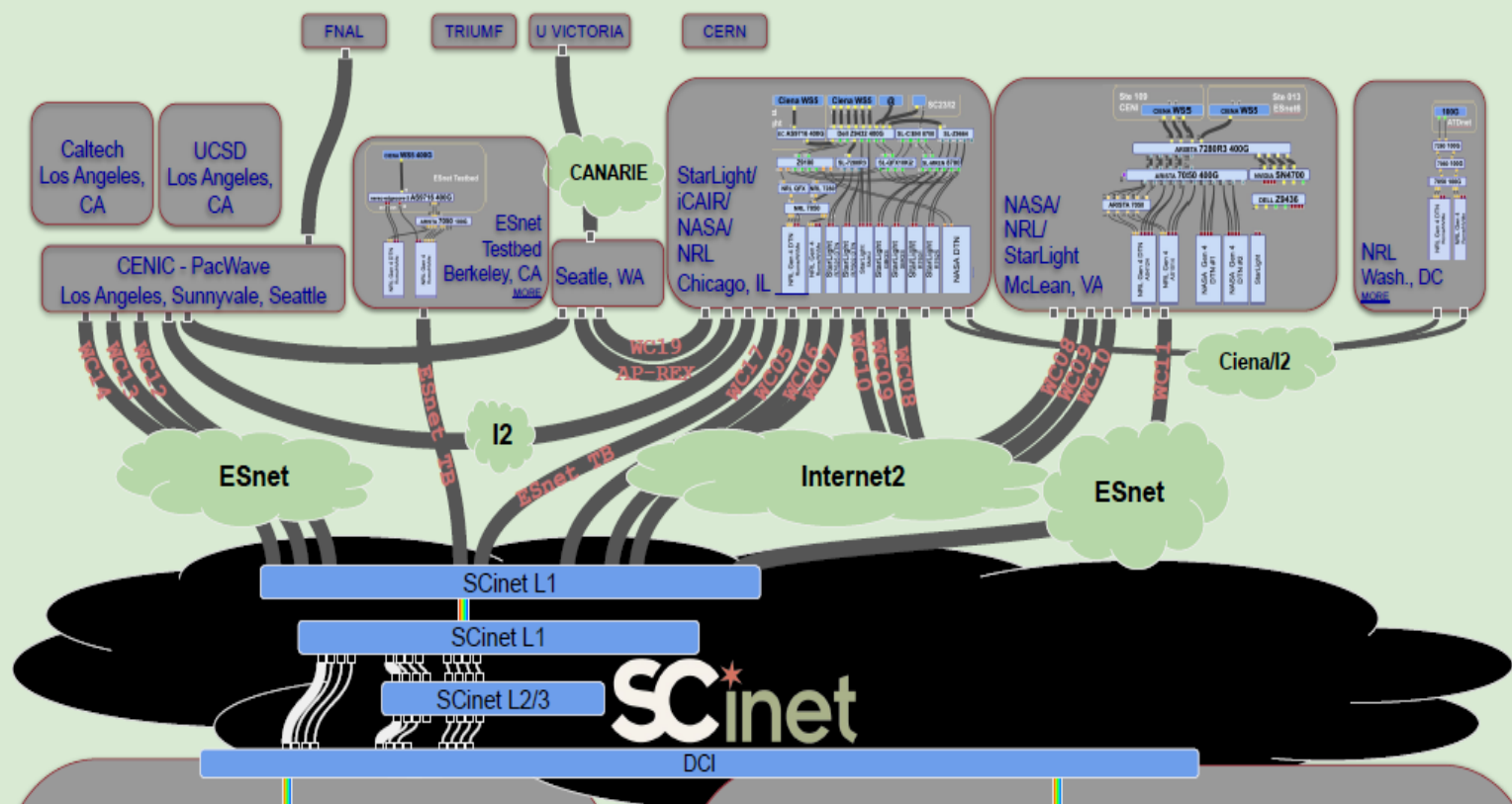
August 29, 2023, a





SC23
Denver, CO | i am hpc.

JOINT BIG DATA TESTBED



- 400G - LR4
- 400G - FR4
- 400G - DAC
- 200G - SR4 or DAC
- 100G - CWDM4
- 100G - LR4
- 100G - SR4
- 100G - DAC
- 40G - SR4
- 40G - DAC
- 10G
- 1G

10/16/2023

Latest Version at:
<https://tinivul.com/SC23-JBDT>
 To request changes, please leave a comment

