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

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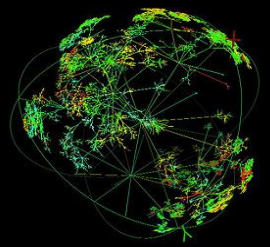
PI: StarLight SDX, Co-PI Chameleon, PI-iGENI, PI-OMNINet

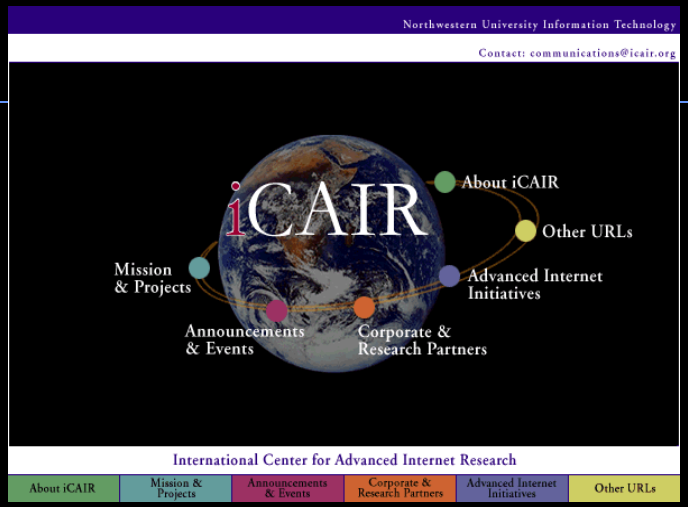
Illinois Institute of Technology
Chicago, Illinois
September 22, 2023



iCAIR

STARLIGHT SDX

Introduction to iCAIR:



Accelerating Leading Edge Innovation and Enhanced Global Communications through Advanced Internet Technologies, in Partnership with the Global Community

- **Creation and Early Implementation of Advanced Networking Technologies - The Next Generation Internet All Optical Networks, Terascale Networks, Networks for Petascale Science**
- **Advanced Applications, Middleware, Large-Scale Infrastructure, NG Optical Networks and Testbeds, Public Policy Studies and Forums Related to NG Networks**
- **Three Major Areas of Activity: a) Basic Research b) Design and Implementation of Prototypes and Large Scale Research Testbeds (Currently ~ 25) c) Operations of Specialized Communication Facilities (e.g., StarLight International/National Communications Exchange Facility, Metropolitan Research and Education Network)**

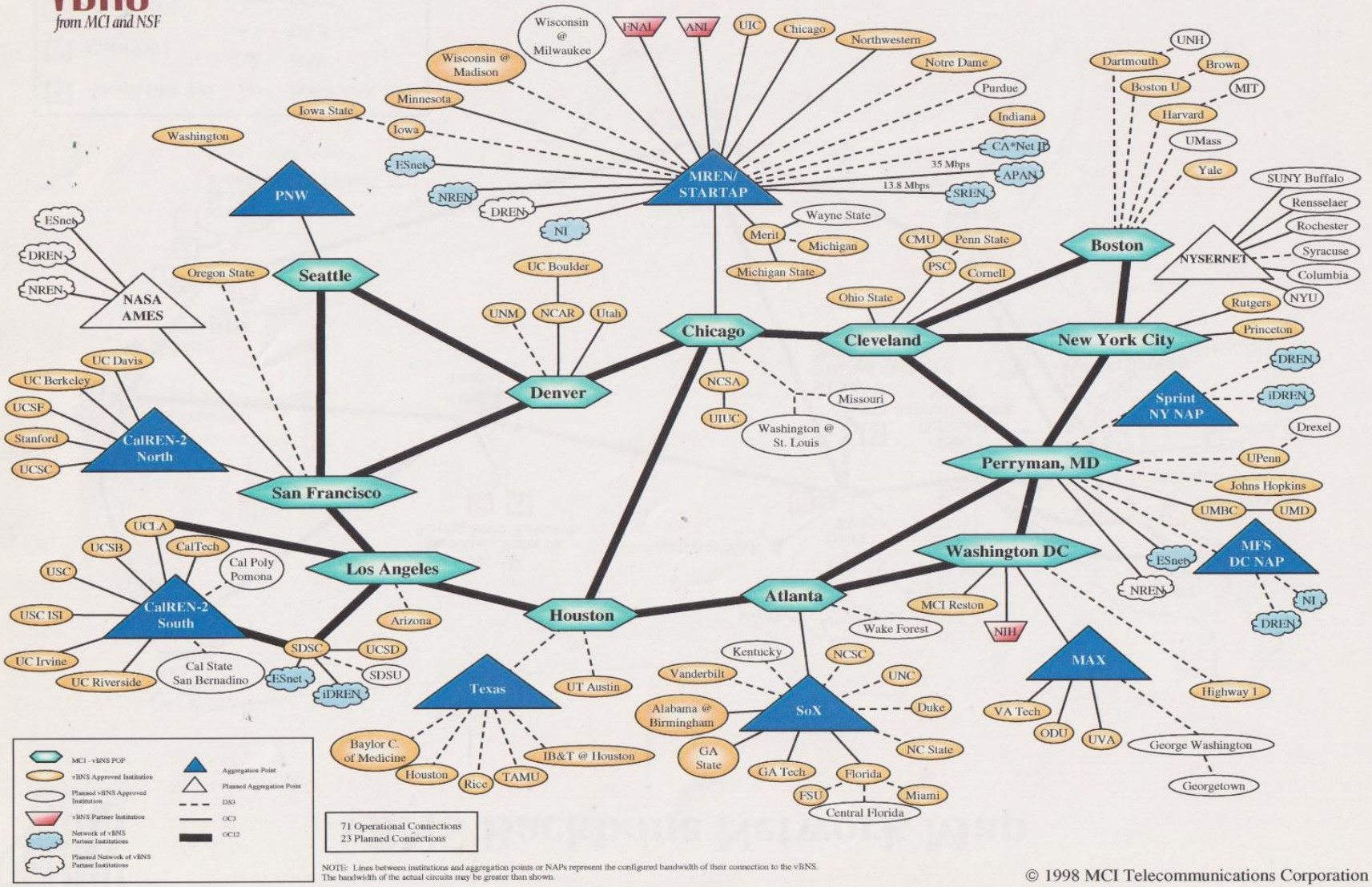
NSF's Cyberinfrastructure Framework for the 21st Century (CIF21)

- ***"Across the full range of NSF--supported fields increasingly sophisticated instrumentation and expanded computational resources are opening new windows onto phenomena from the universe to the human brain, from the largest scales to the smallest. Across all domains, data play the key role in a profound transformation of the culture and conduct of science and society.***
- ***This Revolution Will Transform Research, Practice, And Education In Science and Engineering As Well As Advance Innovation In Society***
- ***This vision of the near future shows clearly the urgent need for a comprehensive, scalable, cyberinfrastructure that bridges diverse scientific communities and integrates high--performance computing, data, software, and facilities in a manner that brings theoretical, computational, experimental, and observational approaches together to advance the frontier."***

A Quick Glance At History And Science Drivers

- US Supercomputing Program/NSFNET (Mid-1980s)
- Midwest Regional Network Connects To NSFNET
- Design (1993) And Implementation (1994) of Metropolitan Research and Education Network (MREN) Based On
- World's First Major Internet Exchange And GigaPoP – Chicago Network Access Point (NAP) (1994)
- I-WAY Demonstration SC95 (1995)
- National Science Foundation Science Technology And Research Transit Access Point (STAR-TAP) Best International Transit (1997)
- NSF National very high speed Backbone Network System (vBNS) (1998)
- National R&E Networks (e.g., ESnet, I2), NGX Exchanges (1998)
- National Science Foundation StarLight International/National Communications Exchange Facility (2000)
- Illinois Wired/Wireless Research and Education Network (I-WIRE)
- TeraGrid (Distributed Computational Science Facility)

vBNS Logical Network Map



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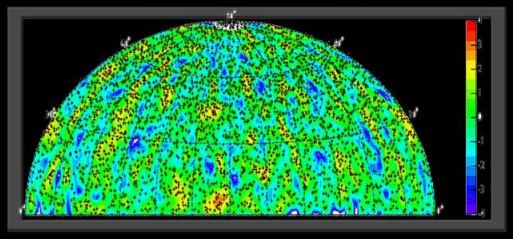
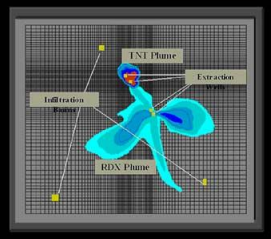
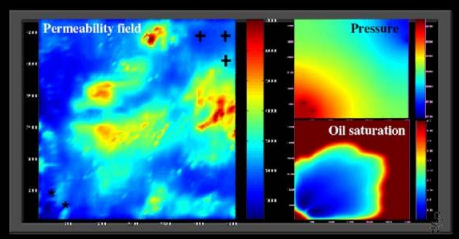
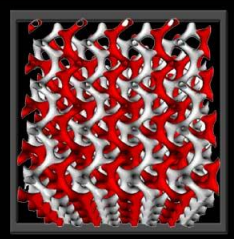
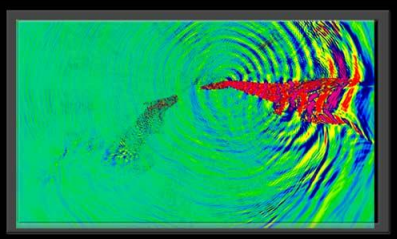
TERAGRID
Extensible Terascale Facility

ANL/UC
PSC
NCSA
PU
IU
ORNL
SDSC
TACC



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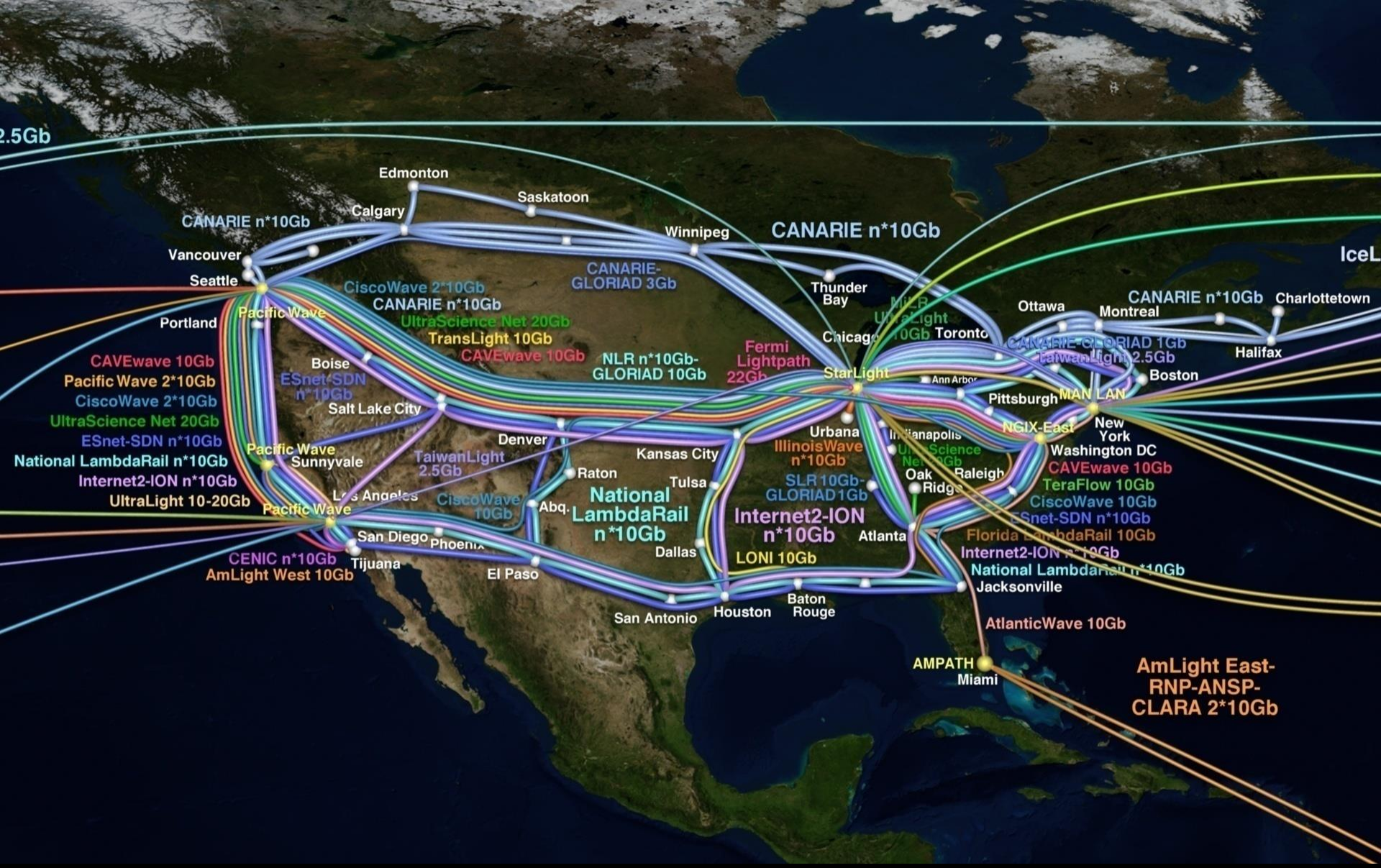

US GLIF Circuits 2017

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Large Scale Global Science & Research Platforms

- Science Domains Create Cyberinfrastructure Ecosystems, Some Distributed World Wide, Some Devoted To Domains, Some Shared Among Domains
- Opportunities For Information Sharing On Cyberinfrastructure Architecture, Implementation, Technologies and Operations Among Projects
- GRP Initiatives Are Especially Useful For Cross Disciplinary Research – Creating:
  - Large Scale Regional Science DMZs
  - Super Facilities
  - National Research Platforms
  - Continental Research Platforms

The GRP: A Platform For Global Science

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

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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

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AutoGOLE Open R&E Exchanges

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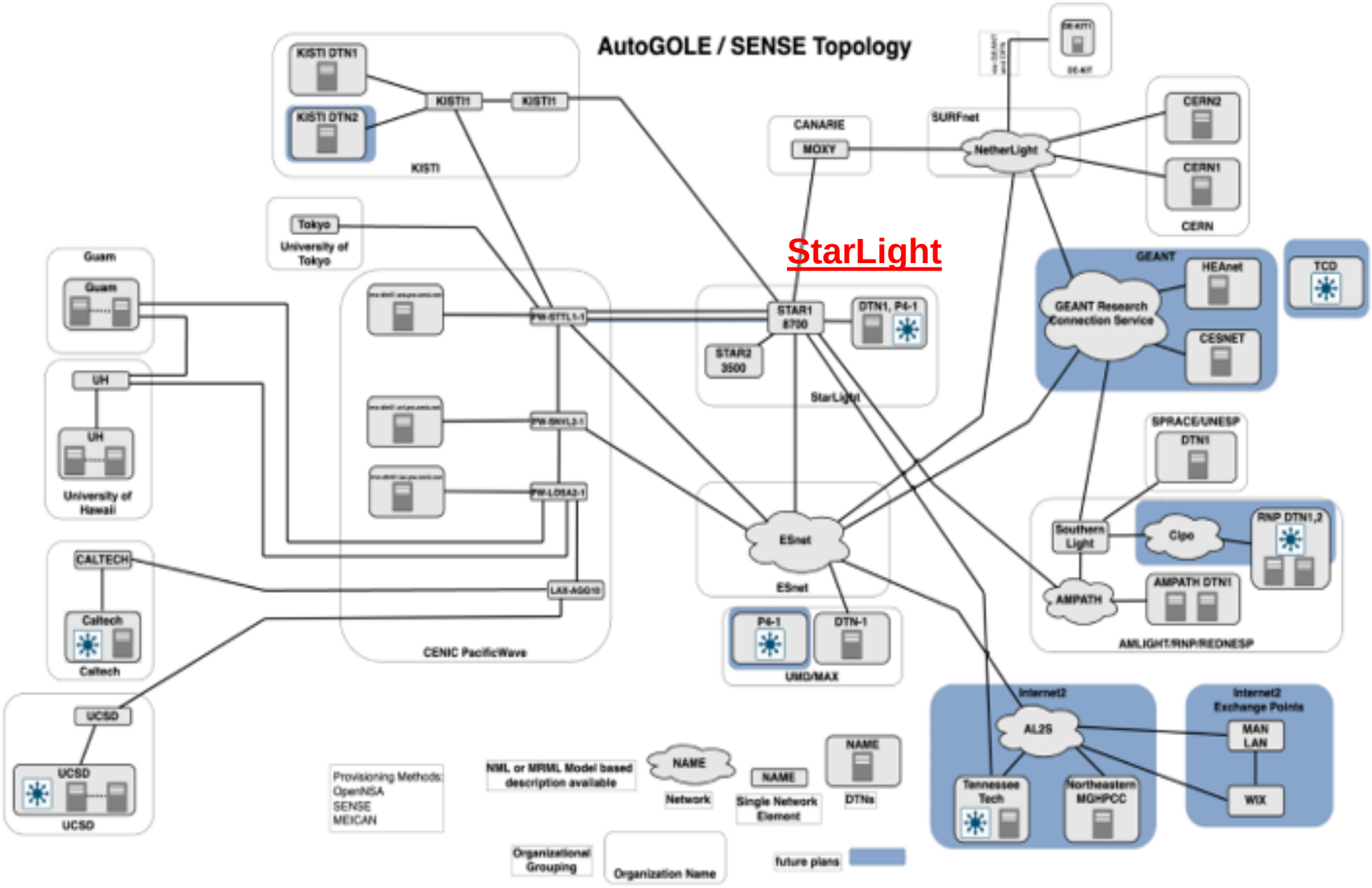
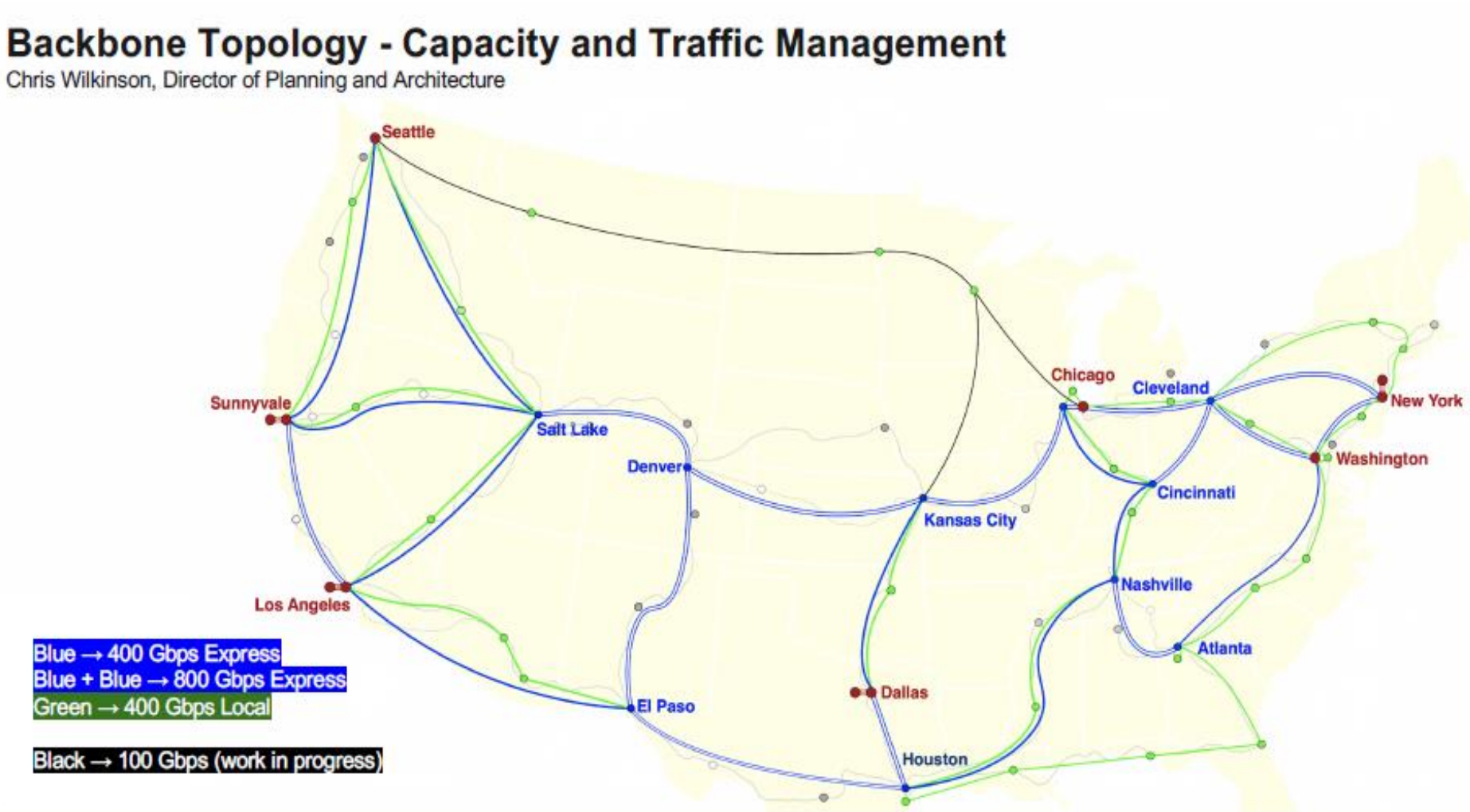
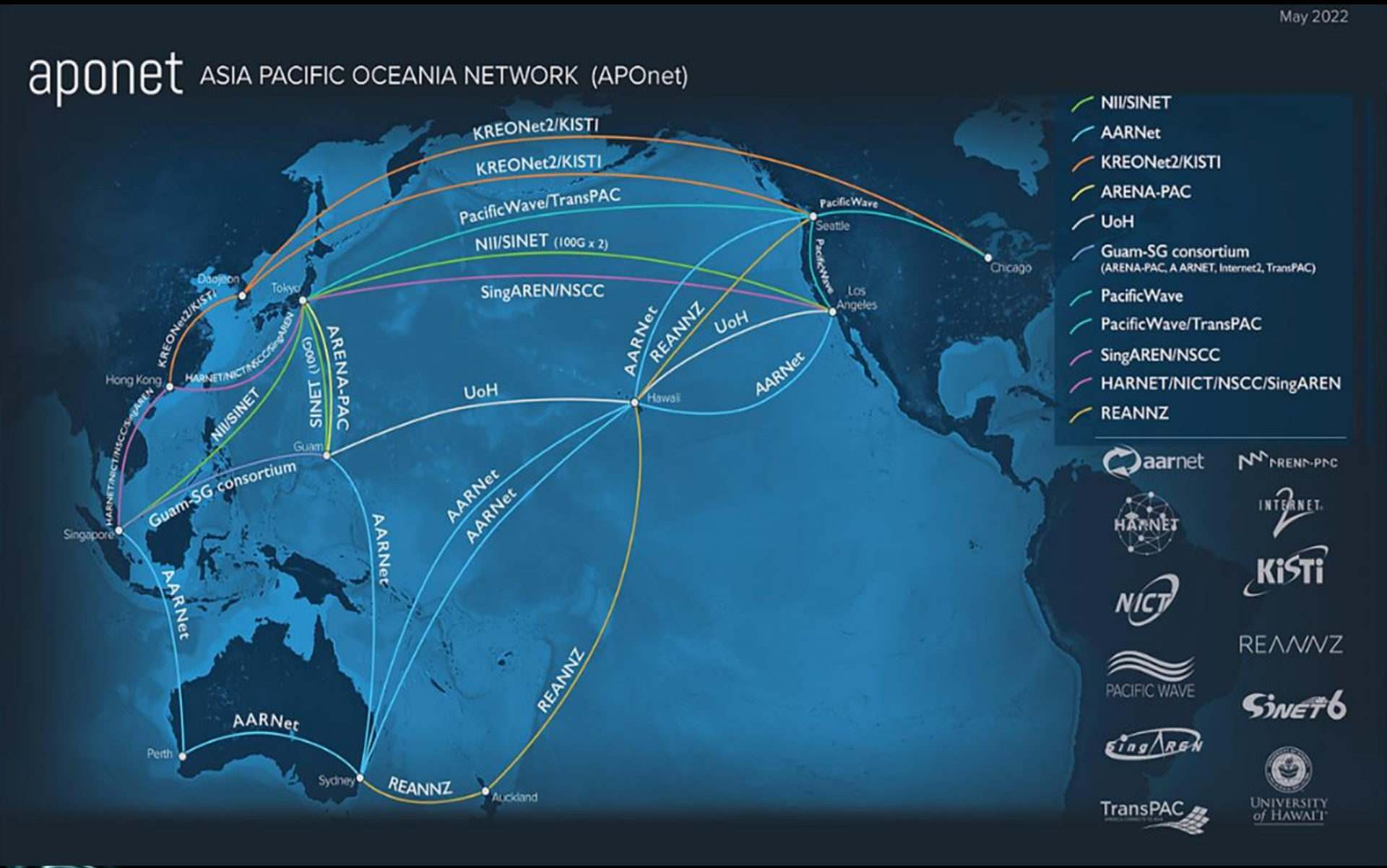

AutoGOLE / SENSE Topology
StarLight
KISTI DTN1
KISTI DTN2
KISTI1
KISTI1
KISTI
Tokyo
University of Tokyo
Guam
Guam
UH
UH
University of Hawaii
CALTECH
Caltech
Caltech
UCSD
UCSD
UCSD
CENIC PacificWave
FW-STTL1-1
FW-SNVL2-1
FW-LOSA2-1
LAX-AGG10
CANARIE
MOXY
SURFnet
NetherLight
CERN2
CERN1
CERN
STAR1 8700
STAR2 3500
DTN1, P4-1
StarLight
GEANT
GEANT Research Connection Service
HEAnet
CESNET
TCD
SPRACE/UNESP
DTN1
ESnet
ESnet
P4-1
DTN-1
UMD/MAX
Southern Light
Cipo
RNP DTN1,2
AMPATH
AMPATH DTN1
AMLIGHT/RNP/REDNESP
Internet2
AL2S
Tennessee Tech
Northeastern MGHPCC
Internet2 Exchange Points
MAN LAN
WIX
Provisioning Methods:
OpenNSA
SENSE
MEICAN
NML or MRML Model based description available
NAME
Network
NAME
Single Network Element
NAME
DTNs
Organizational Grouping
Organization Name
future plans


ESnet6
LSQ
HLAN
NETL-ALB
PNWL
INL
LBNL
NERSC
SLAC
LLNL
SNLCA
NREL
NGA-SW
Salt Lake City
AMES
ANL
FNAL
FRIB
KCNSC
NETL-PGH
NETL-MGN
BNL
LNS
PSFC
CERN
NREL-DC
JLAB
PPPL
ORAU
ORCC
Y-12
ORNL
LANL
LANL-NNSS
KCNSC-NM
SNLA
GA
NNSS
PANTEX
SRS
Hubs
increasing bandwidth
SITES
*Locations generalized for clarity
ESnet
ENERGY
Office of Science
STARLIGHT SM

Internet2 Backbone Topology



Advanced North Atlantic Networks (ANA)


