Federated International Network Research Testbeds

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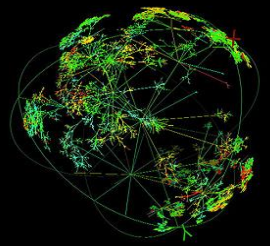
International Center for Advanced Internet Research (www.icair.org)
Northwestern University
Director, Metropolitan Research and Education Network (www.mren.org)
Co-Director, StarLight (www.startap.net/starlight), Director, StarLight International/National Communications Exchange Facility (www.startap.net/starlight),
PI IRNC: RXP: StarLight SDX, Co-PI Chameleon, PI-iGENI, PI-OMNINet

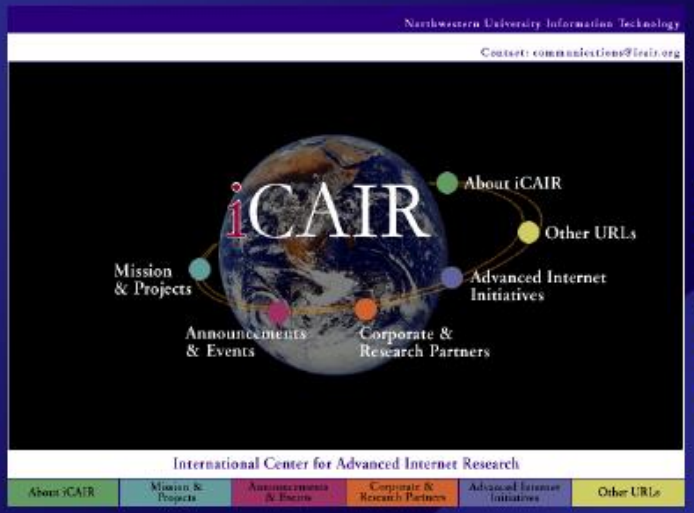
Global Experimentation For Future Internet, Co-Located With
IEEE CloudNet 2019
Coimbra, Portugal
November 7-8, 2019



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 and Exascale Science
- Advanced Applications, Middleware, Large-Scale Infrastructure, NG Optical Networks and Testbeds, Public Policy Studies and Forums Related to Optical Fiber and Next Generation Networks
- Three Major Areas of Activity: a) Basic Research b) Design and Implementation of Prototypes and Research Testbeds, c) Operations of Specialized Communication Facilities, and Networks (e.g., StarLight, Specialized Science Networks, the Metropolitan Research and Education Network et al)

Selected iCAIR Research Topics

- Transition From Legacy Networks To Networks That Take Full Advantage of IT Architecture and Technology
- Extremely Large Capacity (Multi-Tbps Streams)
- Specialized Network Services, Architecture and Technologies for Data Intensive Science , Including Network Appliances such as data Transfer Nodes (DTNs)
- High Degrees of Communication Services Customization
- Highly Programmable Networks
- Network Facilities As Enabling Platforms for Any Type of Service
- Network Virtualization
- Tenet Networks
- Network Virtualization
- Network Programming Languages (e.g., P4) API (e.g., Jupyter)
- Disaggregation
- Orchestrators
- Highly Distributed Signaling Processes
- Network Operations Automation (Including Through AI/Machine Learning)
- SDN/SDX/SDC/SDS/SDI/SDE

NSF iCAIR STARLIGHT SM

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

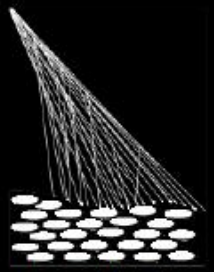
Virgo
www.virgo-gw.eu

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

LIGO
www.ligo.caltech. edu

SKA
www.skatelescope. org

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

USGS EROS
www.usgs.gov/ centers/eros

Blue Waters
bluewaters.ncsa. illinois.edu

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

Jetstream
www.jetstream-cloud.org

Belle II
www.belle2.org

XENON
xenon.astro. columbia.edu

SDSS
www.sdss.org

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

NEON
www.neonscience. org

CENTRA
www.global centra.org

SAGE2
sage2.sagecommons. org

Genomic Science Program
genomicscience. energy.gov

LBNF/DUNE/ ProtoDUNE
lbnf.fnal.gov

NOvA
novaexperiment. fnal.gov

ALMA
www.alma observatory.org

IVOA
www.ivoa.net

Compilation by Maxine Brown and Joe Mambretti

STARLIGHT℠

International Federated Testbeds As Instruments for Computer Science/Network Science

- The StarLight Communications Exchange Facility Supports ~ 25-30 Network Research Testbeds (Instruments For Computer Science/Networking Research)
- Software Defined Networking Techniques Are Used To Segment ("Slice") Distributed Virtual Environments
- 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 SDX Overview

- This IRNC StarLight SDX Initiative Is Designing, Implementing, and Operating New Services For Global Data Intensive Sciences, Based On Emerging Next Generation Architecture and Technolgies, Including Virtualization, Orchestration, Segmentation (Slicing), Software Defined Resources, Programmability and Customization.
- These Macro Trends Enable Exchanges To Be Agile Platforms For Dynamic Services Provisioning, Real-Time Responsiveness, and Distributed Control Over Core Resources, Including By Applications, Edge Processes and Devices.

This Project Is Transitioning Network Exchanges To Open Innovation Platforms

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 (60+ Paths)