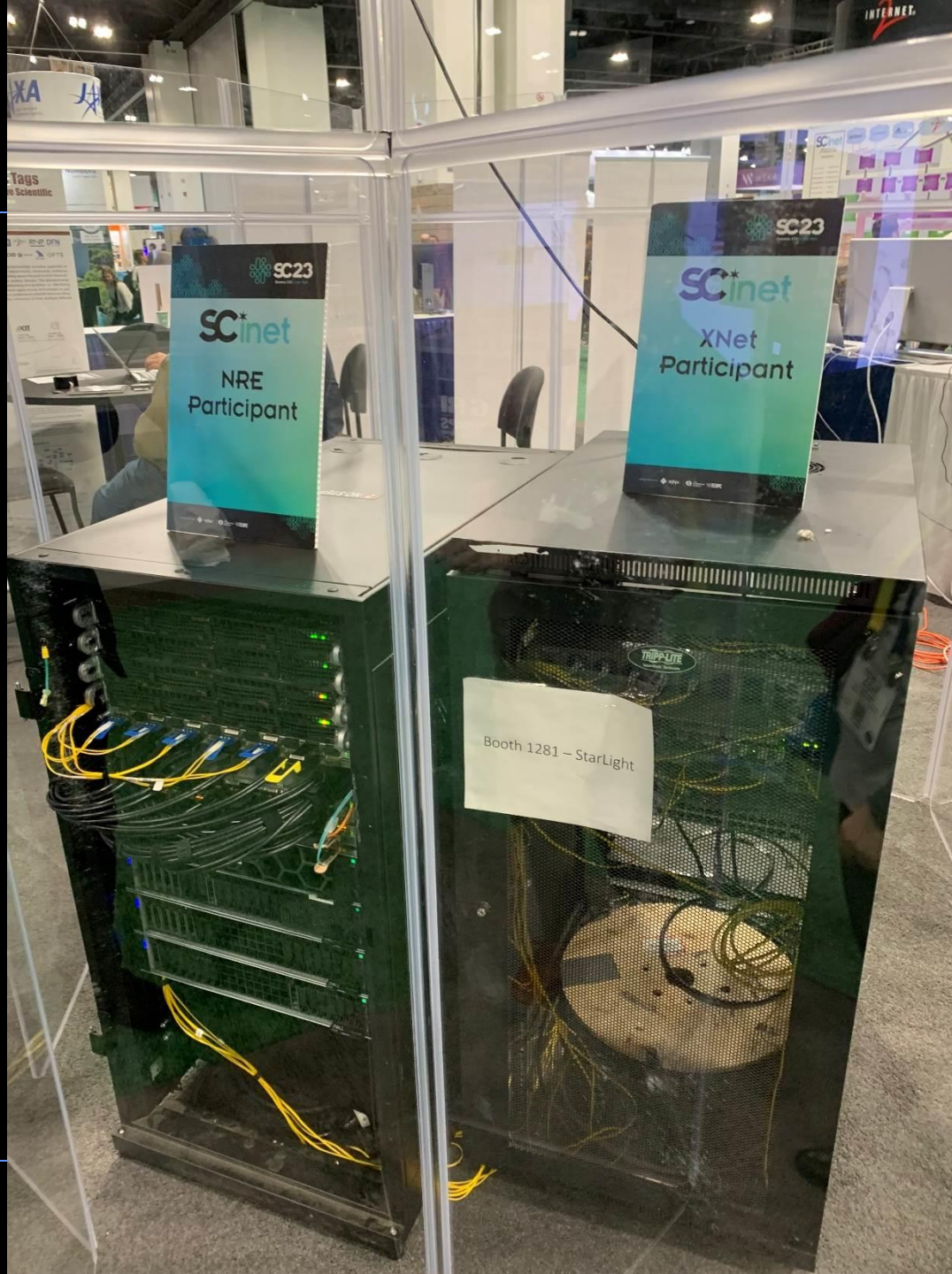
SC23 floorplan

SC22

SC21

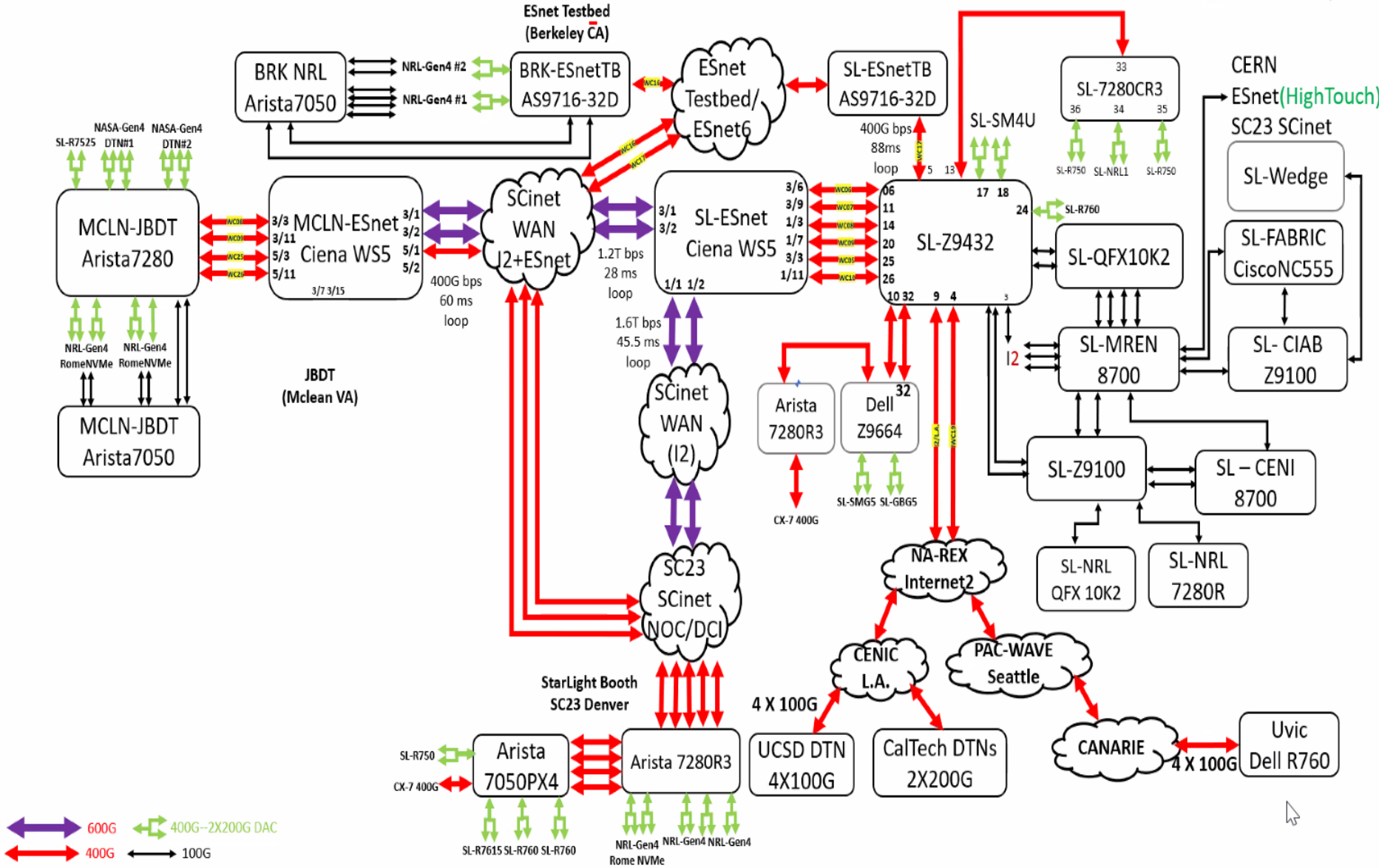
SC19

StarLight
SC23 Booth
1281



9 X 400G WAN Testbed by ESnet(ESnet Testbed)-I2(NA-REX)-CENIC- PAC-WAVE-CANARIE-SCinet-StarLight-JBDT

10/21/2023

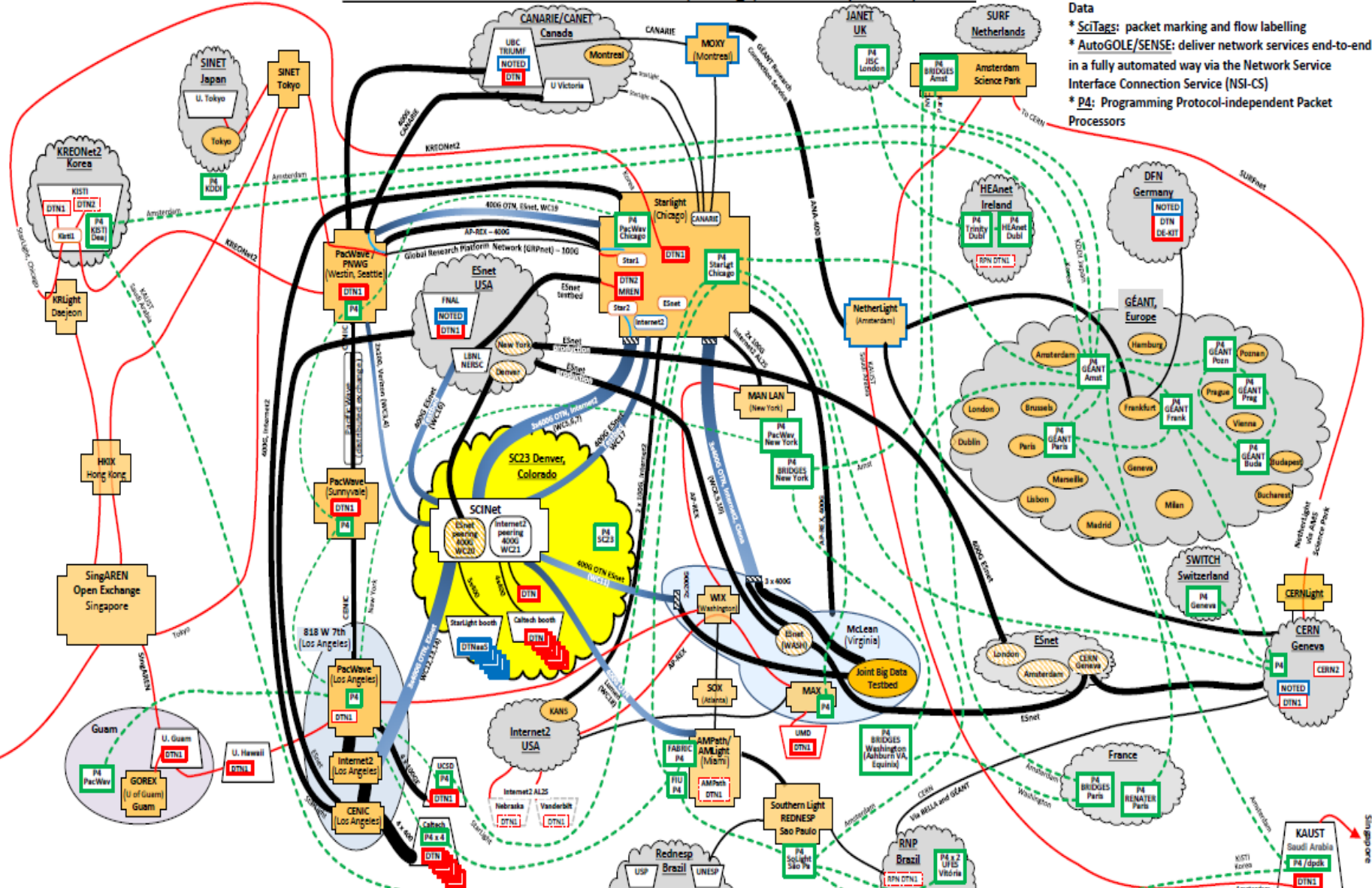


Example SC23 SCinet Network Research Exhibitions

- Global Research Platform (GRP)
- SDX 1.2 Tbps WAN Services
- SDX E2E 400 Gbps 800 Gbps WAN Services
- 400 Gbps DTNs & Smart NICs
- Network Optimized Transport for Experimental Data (NOTED) – With AI/ML Driven WAN Network Orchestration
- Orchestration With Packet Marking (SciTags)
- ESnet High Touch 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
- P4 Integration With Kubernetes, P4 Global Lab
- High Perf Network Entropy Platform Using P4
- NASA Goddard Space Flight Center HP WAN Transport Services (400 G Dsk-Dsk)
- Resilient Distributed Processing & Rapid Data Transfer
- AutoGOLE/SENSE E2E Orchestration Net Services And Workflow Integration
- Open Science Grid Demonstrations
- N-DISE Named Data Networking for Data Intensive Science
- Chameleon FABRIC/FAB Integration
- SciStream Multi Site Data Streaming Orchestration
- Distributed Pipelines Over WANs For On-Line Data Analysis
- DTNs for Research Enhanced Environments (ONION-RED ONION)

SC23 Network Research Exhibitions NOTED, SciTags, AutoGOLE, SENSE, and P4

- * NOTED: Network-Optimized Transfer of Experiment Data
- * SciTags: packet marking and flow labelling
- * AutoGOLE/SENSE: deliver network services end-to-end in a fully automated way via the Network Service Interface Connection Service (NSI-CS)
- * P4: Programming Protocol-independent Packet Processors

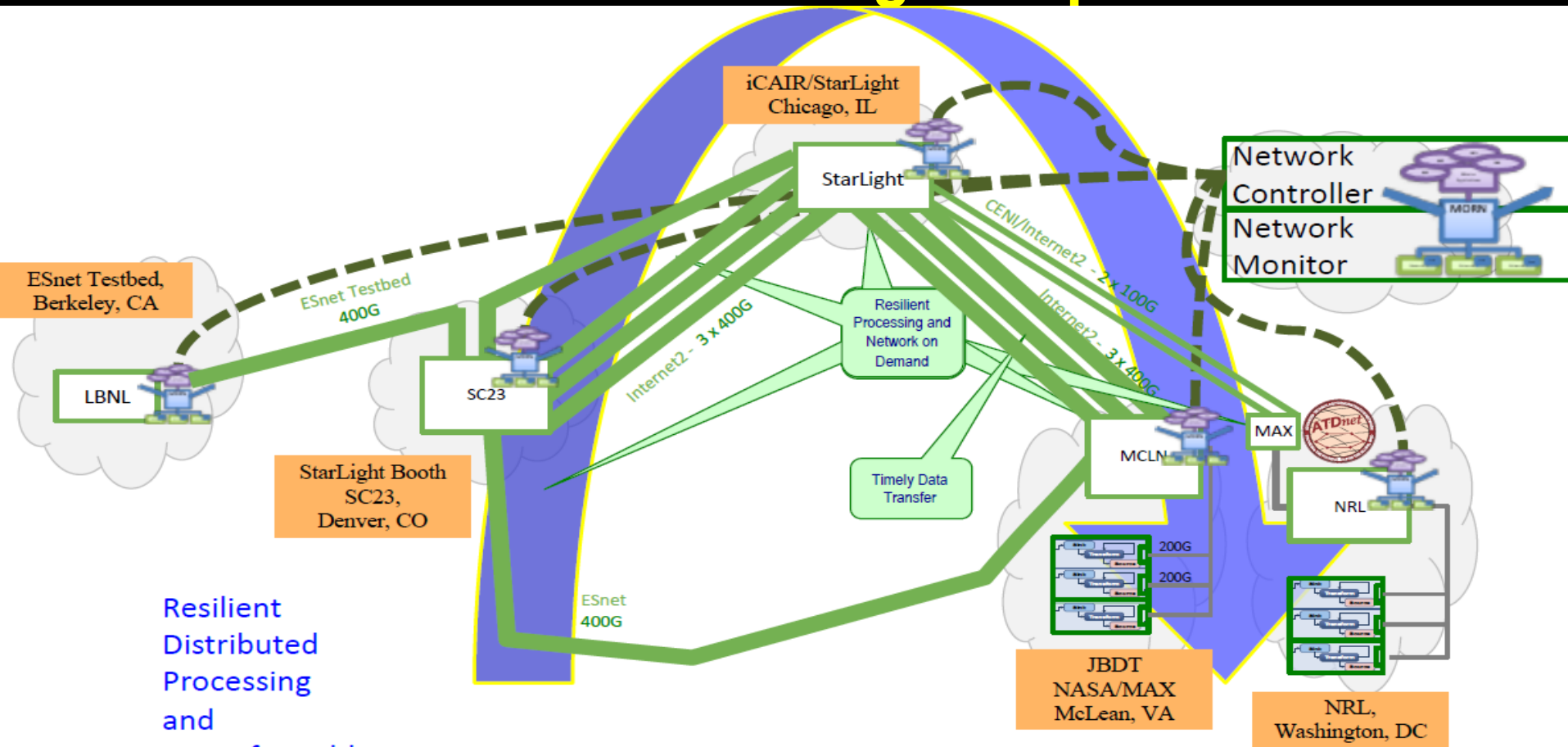


SC23 NRE map v.11, 2023-10-10 - WEJohnston, ESnet, wej@es.net

NOTED	SC21 NOTED infrastructure is in blue	ESnet	ESnet PoPs with High-Touch (line-rate, per packet) monitoring	McLean	Carrier hotels, etc
AutoGOLE/SENSE	AutoGOLE / SENSE infrastructure is in red	Shared Circuits	Shared circuits supporting demonstrations	Paris	Ovals are points of presence in regional infrastructure
P4	P4 infrastructure is in green	Circuits	Circuits supporting AutoGOLE / SENSE	ESnet	Rounded rectangles are individual switch/router
General	Shared or general infrastructure is in black	P4 Connectivity	P4 connectivity (not particular circuit infrastructure or bandwidth)	Caltch	Sites
		Bandwidth	Line width does not usually indicate bandwidth	SOX	Exchange points (external or internal to a site)
		SC21 Managed		Internet2	

- NOTES**
- 1) Within exchange points, etc., line width does not usually indicate bandwidth
 - 2) Map files (JPEG, PDF, and PPTX) are at <https://www.dropbox.com/sh/p2wcyppubel7q/AAAMGFS08xvUfospm3pRLLa1d?dl=0>
 - 3) P4 connections are only topological and are not associated with particular network link

Resilient Distributed Processing & Rapid Data Transfer



Resilient
Distributed
Processing
and
Reconfigurable
Networks

Naval Research Laboratory
Center for Computational Science
SC23 Demonstration

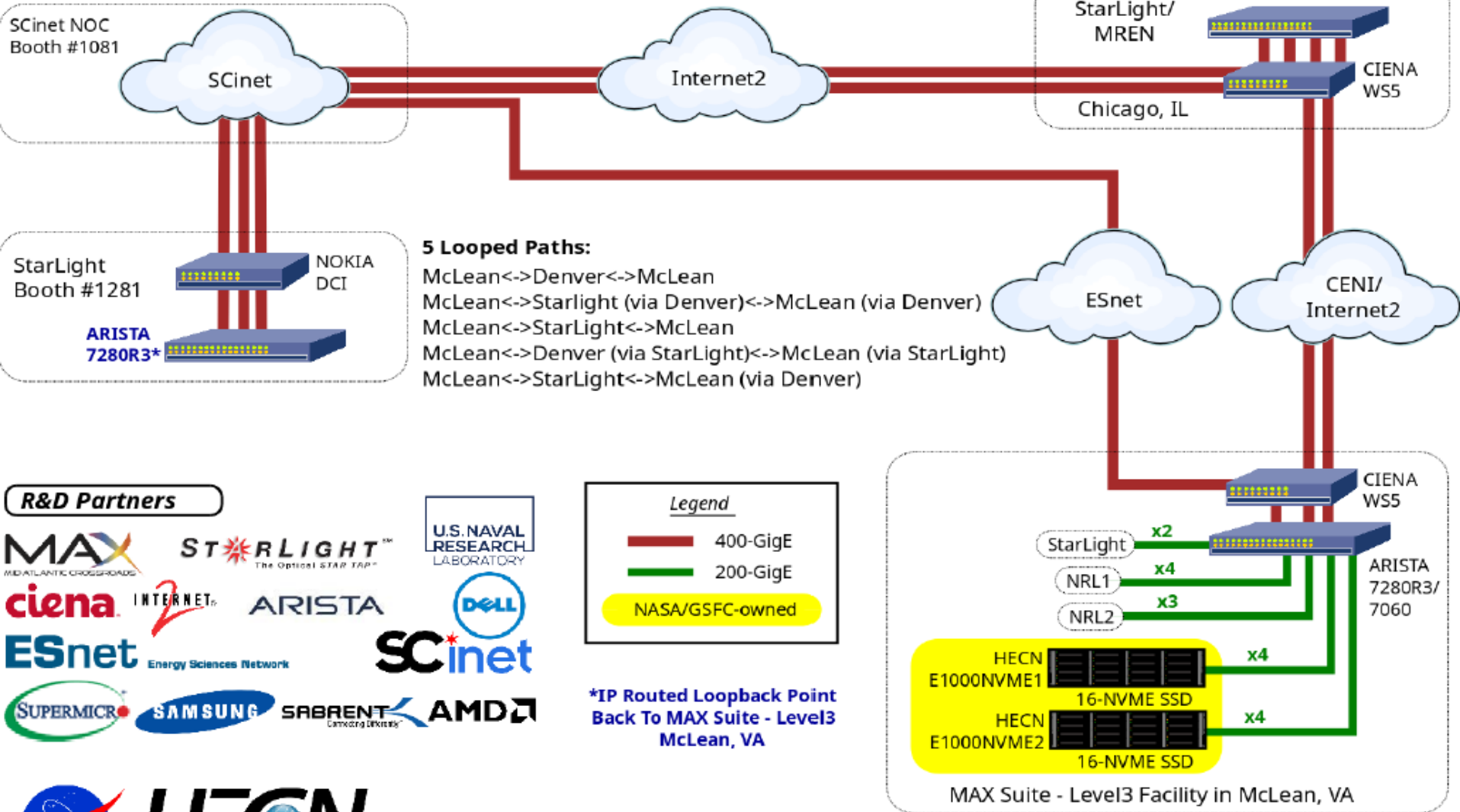


SC23 Joint Big Data Testbed

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

An SC23 Collaborative Initiative Among NASA and Several Partners

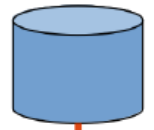
SC23 @ Denver, CO



R&D Partners

In memory of Paul Lang and Pat Gary

NASA/GSFC High End Computer Networking (HECN) Team
Diagram by Bill Fink - 10/13/2023



Rucio

FTS

NOTED at KIT

NOTED at CERN

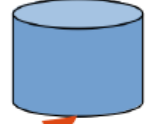
AutoGOLE SENSE



Data transfer



TRIUMF



FTS
File Transfer Service

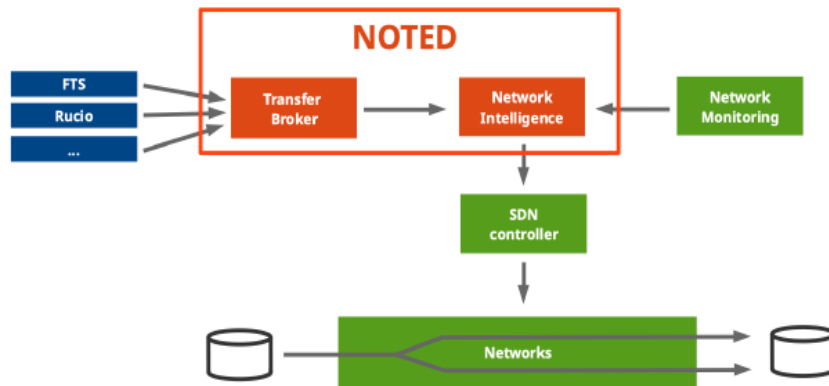


CRIC
Computing Resource Information Catalog



elasticsearch

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):