May 2022
aponet ASIA PACIFIC OCEANIA NETWORK (APOnet)
KREONet2/KISTI
KREONet2/KISTI
PacificWave/TransPAC
NII/SINET (100G x 2)
SingAREN/NSCC
Daejeon
Tokyo
Hong Kong
Singapore
Guam
Hawaii
Seattle
Los Angeles
Chicago
PacificWave
ARENA-PAC
SINET (100G)
NII/SINET
UoH
AARNet
REANNZ
Guam-SG consortium
Perth
Sydney
Auckland
NII/SINET
AARNet
KREONet2/KISTI
ARENA-PAC
UoH
Guam-SG consortium
(ARENA-PAC, A ARNET, Internet2, TransPAC)
PacificWave
PacificWave/TransPAC
SingAREN/NSCC
HARNET/NICT/NSCC/SingAREN
REANNZ
aarnet
ARENA-PAC
HARNET
INTERNET2
KISTI
NICT
REANNZ
PACIFIC WAVE
SINET6
SingAREN
TransPAC
UNIVERSITY of HAWAI'I

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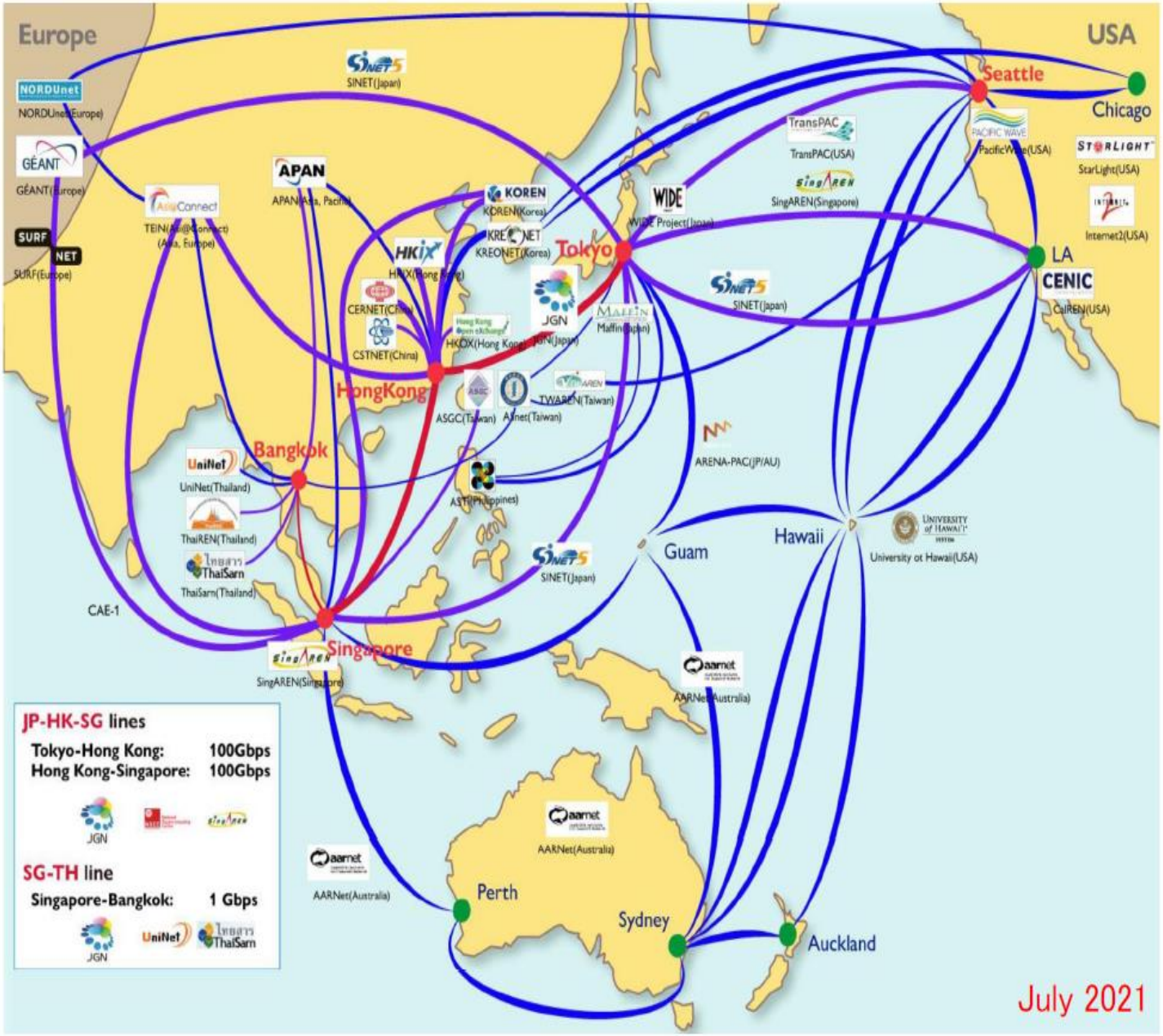
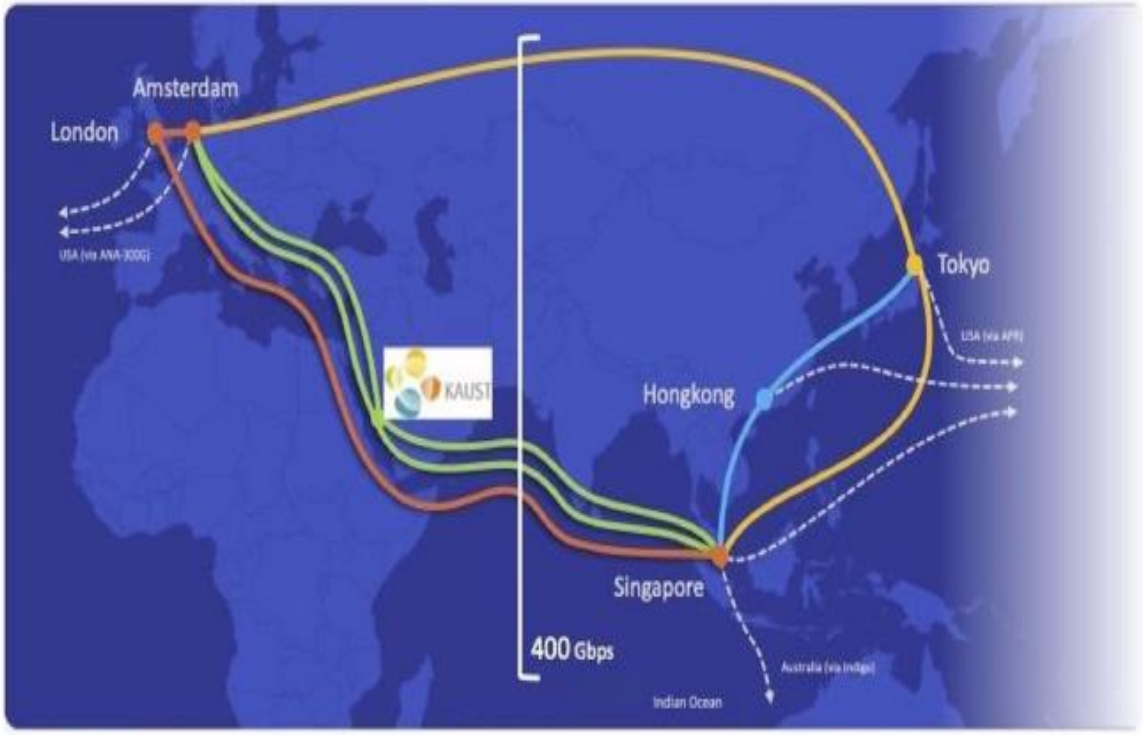
JGN Global Networks: Connections



International Networking: Asia-Pacific Europe Ring (AER)

March 7th 2022: KAUST joined the AER (APAN 53)



NII
NORDUnet
NICT
aarnet
SingAREN
KAUST
TEIN*CC
GÉANT
SURF

SURF

Renewal of MoU expands collaboration between Europe and Asia-Pacific regions, new members added

Image credit: Alexander van den Hil, SURFnet

Selected Applications

GENI
www.geni.net

Open Storage Network
www.openstorage network.org

OSG
www.openscience grid.org

Polar Geospatial Center
www.pgc.umn.edu

LSST
www.lsst.org

ISS
www.nasa.gov/ station

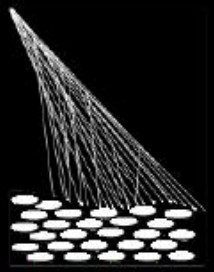
Virgo
www.virgo-gw.eu

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

GLEON
www.gleon.org

GRP
theglobalresearch platform.net/

IceCube
icecube.wisc.edu



Pierre Auger Observatory
www.auger.org

SKA
www.skatelescope. org

LIGO
www.ligo.caltech. edu

USGS EROS
www.usgs.gov/ centers/eros

Blue Waters
bluewaters.ncsa. illinois.edu

PRAGMA
www.pragma-grid.net

NEON
www.neonscience. org

CENTRA
www.global centra.org

SAGE2
sage2.sagecommons. org

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

Jetstream
www.jetstream-cloud.org

Chameleon
www.chameleon cloud.org

PRP
pacificresearch platform.org

Genomic Science Program
genomicscience. energy.gov

Belle II
www.belle2.org

LBNF/DUNE/ ProtoDUNE
lbnf.fnal.gov

XENON
xenon.astro. columbia.edu

NOvA
novaexperiment. fnal.gov

SDSS
www.sdss.org

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

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

ALMA
www.alma observatory.org

IVOA
www.ivoa.net

Compilation by Maxine Brown and Joe Mambretti

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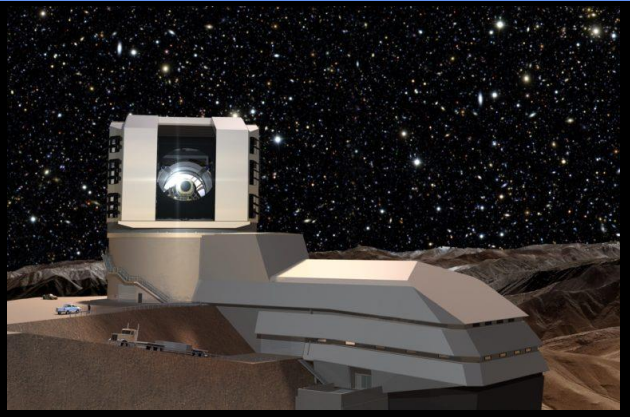
Instruments: Exebytes Of Data

High Luminosity LHC

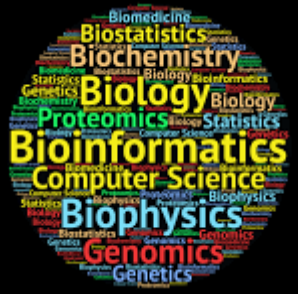
SKA Australia Telescope Facility



Vera Rubin Observatory

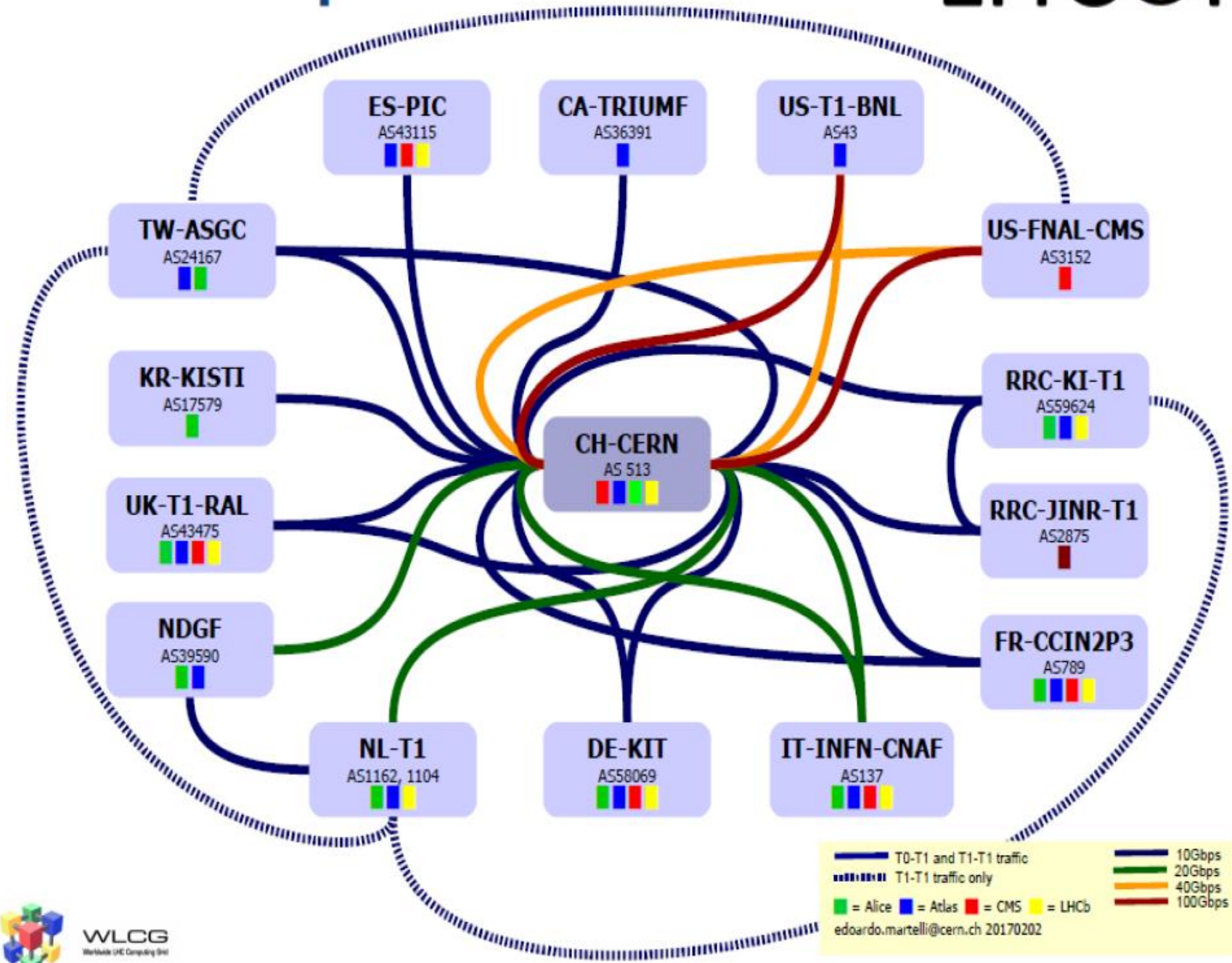
KSTAR Korea Superconducting Tokamak

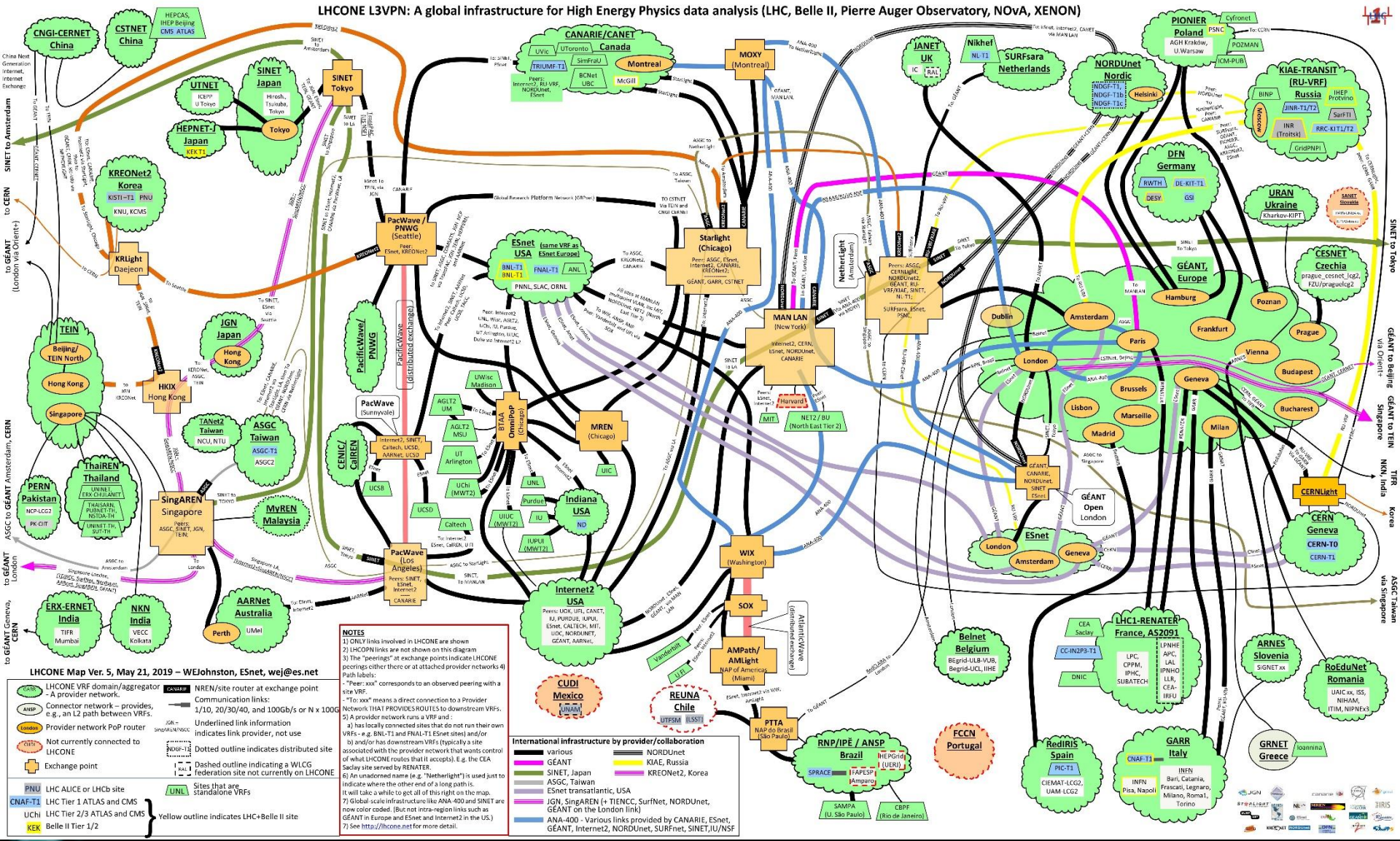
Next Gen Advanced Photon Source



Bioinformatics/Genomics

LHCOPN map


ES-PIC
AS43115
CA-TRIUMF
AS36391
US-T1-BNL
AS43
TW-ASGC
AS24167
US-FNAL-CMS
AS3152
KR-KISTI
AS17579
RRC-KI-T1
AS59624
CH-CERN
AS 513
UK-T1-RAL
AS43475
RRC-JINR-T1
AS2875
NDGF
AS39590
FR-CCIN2P3
AS789
NL-T1
AS1162, 1104
DE-KIT
AS58069
IT-INFN-CNAF
AS137
T0-T1 and T1-T1 traffic
T1-T1 traffic only
= Alice = Atlas = CMS = LHCb
edoardo.martelli@cern.ch 20170202
10Gbps
20Gbps
40Gbps
100Gbps



New Science Communities Using LHCONE

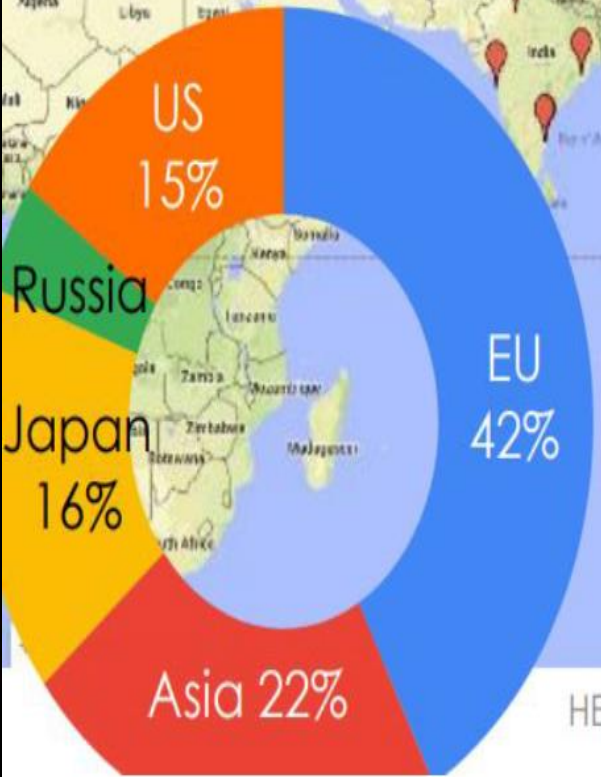
- Belle II Experiment, Particle Physics Experiment Designed To Study Properties of B Mesons (Heavy Particles Containing a Bottom Quark).
- Pierre Auger Observatory, Studying Ultra-High Energy Cosmic Rays, the Most Energetic and Rarest of Particles In the Universe.
- In August 2017 the PAO, LIGO and Virgo Collaboration Measured a Gravitational Wave Originating From a Binary Neutron Star Merger.
- The NOvA Experiment Is Designed To Answer Fundamental questions in neutrino Physics.
- The XENON Dark Matter Project Is a Global Collaboration Investing Fundamental Properties of Dark Matter, Largest Component Of The Universe.

Recent=> DUNE/ProtoDUNE – Deep Underground Nutrino Experiment

Belle II Collaboration

A Global Collaboration

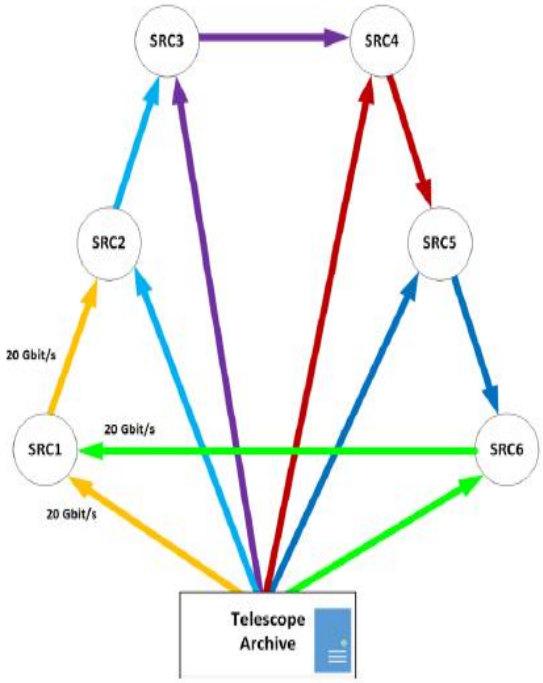
as wide as an LHC experiment

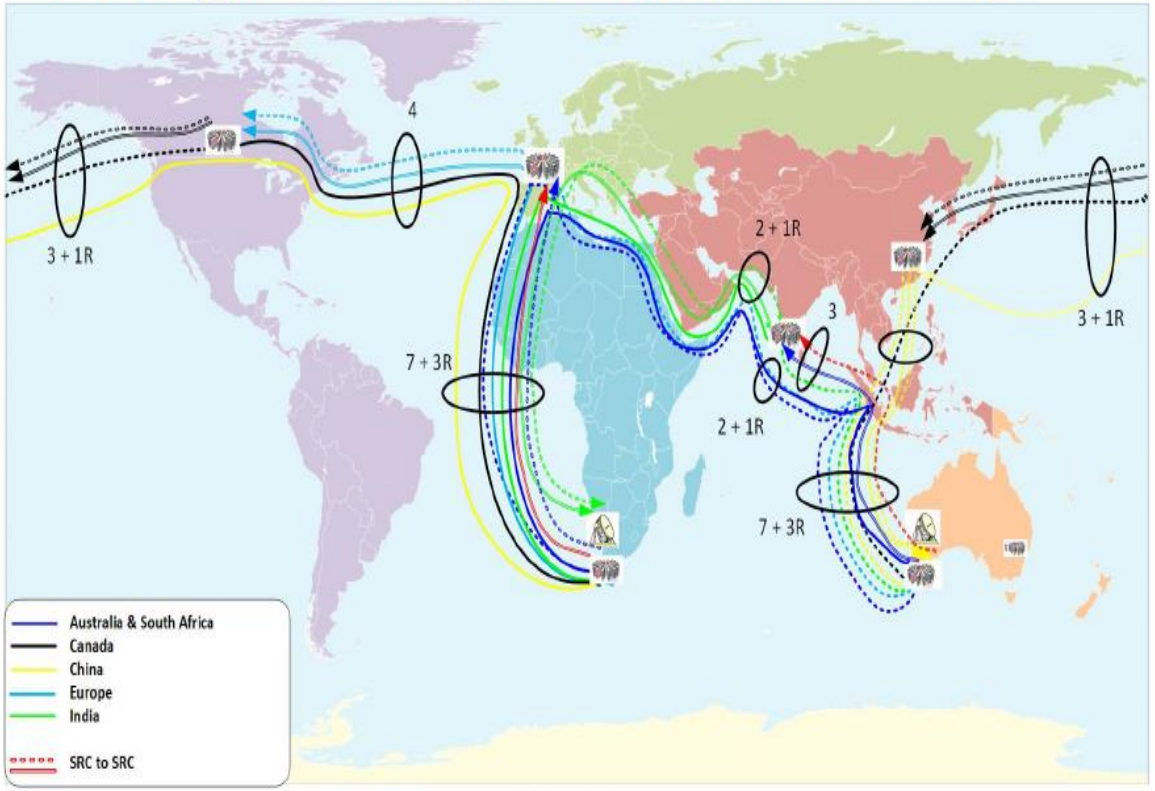


26 countries/regions
123 institutes
1,075 researchers

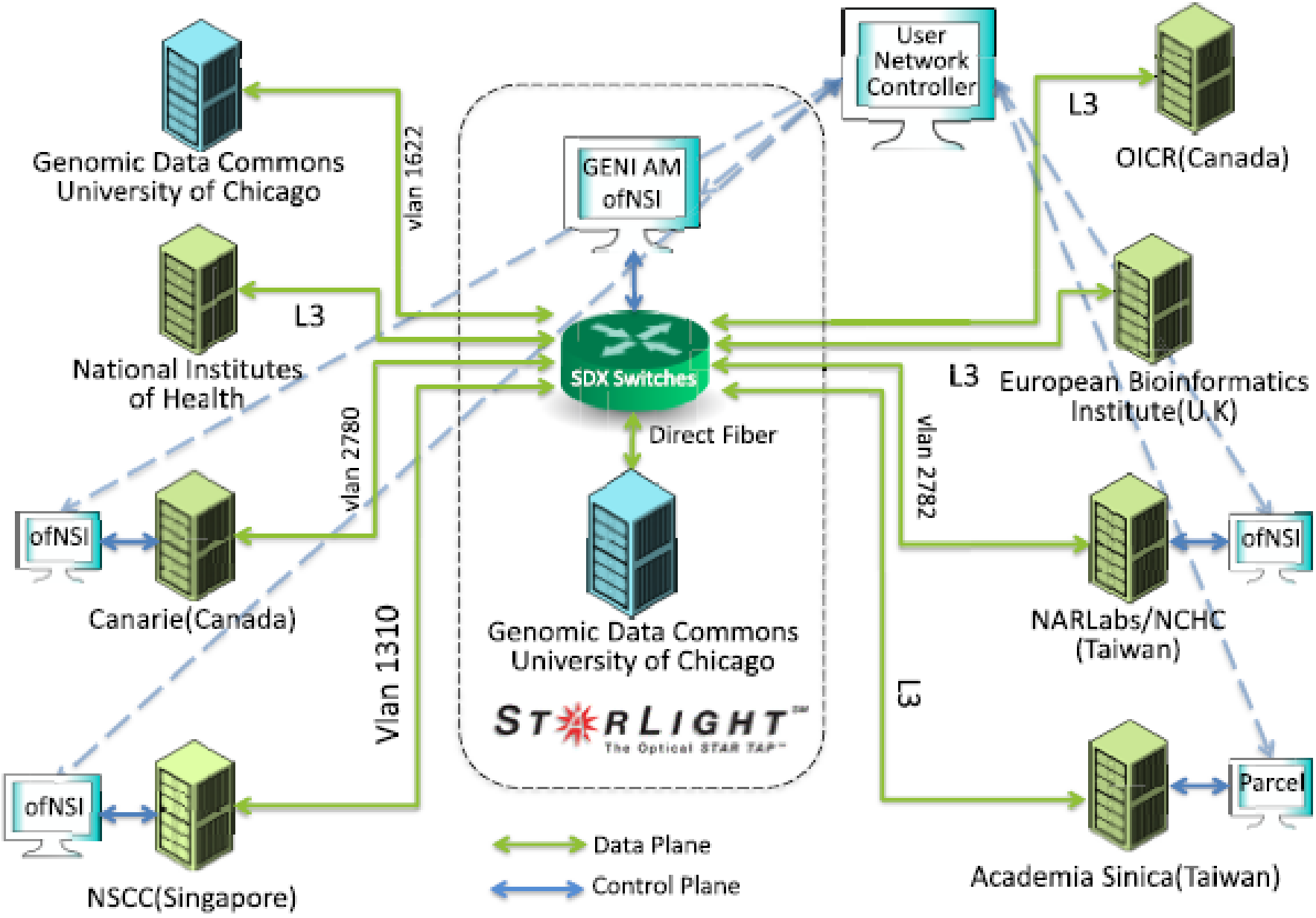
Global Data Flows if the SRC Re-distribute data – 2 Replicas

- 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**





2016 Bioinformatics SDXs Network



GRP And Orchestration Among Multiple Domains

- Instrumentation and Analytic, Storage Resources Are Highly Distributed Among Multiple Domains Interconnected With High Performance Networks
- A Key Issues Is Discovering Resources, Claiming Them, Integrating Them, Utilizing Them and Releasing Them
- Increasingly, New Software Defined Infrastructure Architecture, Services, Techniques And Technologies Are Addressing These Issues, Especially Network Programmability (e.g., Software Defined Networking, Software Defined Exchanges, Software Defined Infrastructre, etc.)