StarWave

100 G Exchange

World's Most Advanced Exchange

Multiple First of a Kind Services and Capabilities

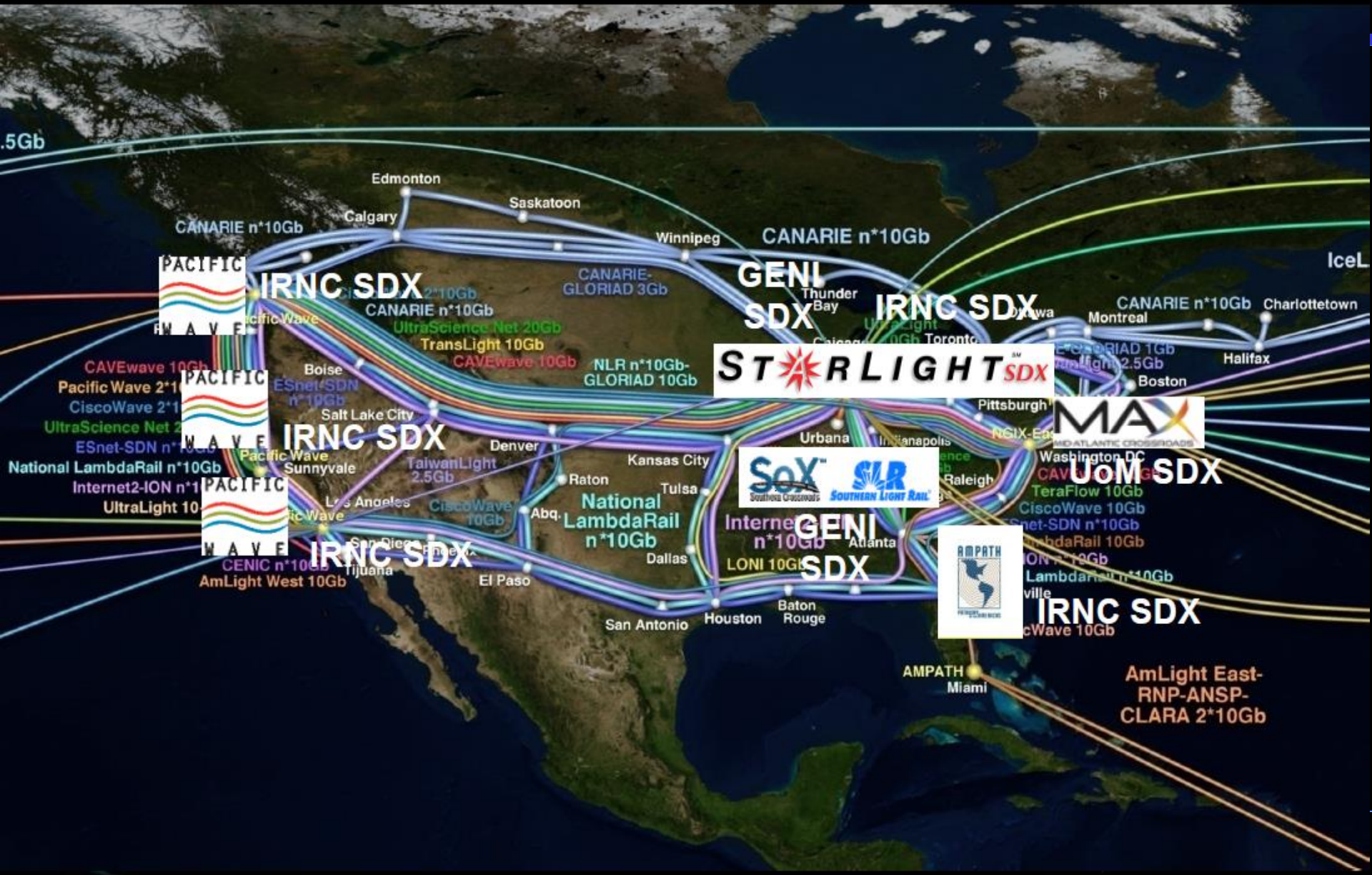
View from StarLight

Abbott Hall, Northwestern University's Chicago Campus

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

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

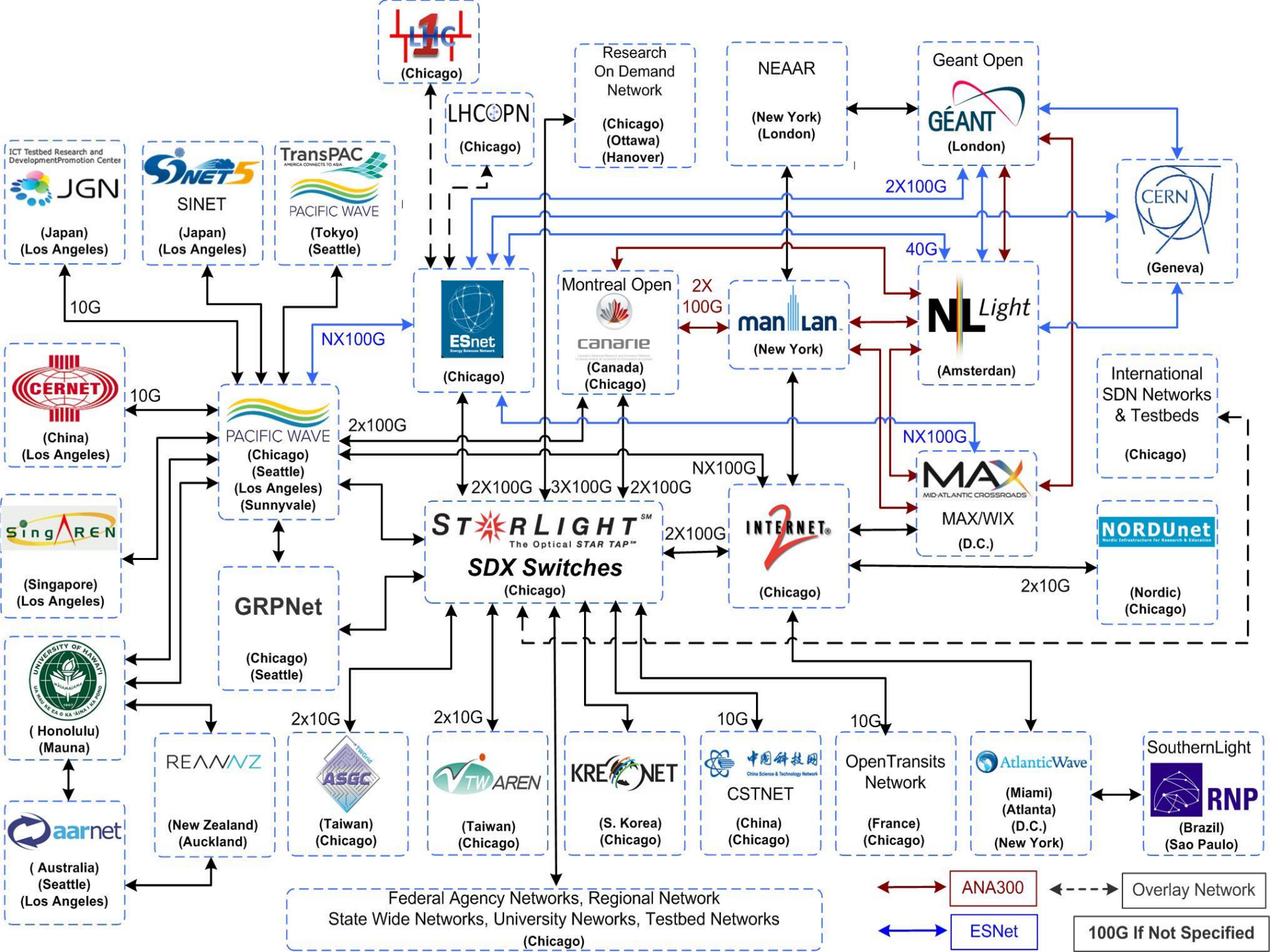
Emerging US SDX Interoperable Fabric



GLIF Automated GOLE Fabric 2018

SURF

STARLIGHT SM


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)
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NL Light
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SDN Networks
& Testbeds
(Chicago)
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(Los Angeles)
10G
PACIFIC WAVE
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(Sunnyvale)
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MAX
MID-ATLANTIC CROSSROADS
MAX/WIX
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SingAREN