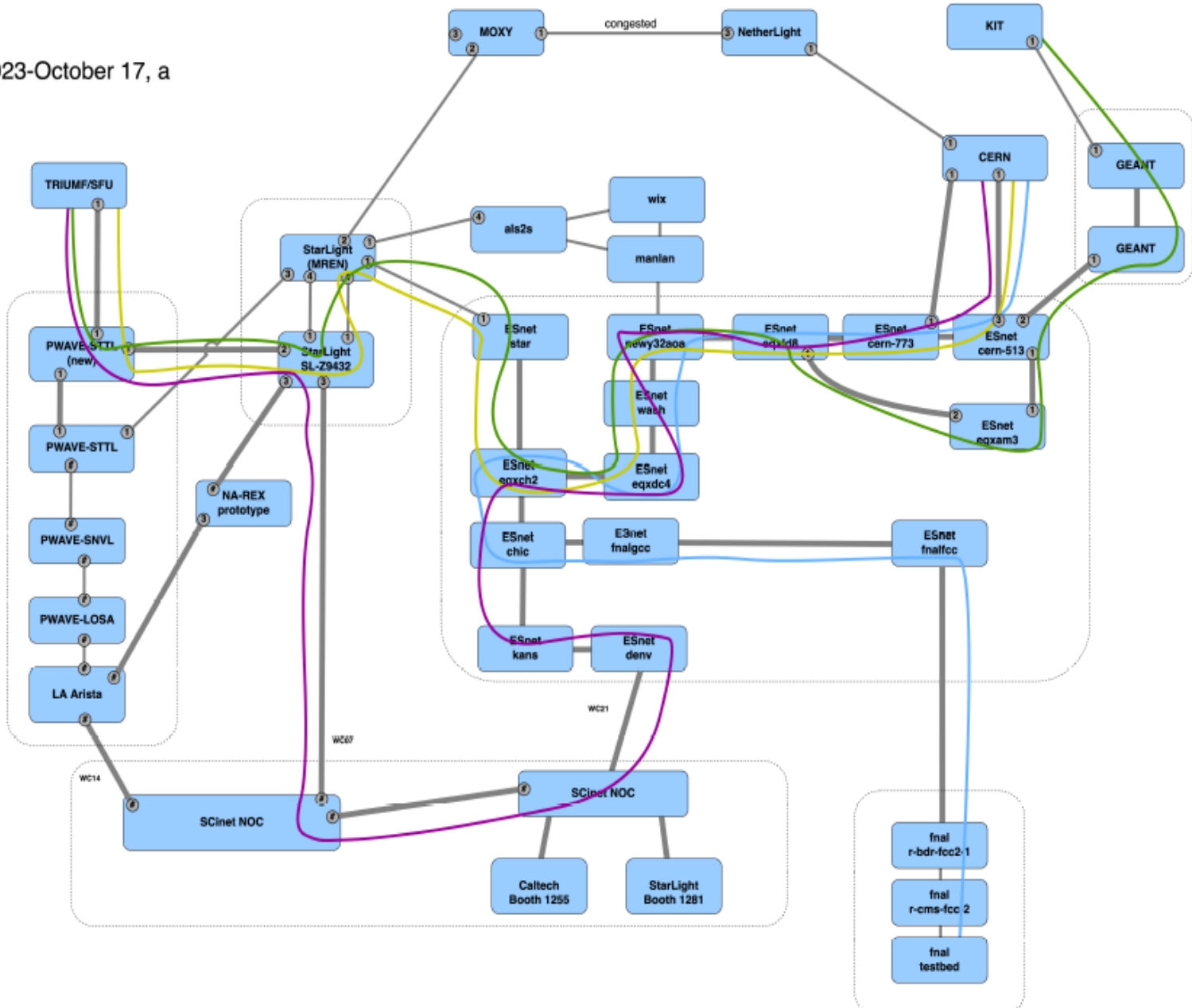
- ▶ Enrichment to **get an overview** and knowledge of the **network topology** → get IPv4/IPv6 addresses, endpoints, rcsite and federation.

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.

NRE-005, LHC Networking And NOTED

2023-October 17, a



2023: CERN-FNAL
 2024: CERN-TRIUMF
 2025: CERN-TRIUMF (via NetherLight)
 2027: CERN-TRIUMF (via SC23 Floor)
 3694: KIT-TRIUMF

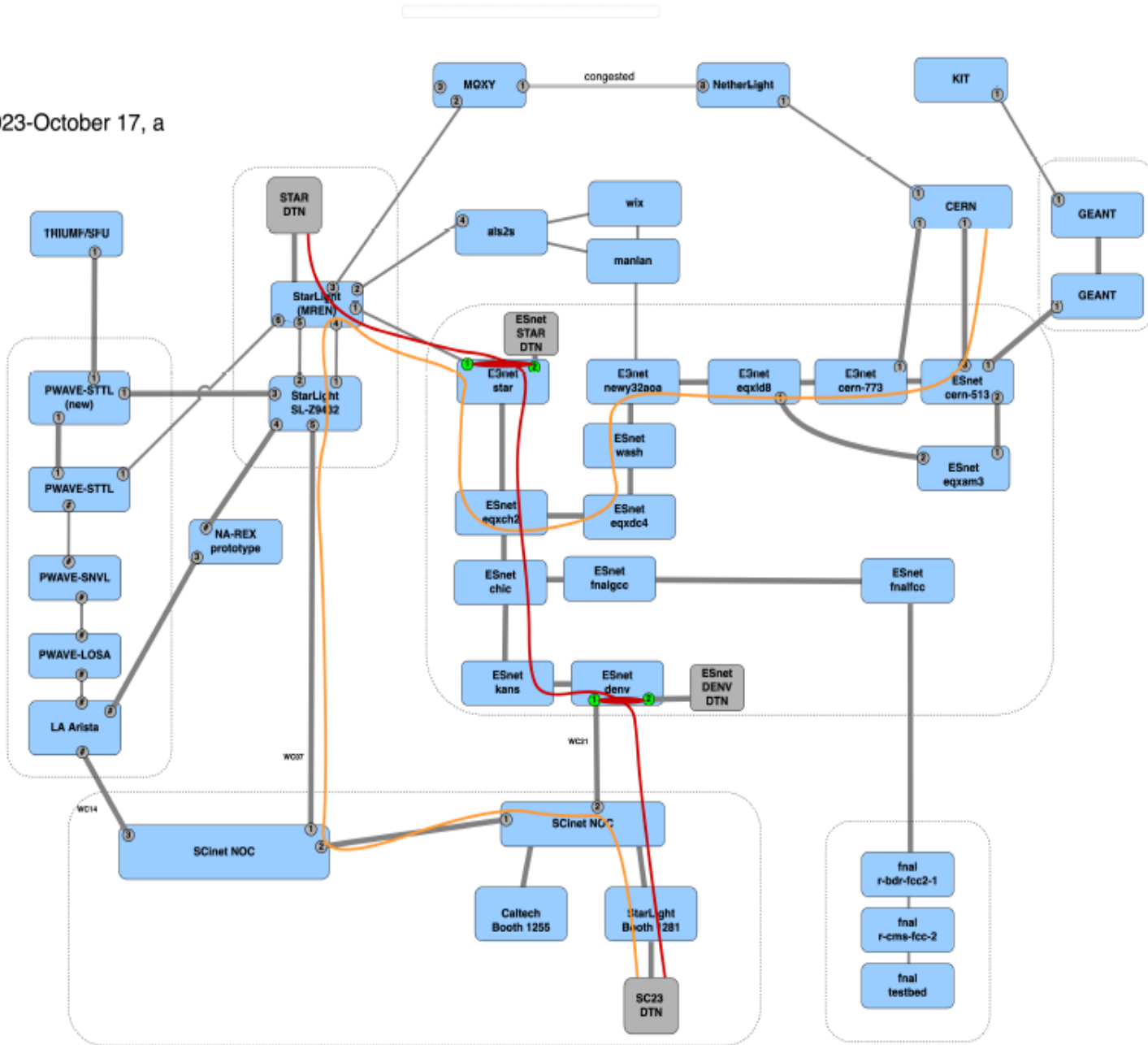
Link #1 - VLAN 2023
 Link #2 - VLAN 2024
 Link #3 - VLAN 2025
 Link #4 - VLAN 2027
 Link #5 - VLAN 3694

Notes:
 -These VLAN numbers are the tags on the ports facing the sites (CERN, KIT, or TRIUMF)
 -There may be VLAN translation on one or more of the links in between

OSCARS provisioned segments:
<https://my.es.net/oscars/view/###>

NRE-006, Packet Marking and Flow Labeling for Networked Scientific Workflows

2023-October 17, a



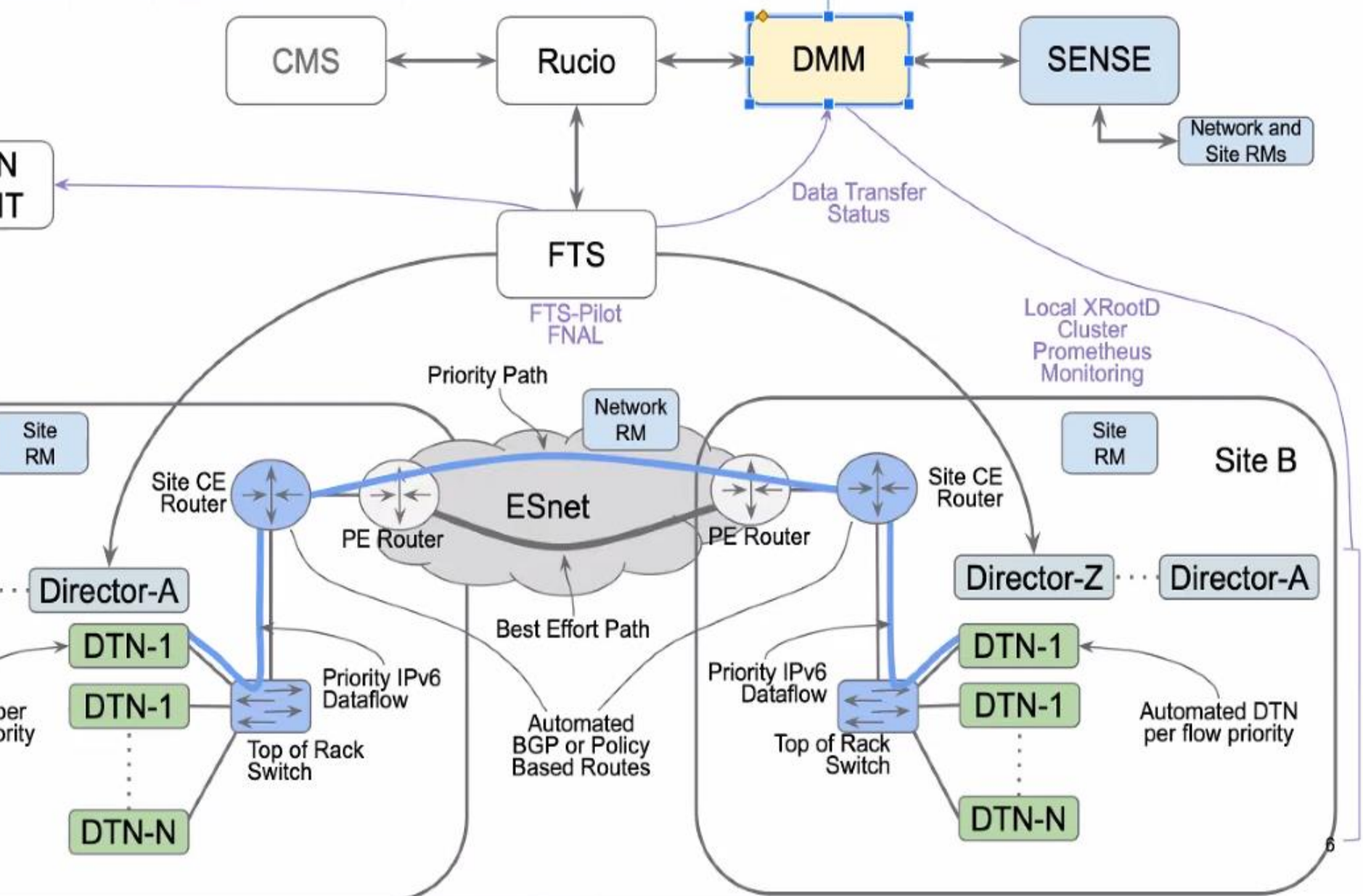
— SciTag - VLAN 2026
 — SciTag - VLAN 1799

Notes:
 -VLAN 1799 is multipoint at the ESnet star and ESnet denv routers, includes a port connection an ESnet DTN

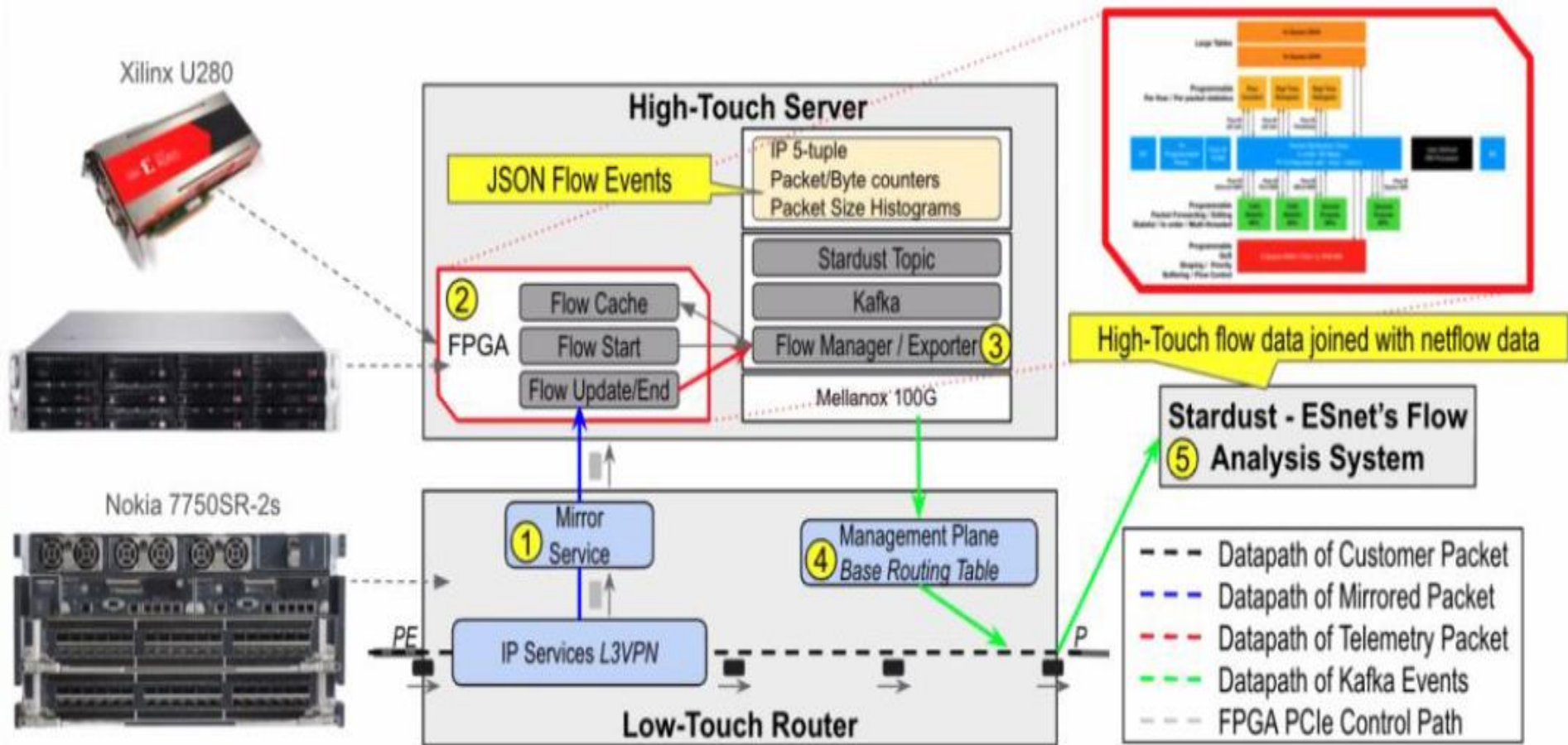
① HiTouch Monitoring Point/Port

ESnet Ports:
 ESnet-ern-513-1:###
 ESnet-star-1: 2/1/c5/1
 ESnet-star-2: 2/1/c12/1
 ESnet-denv-1:1/1/c25/1
 ESnet-denv-2:1/1/c6/1