GRP And Large-Scale High Capacity Data WAN Transport

- Large-Scale High Capacity Data WAN Transport Has Always Been And Remains A Major Challenge, Especially Over Global Paths
- This Issue Is Emphasized By A Next Generation Of Instrumentation That Will Generate Exponentially Large Volumes Of Data That Has To Be Distributed Across the Globe
- Often, This Issue Is Considered Reductively Only In Terms Of Network Capacity
- However, Actually It Is More An E2E Issue, Especially Given Advances In Core Optical Networking Technologies

High-Fidelity Data Flow Monitoring, Visualization, Analytics, Diagnostic Algorithms, Event Correlation AI/ML/DL

- A Major Opportunity For Data Transport Optimization Is Being Provided By New Methods For Directly Detecting And Analyzing All Data Flows And Their Characteristics
- Because These Techniques Enable High-Fidelity Views Of All Flows, Real Time, Dynamic Traffic Engineering Is Possible With Much More Sophistication Than Traditional Approaches
- These Techniques Can Be Significant Enhanced Using AI/ML/DL, Which (Although Still Emerging) Are Becoming Critically Important Tools

International Testbeds for Data-Intensive Science

- Given Challenges Of Anticipated Large Scale Science Projects Along With Accelerated Rates Of Ongoing Innovation, International Testbeds Are Required for Pre-Production Investigations And Prototyping Of New Technologies And Techniques Specifically Related To Data Intensive Science
- Such Global Experimental Research Testbeds Exist Today, And They Are Being Developed With Enhanced Capacities, Sites, And Capabilities

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 Tbps

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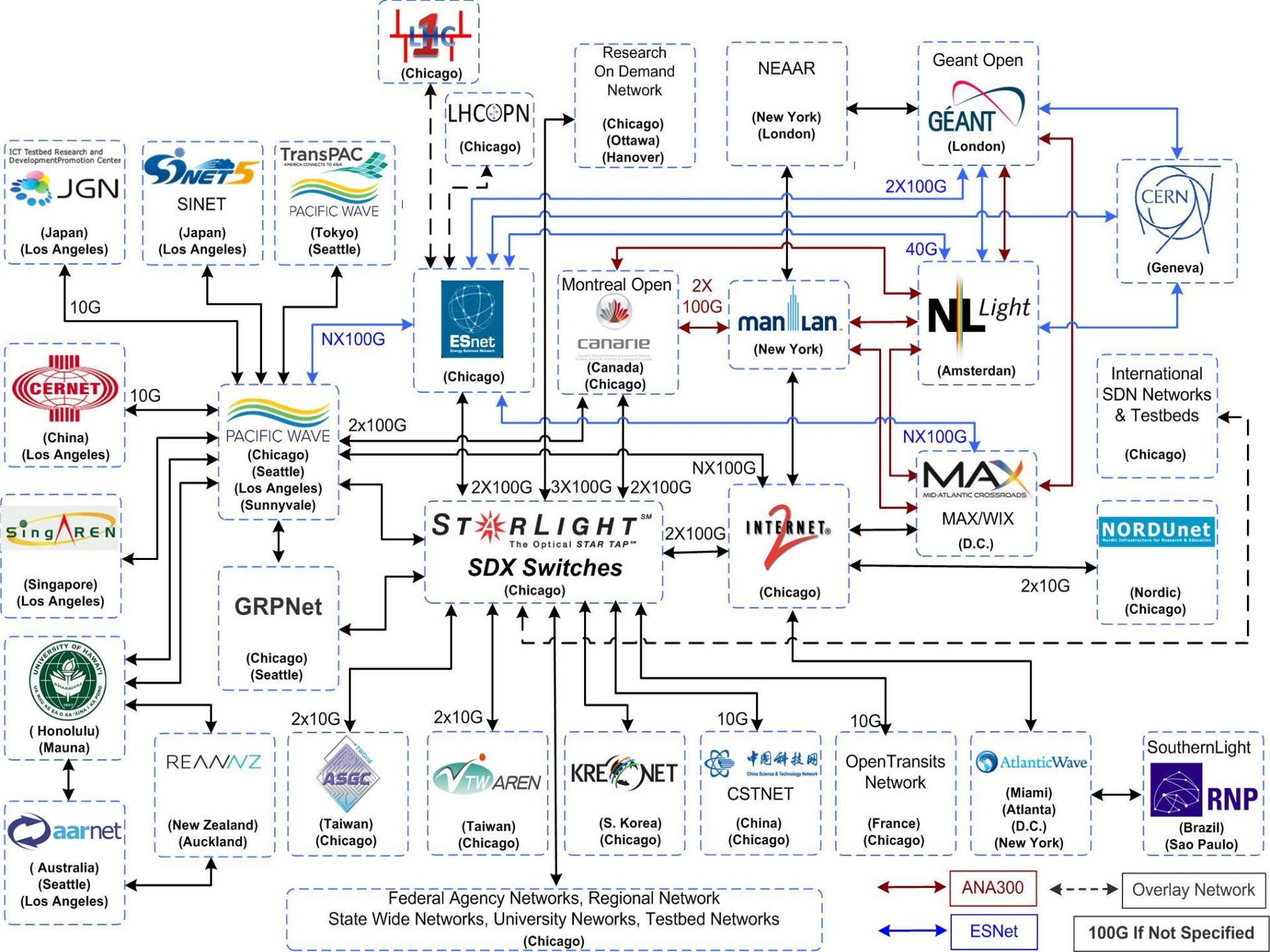
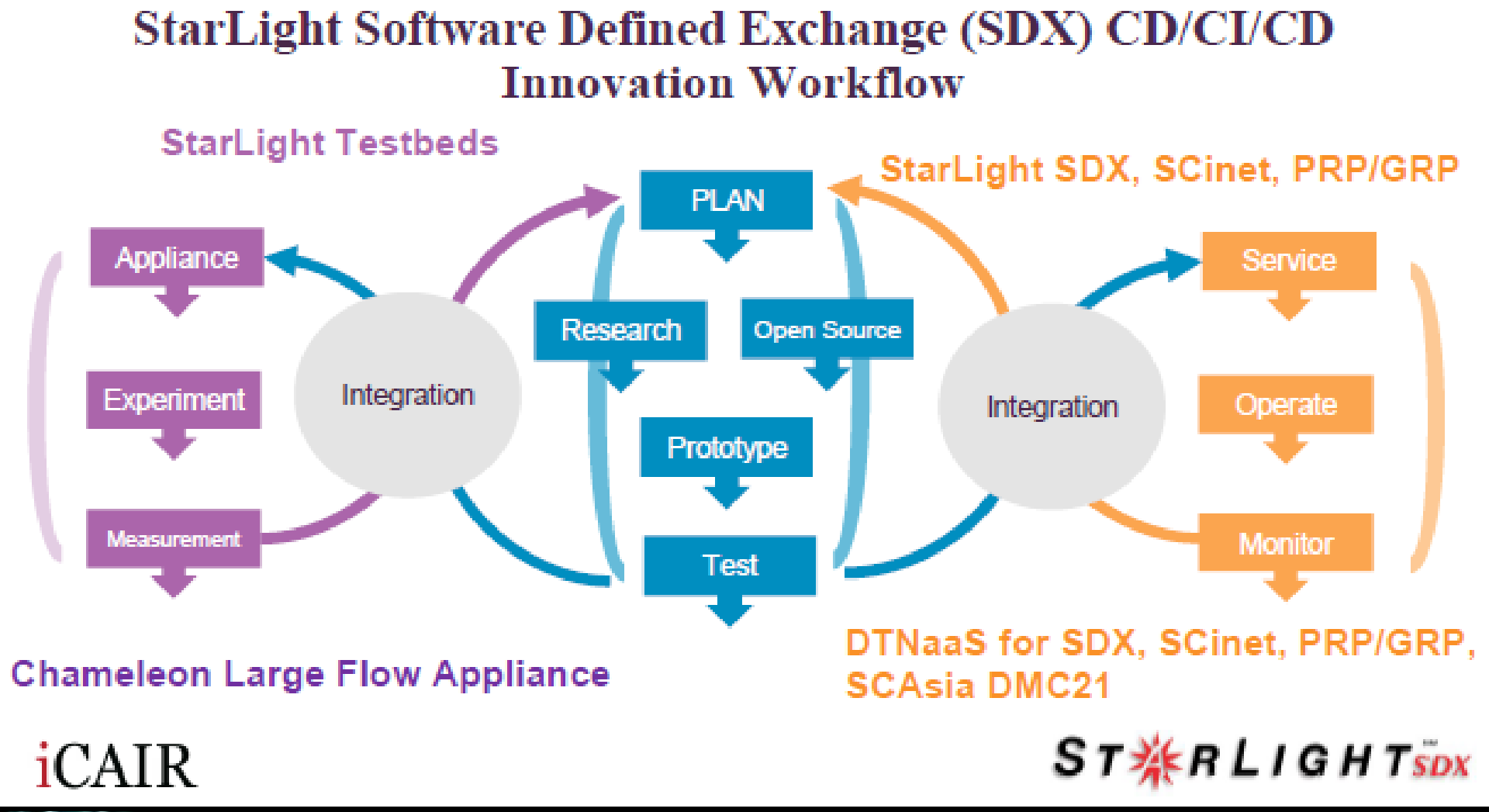

LHC
(Chicago)
LHCOPN
(Chicago)
Research On Demand Network
(Chicago)
(Ottawa)
(Hanover)
NEAAR
(New York)
(London)
Geant Open
GÉANT
(London)
CERN
(Geneva)
2X100G
40G
ICT Testbed Research and DevelopmentPromotion Center
JGN
(Japan)
(Los Angeles)
SINET
(Japan)
(Los Angeles)
TransPAC
PACIFIC WAVE
(Tokyo)
(Seattle)
10G
NX100G
ESnet
(Chicago)
Montreal Open
canarie
(Canada)
(Chicago)
2X 100G
manLan
(New York)
NL Light
(Amsterdan)
CERNET
(China)
(Los Angeles)
10G
PACIFIC WAVE
(Chicago)
(Seattle)
(Los Angeles)
(Sunnyvale)
2x100G
International SDN Networks & Testbeds
(Chicago)
NX100G
MAX
MID-ATLANTIC CROSSROADS
MAX/WIX
(D.C.)
NX100G
2X100G
3X100G
2X100G
SingAREN
(Singapore)
(Los Angeles)
STARLIGHT
The Optical STAR TAP
SDX Switches
(Chicago)
2X100G
INTERNET2
(Chicago)
2x10G
NORDUnet
(Nordic)
(Chicago)
GRPNet
(Chicago)
(Seattle)
(Honolulu)
(Mauna)
2x10G
2x10G
10G
10G
REANNZ
(New Zealand)
(Auckland)
ASGC
(Taiwan)
(Chicago)
TWAREN
(Taiwan)
(Chicago)
KREONET
(S. Korea)
(Chicago)
CSTNET
(China)
(Chicago)
OpenTransits Network
(France)
(Chicago)
AtlanticWave
(Miami)
(Atlanta)
(D.C.)
(New York)
SouthernLight
RNP
(Brazil)
(Sao Paulo)
aarnet
(Australia)
(Seattle)
(Los Angeles)
Federal Agency Networks, Regional Network
State Wide Networks, University Neworks, Testbed Networks
(Chicago)
ANA300
ESNet
Overlay Network
100G If Not Specified

StarLight Software Defined Exchange



iCAIR

STARLIGHT SDX

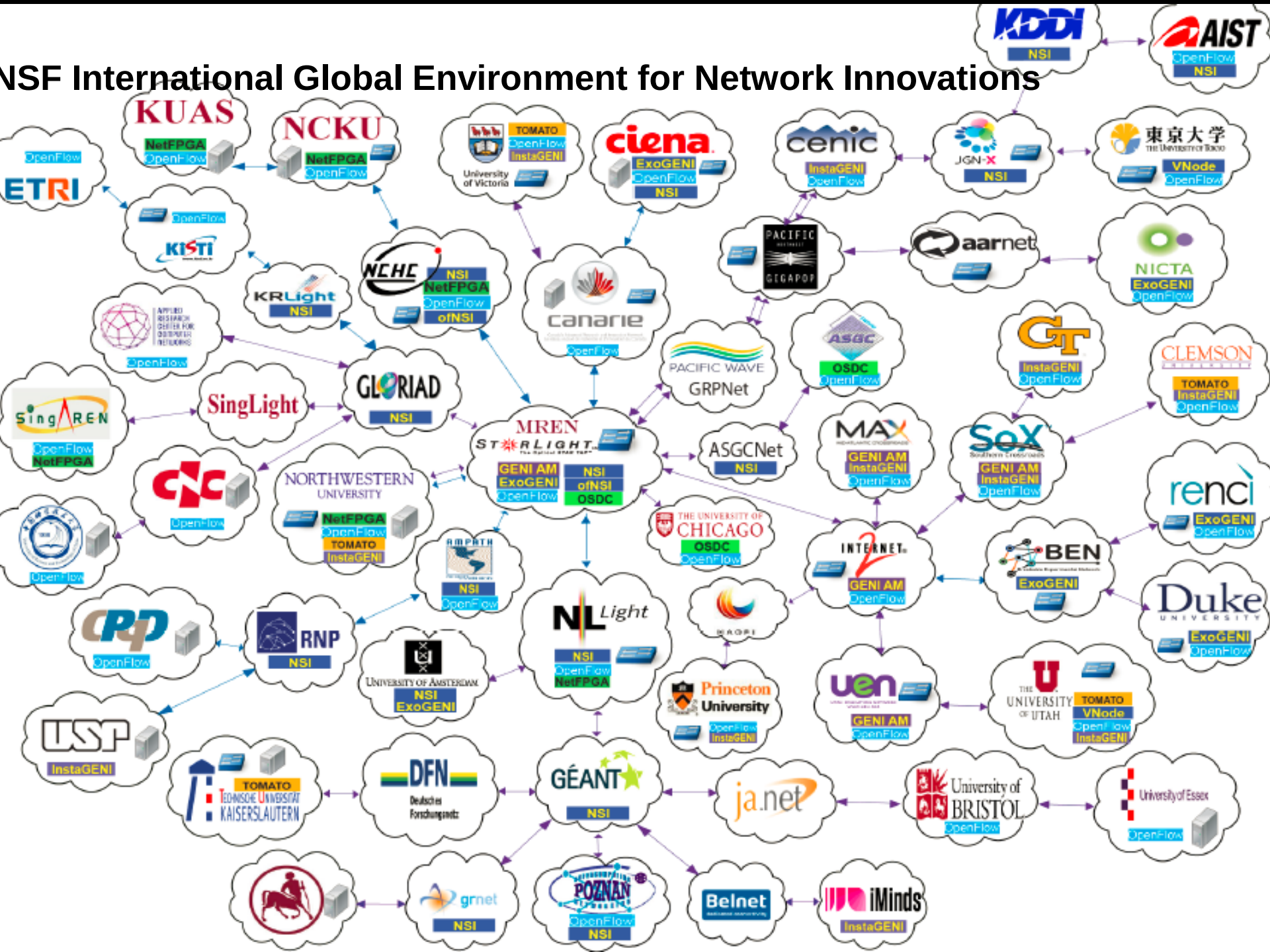
Source: Jim Chen

STARLIGHT SM

International Federated Testbeds As Instruments for Computer Science/Network Science

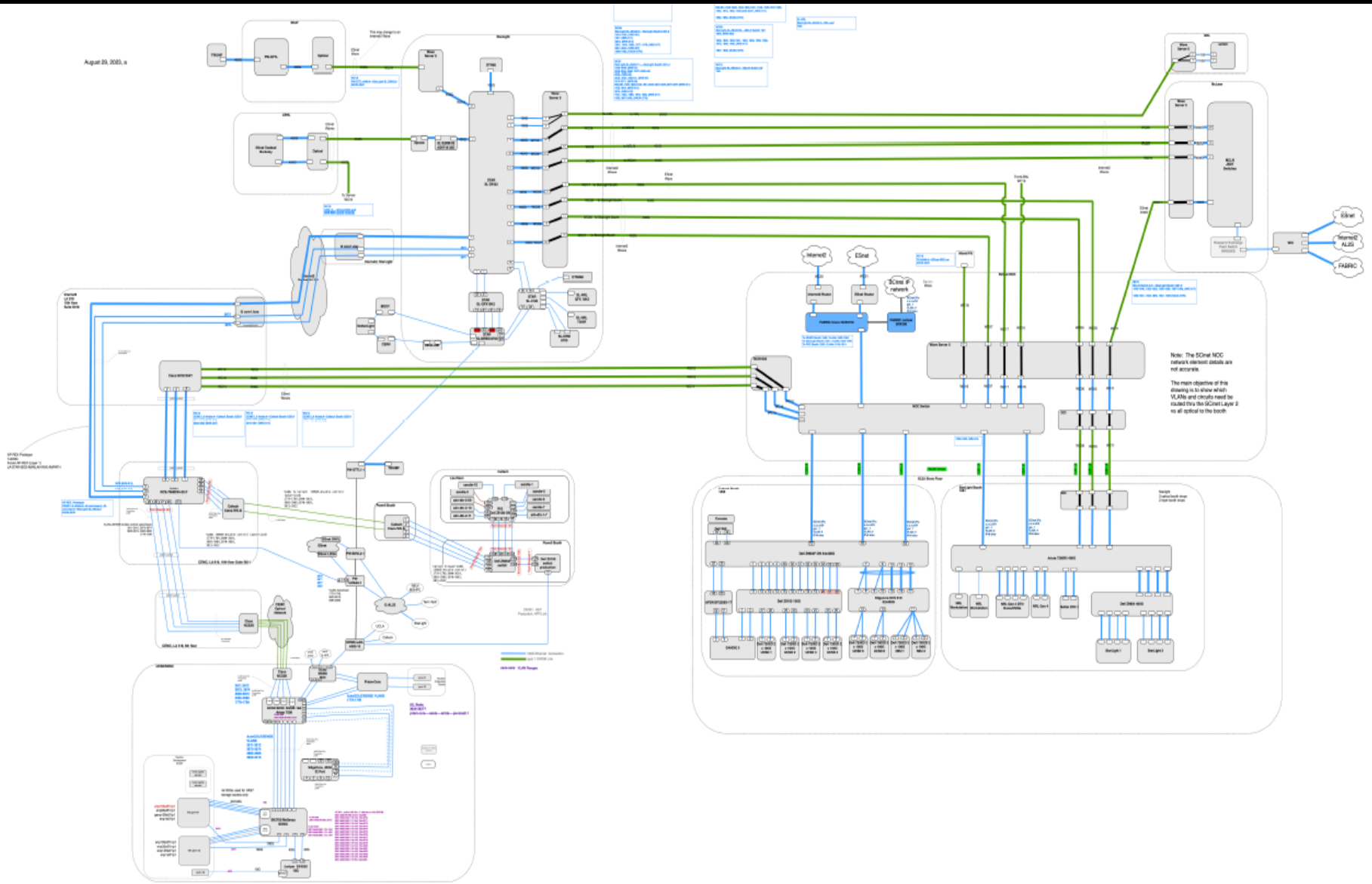
- The StarLight Communications Exchange Facility Supports ~ 25 Network Research Testbeds (Instruments For Computer Science/Networking Research)
- StarLight Supports Two Software Defined Exchanges (SDXs), An NSF IRNC SDX & A Network Research GENI SDX (Global Environment for Network Innovations)
- The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

NSF International Global Environment for Network Innovations



SCinet National WAN Testbed

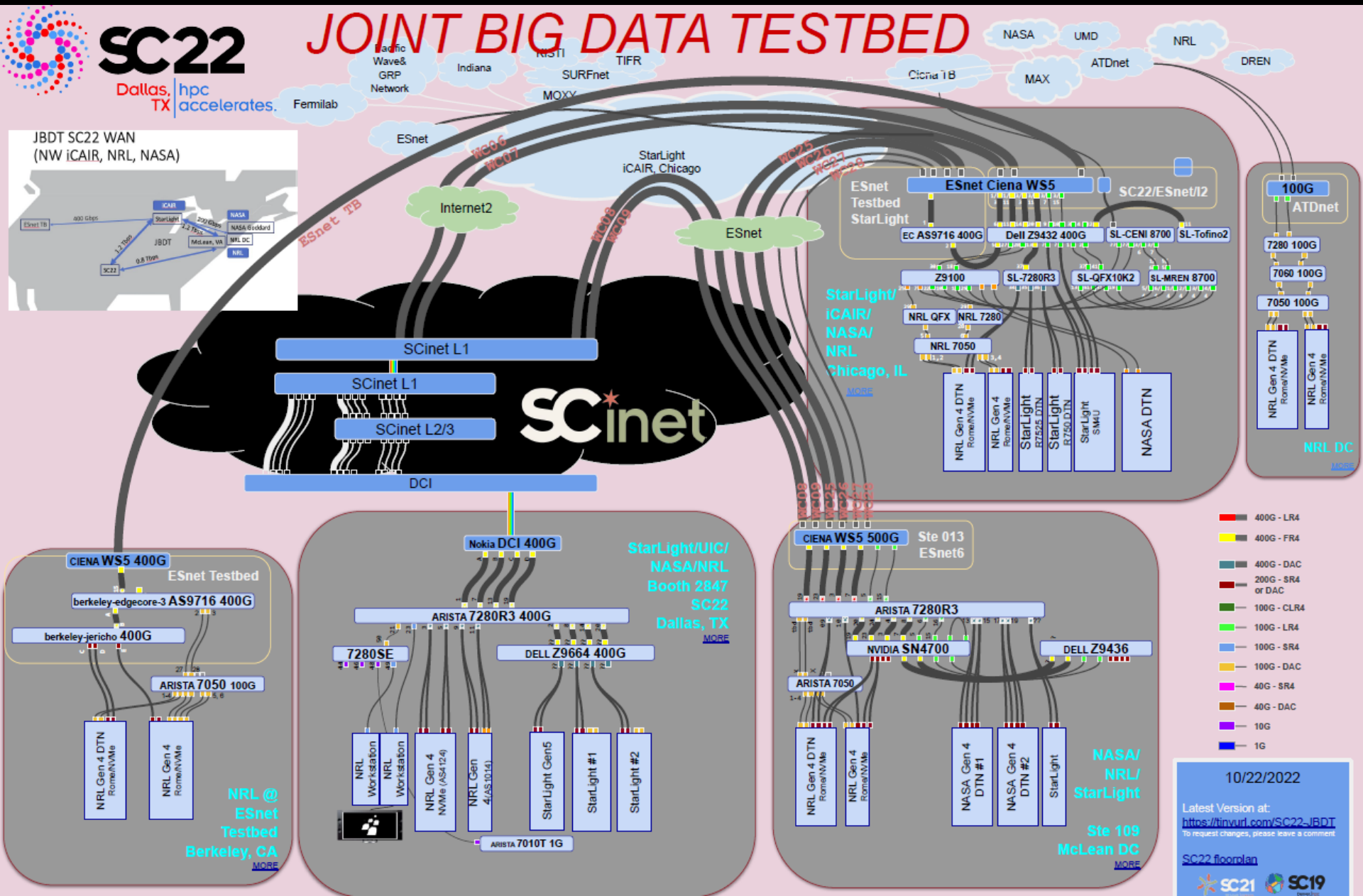
- As In Previous Years, iCAIR Supports SCinet In Designing and Implementing a National WAN Testbed
- A Key Focus Is 400, 800, and 1.2 Tbps Path Services and Interconnections, Including Direct Connections To Edge Nodes, Primarily High Performance DTNs
- The SC23 National WAN Testbed Is Being Designed and Implemented To Support Demonstrations and Experiments Of Innovations Related To Data Intensive Science