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(Los Angeles)
STARLIGHT
The Optical STAR TAP
SDX Switches
(Chicago)
2X100G
INTERNET2
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2x10G
NORDUnet
(Nordic)
(Chicago)
GRPNet
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(Seattle)
(Honolulu)
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REANNZ
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ASGC
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KREONET
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AtlanticWave
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SouthernLight
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aarnet
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Federal Agency Networks, Regional Network
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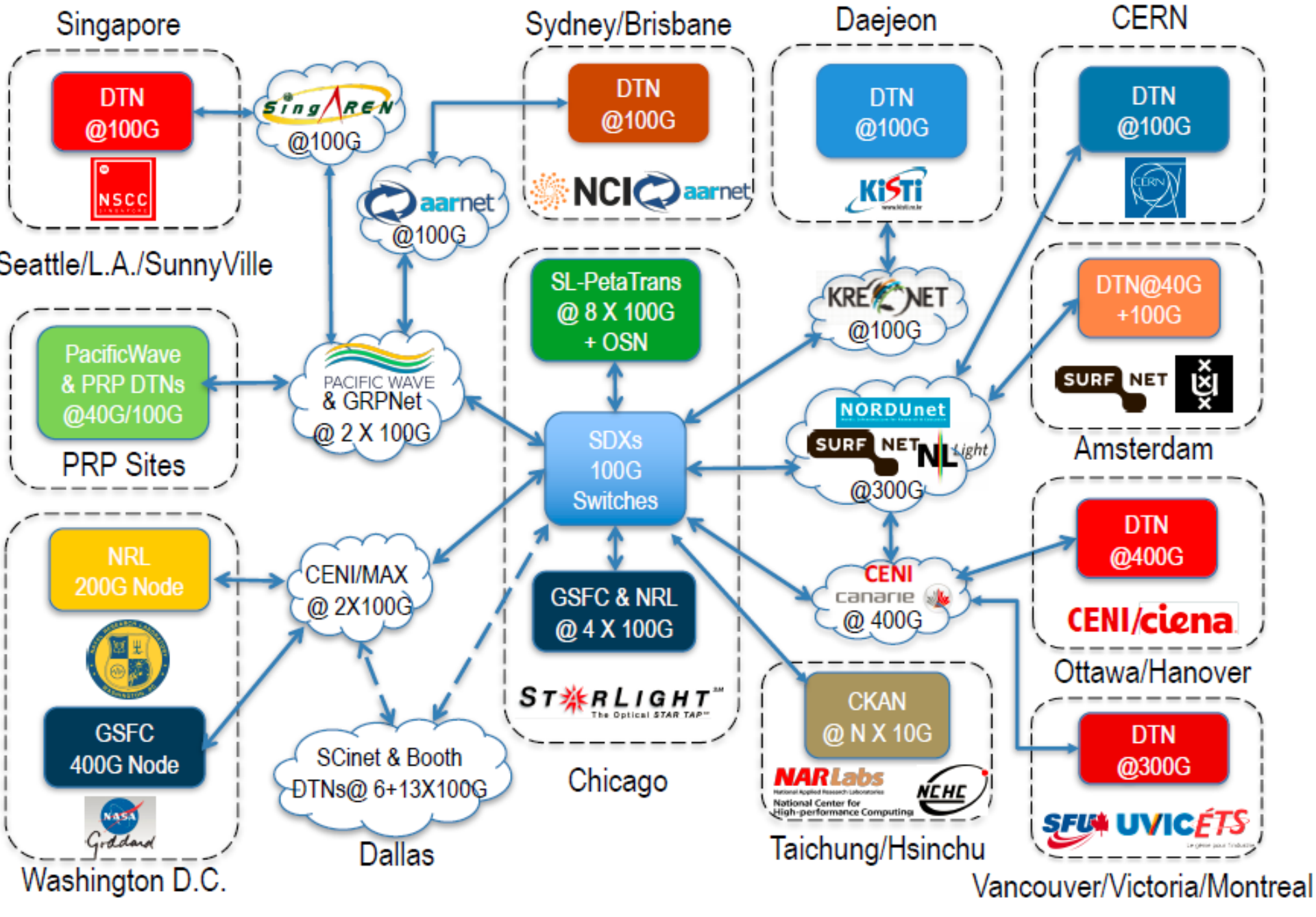
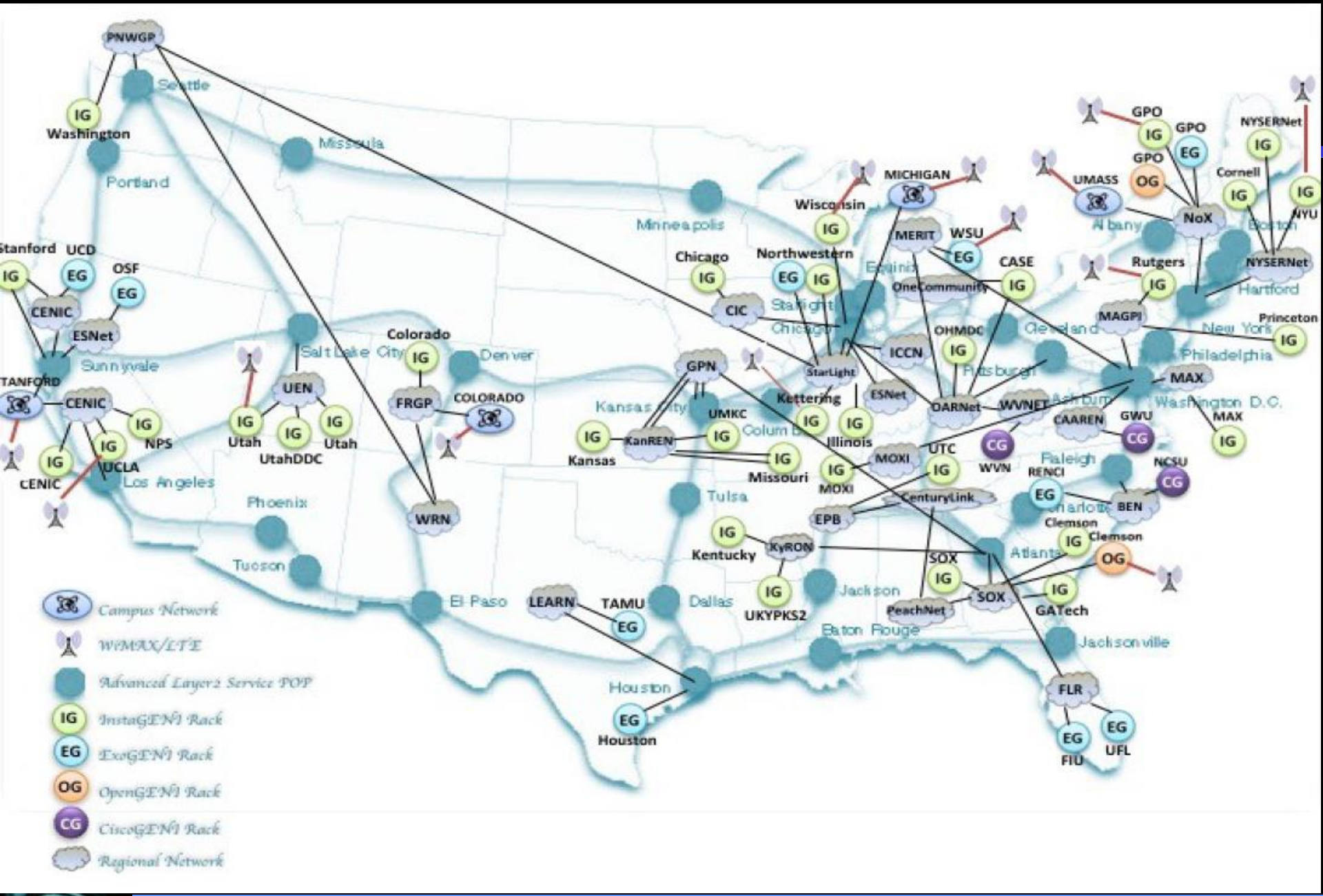
ANA300
ESNet
Overlay Network
100G If Not Specified