SE Rucio/FTS/XRootD Workflow



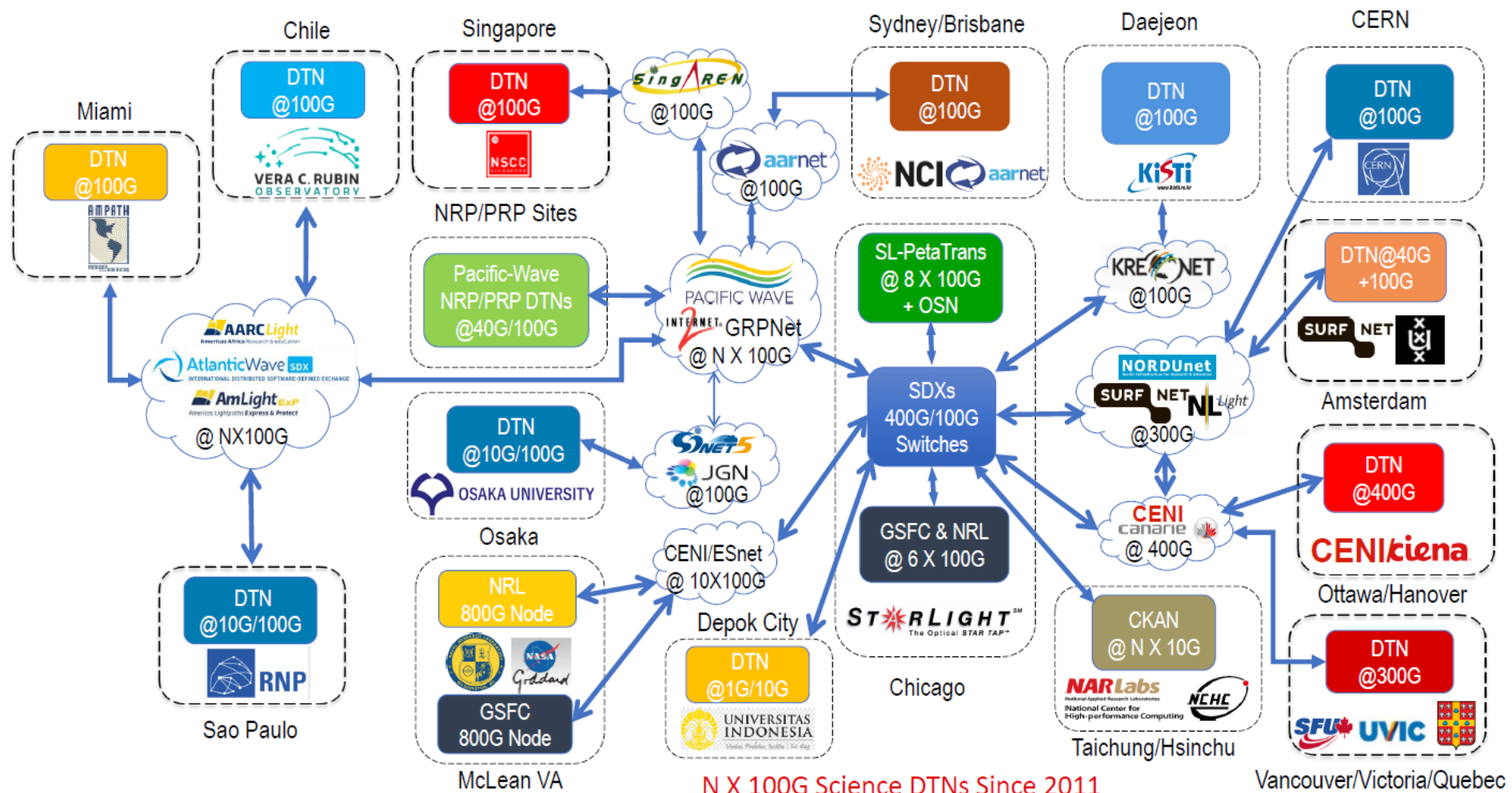
ESnet6 High-Touch Platform - Unprecedented Packet Visibility



1. Mirror Service - Allows selective flows in the dataplane to be duplicated, truncated and sent to the FPGA for processing.
2. Programmable Dataplane (DP) - Every packet updates internal counters/flow state. Only flow start/end packets sent to SW.
3. Flow Exporter - Processes flow start/end events to update the Dataplane flow cache. Periodically collects flow state and publishes summary records into Kafka.
4. Management Plane Base Routing Table - Provides connectivity to Remote Servers.
5. Stardust Logstash - Subscribes to Hightouch Kafka Topic for Stardust and consumes flow event records, inserting the records into Elastic

GRP DTNaaS For Petascale Science

GRP Service: DTNaaS for Petascale Sciences Data Movement



DTN-as-a-Service – Demonstrated At SC23

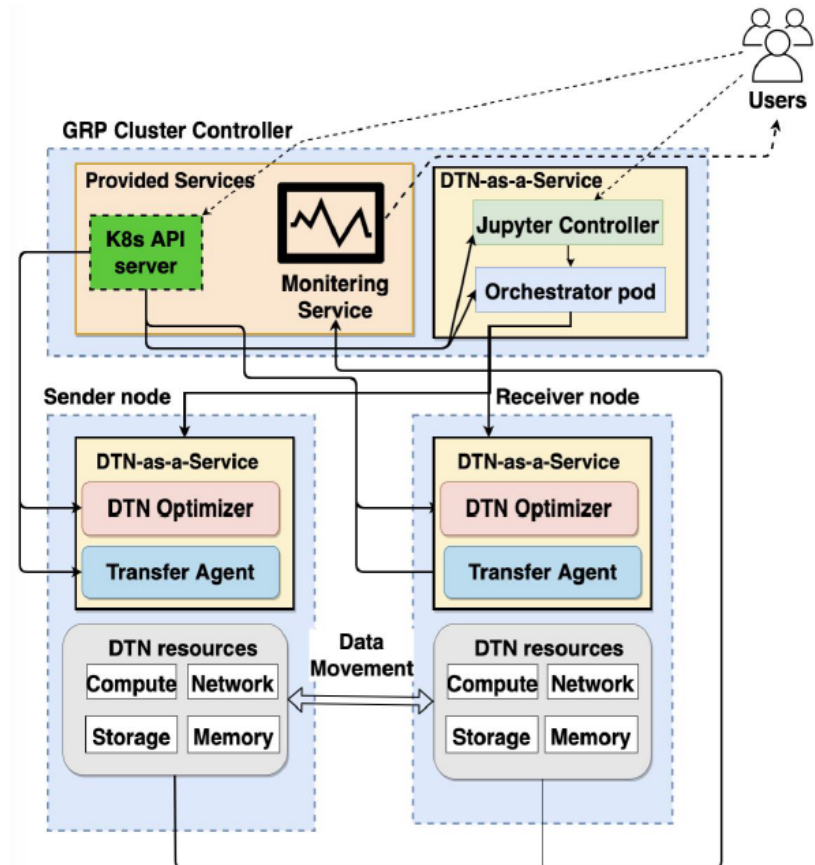
GRP Cluster with DTN-as-a-Service

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

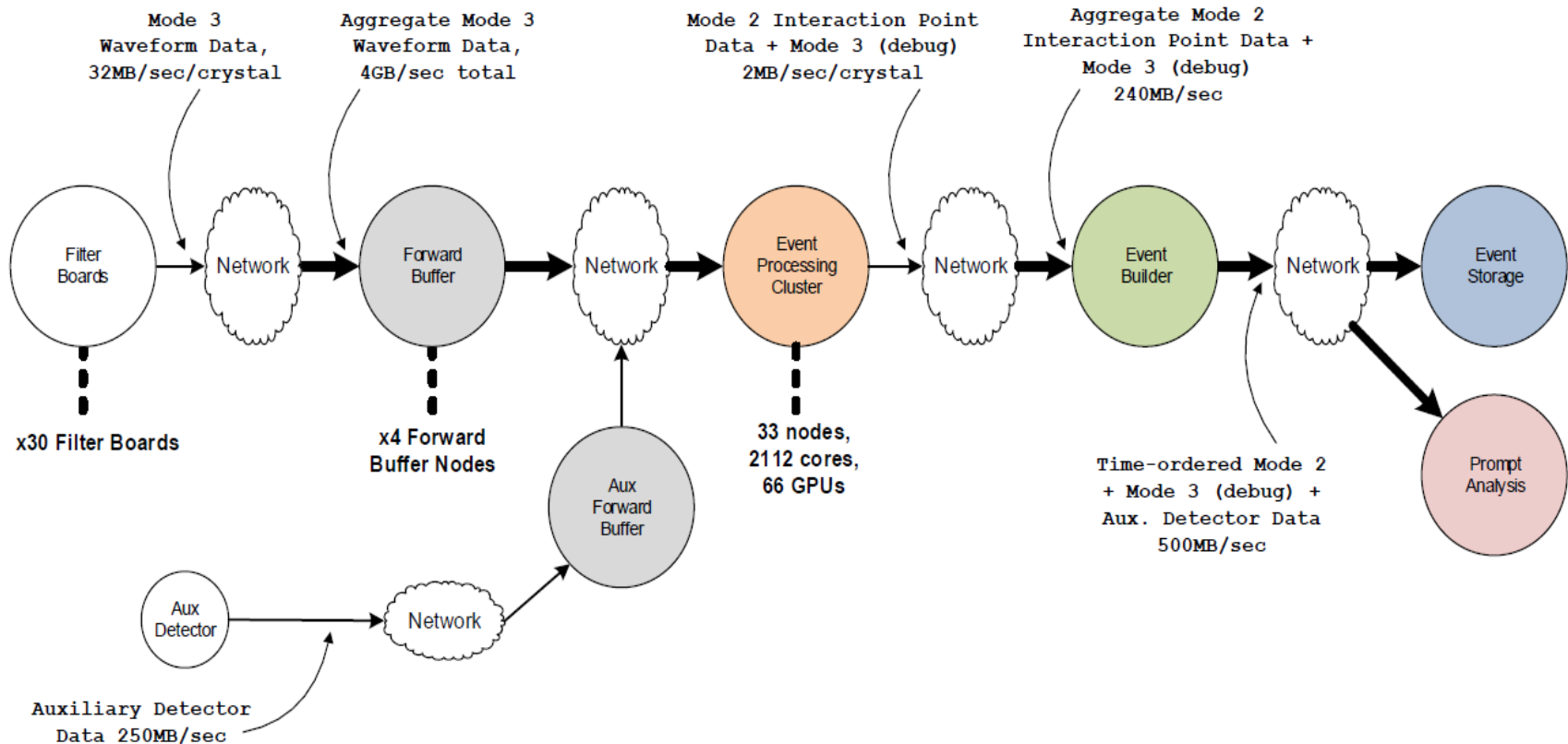
GRP DTNaaS Components:

- 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

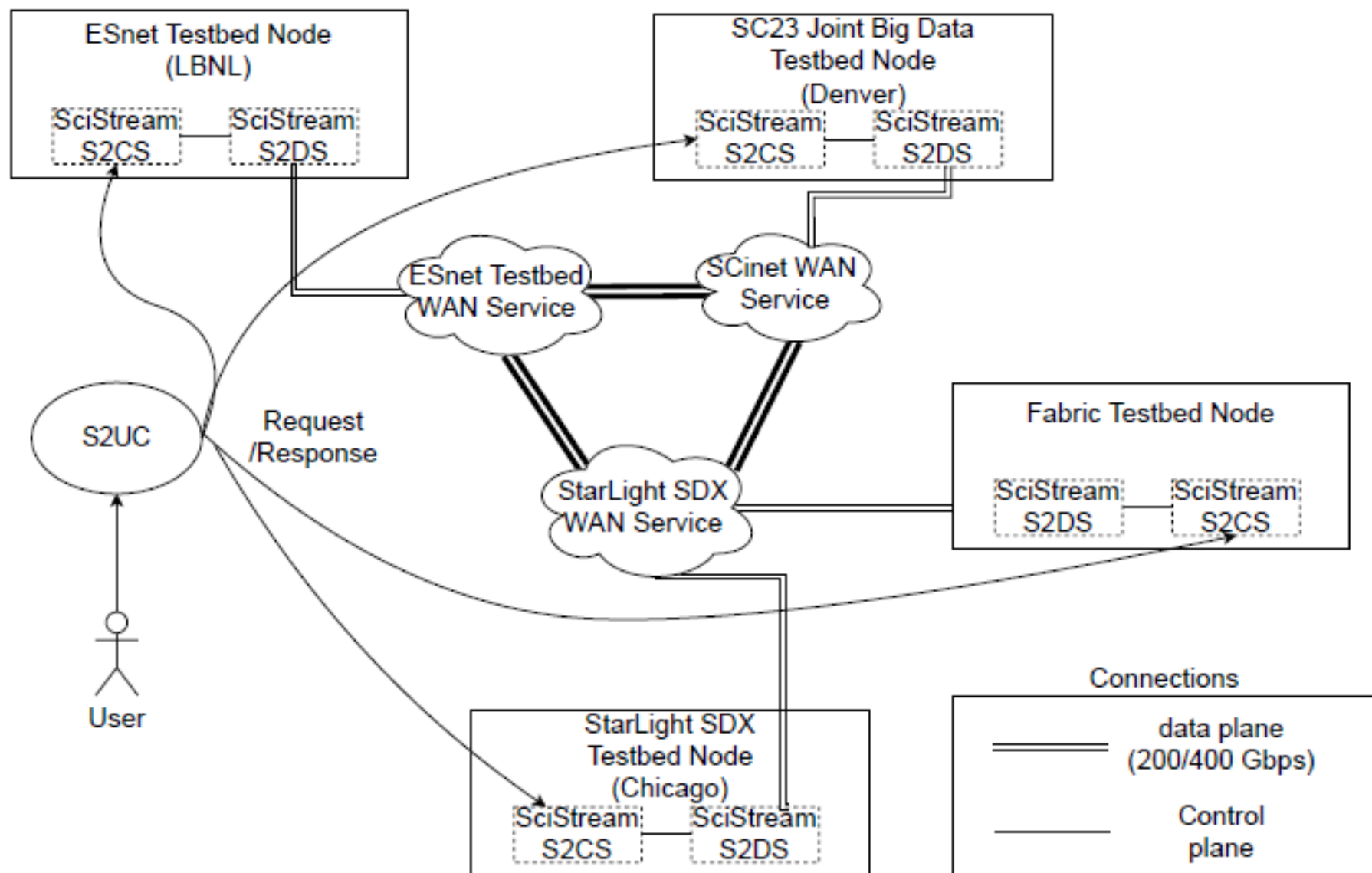


ESnet Gamma Ray Energy Tracking Array (GRETA)