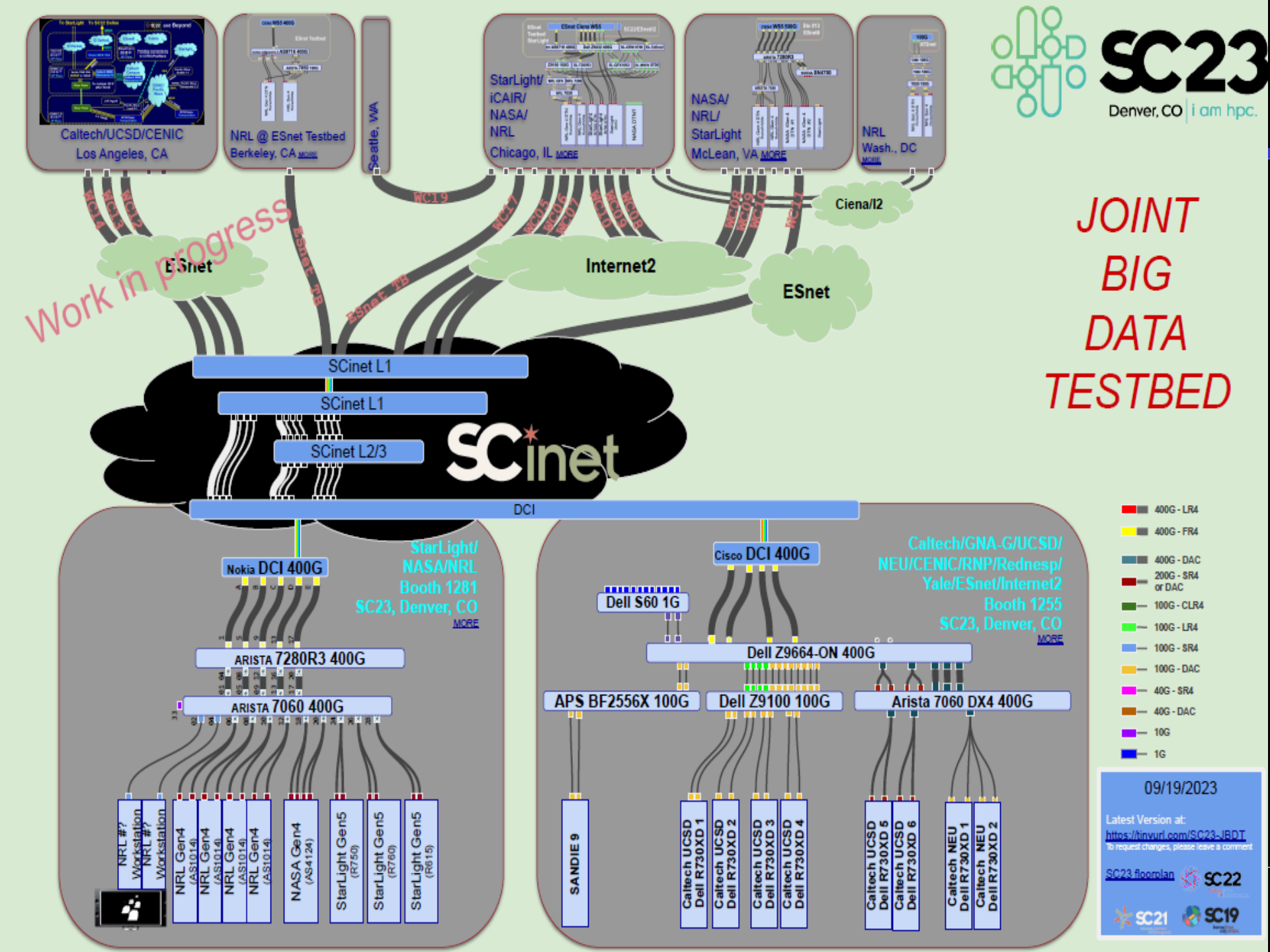


Planned SC23 SCinet WAN Source Tom Lehman

STARLIGHT SM

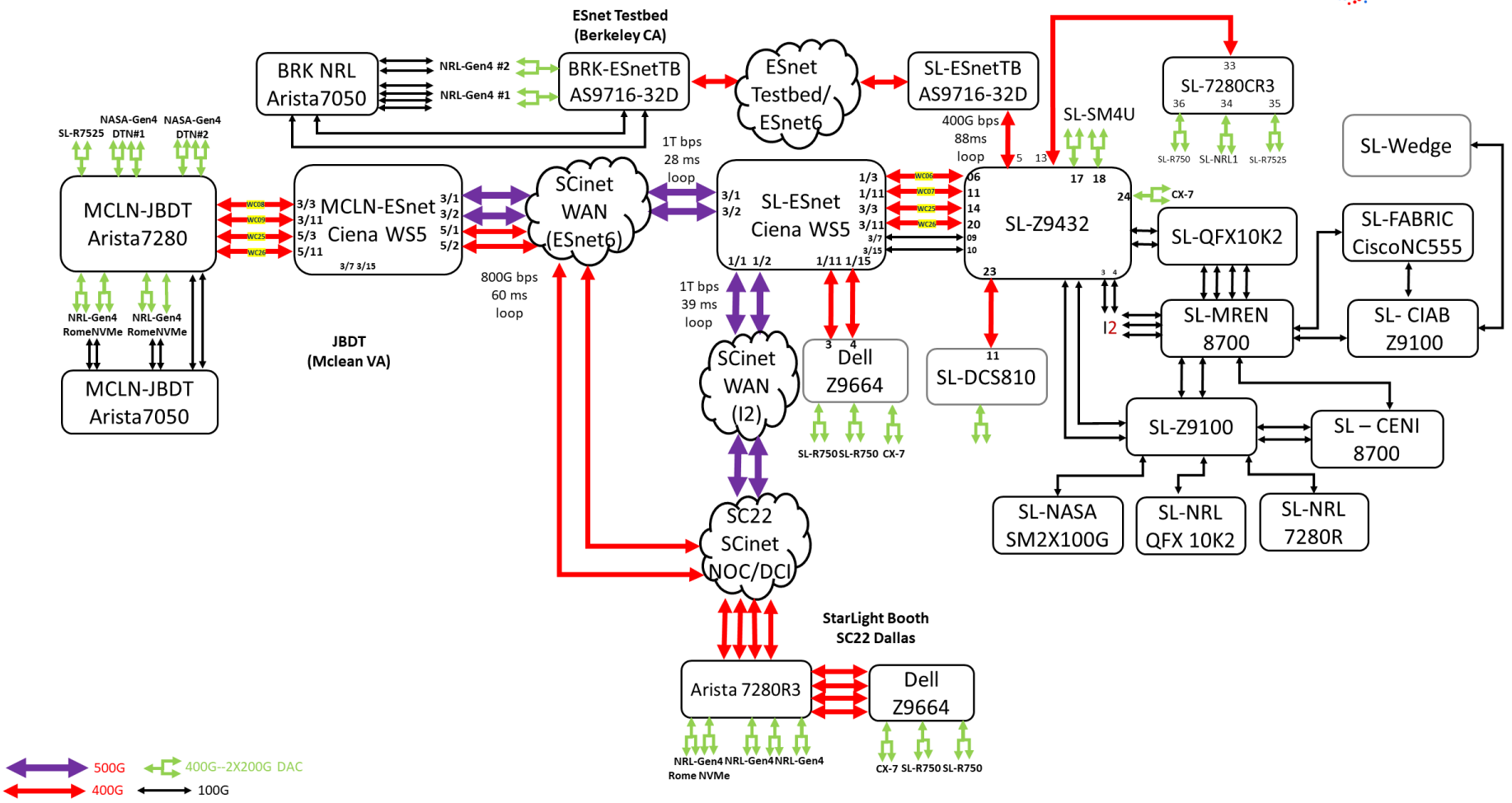
Persistent Communication Services For Petascale Sciences: Demonstrations At IEEE/ACM Supercomputing Conference – SC22, Dallas Texas




SC23
Denver, CO | i am hpc.
JOINT BIG DATA TESTBED
Work in progress
Caltech/UCSD/CENIC
Los Angeles, CA
NRL @ ESnet Testbed
Berkeley, CA MORE
Seattle, WA
StarLight/
iCAIR/
NASA/
NRL
Chicago, IL MORE
NASA/
NRL/
StarLight
McLean, VA MORE
NRL
Wash., DC MORE
Ciena/I2
ESnet
Internet2
ESnet
SCinet L1
SCinet L1
SCinet L2/3
SCinet
DCI
StarLight/
NASA/NRL
Booth 1281
SC23, Denver, CO
MORE
Nokia DCI 400G
ARISTA 7280R3 400G
ARISTA 7060 400G
NRL #? Workstation
NRL #? Workstation
NRL Gen4 (AS1014)
NRL Gen4 (AS1014)
NRL Gen4 (AS1014)
NRL Gen4 (AS1014)
NASA Gen4 (AS4124)
StarLight Gen5 (R750)
StarLight Gen5 (R760)
StarLight Gen5 (R615)
Caltech/GNA-G/UCSD/
NEU/CENIC/RNP/Rednesp/
Yale/ESnet/Internet2
Booth 1255
SC23, Denver, CO
MORE
Cisco DCI 400G
Dell S60 1G
Dell Z9664-ON 400G
APS BF2556X 100G
Dell Z9100 100G
Arista 7060 DX4 400G
SANDIE 9
Caltech UCSD Dell R730XD 1
Caltech UCSD Dell R730XD 2
Caltech UCSD Dell R730XD 3
Caltech UCSD Dell R730XD 4
Caltech UCSD Dell R730XD 5
Caltech UCSD Dell R730XD 6
Caltech NEU Dell R730XD 1
Caltech NEU Dell R730XD 2
400G - LR4
400G - FR4
400G - DAC
200G - SR4 or DAC
100G - CLR4
100G - LR4
100G - SR4
100G - DAC
40G - SR4
40G - DAC
10G
1G
09/19/2023
Latest Version at:
https://tinyurl.com/SC23-JBDT
To request changes, please leave a comment
SC23 floorplan
SC22
SC21
SC19

SC22 SCinet WAN Testbed

1T/800G/400G WAN Testbed by ESnet Testbed-I2-SCinet-StarLight-JBDT 11/14/2022

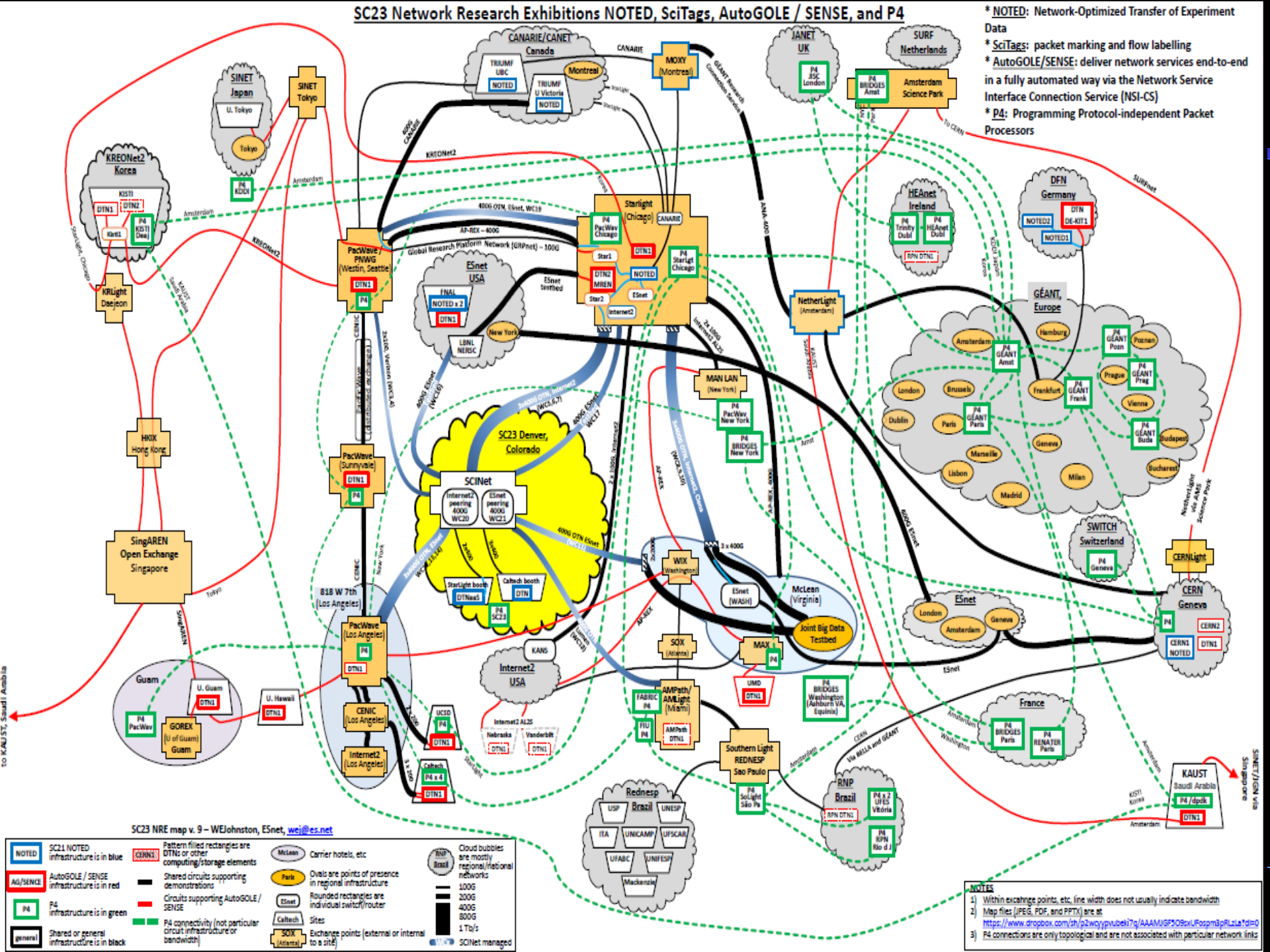


Example SC22 SCinet Network Research Exhibitions

- Global Research Platform (GRP)
- SDX 1.2 Tbps WAN Services
- SDX E2E 400 Gbps WAN Services
- 400 Gbps DTNs & Smart NICs
- Network Optimized Transport for Experimental Data (NOTED) – With AI/ML Driven WAN Network Orchestration
- SDX International Testbed Integration
- StarLight SDX for Petascale Science
- DTN-as-a-Service For Data Intensive Science
- P4 Integration With Kubernetes
- PetaTrans Services Based on NVMe-Over-Fabric
- NASA Goddard Space Flight Center HP WAN Transport Services
- Resilient Distributed Processing & Rapid Data Transfer
- PRP/NRP Demonstrations
- Open Science Grid Demonstrations
- N-DISE Named Data Networking for Data Intensive Science
- Orchestration With Packet Marking (SciTags)
- Smart Amplified Group Environment Enhanced with Artificial Intelligence for Global Collaboration (SAGE3)
- JANUS Container Orchestration

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

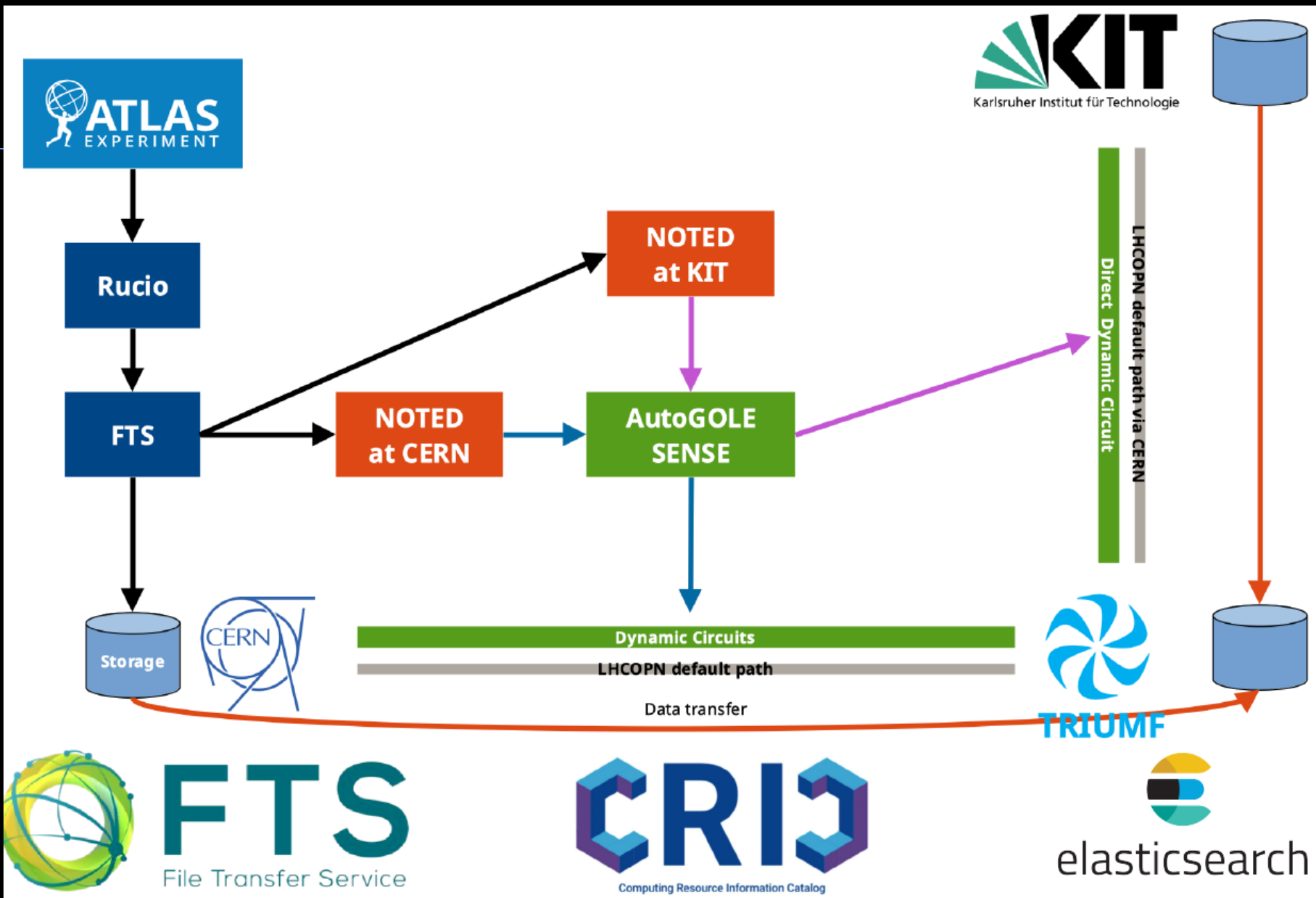
* NOTED: Network-Optimized Transfer of Experiment Data
* SciTags: packet marking and flow labelling
* AutoGOLE/SENSE: deliver network services end-to-end in a fully automated way via the Network Service Interface Connection Service (NSI-CS)
* P4: Programming Protocol-independent Packet Processors



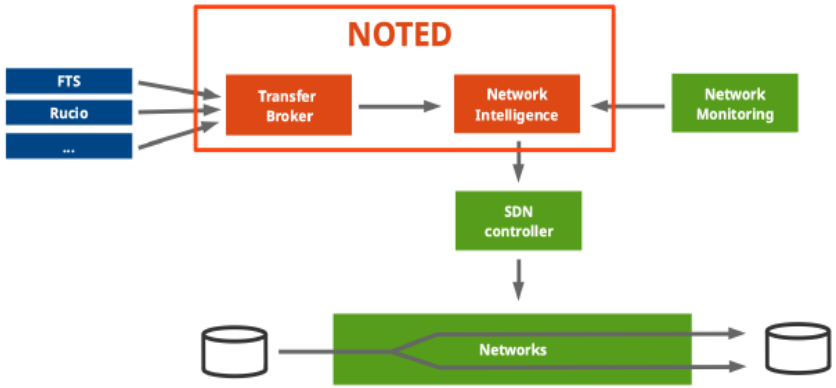
SC23 NRE map v. 9 – WEJohnston, ESnet, wej@es.net

NOTED: SC21 NOTED infrastructure is in blue	CERN1: Pattern filled rectangles are DTNs or other computing/storage elements	McLean: Carrier hotels, etc	RNP Brazil: Cloud bubbles are mostly regional/national networks
AG/SENSE: AutoGOLE / SENSE infrastructure is in red	Shared circuits supporting demonstrations	Paris: Ovals are points of presence in regional infrastructure	100G
P4: P4 infrastructure is in green	Circuits supporting AutoGOLE / SENSE	ESnet: Rounded rectangles are individual switch/router	200G
general: Shared or general infrastructure is in black	P4 connectivity (not particular circuit infrastructure or bandwidth)	Caltech: Sites	400G
		SOX (Atlanta): Exchange points (external or internal to a site)	800G
			1 Tb/s
			SCINet managed

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/p2wcyypvubeki7q/AAAMJGF5O8rxUFospm3pRLzIa?dl=0
3) P4 connections are only topological and are not associated with particular network links


ATLAS EXPERIMENT
Rucio
FTS
NOTED at KIT
NOTED at CERN
AutoGOLE SENSE
Direct Dynamic Circuit
LHCOPN default path via CERN
Storage
CERN
Dynamic Circuits
LHCOPN default path
Data transfer
KIT
Karlsruher Institut für Technologie
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 be congested anymore → cancel the dynamic circuit and the traffic is routed back.

SC22 Dallas, TX | hpc accelerates.

scitags.org

Flow and Packet Marking for Global Scientific Computing

DTN-KIT-100g

KIT Karlsruher Institut für Technologie

DFN

DTN-UVIC-100g

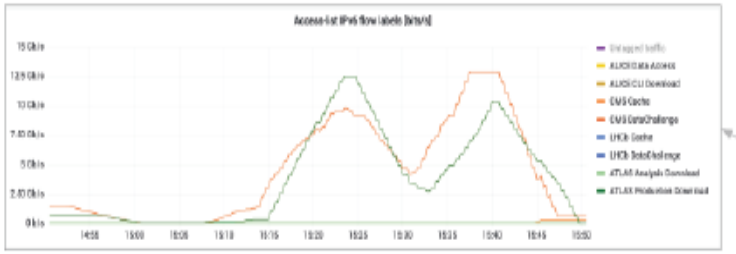
University of Victoria

1.Clients requesting data transfers from/to DTN-SC22-400g while passing science domain and activity fields via transfer protocols.

ESnet

canarie

4.High performance tests using eBPF-TC filters to test encoding of the science domains and activity fields in the IPv6 flow label at scale.



3. P4 programmable switch at CERN collecting the science domains and activity bits encoded in the packets.

CERN-LHCONE

P4 EdgeCore Wedge

CERN

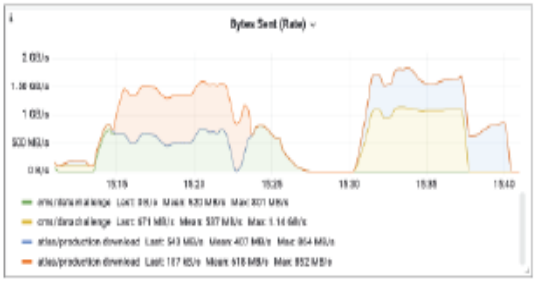
DTN-CERN-100g
2.6GHz/32 cores
SSD, 100Gbps

DTN-SC22-400g
R7503 2.6 GHz
NVMe 2.0
2x200 Gbps

XRootD

SC22 Dallas, TX | hpc accelerates.

STARLIGHT



2. XRootD storage responds to the client requests and marks the data transfer packets with the corresponding science domain and activity.

CERN

5.Sampling of the low level TCP/IP metrics, which can be used by sites and R&Es to better understand the scientific flows.