PetaTrans: Petascale Sciences Data Transfer

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NPS
UCLA
CENIC
Los Angeles
Salt Lake City
UEN
Utah
UtahDDC
Utah
Colorado
Denver
FRGP
COLORADO
WRN
Phoenix
Tucson
El Paso
LEARN
TAMU
Houston
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Missouri
GPN
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CIC
Northwestern
Wisconsin
MICHIGAN
MERIT
WSU
CASE
OneCommunity
Equinix
StarLight
Chicago
Kettering
ESNet
ICCN
OHMDC
Illinois
MOXI
UTC
CenturyLink
EPB
Kentucky
KyRON
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MAX
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New York
Princeton
MAGPI
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NYSERNet
Boston
NYU
Cornell
NoX
Albany
UMASS
GPO
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OG
EG
IG
NYSERNet
Campus Network
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Advanced Layer2 Service POP
InstaGENI Rack
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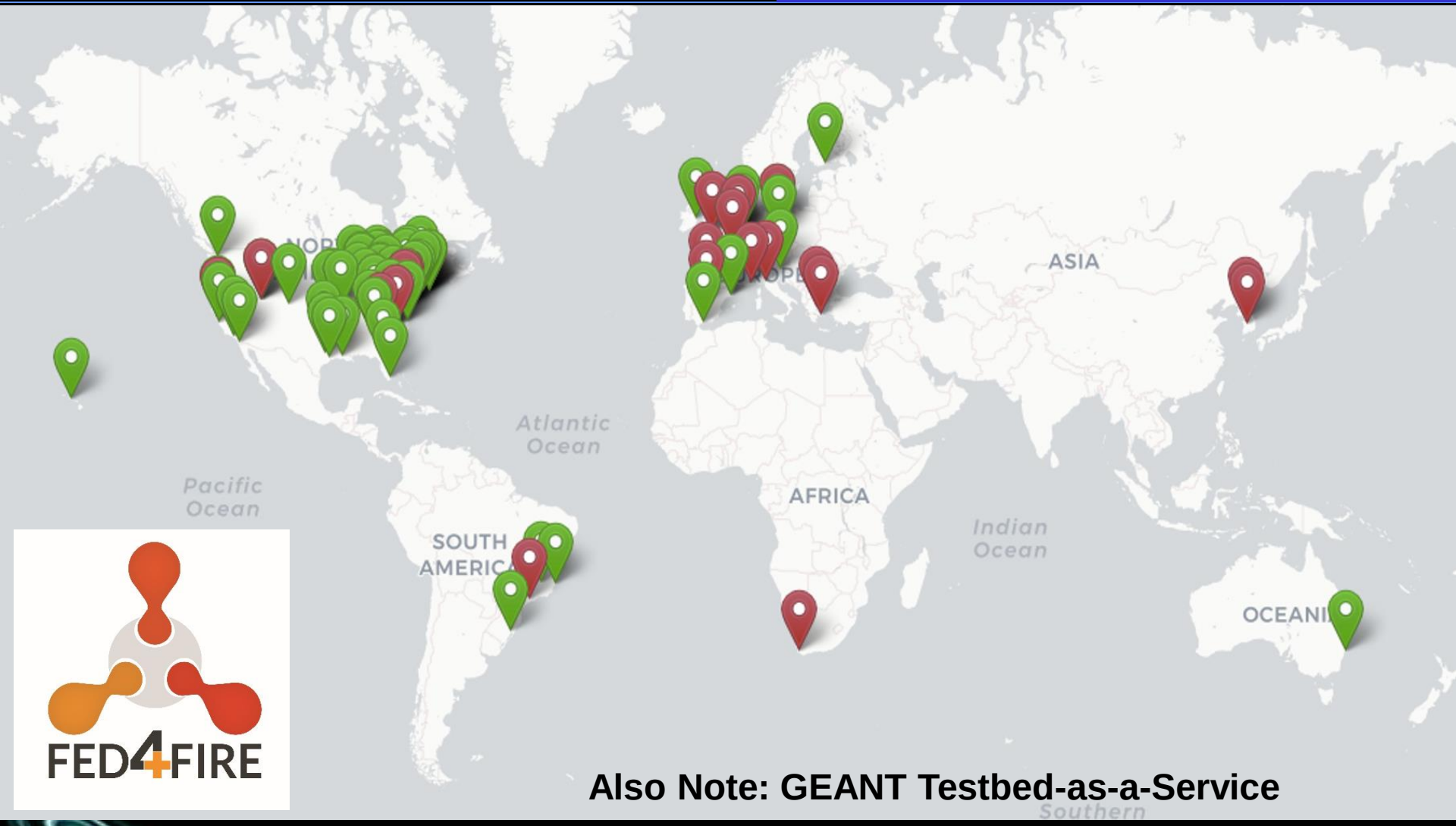
OpenGENI Rack
CiscoGENI Rack
Regional Network