GRETA Data Pipeline

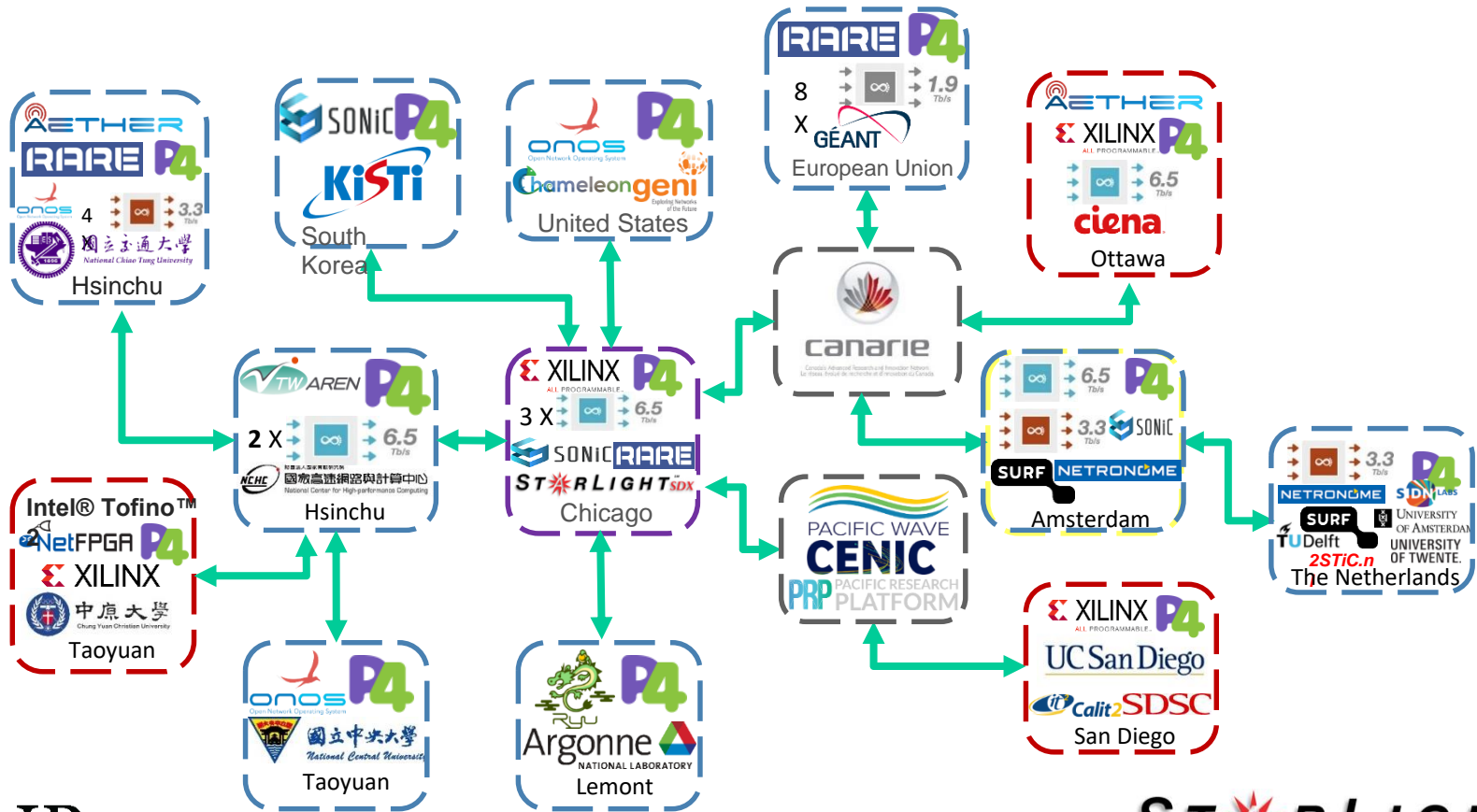


SC23 NRE-010: Multi-site data streaming orchestration with SciStream



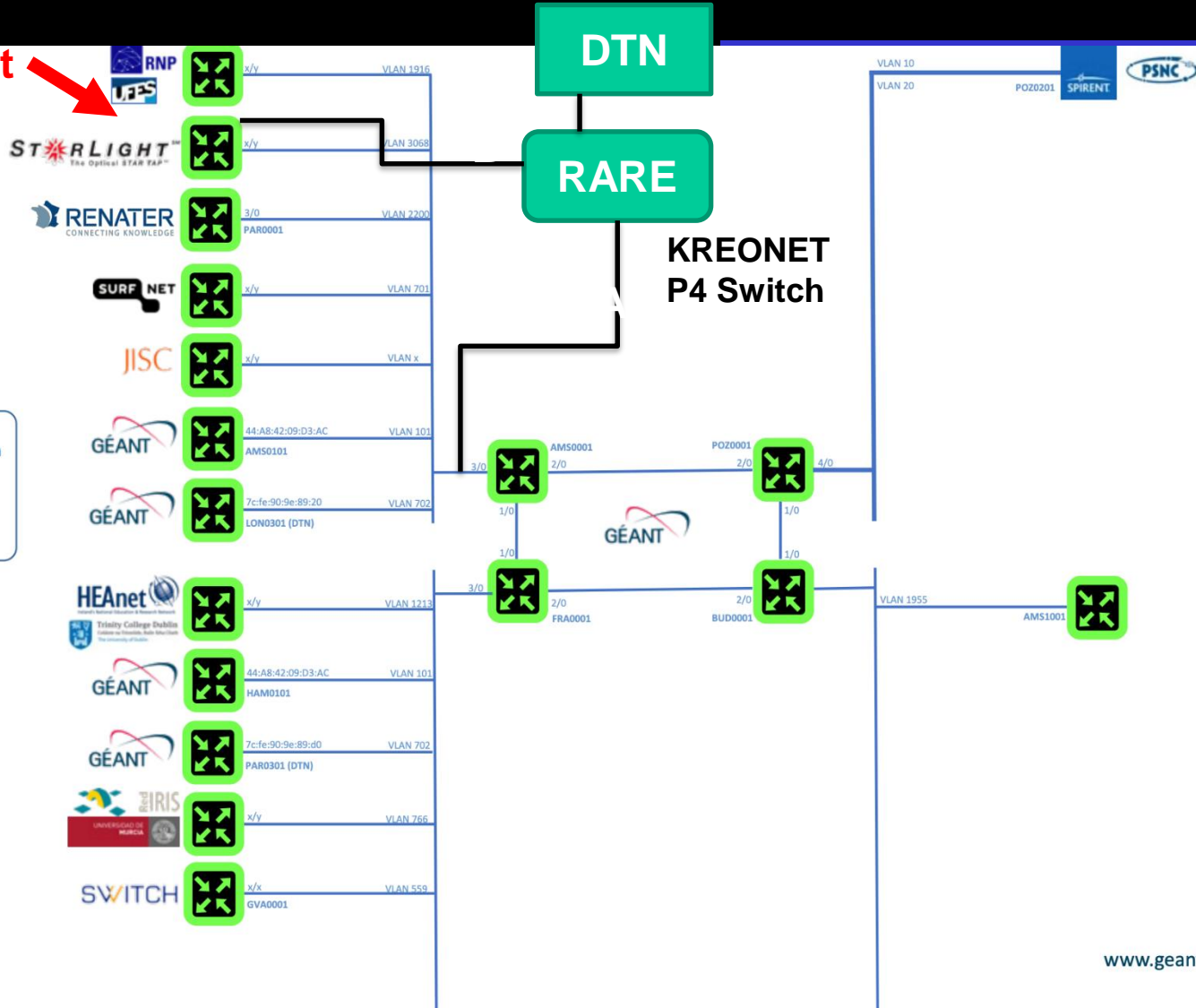
International P4 Testbed Showcase at SC23

GRP Service: International P4 Experimental Networks (iP4EN)

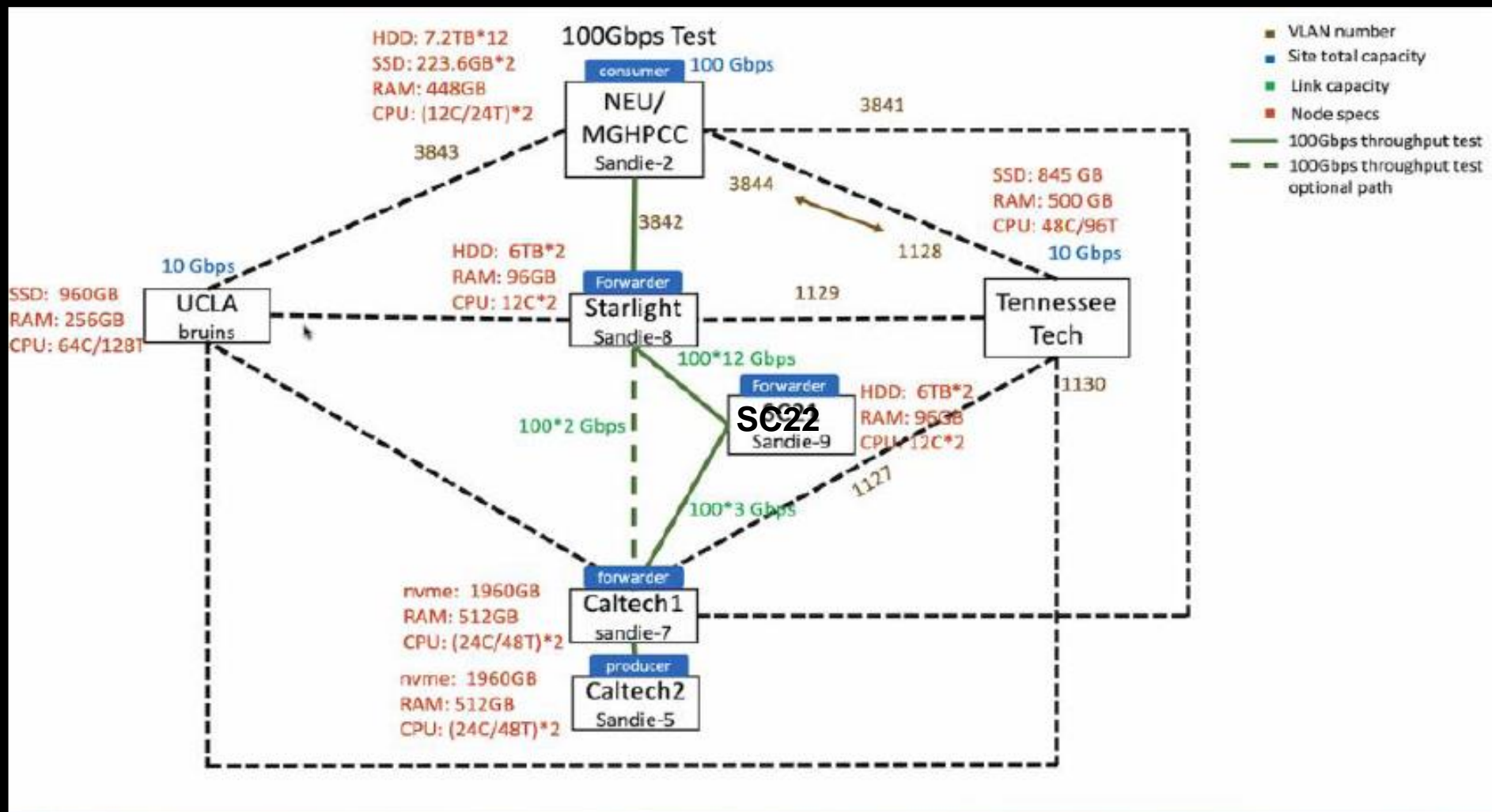


Integration With GEANT P4 Testbed

StarLight



Named Data Networking (NDN) for Data Intensive Science Experiments (N-DISE)