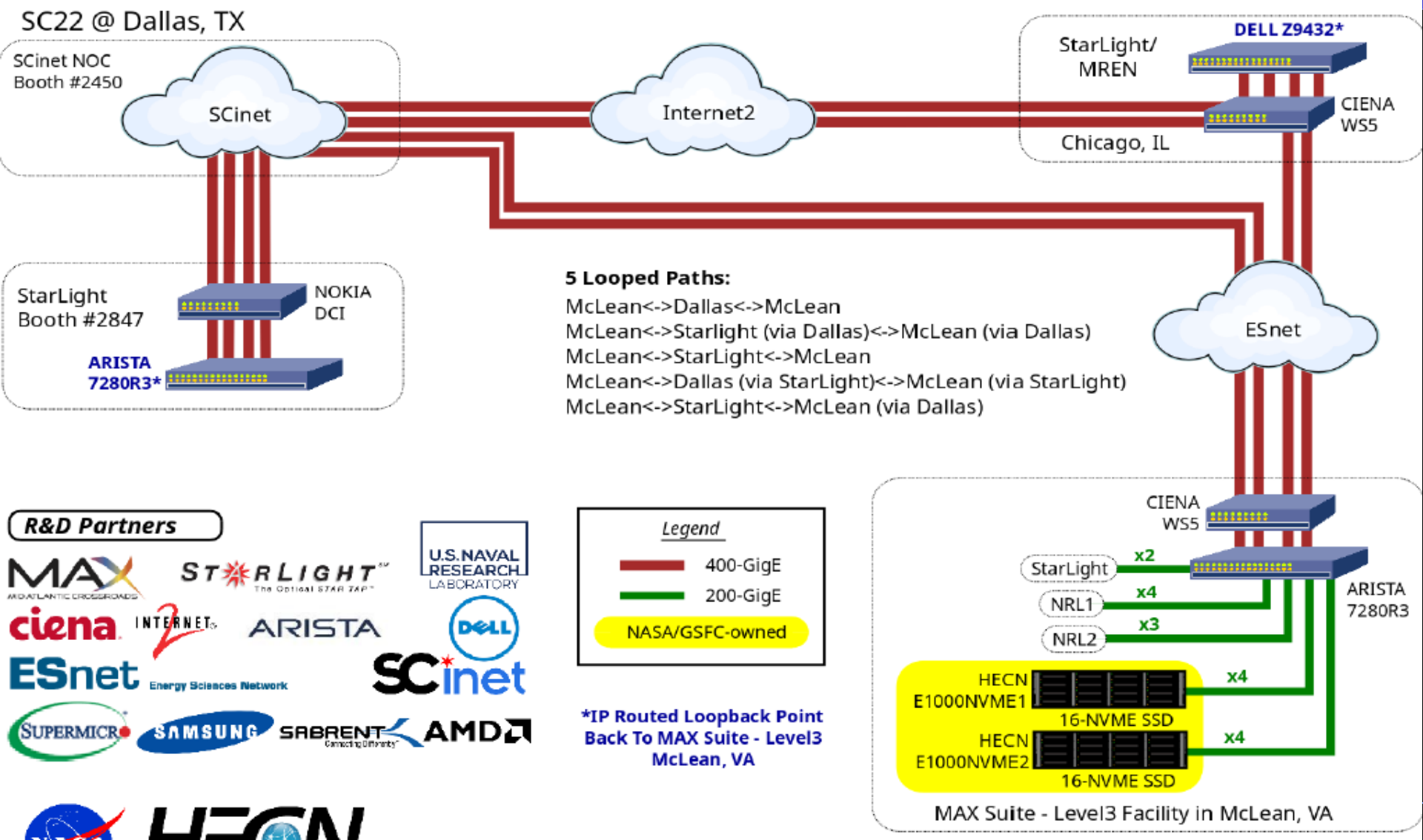
200 Gbps
100 Gbps
50 Gbps

STARLIGHT SM

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



R&D Partners

MAX MID-ATLANTIC CROSSROADS · STARLIGHT The Optical STAR TAP · U.S. NAVAL RESEARCH LABORATORY · ciena · INTERNET2 · ARISTA · DELL · ESnet Energy Sciences Network · SCinet · SUPERMICRO · SAMSUNG · SABRENT · AMD

Legend

400-GigE

200-GigE

NASA/GSFC-owned

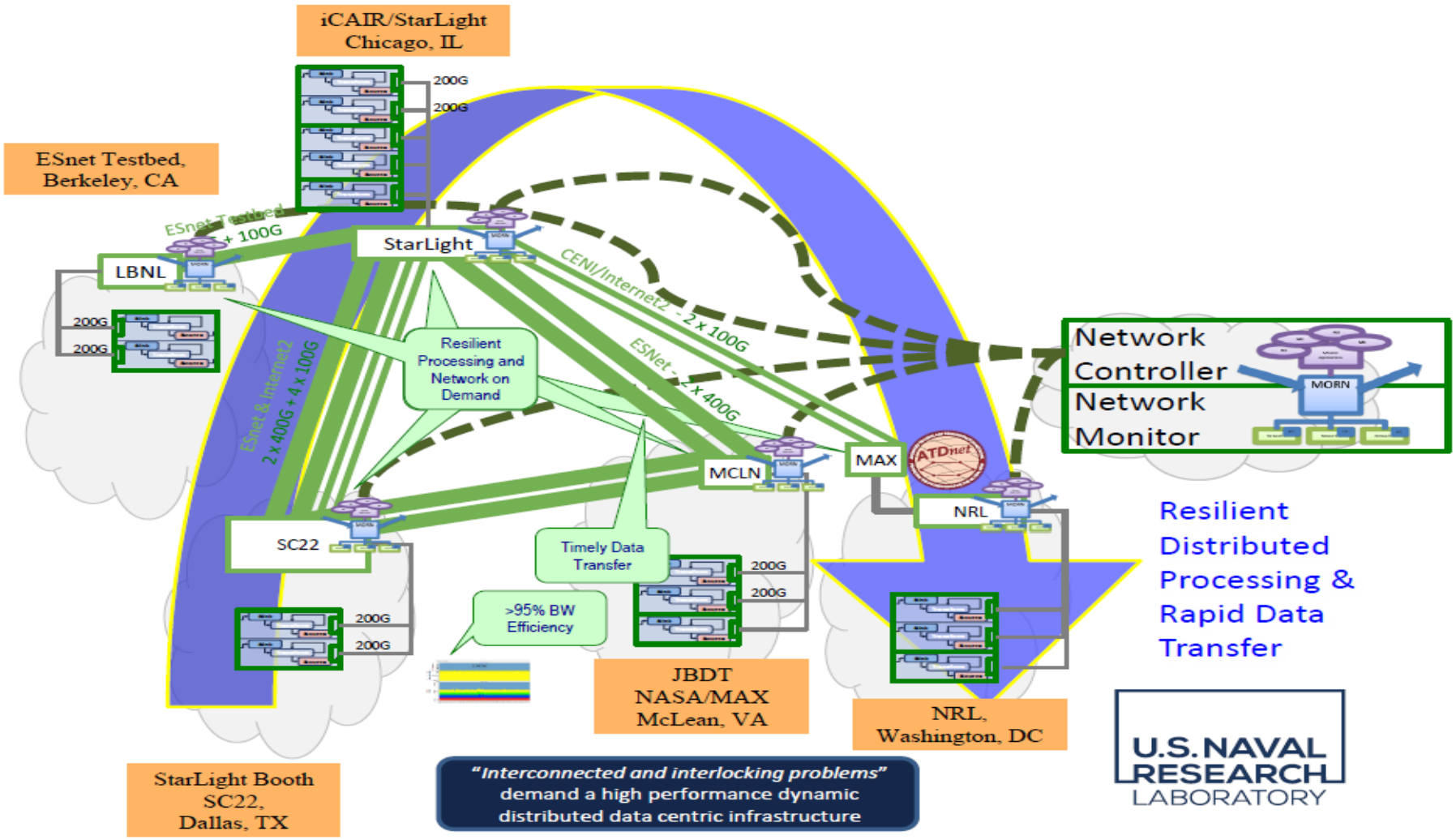
***IP Routed Loopback Point Back To MAX Suite - Level3 McLean, VA**

NASA · HECN High End Computer Networking

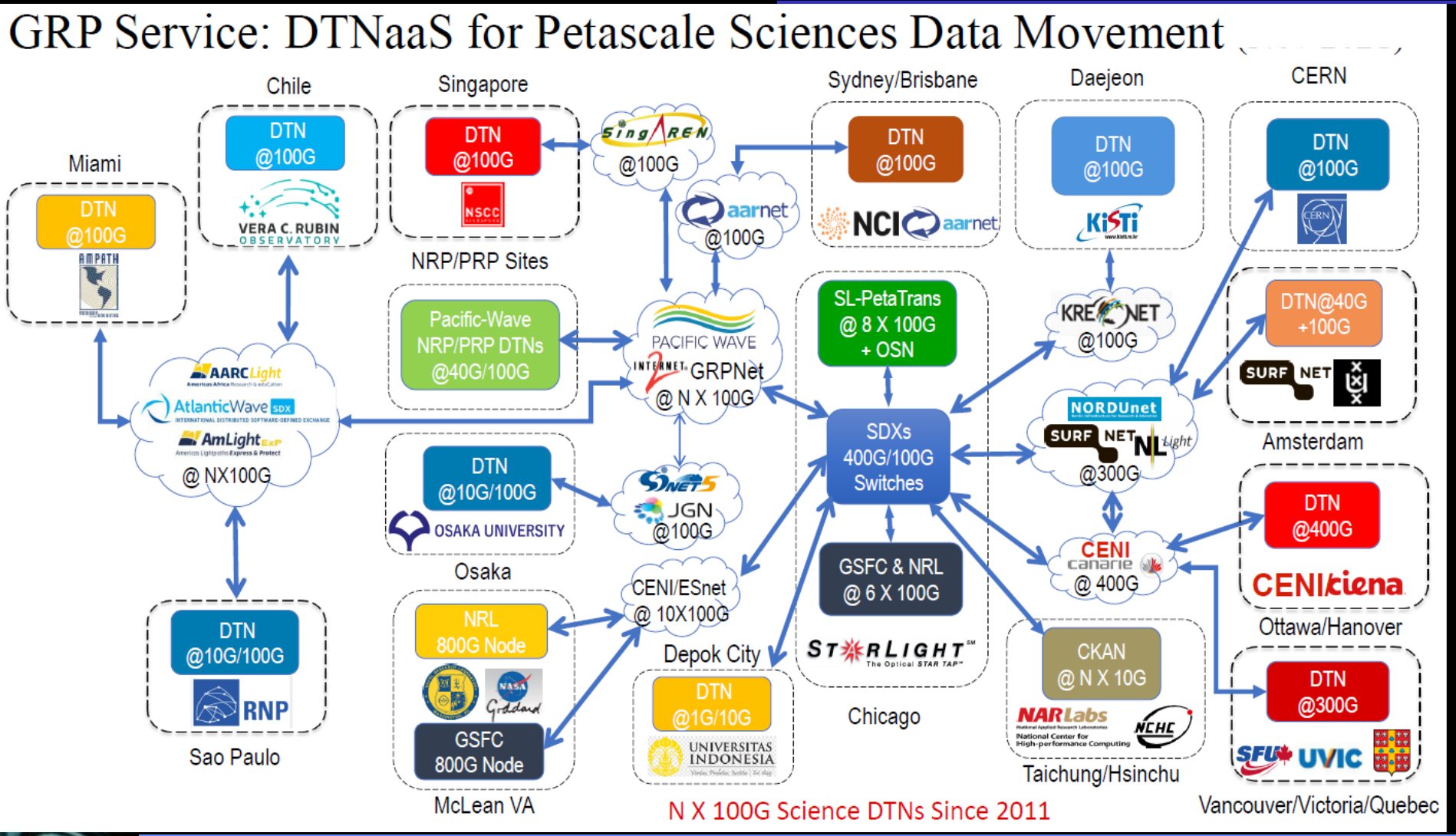
In memory of Paul Lang and Pat Gary

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

Resilient Disributed Processing & Rapid Data Transfer



GRP DTNaaS For Petascale Science



DTN-as-a-Service – Demonstrated At SC22

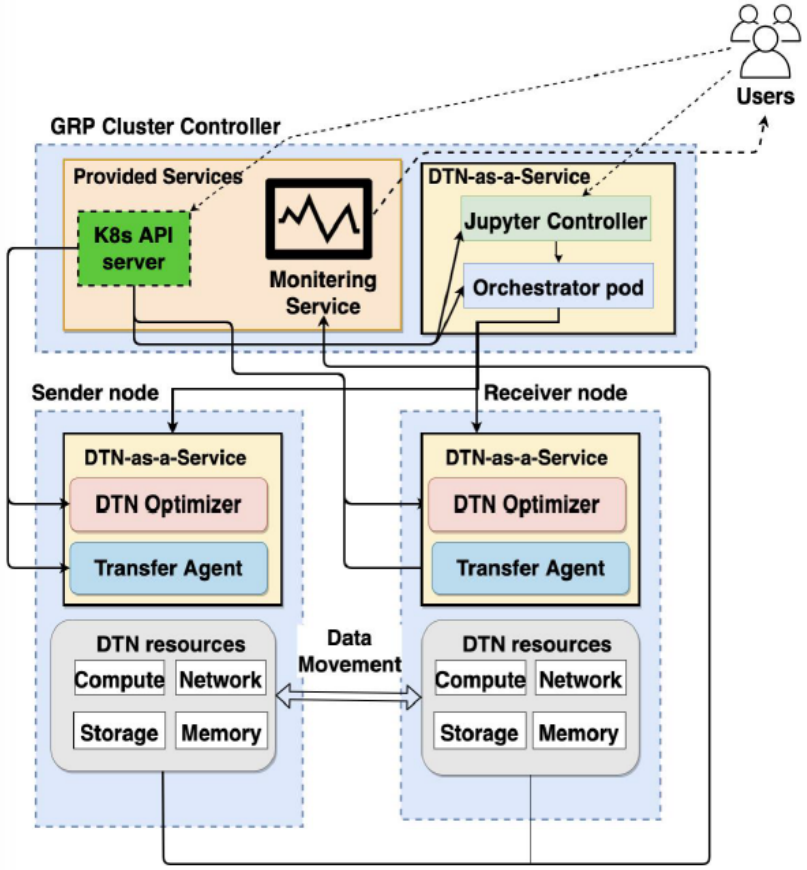
GRP Cluster with DTN-as-a-Service

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



iCAIR

STARLIGHT SDX

STARLIGHT

Janus Container Orchestration

Overview

Janus is a container management framework with a focus on advanced networking configurations. Our approach minimizes external dependencies and provides tooling to support data mover tuning and lifecycle management. A goal of Janus is to provide a Data Transfer Node *as-a-Service* (DTNaaS) capability. Janus has also found use within the ESnet Advanced Network Testbed and enables the ESnet in-network Data Caching pilots.

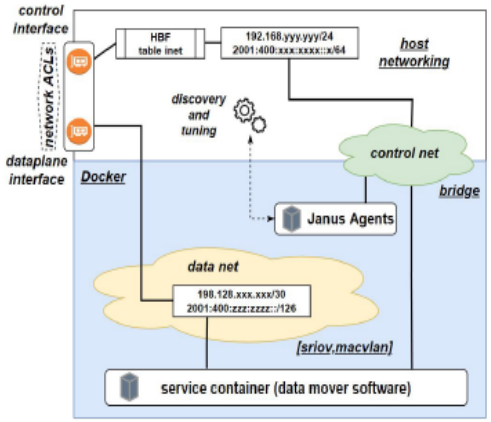
Networking

Janus manages a Data Transfer Node's container networking attachments

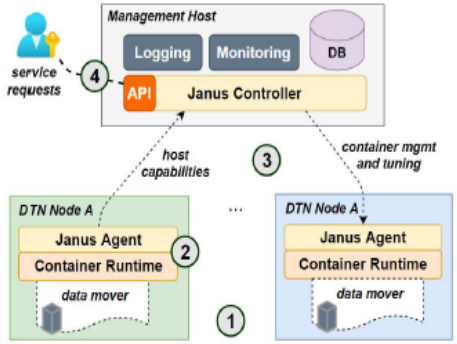
- Multi-homing of control and data networks
- Dual-stack configurations (IPv4/IPv6)
- Selection of container networks (host, macvlan, sriov, ...)

Janus service profiles provide external network configuration hooks

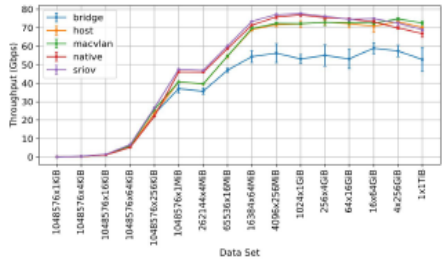
- Ansible playbooks
- Host-based QoS



Architecture



1) Data mover software in managed containers
2) Container network and storage optimization
3) Host discovery and tuning
4) Lightweight service orchestration through APIs



Comparing performance of various container networks, disk-to-disk on 100G network

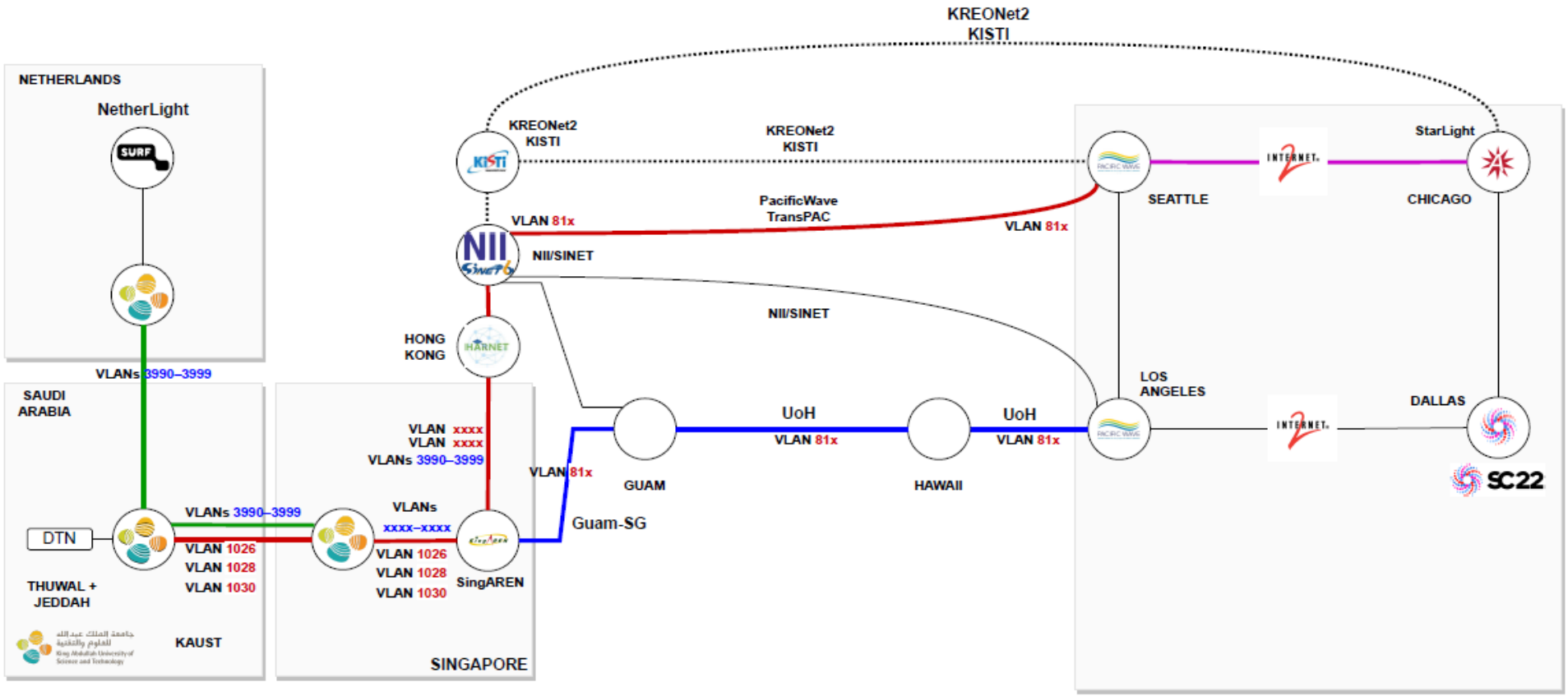
data mover: **EScp**
https://github.com/esnet/EScp

Thank you to Md Arifuzzaman and Charles Shiftlett for their many contributions.

Contact: Ezra Kissel
kissel@es.net

U.S. DEPARTMENT OF ENERGY
Office of Science
BERKELEY LAB
ESnet
ENERGY SCIENCES NETWORK

STARLIGHT SM



KAUST-US NEW PERMANENT CIRCUITS (PNWGP Proposal: use VLANs 811, 812, 813)

1) StarLight (VLAN 81x - TBD)
Amsterdam > Jeddah > Singapore > Hong Kong > Daejeon > Chicago
NetherLight > KAUST > SingAREN > NICT/NSCC > KREONet2/KISTI > STARLIGHT

2) PNWGP / TransPAC (VLAN 81x - TBD)
Amsterdam > Jeddah > Singapore > Tokyo > Seattle
NetherLight > KAUST > SingAREN > TransPAC/PacWave

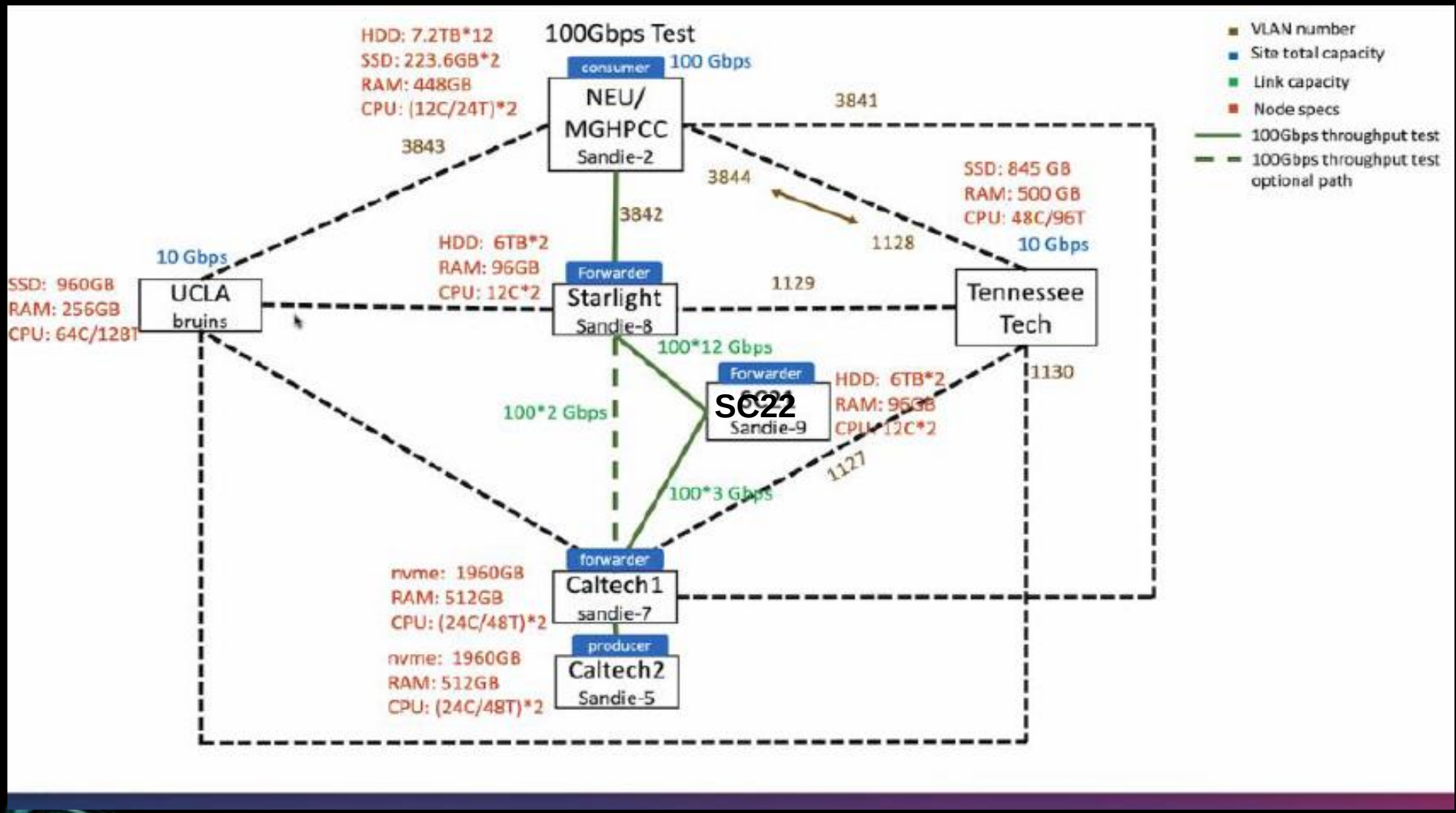
3) CENIC (VLAN 81x - TBD)
Amsterdam > Jeddah > Singapore > Guam > Hawaii > Los Angeles
NetherLight > KAUST > SingAREN > Guam-SG > UoH > Pacific Wave

KAUST has deployed 3 circuits - VLANs 1026, 1028, and 1030 – to peer with PacificWave/Cenic, StarLight and SC22

The range 3990-3999 is also available between KAUST Routers in NetherLight PoP and in SingAREN PoP.
The AutoGOLE / SENSE can be used to stitch circuits to each end in NetherLight and in SingAREN, and pass traffic through between Europe and Singapore.

Mike: -> I'm responsible specifically for the path between 'Tokyo > Seattle', our suggestion is to use the following VLANs for the permanent VLAN assigments: 811, 812, 813. I can configure the Tokyo side of device interfaces facing NII/SINET & TransPAC towards Seattle.
Please contact StartLight NOC for the circuit 1, and CENIC NOC for circuit 3

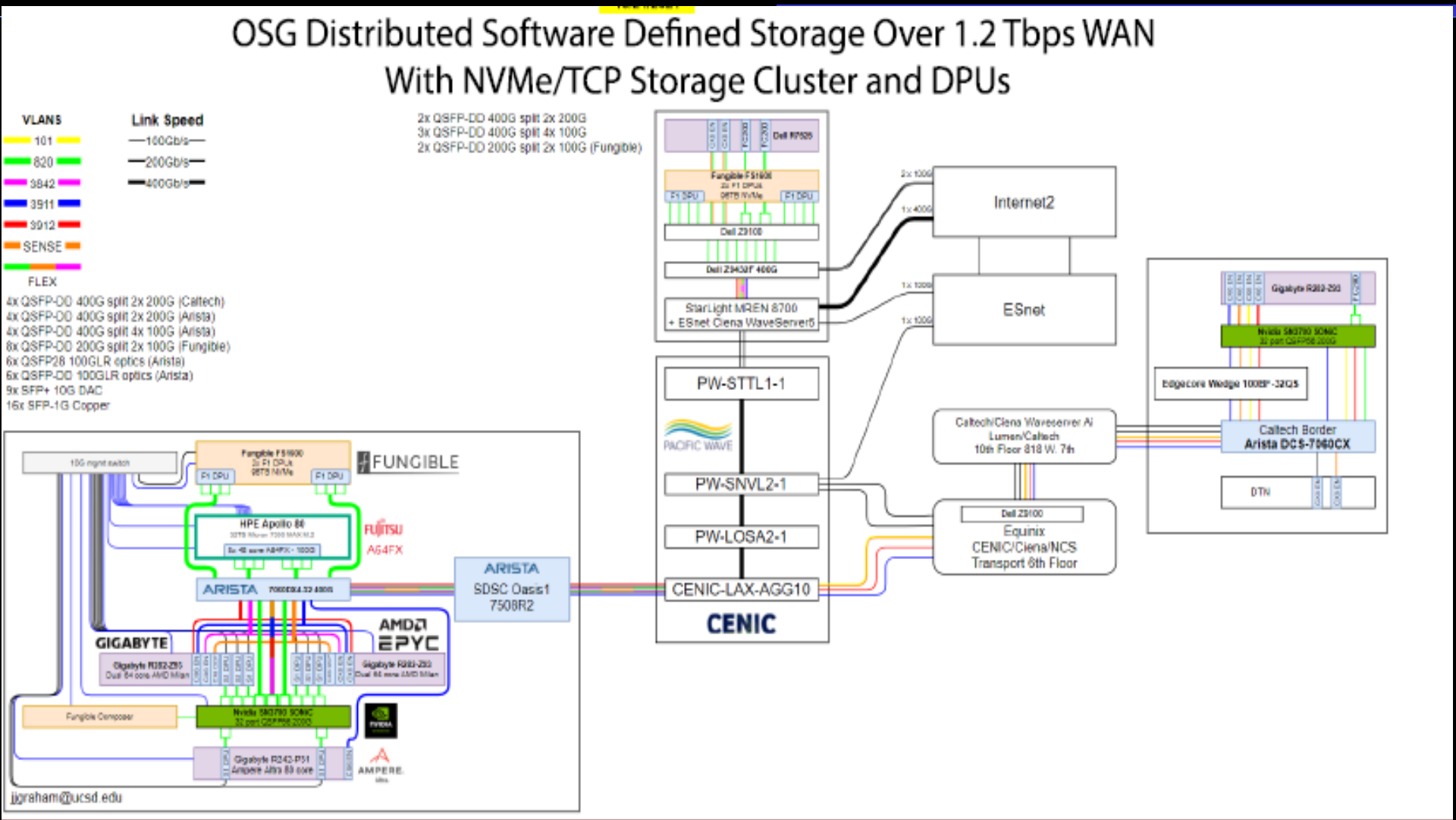
Named Data Networking (NDN) for Data Intensive Science Experiments (N-DISE)