EU FED4FIRE International Federation



Also Note: GEANT Testbed-as-a-Service

Chameleon

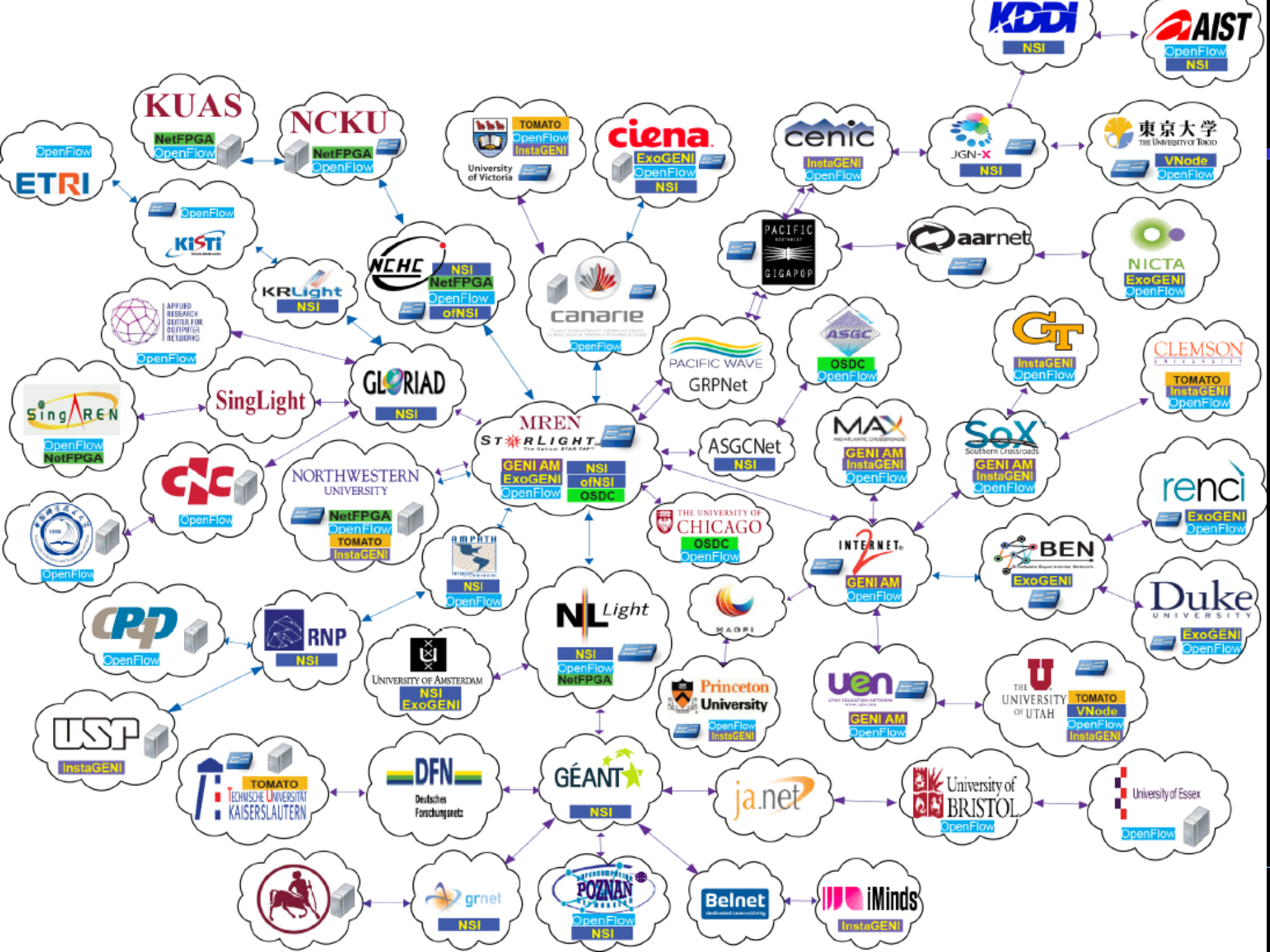
www.chameleoncloud.org

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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ja.net