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

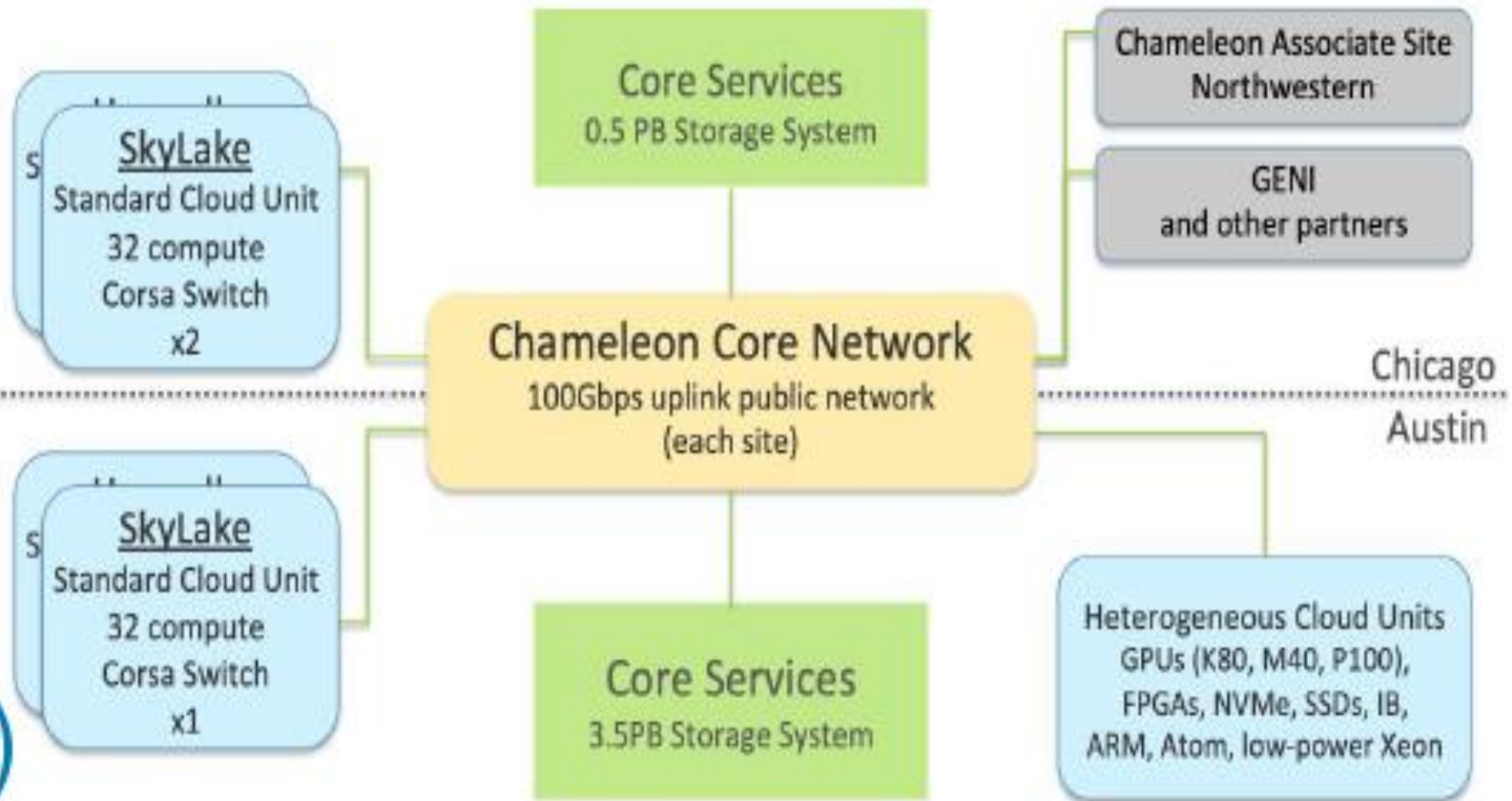


TACC

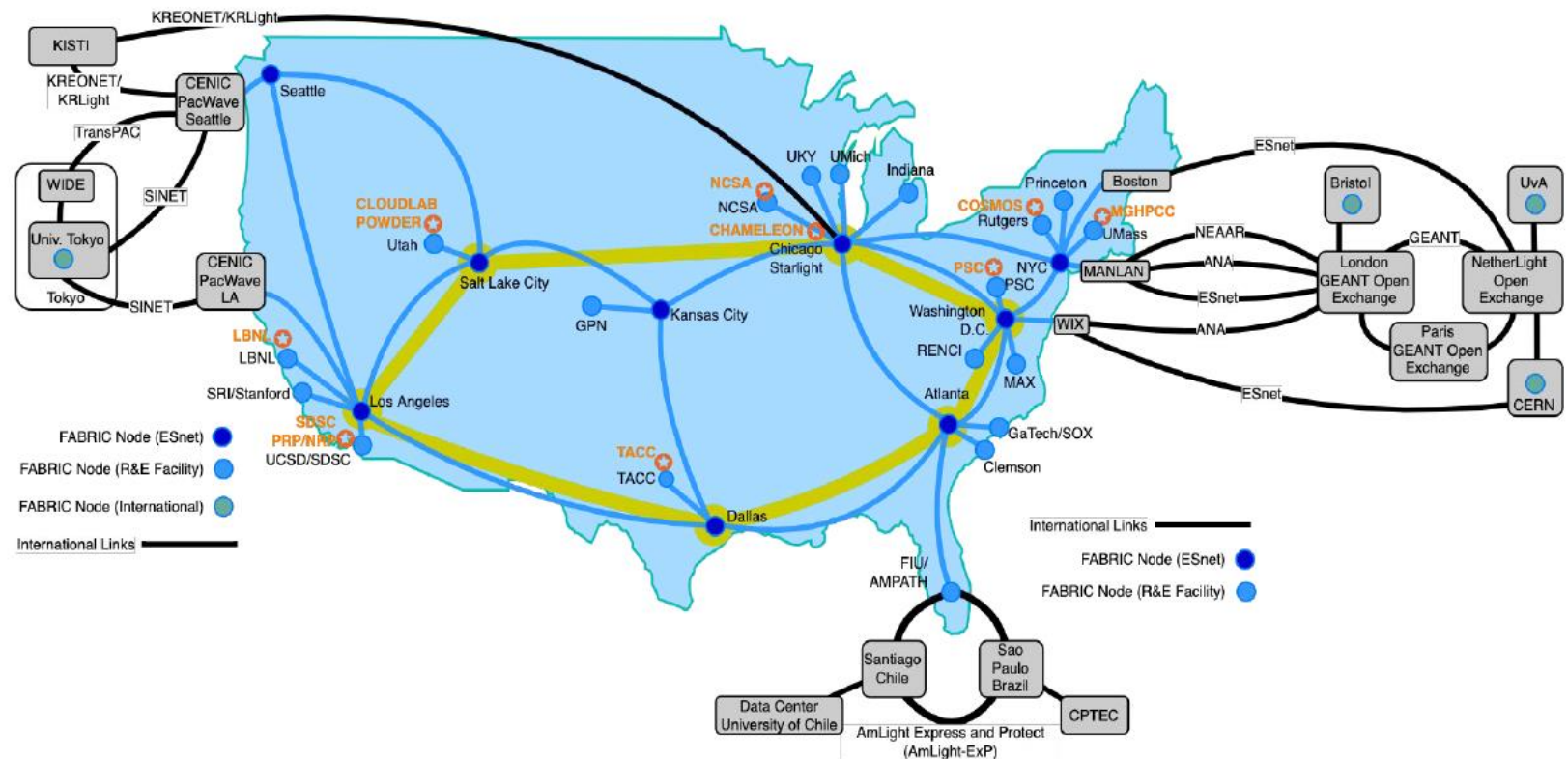
renci



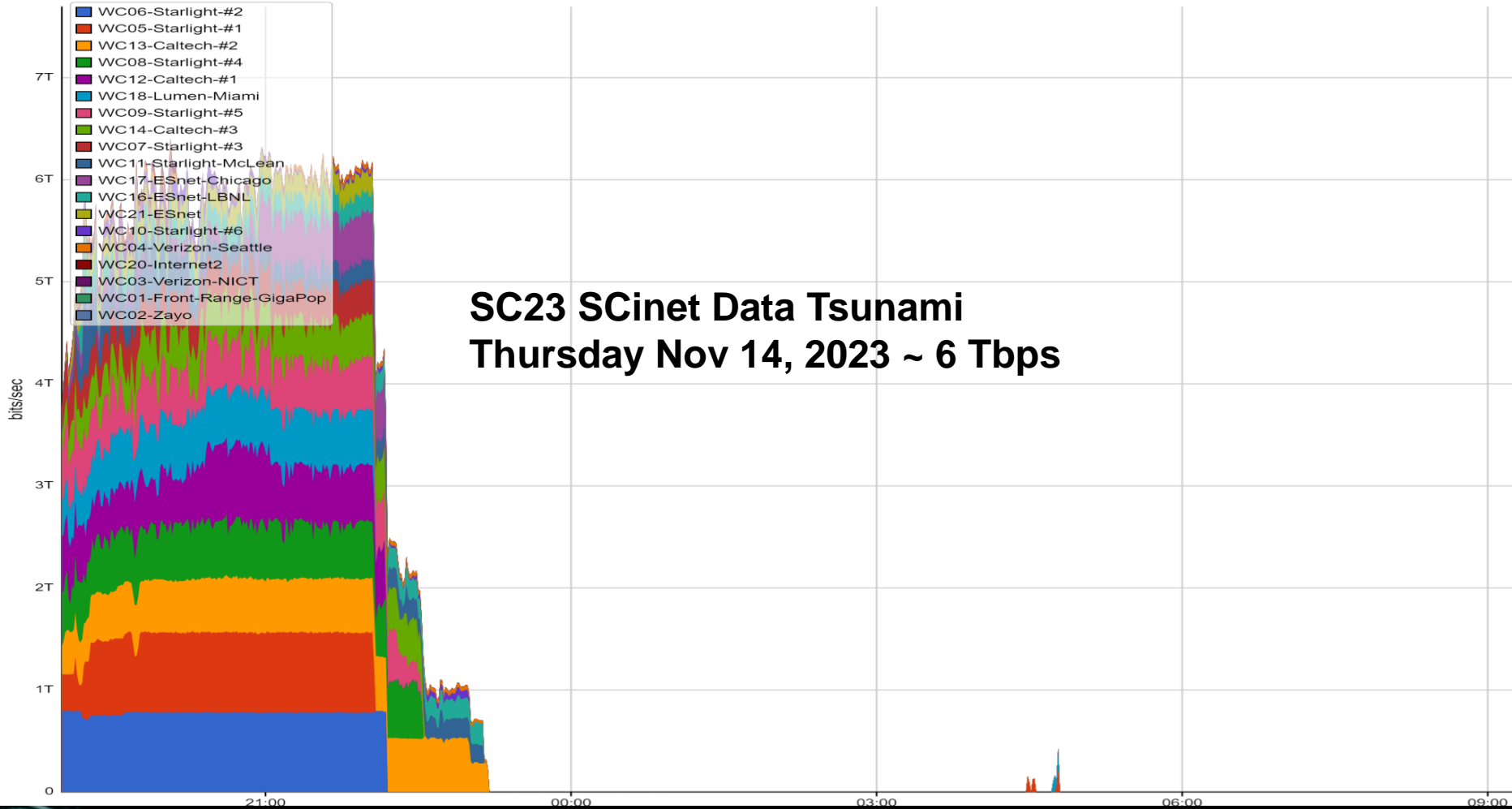
Chameleon CHI In A Box(CIAB) at StarLight



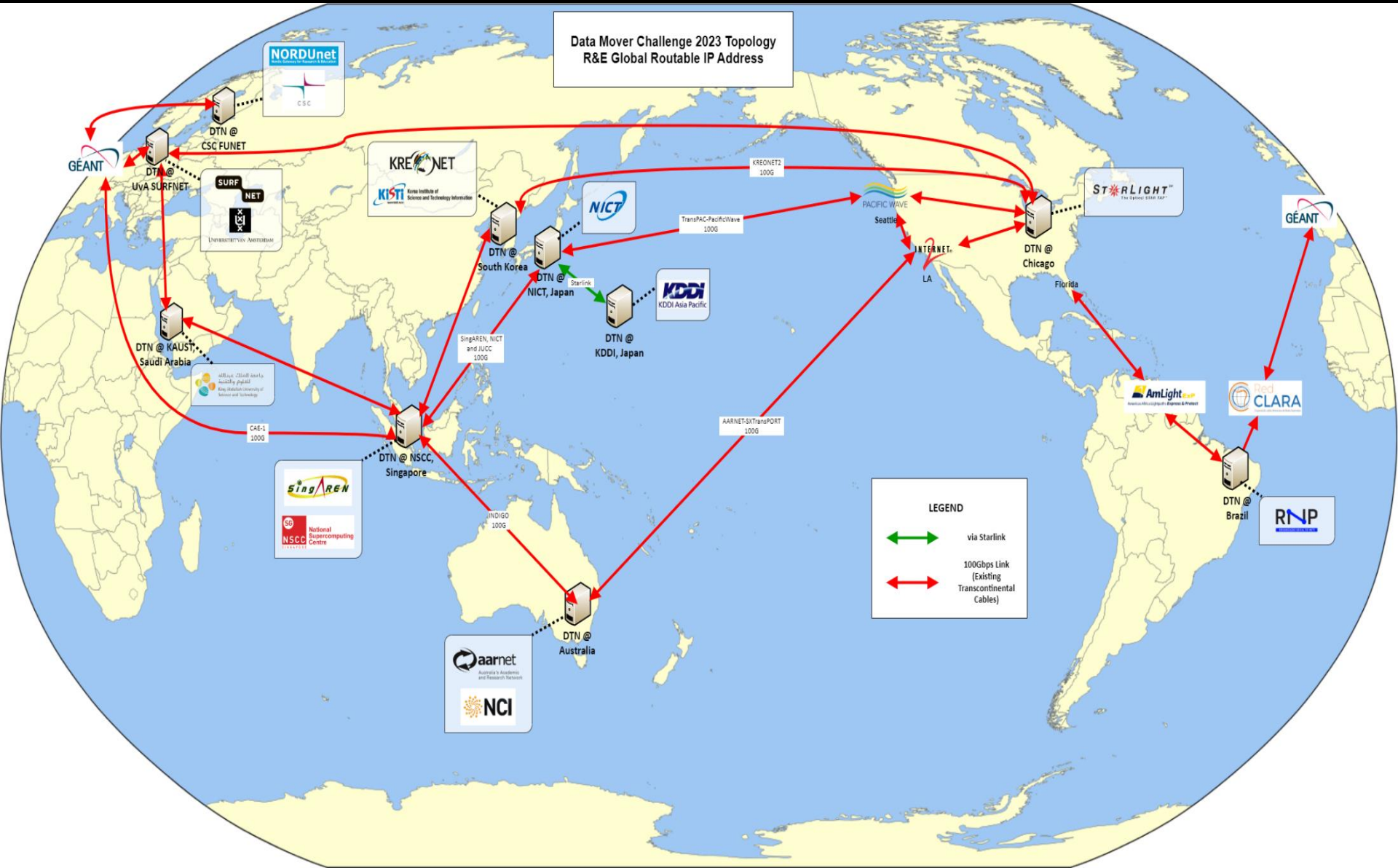
FABRIC Testbed (+FAB)