Source Edmund Yeh

STARLIGHT SM

Open Science Grid SD Distributed Storage

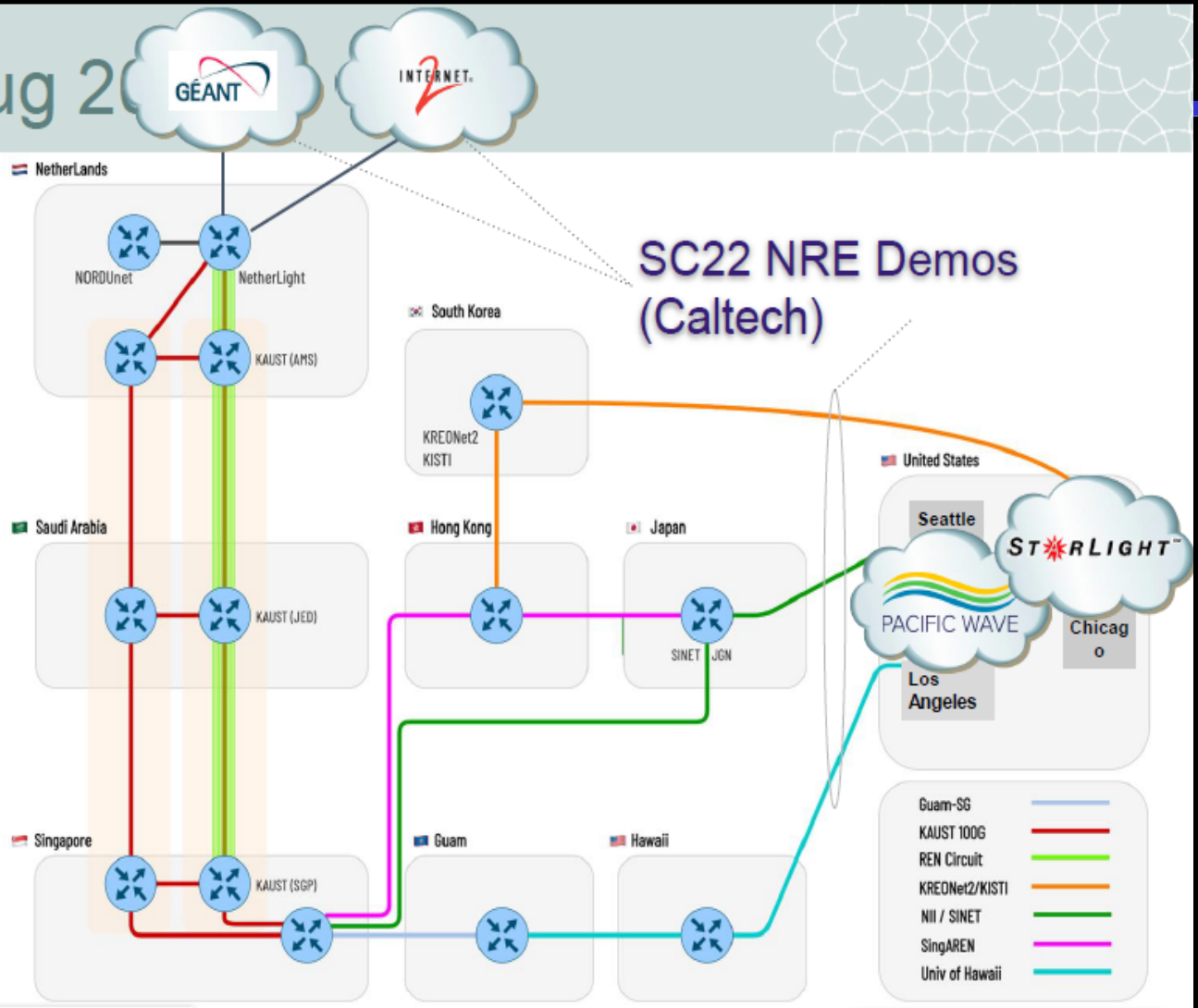


Source: John Graham

STARLIGHT SM

AER Update - Aug 2

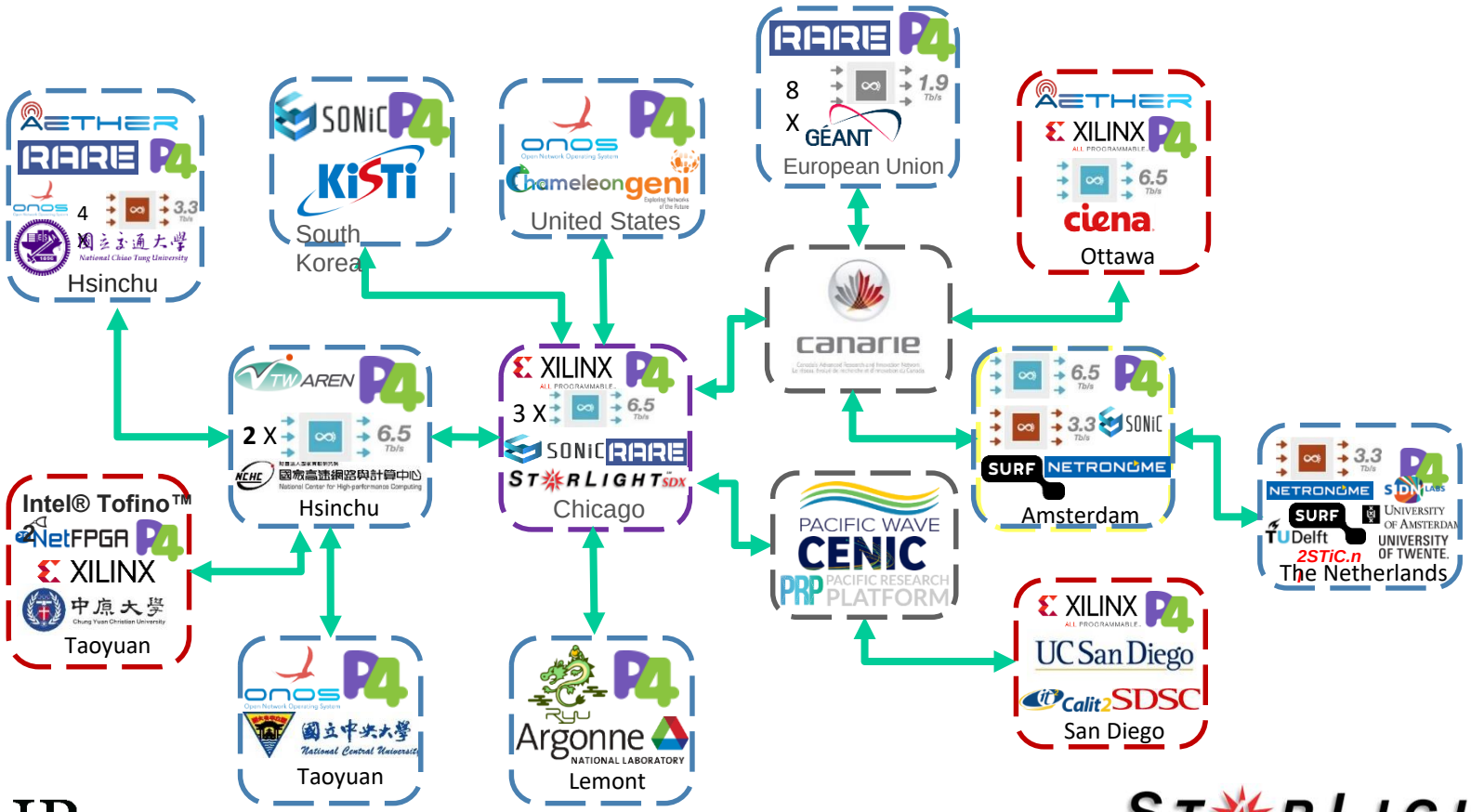
- Since the AER MoU, KAUST is coordinating with REN partners deployment of sharing spare capacity
- KAUST is supporting the following partners by offering point-to-point circuits for submarine cable backup paths:
  - AARnet
  - GÉANT
  - NetherLight
  - NII/SINET
  - SingAREN
- The SC22 NRE Demonstrations will also be supported by KAUST closing the ring from Amsterdam to Singapore and back to the US
  - SC22 NRE



INTERNET2 · GÉANT Networks · Services · People · NL Light · Asi@Connect · APAN · aponet · TransPAC America Connects to Asia · International Networks at Indiana University

International P4 Testbed Showcase at SC22

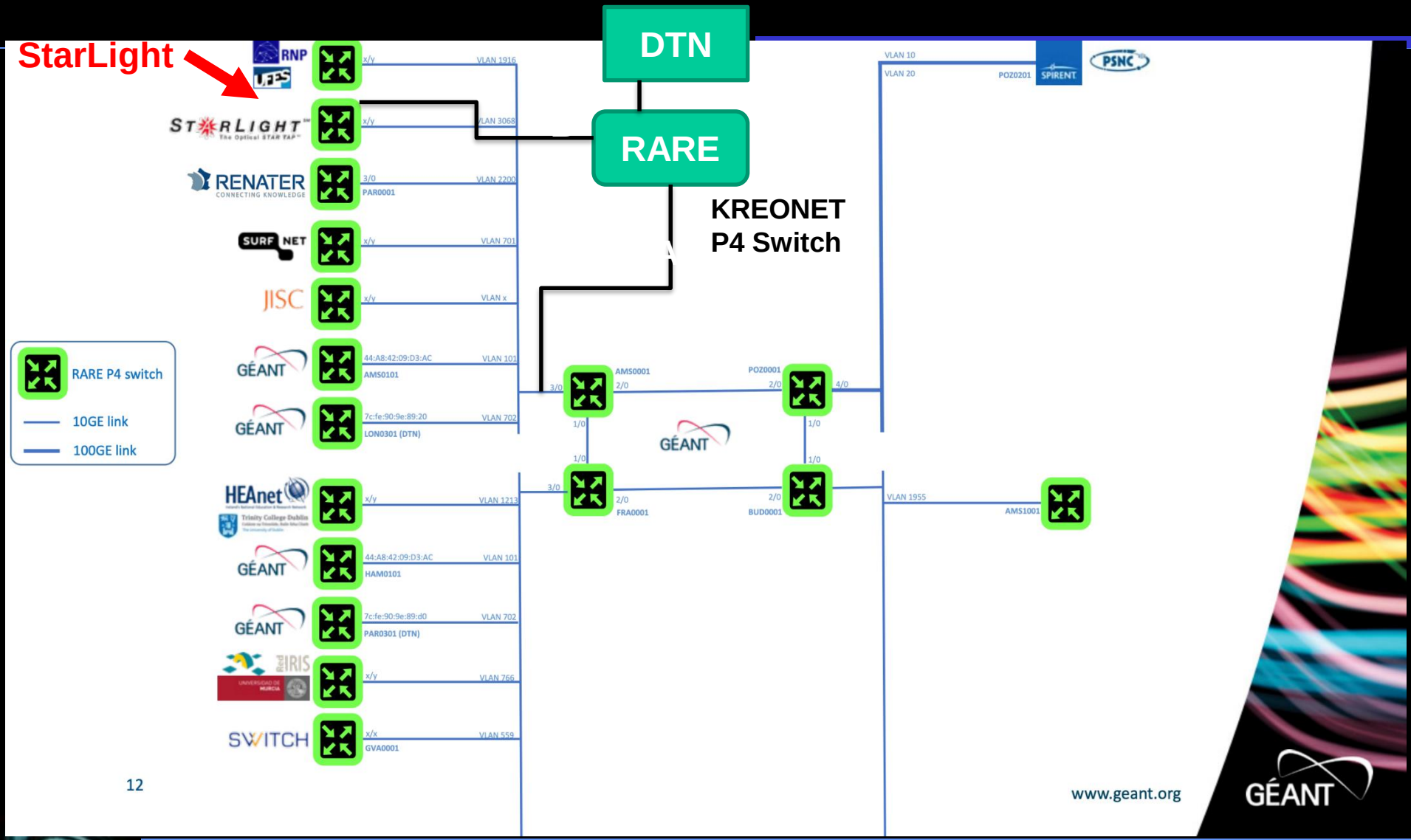
GRP Service: International P4 Experimental Networks (iP4EN)



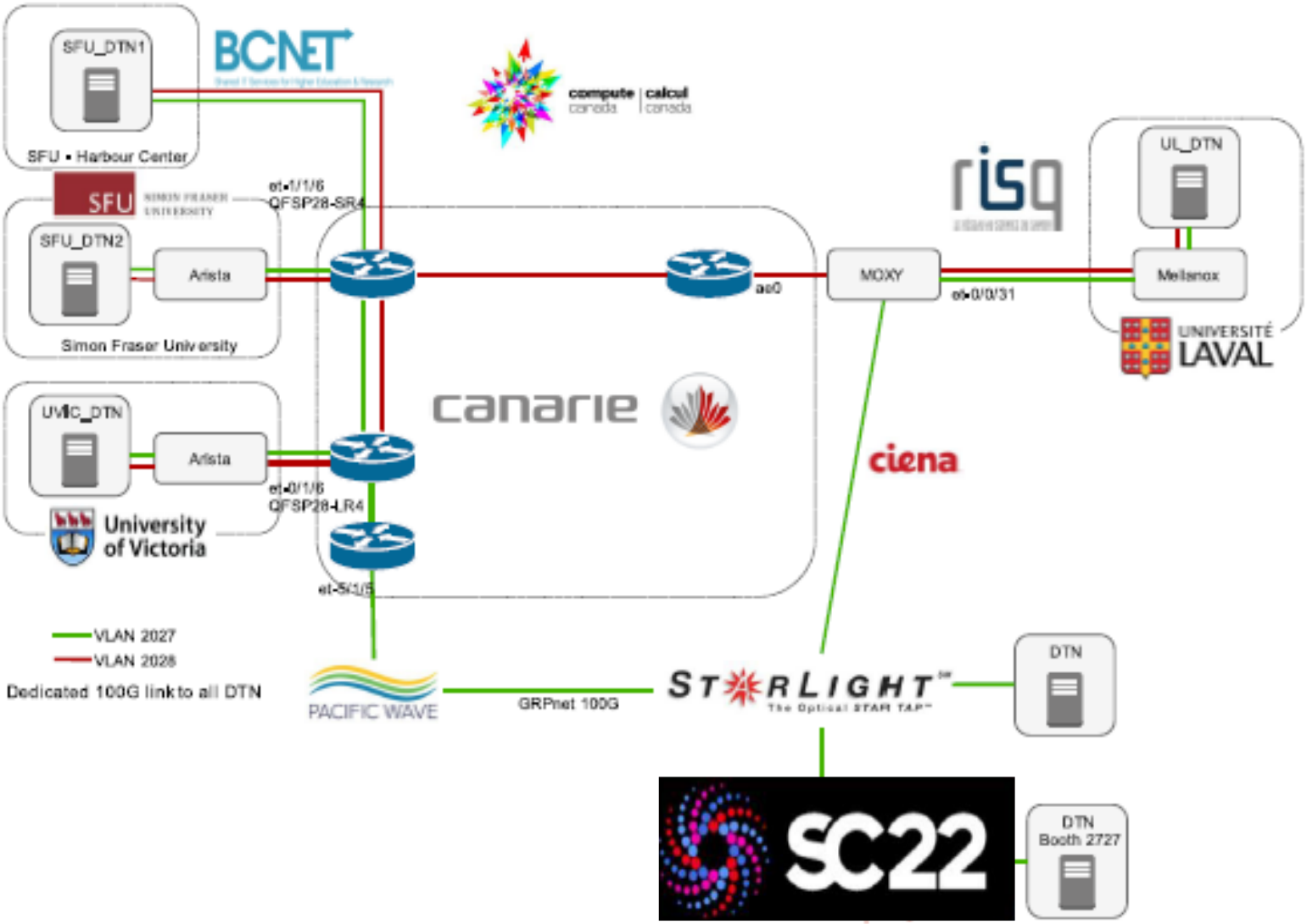
iCAIR

STARLIGHT SDX

Integration With GEANT P4 Testbed



Digital Alliance Demonstrations
Of Data Intensive Science WAN Transport



Chameleon

www.chameleoncloud.org

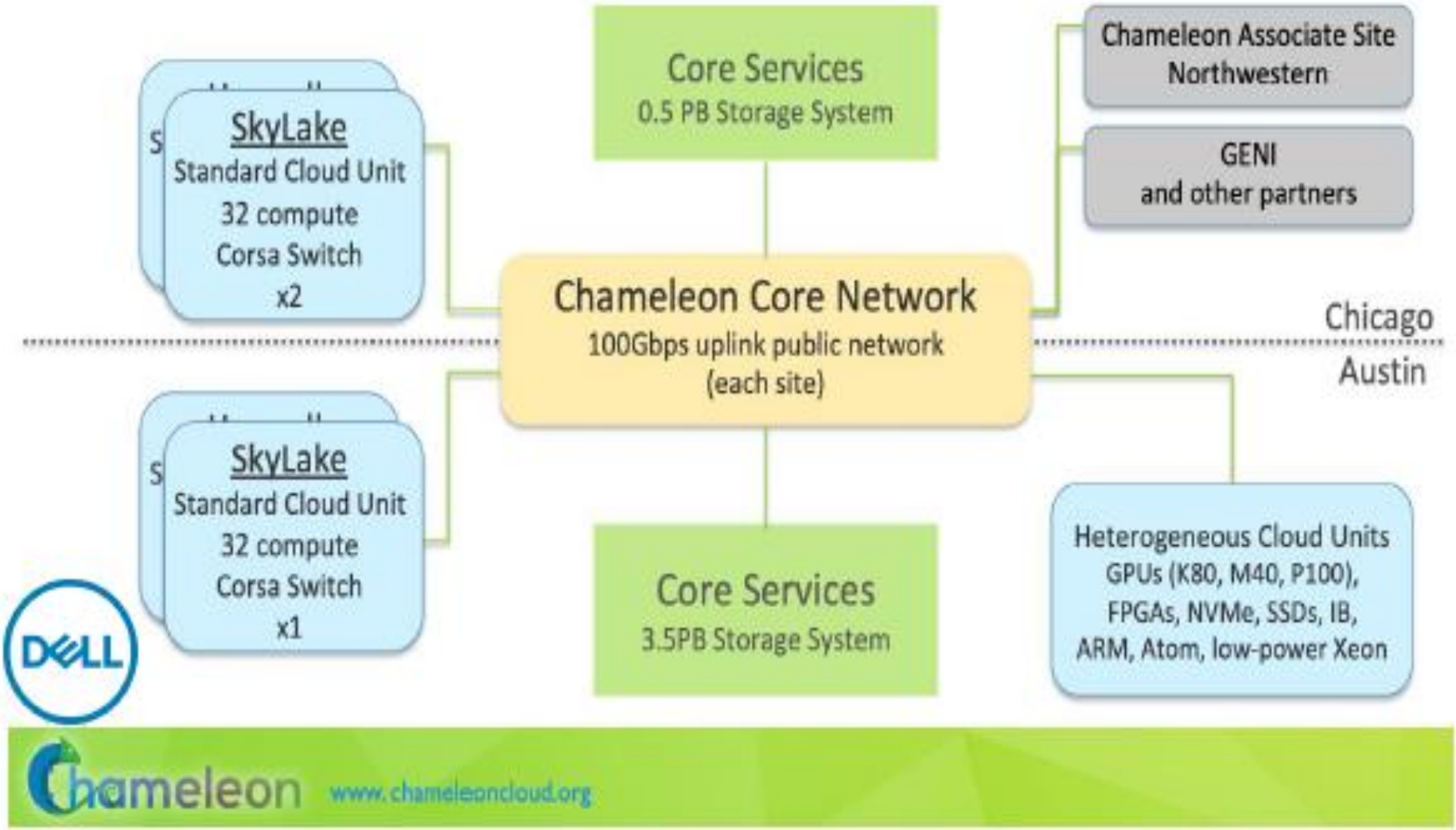
CHAMELEON: A LARGE SCALE, RECONFIGURABLE EXPERIMENTAL INSTRUMENT FOR COMPUTER SCIENCE

Kate Keahey

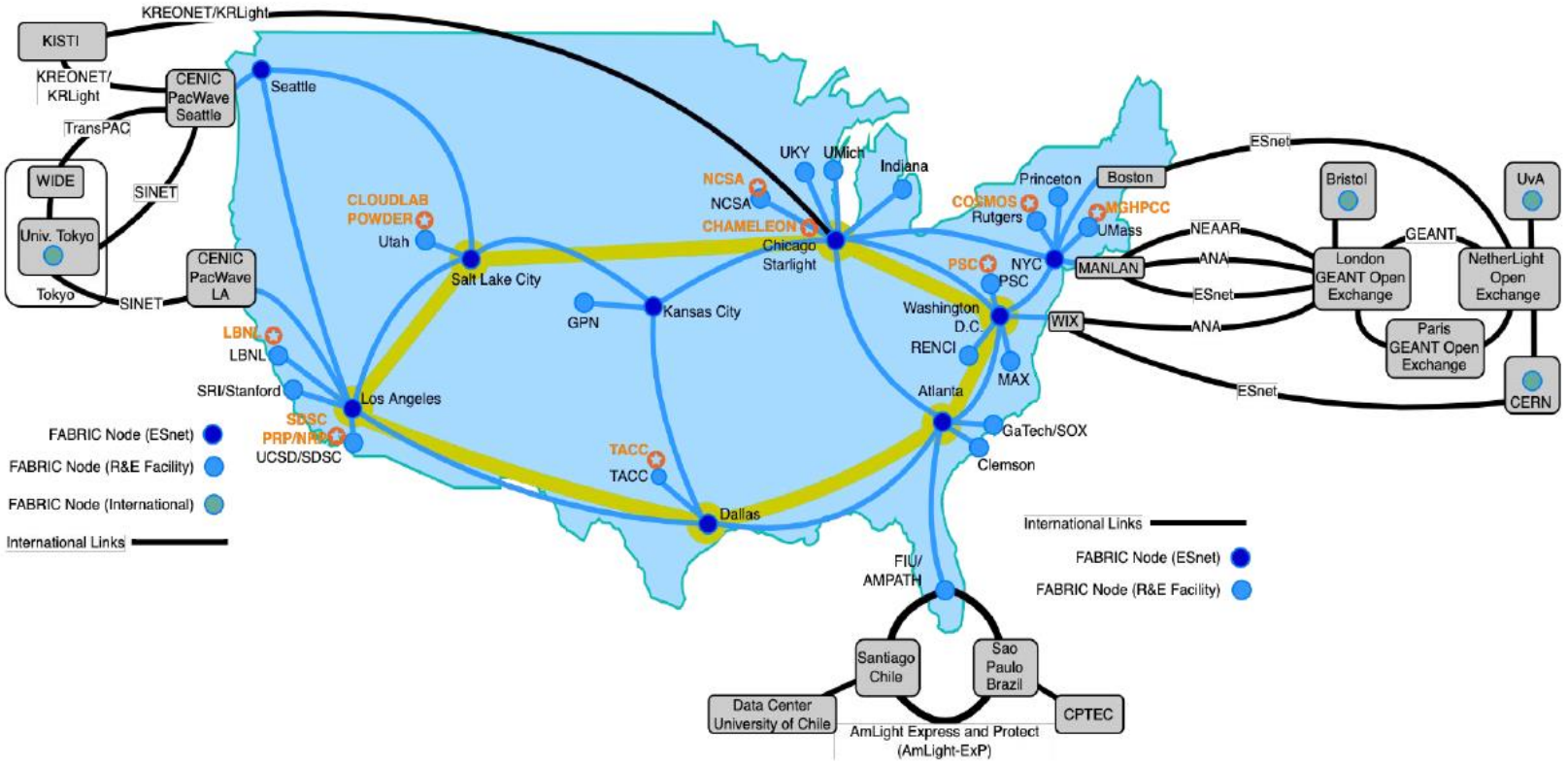
Joe Mambretti, Pierre Riteau, Paul Ruth, Dan Stanzione

THE UNIVERSITY OF CHICAGO TACC renci NORTHWESTERN UNIVERSITY NSF

Chameleon CHI In A Box(CIAB) at StarLight



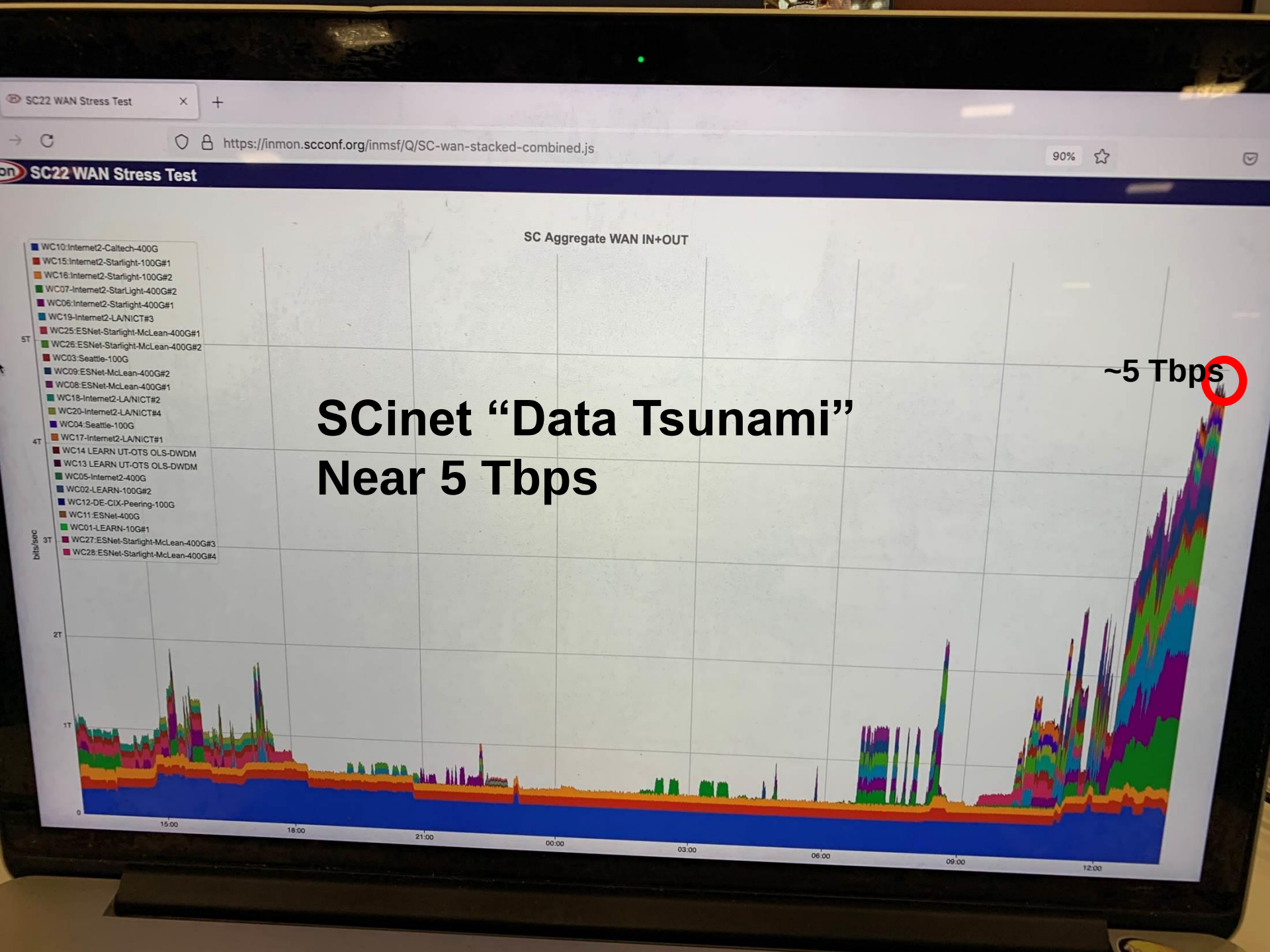
FABRIC Testbed (+FAB)