University of BRISTOL
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University of Essex
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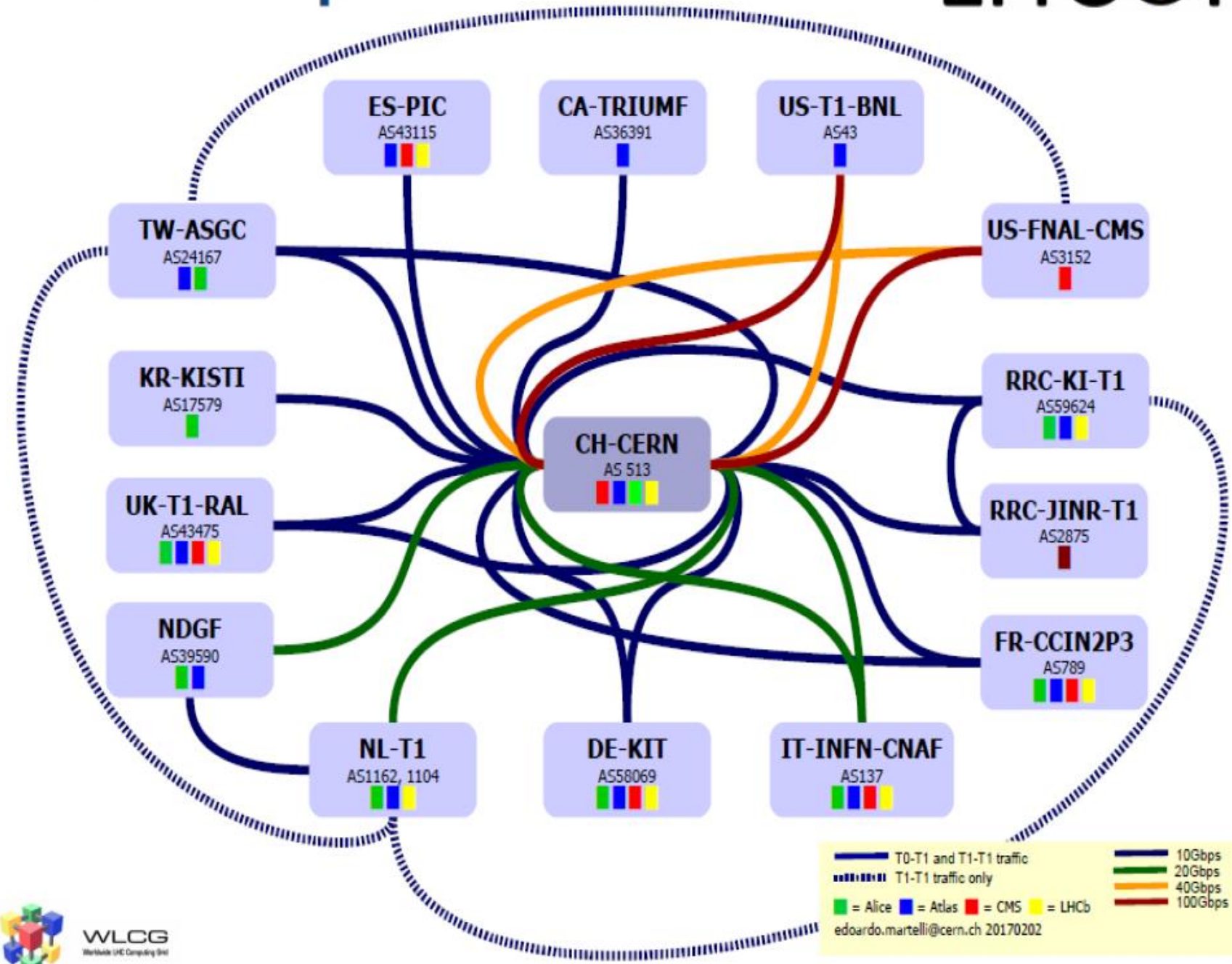
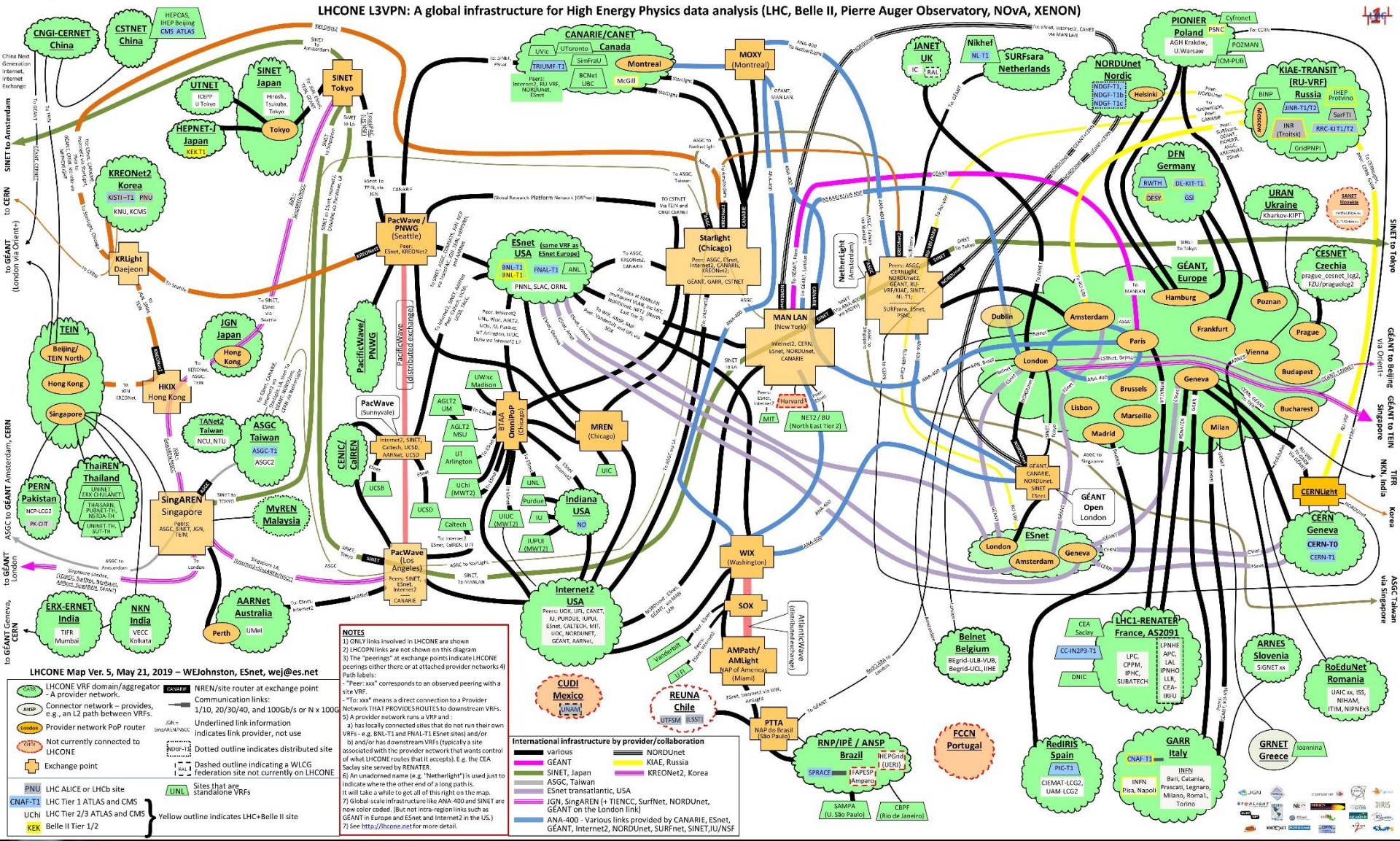
grnet
NSI
POZNAN
OpenFlow
NSI
Belnet
iMinds
InstaGENI