FABRIC Topology - with FAB Sites

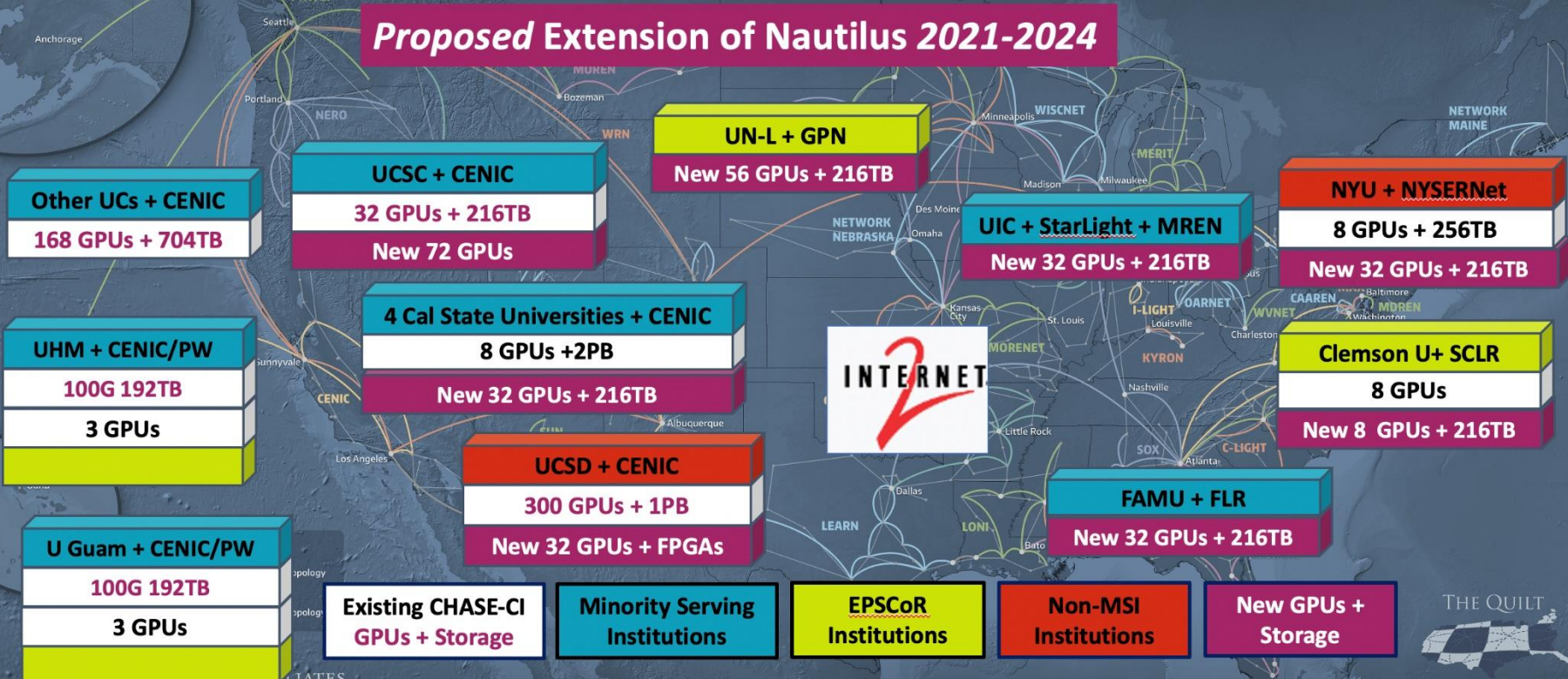


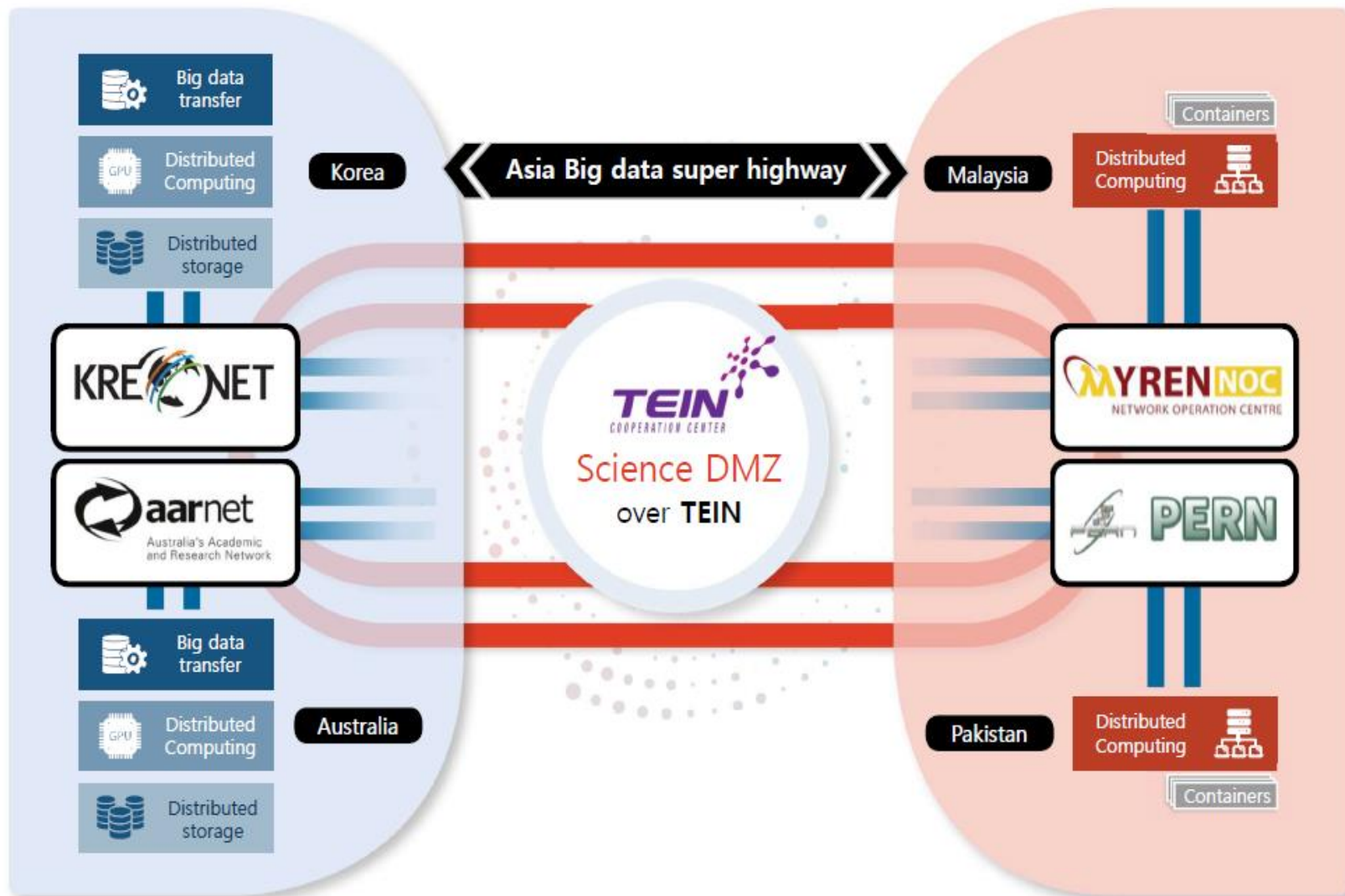
Data Mover Challenge 2023 Topology
R&E Global Routable IP Address

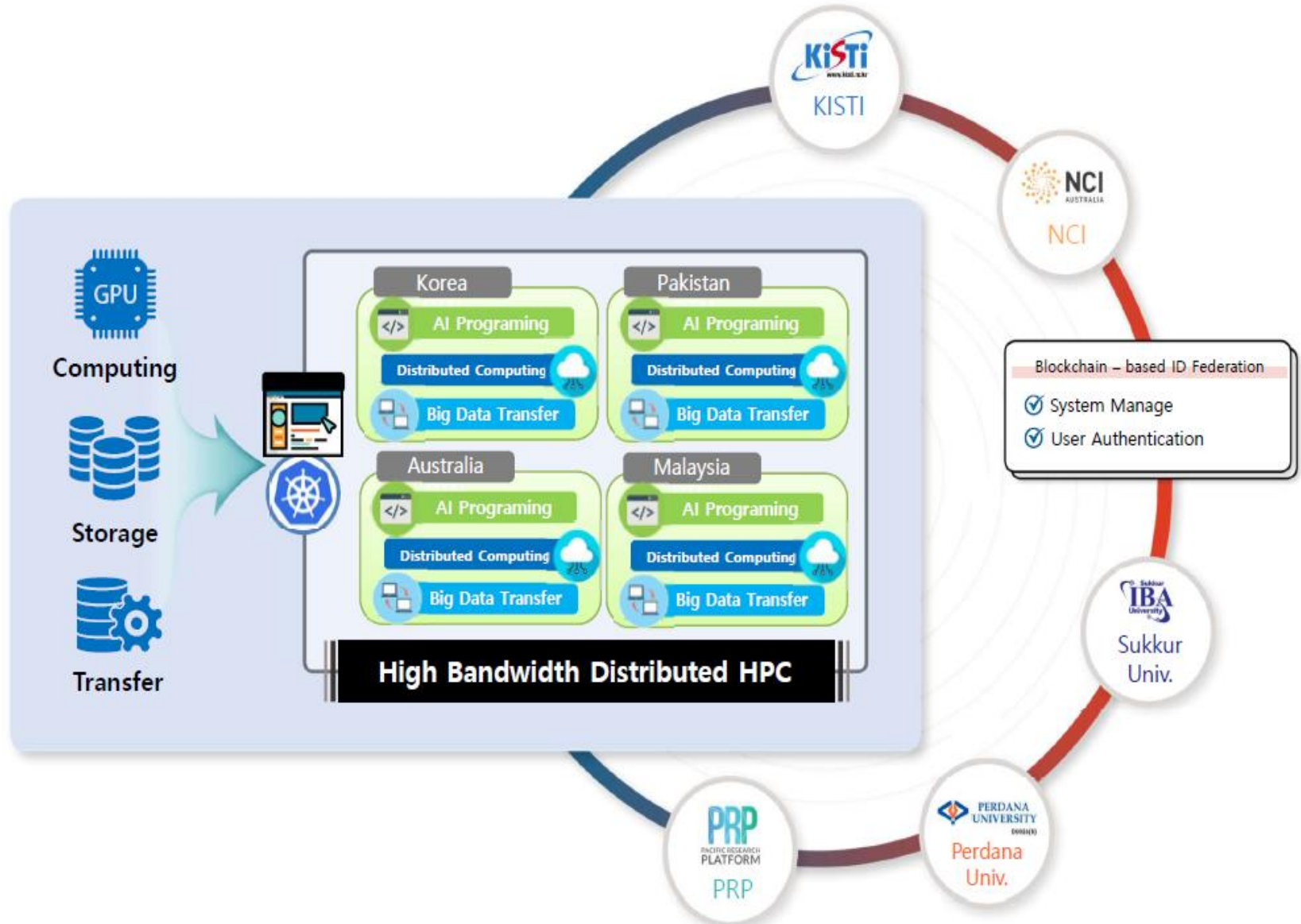


REGIONAL RESEARCH AND EDUCATION NETWORKS IN THE UNITED STATES

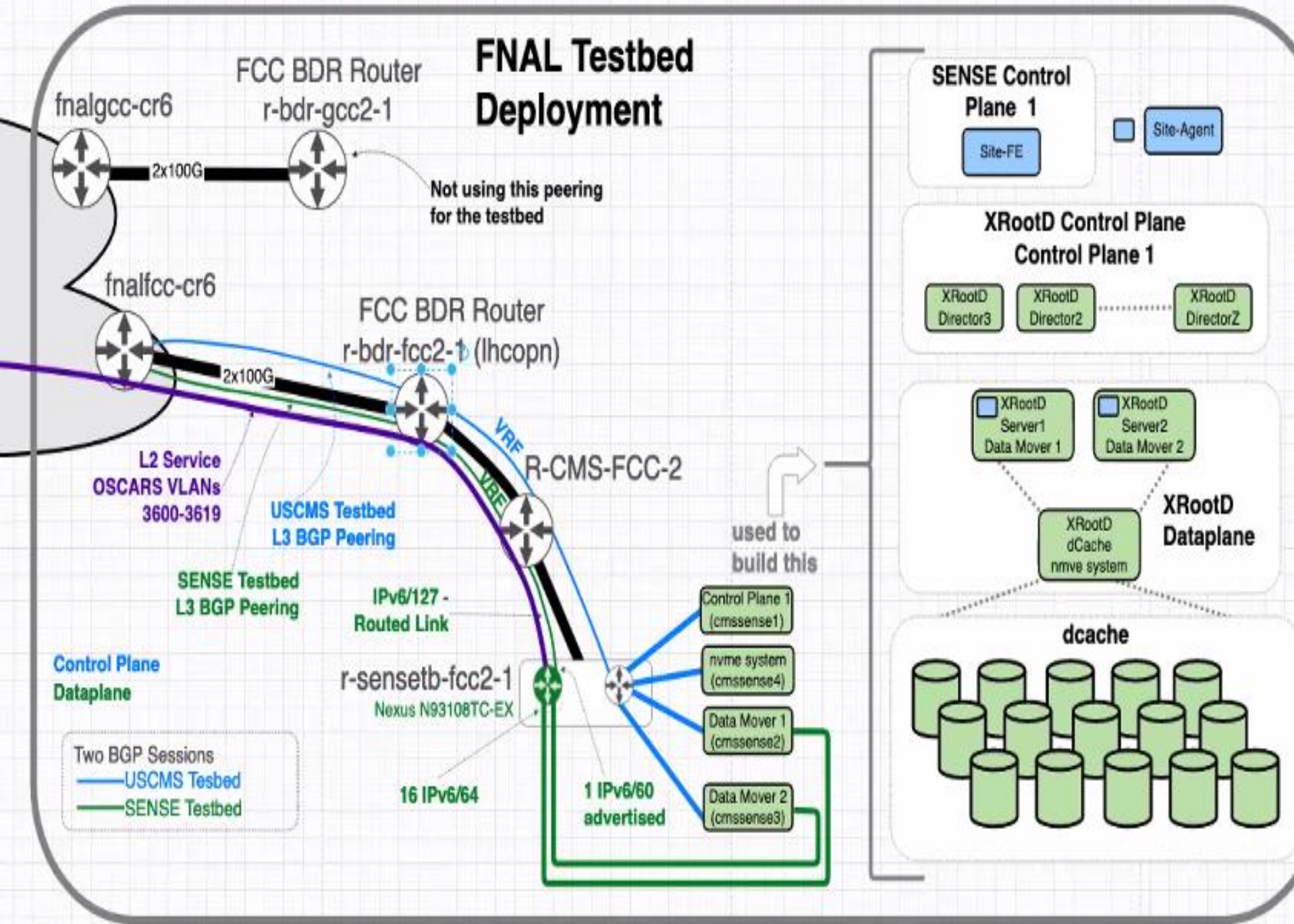
Proposed Extension of Nautilus 2021-2024