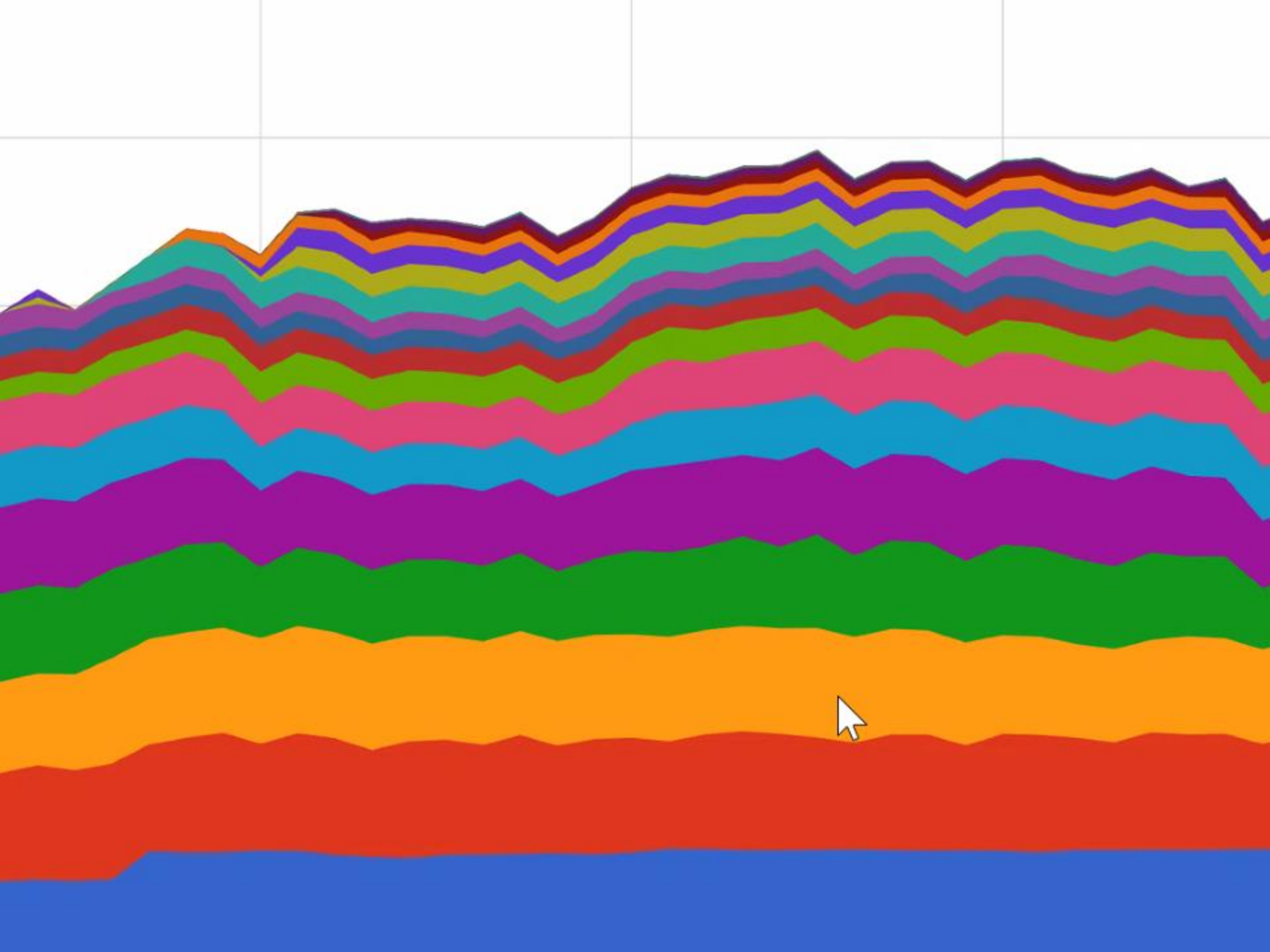


FABRIC Topology - with FAB Sites

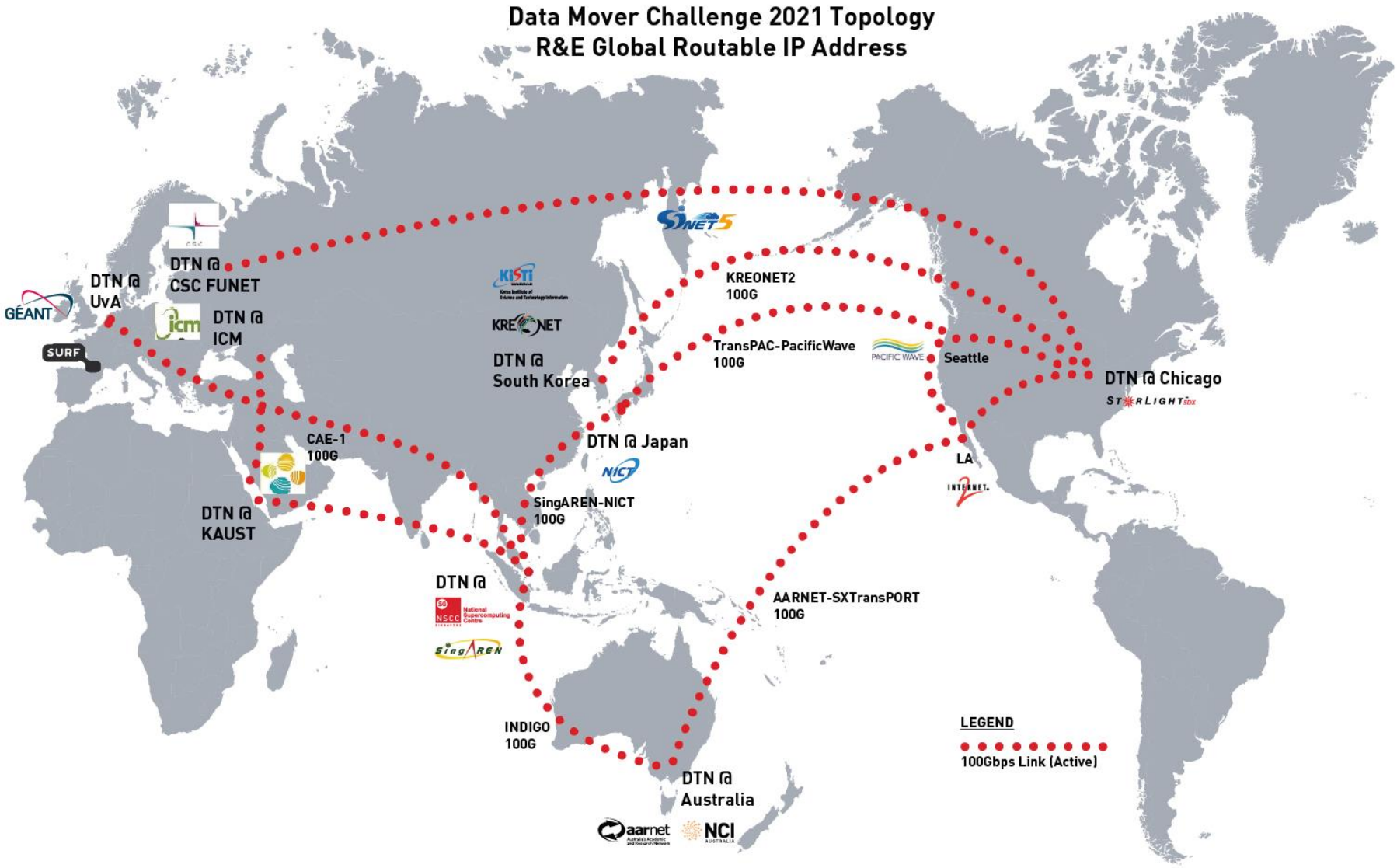
Chameleon & FABRIC

- Currently, Two NSF Testbeds Are Investigating Methods For Optimizing Cross Platform Research: Chameleon, A Large-Scale, Deeply Reconfigurable Experimental Platform for Computer Sciences Systems Research, and FABRIC, Which Enables Edge And Exploratory Research At-Scale in Networking, Cybersecurity, Distributed Computing And Storage Systems, Machine Learning, and Science Applications.
- These Projects Plan Demonstrations At SC23
- Demonstrations Will Use Jupyter Notebooks (Which Can Be Shared By Publishing via Trovi) to Integrate Chameleon and FABRIC Resources.
- One Demonstration Will Implement An L2 Stitched Network Between Chameleon and FABRIC That Can Be Used With Slices Deployed With a Jupyter Notebook


SC22 WAN Stress Test
https://inmon.scconf.org/inmsf/Q/SC-wan-stacked-combined.js
90%
SC22 WAN Stress Test
SC Aggregate WAN IN+OUT
WC10:Internet2-Caltech-400G
WC15:Internet2-Starlight-100G#1
WC16:Internet2-Starlight-100G#2
WC07-Internet2-StarLight-400G#2
WC06:Internet2-Starlight-400G#1
WC19-Internet2-LA/NICT#3
WC25:ESNet-Starlight-McLean-400G#1
WC26:ESNet-Starlight-McLean-400G#2
WC03:Seattle-100G
WC09:ESNet-McLean-400G#2
WC08:ESNet-McLean-400G#1
WC18-Internet2-LA/NICT#2
WC20-Internet2-LA/NICT#4
WC04:Seattle-100G
WC17-Internet2-LA/NICT#1
WC14 LEARN UT-OTS OLS-DWDM
WC13 LEARN UT-OTS OLS-DWDM
WC05-Internet2-400G
WC02-LEARN-100G#2
WC12-DE-CIX-Peering-100G
WC11:ESNet-400G
WC01-LEARN-10G#1
WC27:ESNet-Starlight-McLean-400G#3
WC28:ESNet-Starlight-McLean-400G#4
5T
4T
3T
2T
1T
0
bits/sec
15:00
18:00
21:00
00:00
03:00
06:00
09:00
12:00
~5 Tbps
SCinet “Data Tsunami”
Near 5 Tbps



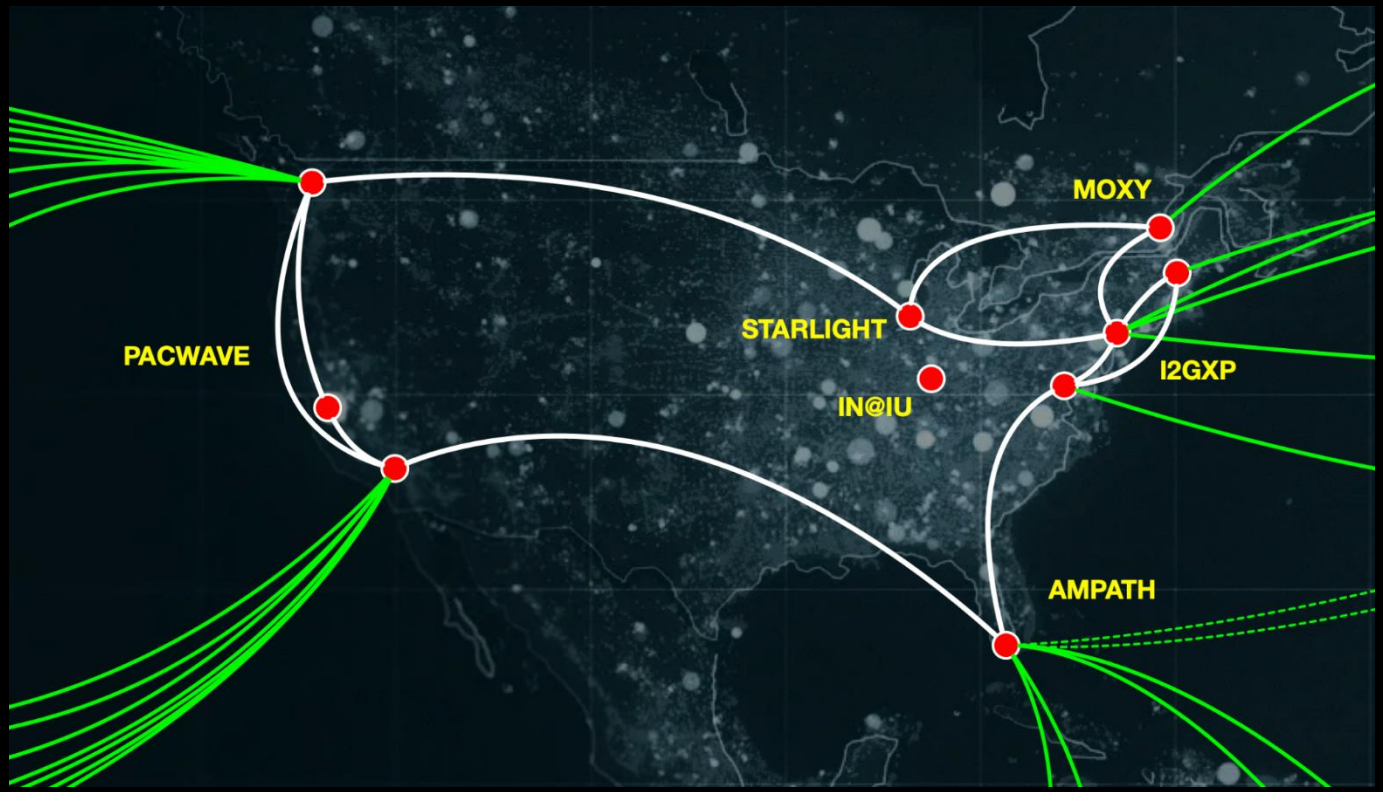
StarLight: Founding Partner Of Supercomputing Asia DMC International Testbed

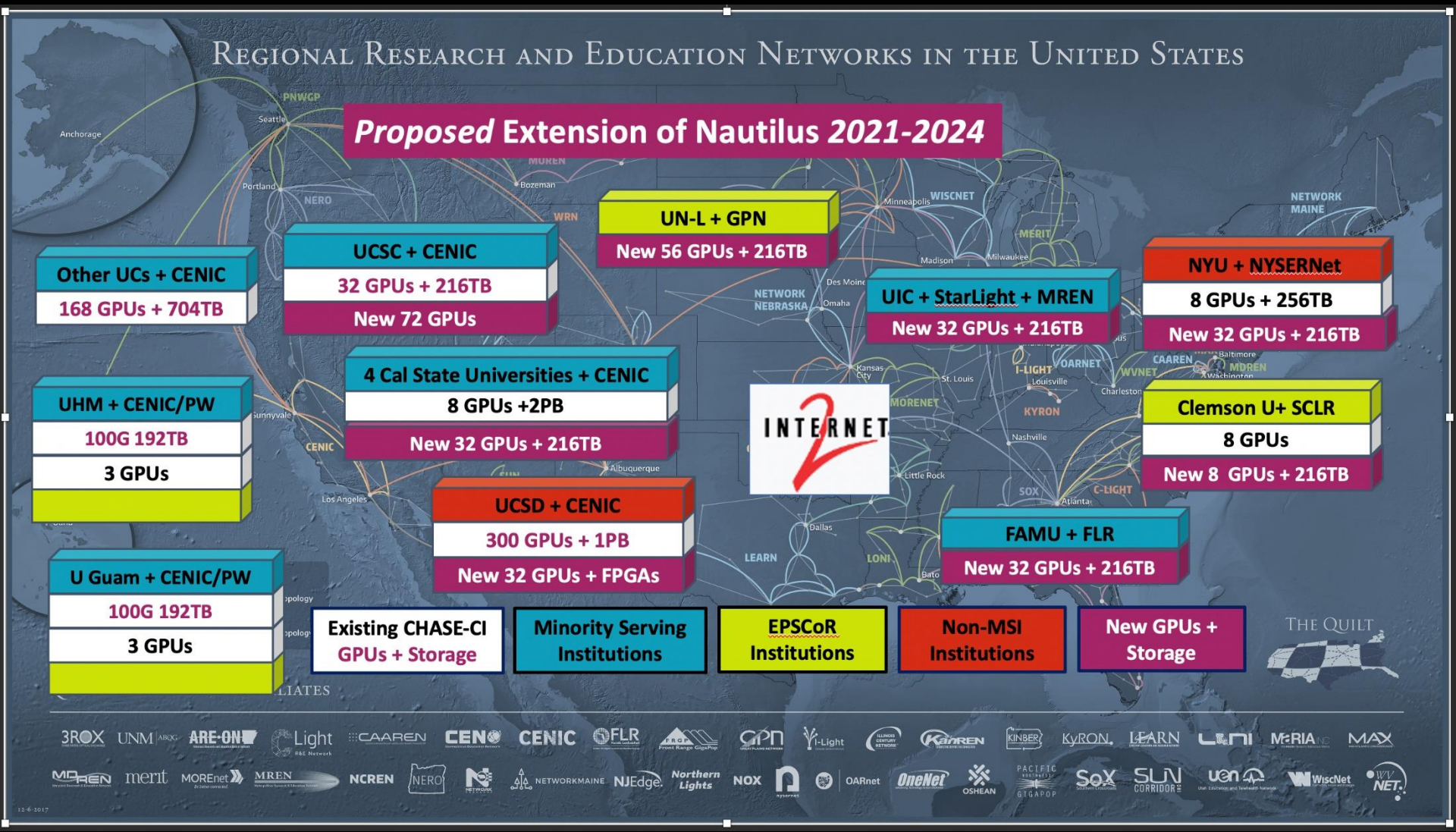


AP-REX 2.0 – NA-REX

Addition of partners:

- AMPATH / FIU
- CANARIE
- IU International
- MOXY
- StarLight International / National Communications Networks Exchange Facility




Regional Research and Education Networks in the United States
Proposed Extension of Nautilus 2021-2024
Other UCs + CENIC
168 GPUs + 704TB
UCSC + CENIC
32 GPUs + 216TB
New 72 GPUs
UN-L + GPN
New 56 GPUs + 216TB
UIC + StarLight + MREN
New 32 GPUs + 216TB
NYU + NYSERNet
8 GPUs + 256TB
New 32 GPUs + 216TB
UHM + CENIC/PW
100G 192TB
3 GPUs
4 Cal State Universities + CENIC
8 GPUs +2PB
New 32 GPUs + 216TB
INTERNET2
Clemson U+ SCLR
8 GPUs
New 8 GPUs + 216TB
UCSD + CENIC
300 GPUs + 1PB
New 32 GPUs + FPGAs
FAMU + FLR
New 32 GPUs + 216TB
U Guam + CENIC/PW
100G 192TB
3 GPUs
Existing CHASE-CI GPUs + Storage
Minority Serving Institutions
EPSCoR Institutions
Non-MSI Institutions
New GPUs + Storage
THE QUILT
PNWGP
Seattle
Anchorage
Portland
Bozeman
NERO
WRN
MREN
Minneapolis
WISCNET
MERIT
NETWORK MAINE
Madison
Milwaukee
NETWORK NEBRASKA
Omaha
Des Moine
Kansas City
St. Louis
I-LIGHT
OARNET
CAAREN
MDREN
Baltimore
Washington
WVNET
Louisville
Charleston
MOREnet
KYRON
Nashville
Sunnyvale
CENIC
Albuquerque
Los Angeles
Little Rock
SOX
C-LIGHT
Atlanta
Dallas
LEARN
LONI
Bato
3ROX
UNM
ABQG
ARE-ON
Light
CAAREN
CENIC
FLR
GPN
I-Light
KanREN
KINBER
KyRON
LEARN
LONI
MCRIA
MAX
MDREN
merit
MOREnet
MREN
NCREN
NERO
NETWORKMAINE
NJEdge
Northern Lights
NOX
OARnet
OneNet
OSHEAN
PACIFIC NORTHWEST GIGAPOP
SoX
SUN CORRIDOR
uen
WiscNet
WVNET

Quantum Communications And Networks: Motivation

- **Quantum Enables Many New Applications**
  - **Security – e.g., Quantum Key Distribution (QKD), Highly Secure Information Transmission, Quantum Encryption**
  - **Quantum Sensors**
  - **Quantum – e.g., Precise Clocks**
  - **New Applications Derived From Unique Properties (e.g., Superposition) And Novel Quantum Devices**
  - **Communications Among Quantum Computers, e.g., To Address Complex Computational Science Problems Through Distributed Quantum Environments (iCAIR's Quantum Research Focus)**

Complexity Of Challenges Requires Consortia

- Northwestern University Established INQUIRE (Initiative at Northwestern for Quantum Information Research and Engineering), For Quantum Science Research

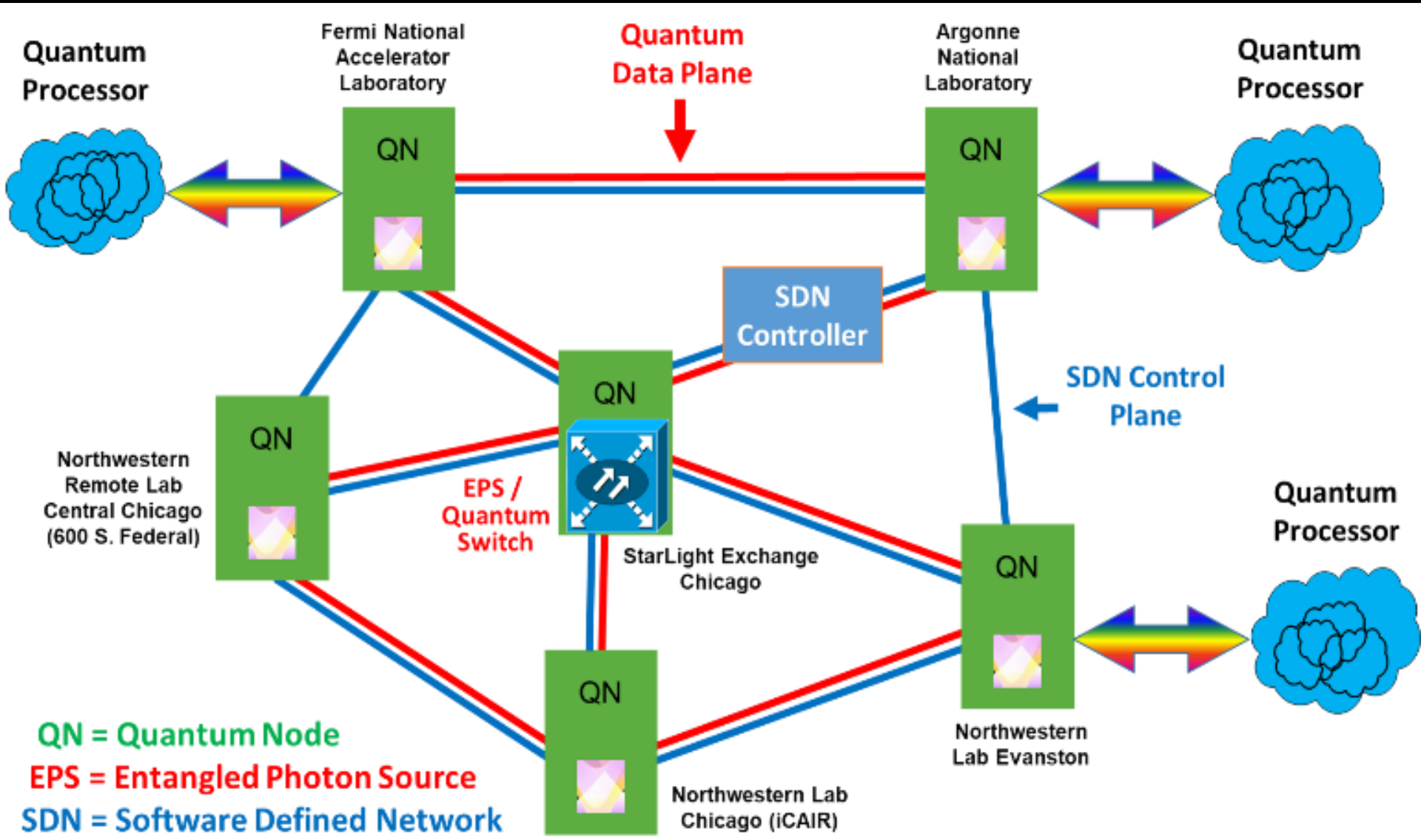
- This Initiative Participates in the Chicago Quantum Exchange and The Illinois Express Quantum Network, which includes the U.S. Department of Energy's Argonne National Laboratory, Fermi National Accelerator Laboratory, Multiple Research Universities, and Several Corporations.

- 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.