LHCOPN map

LHCOPN



WLCG
Worldwide LHC Computing Grid

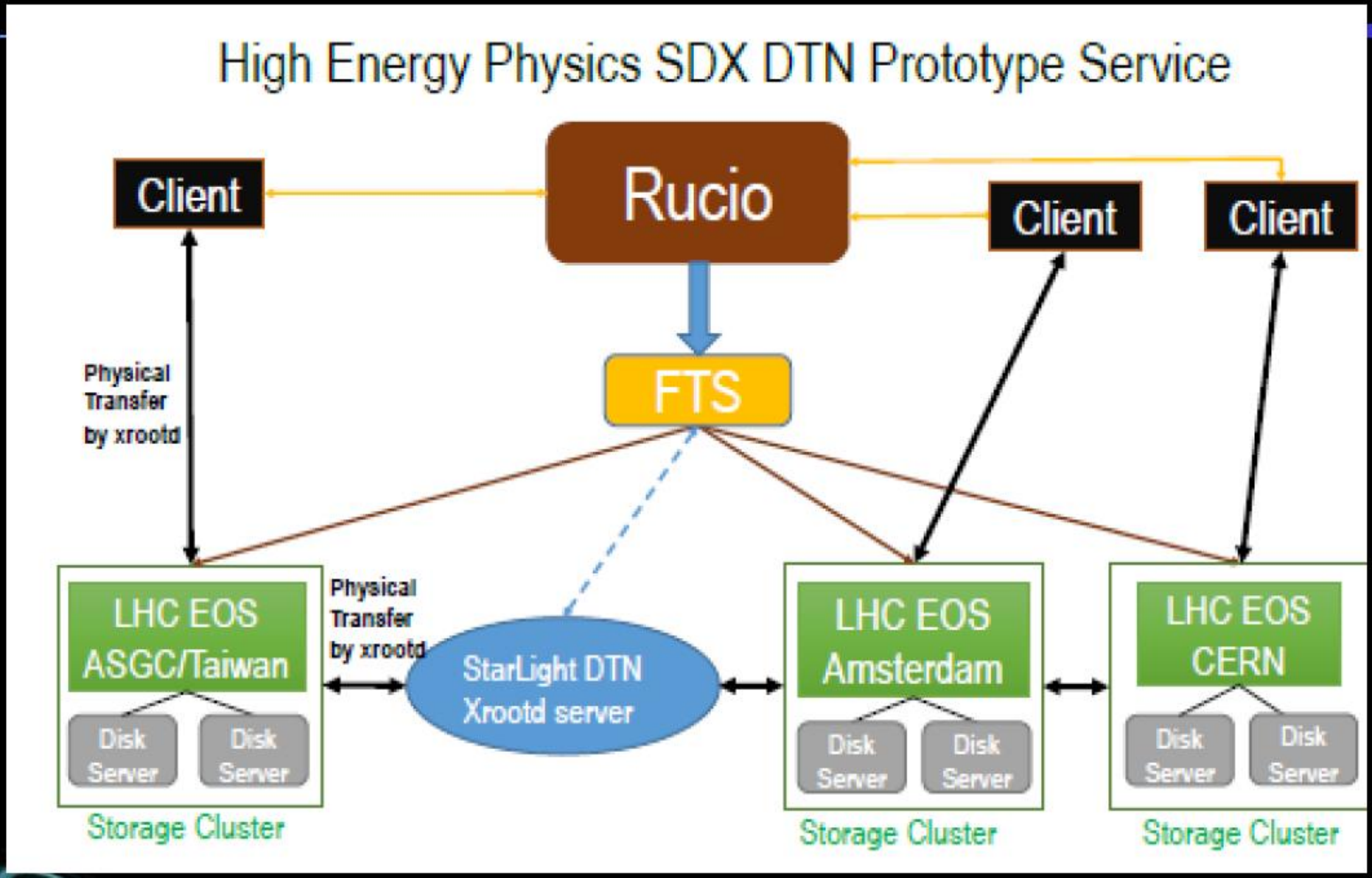


STARLIGHT SM

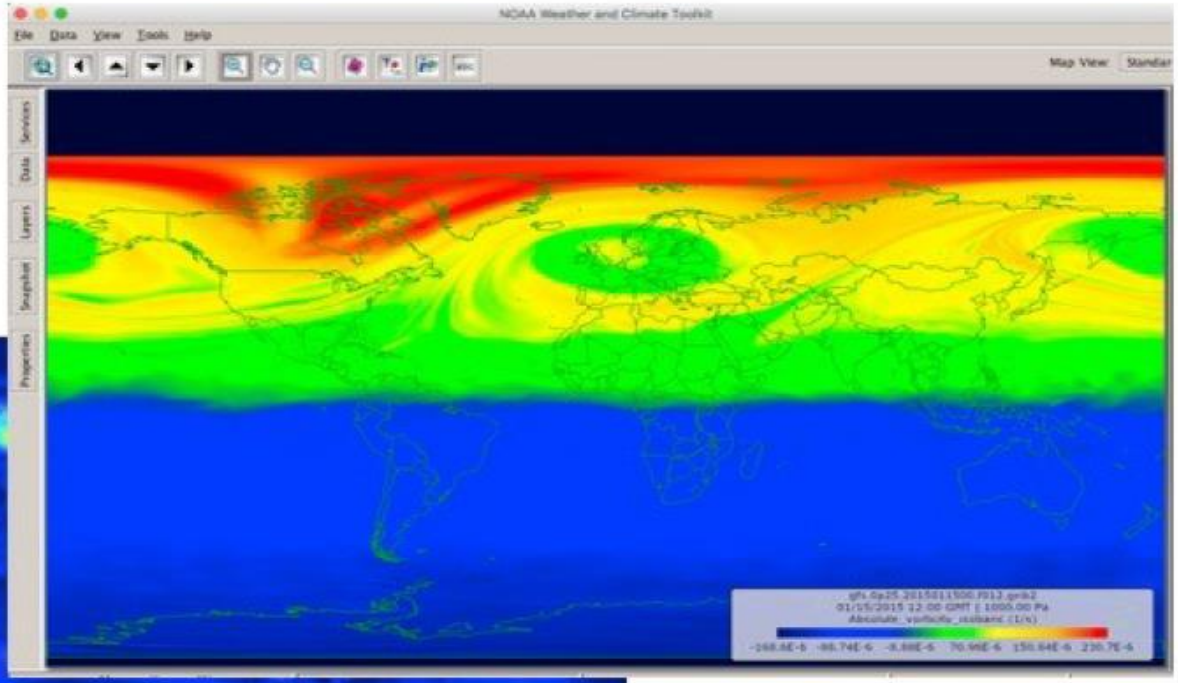
New Science Communities Using LHCONE

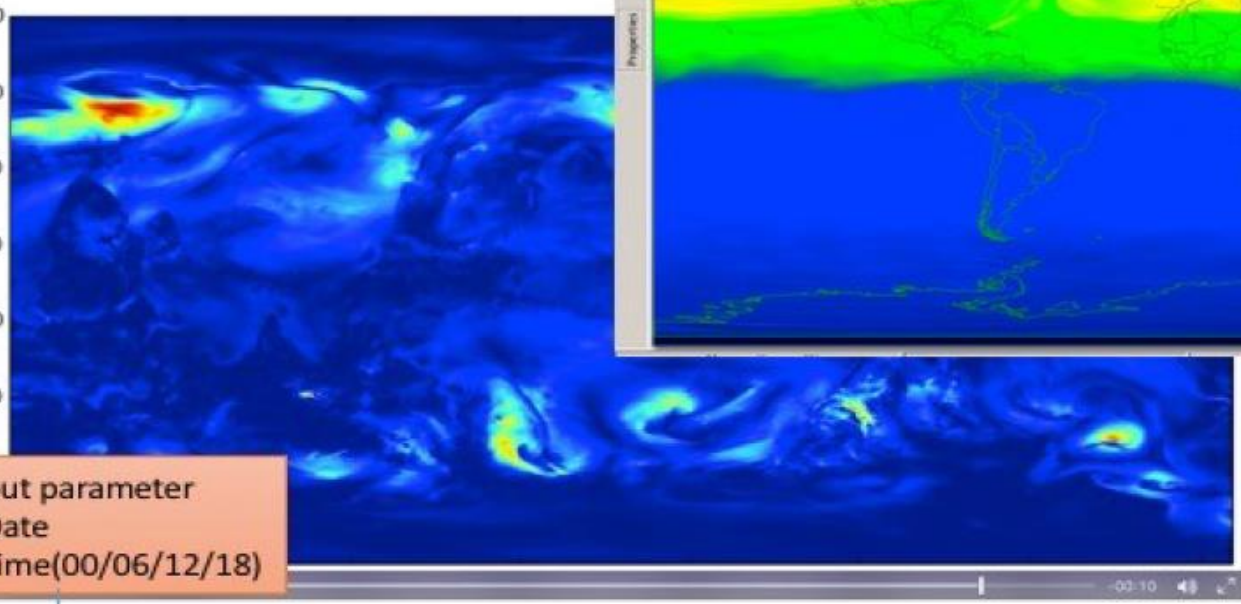
- Belle II Experiment, Particle Physics Experiment Designed To Study Properties of B Mesons (Heavy Particles Containing a Bottom Quark).
- Pierre Auger Observatory, Studying Ultra-High Energy Cosmic Rays, the Most Energetic and Rarest of Particles In the Universe.
- In August 2017 the PAO, LIGO and Virgo 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.

New=> DUNE/ProtoDUNE – Deep Underground Nutrino Experiment


High Energy Physics SDX DTN Prototype Service