FNAL Testbed Deployment

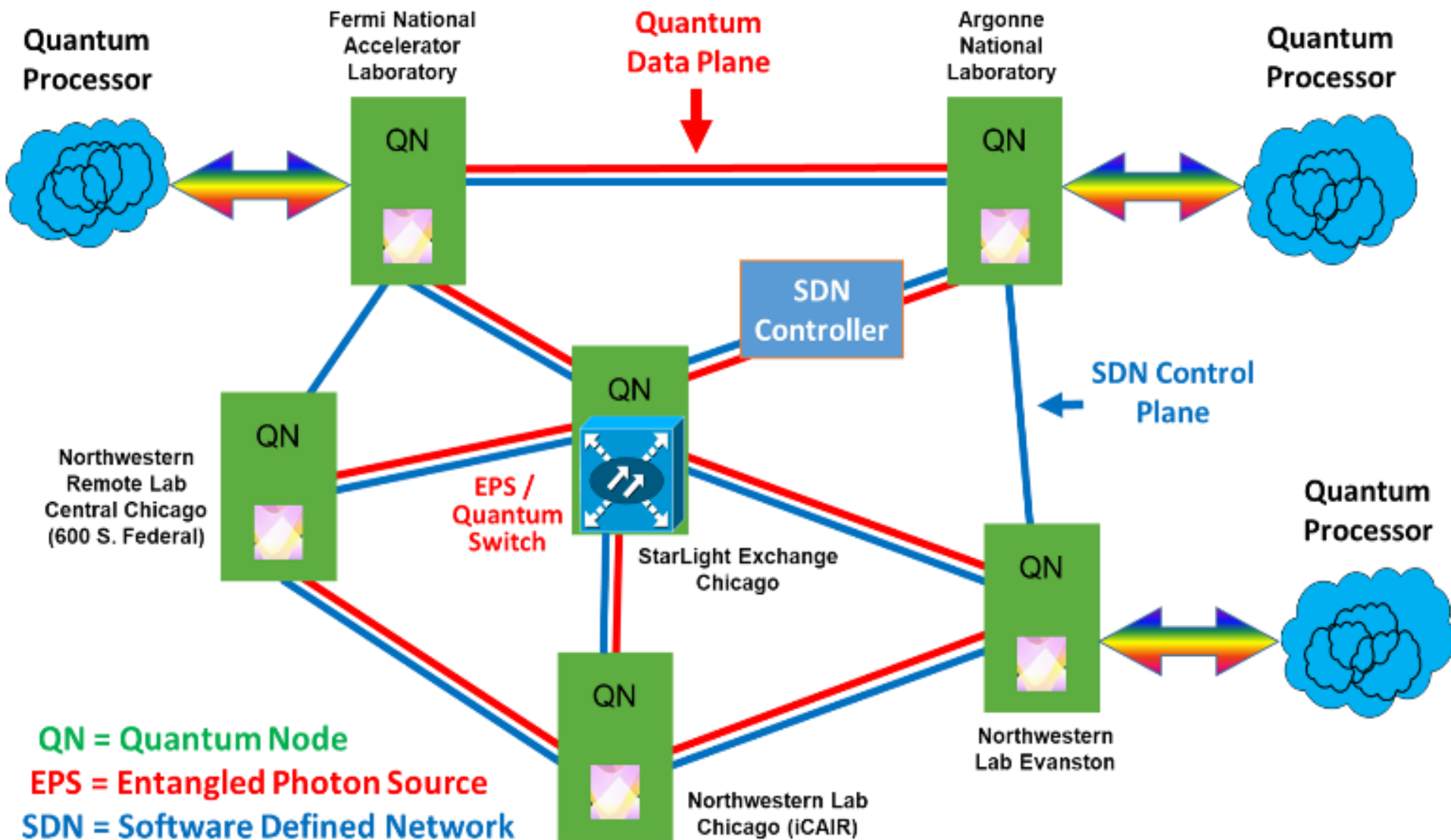


Complexity Of Challenges Requires Consortia

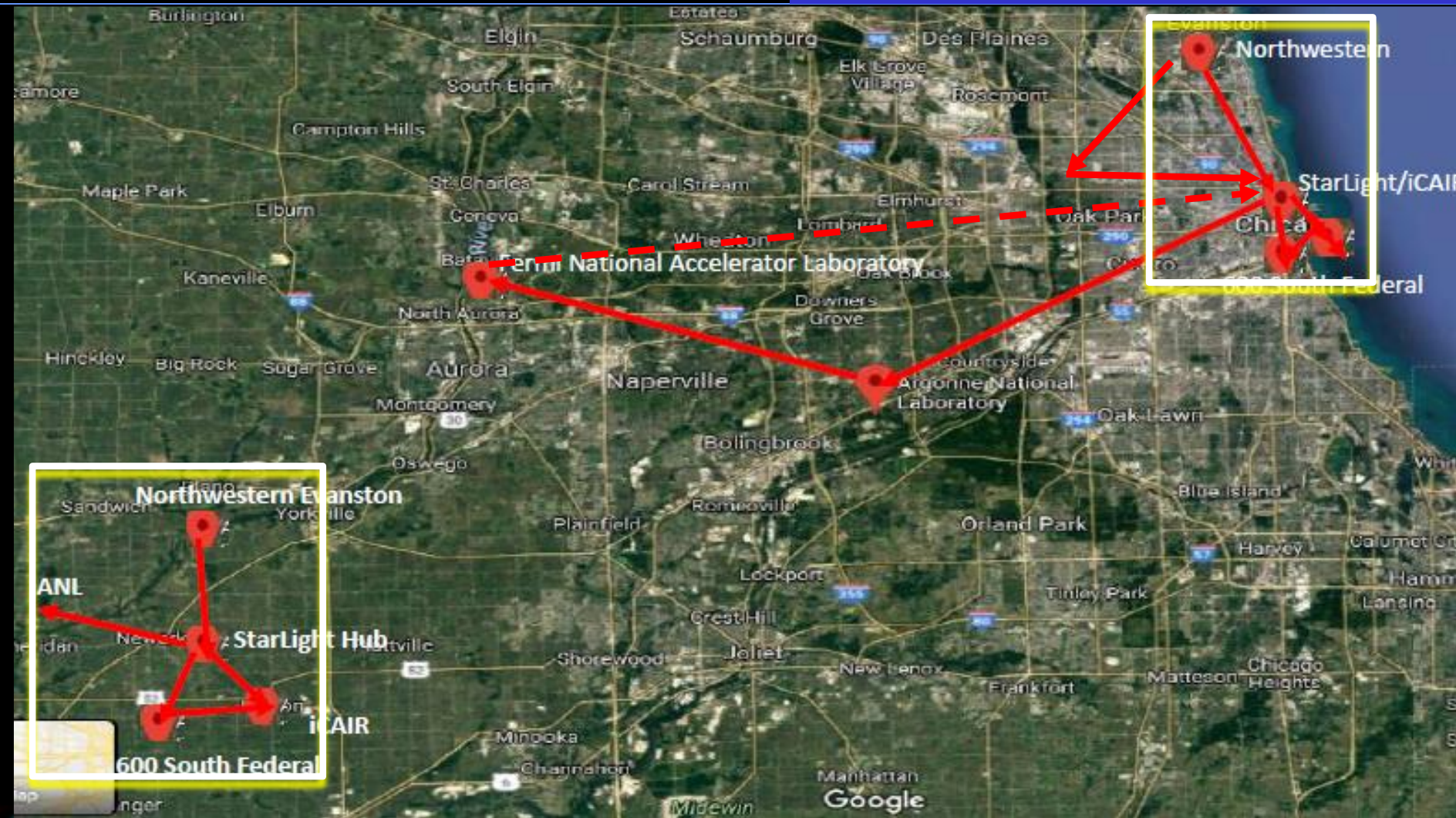
- **On October 23, 2023, the White House and the US Department of Commerce's Economic Development Administration (EDA) Named the Chicago Region an official US Regional and Innovation Technology Hub for quantum technologies, a designation that opens the door to new federal funding and recognizes the growing strength of an ecosystem poised to become the heart of the nation's quantum economy. The hub is a coalition of industry, academic, government, and nonprofit stakeholders led by the Chicago Quantum Exchange.**
- **Northwestern University Established INQUIRE (Initiative at Northwestern for Quantum Information Research and Engineering), For Quantum Science Research**
- **This Initiative Participates in the Chicago Quantum Exchange and The Illinois Express Quantum Network, which includes the U.S. Department of Energy's Argonne National Laboratory, Fermi National Accelerator Laboratory, Multiple Research Universities, and Several Corporations.**
- **These National Laboratories, Northwestern University, Including the International Center for Advanced Internet Research (iCAIR), the StarLight International/National Communications Exchange Facility Consortium, the Metropolitan Research and Education Network (MREN), the Illinois Quantum Information Science and Technology Center (IQUIST) at the University of Illinois at Urbana-Champaign, And Other Research Partners, Including Internationally, Are Collaborating On This initiative.**



Emerging Chicago Quantum Exchange Testbed



Energizing IEQnet Testbed Topology



**BOUGHTON ROAD
TOLL PLAZA**



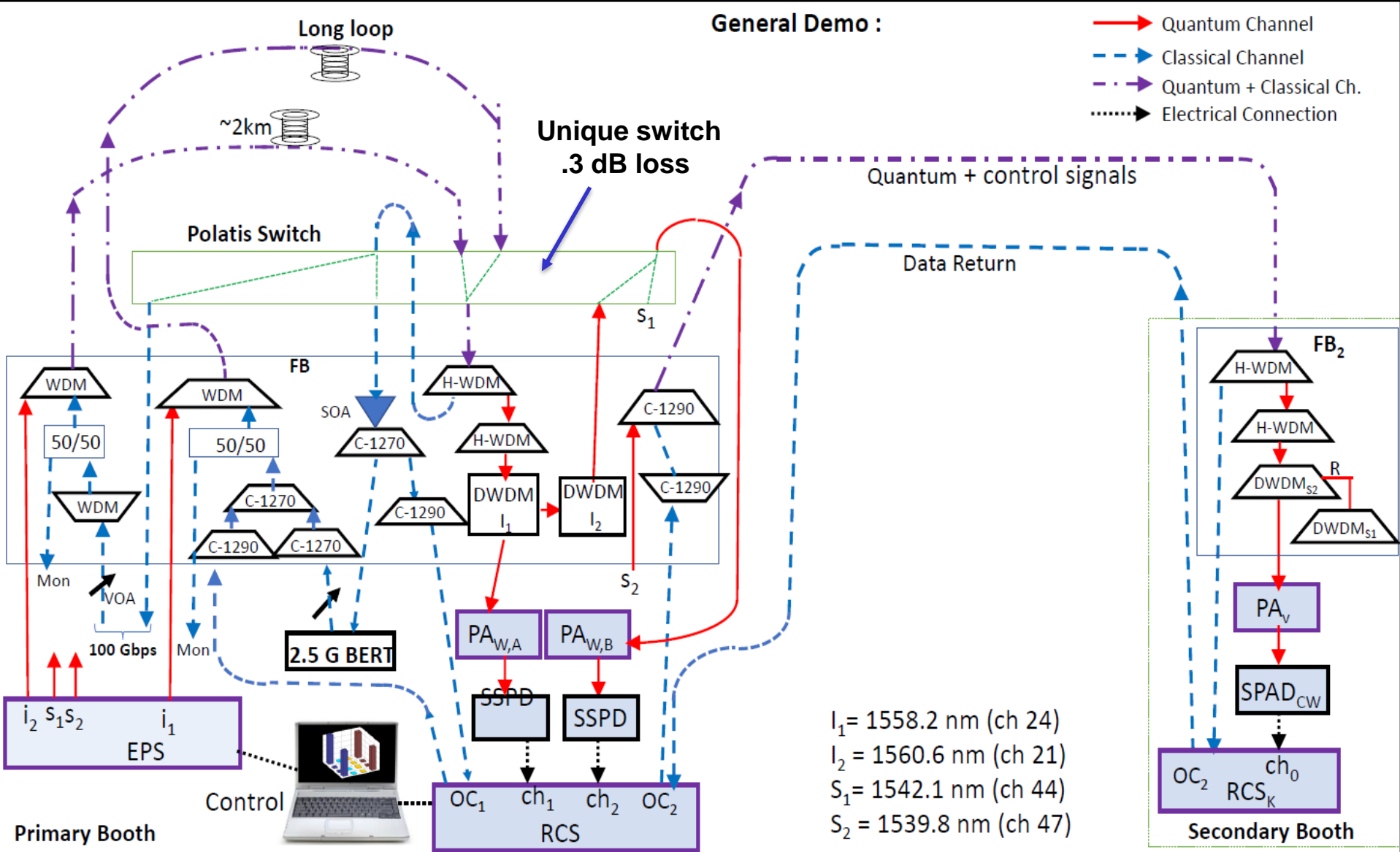
Argonne 
NATIONAL LABORATORY





Demo Lead Partner - NuCrypt (1) - Distribution of Quantum Entanglement Through Fiber With Co-Propagating Classical Data

(1) Spin Off From Northwestern University's Center for Photonic Communications and Computing, Which Was Also A Partner for the OFC 2023 Demonstrations (Prem Kumar, Director)





**Co-Propagation
And 400 Gbps WAN
Demonstrations
OFCnet Booth
March 2023**

STARLIGHTSM

www.startup.net/starlight

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

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