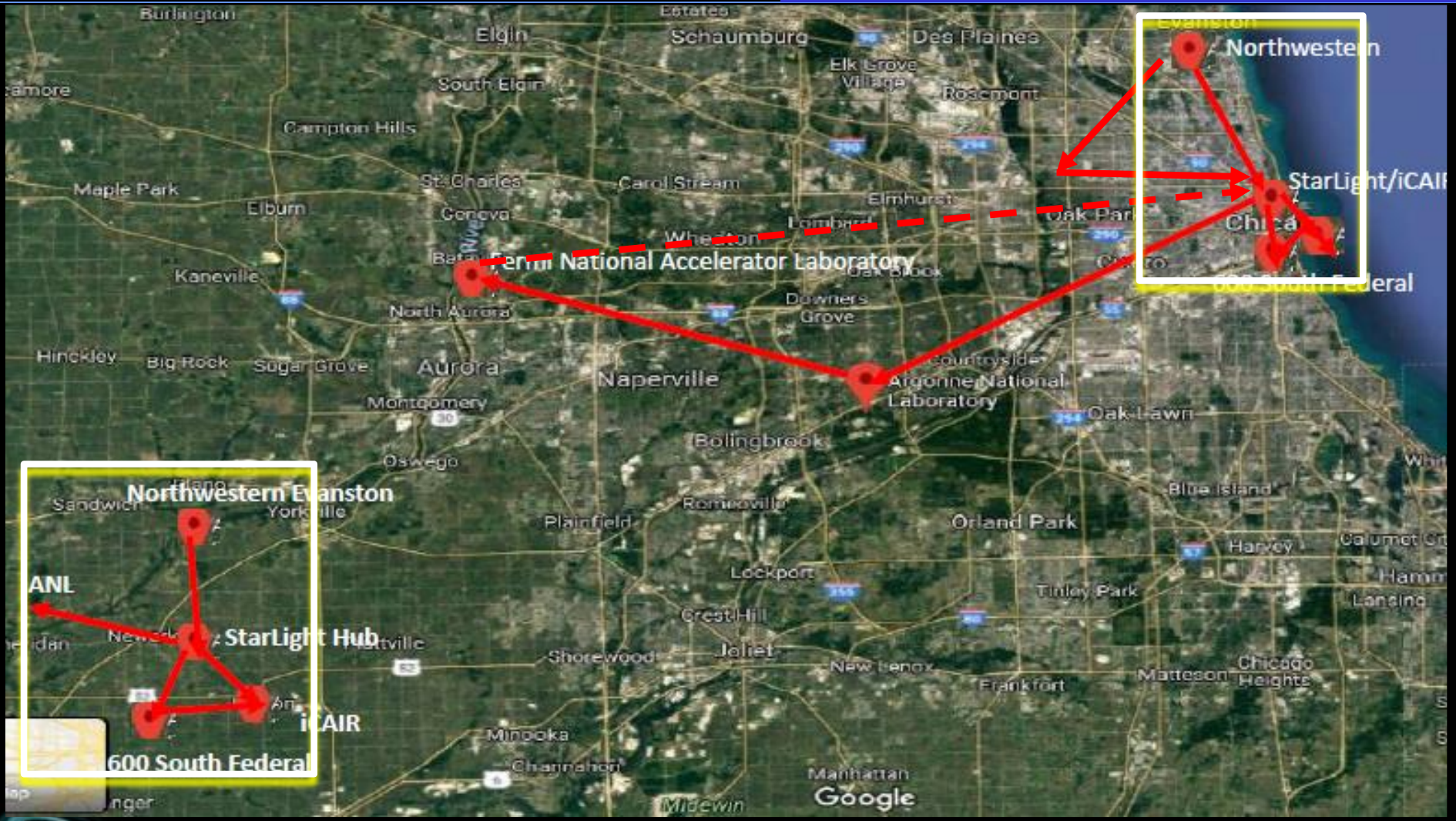
Quantum Networking Testbed Building Blocks

- Advanced Networking And Exchange Facilities
- Architecture (Defining QNode Capabilities, QNet Topology Discovery, Path And Wavelength Assignment, Clock Distribution, Entanglement Distribution Protocols)
- Heterogeneous Components
- High Quality Dedicated Fiber
- Management And Control Planes Based On Classical Networking (*Software Defined Networking Techniques*)
- Interfaces, Protocols, Algorithms
- Low dB Loss Optical Switches
- Quantum Memories As Proxies For Quantum Computers
- Measurement⇔Management Integrations

Emerging Chicago Quantum Exchange Testbed



Energing IEQnet Testbed Topology



Illinois Express Quantum Network

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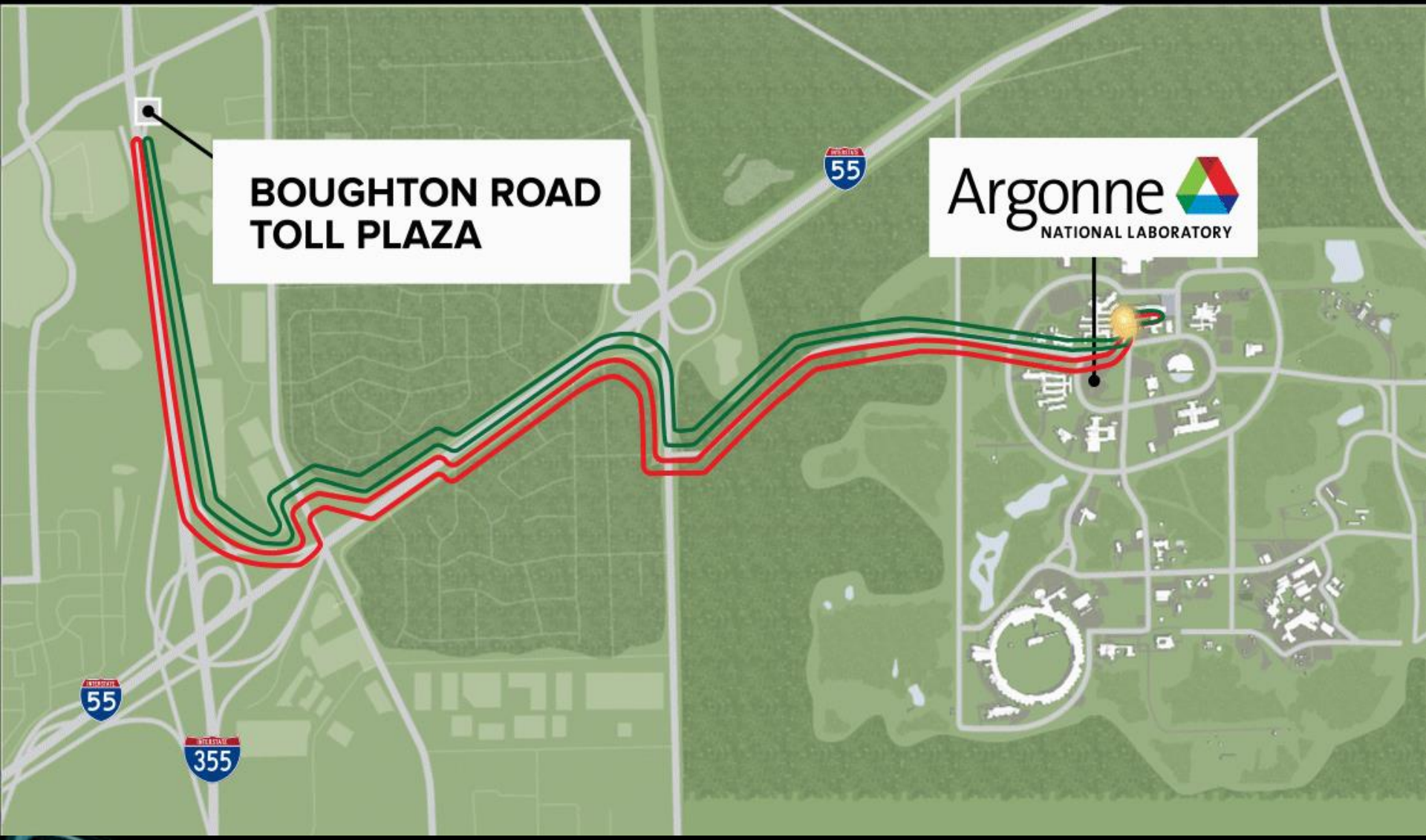
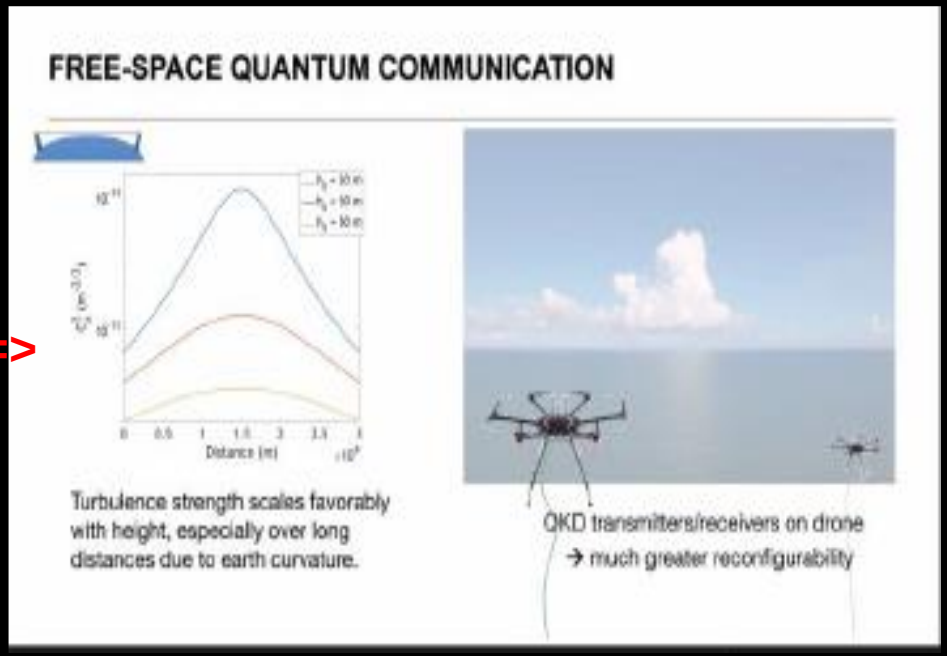

BOUGHTON ROAD
TOLL PLAZA
55
Argonne
NATIONAL LABORATORY
55
355

IQUIST Quantum Network Testbed: QUIUC-NET

(Hyper)Entangled Sources
Photon Detectors
Quantum Memories
Processing Nodes
Net Aps
Protocols
Distributed Processing
Sensing Net Verification
Repeater Enhanced Quantum Links
Free Space Quantum Communications=>



Source: Paul Kwiat, Director, IQUIST

UIUC

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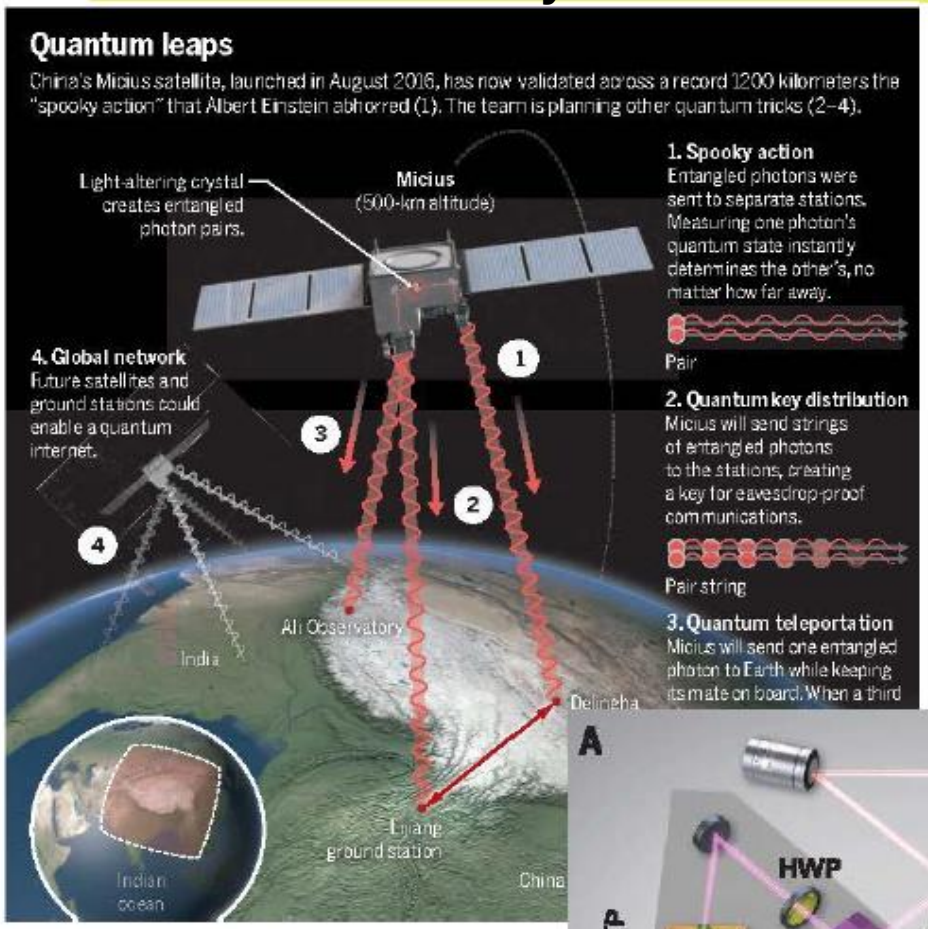
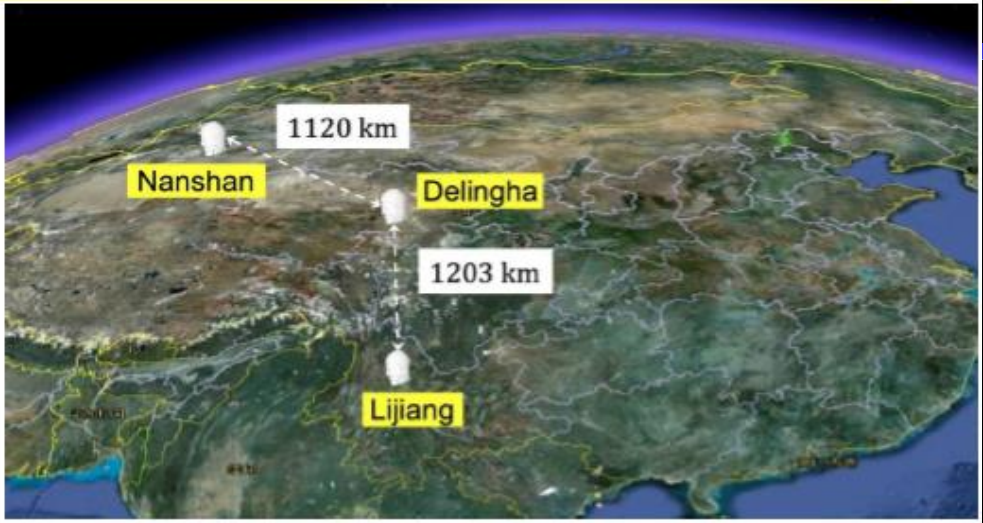
Source:
Prem Kumar
Northwestern University

Source Aboard Satellite Micius
Entanglement Distribution over 1200 km

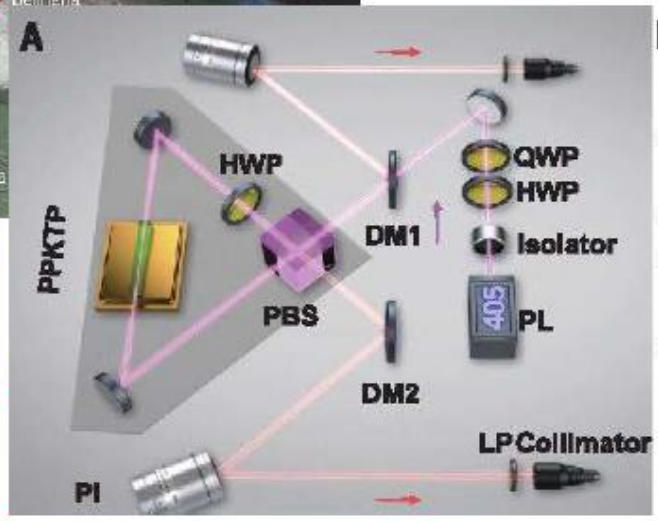
CPCC

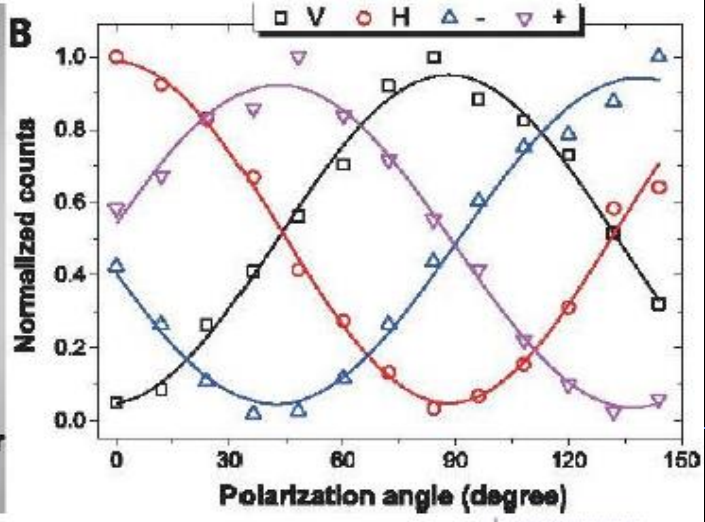




F. N. C. Wong *et al.*, Phys. Rev. A 73, 012316 (2006)

Phase stable Type-II SPDC in a pol. Sagnac loop



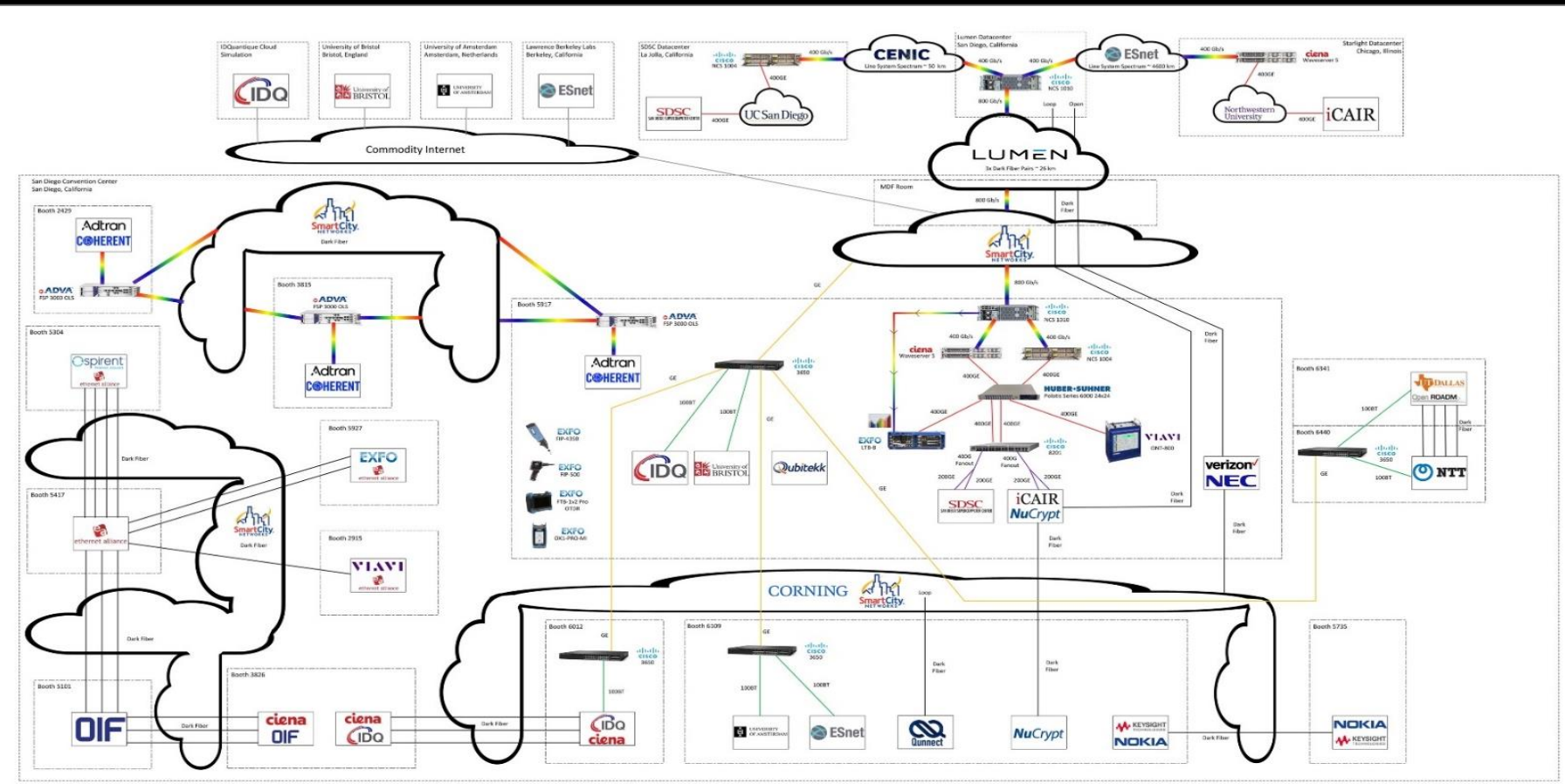


Yin *et al.*, Science **356**, 1140–1144, June 2017.

Bell inequality violation over 1200 km

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

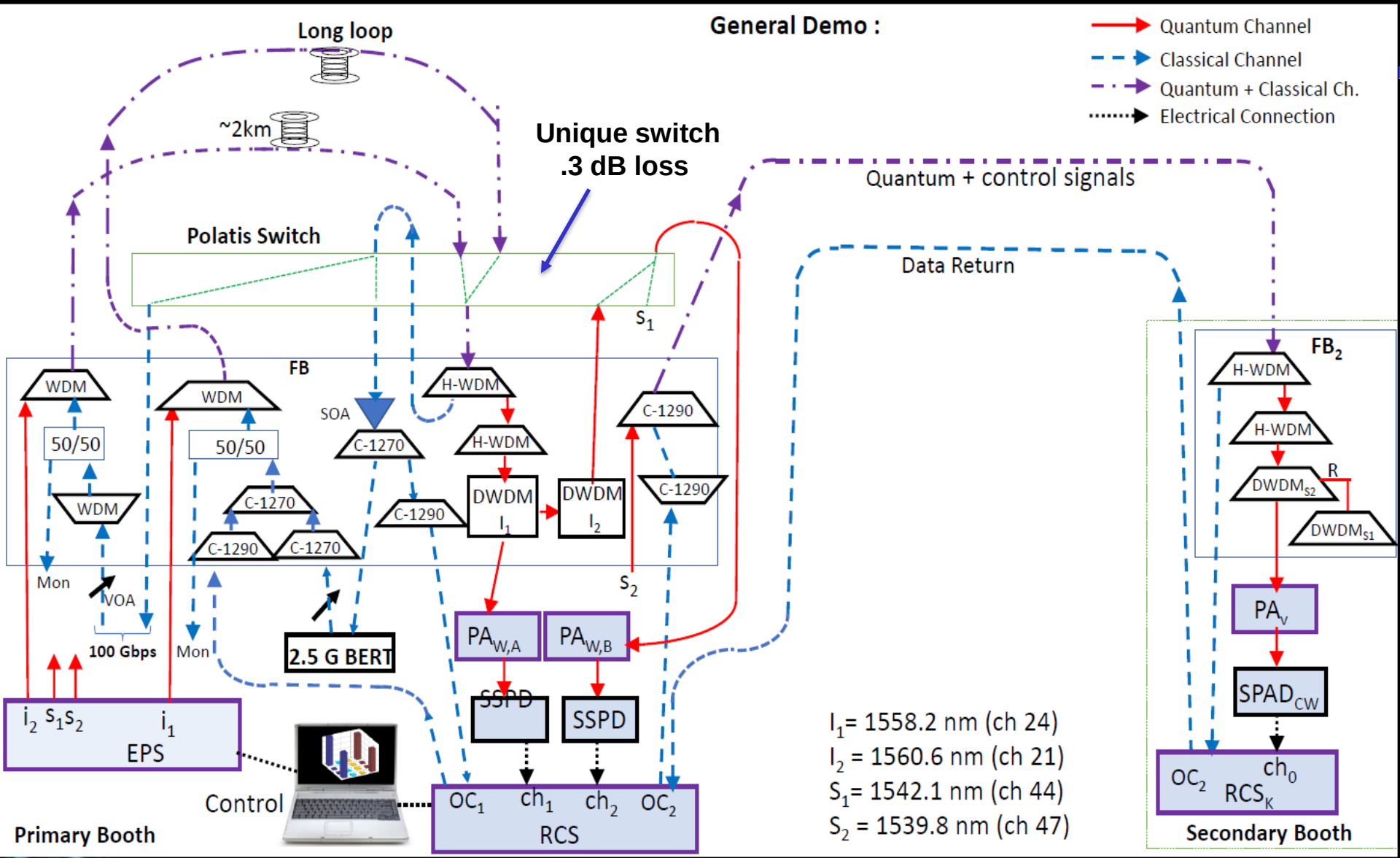
(1) Spin Off From Northwestern University's Center for Photonic Communications and Computing, Which Was Also A Partner for the OFC 2023 Demonstrations (Prem Kumar, Director)



OFC 2023 – OFCnet Architecture Diagram

Distribution of Quantum Entanglement Through Fiber With Co-Propagating Classical Data

- A complete system for distributing and measuring quantum entangled signals over fiber was demonstrated. Distributed measurements were collected and controlled from a single location using an embedded optical data link. An optical switch was programmed to send different quantum entangled wavelengths to spatially separated users. The demonstration centered around the use of commercially available components that interface to multiple types of single photon detectors. The demonstrations of coordinated control of quantum photonic instruments at multiple sites highlights the capability for robust operation of commercially available quantum optical equipment over existing fiber optic infrastructure.


General Demo :
Quantum Channel
Classical Channel
Quantum + Classical Ch.
Electrical Connection
Long loop
~2km
Unique switch
.3 dB loss
Polatis Switch
Quantum + control signals
Data Return
FB
WDM
50/50
WDM
C-1270
C-1290
Mon
VOA
100 Gbps
SOA
H-WDM
C-1270
H-WDM
C-1290
DWDM I1
DWDM I2
C-1290
C-1290
S1
S2
Mon
2.5 G BERT
PA W,A
PA W,B
SSPD
SSPD
i2 S1S2 i1
EPS
Control
OC1 ch1 ch2 OC2
RCS
Primary Booth
I1= 1558.2 nm (ch 24)
I2 = 1560.6 nm (ch 21)
S1= 1542.1 nm (ch 44)
S2 = 1539.8 nm (ch 47)
FB2
H-WDM
H-WDM
DWDMS2
R
DWDMS1
PAv
SPADCW
OC2 RCSK ch0
Secondary Booth

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

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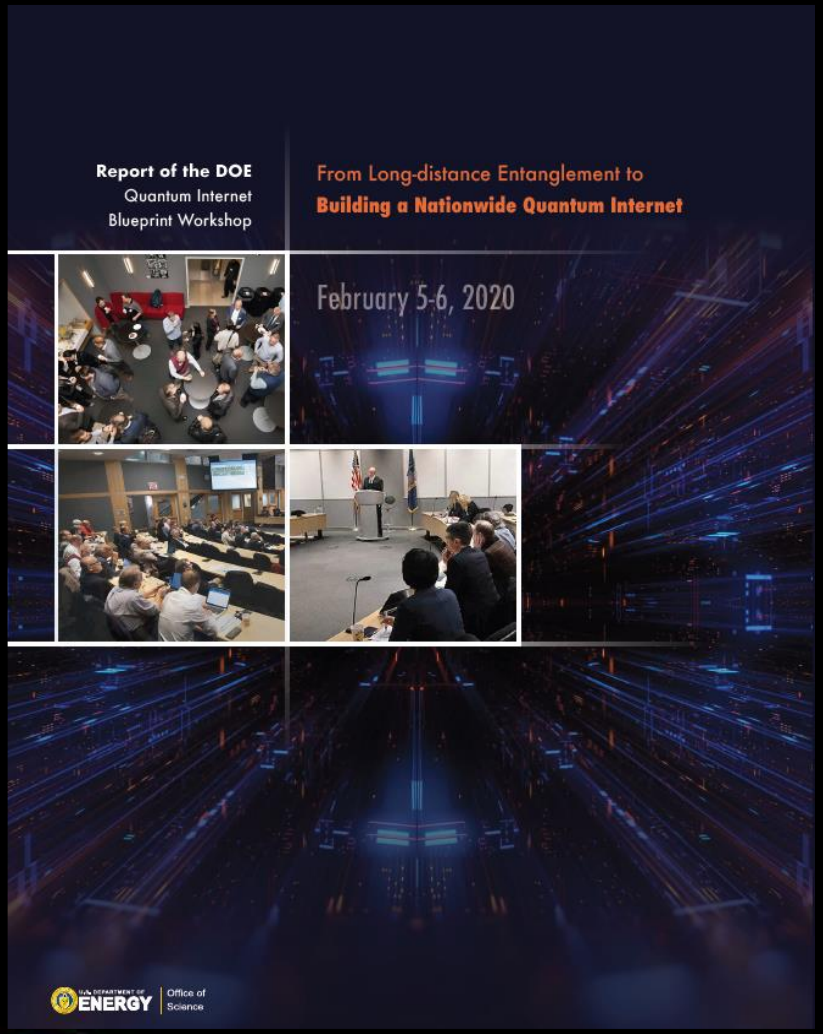
National Policy Report On Quantum Networks

ESnet Quantum Internet Initiative



Report of the DOE Quantum Internet Blueprint Workshop: From Long-Distance Entanglement To Building a Quantum Internet

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Annual Global Research Platform Workshop – Co-Located With IEEE International Conference On eScience Oct 9-10, 2023

'23 eScience

CALLS PROGRAM TRAV

'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

www.startap.net/starlight

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

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