Client
Rucio
Client
Client
Physical
Transfer
by xrootd
FTS
LHC EOS
ASGC/Taiwan
Disk
Server
Disk
Server
Storage Cluster
Physical
Transfer
by xrootd
StarLight DTN
Xrootd server
LHC EOS
Amsterdam
Disk
Server
Disk
Server
Storage Cluster
LHC EOS
CERN
Disk
Server
Disk
Server
Storage Cluster

StarLight SDX Geoscience Research Workflow





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2.Time(00/06/12/18)

Designing and Deploying A

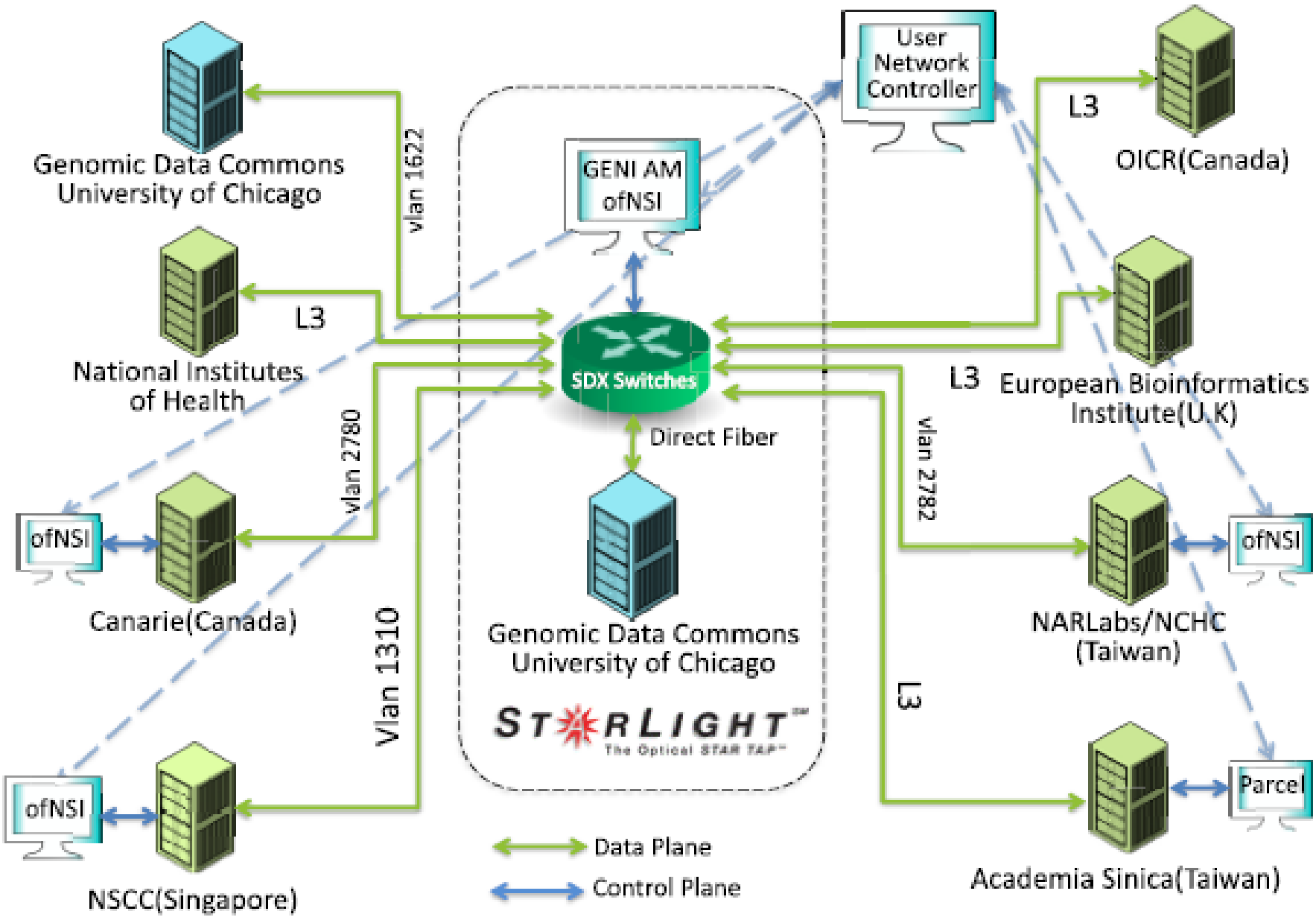
Bioinformatics Software-Defined Network Exchange (SDX): Architecture, Services, Capabilities, and Foundation Technologies

Joe Mambretti, Jim Chen, Fei Yeh
International Center for Advanced Internet Research
Northwestern University
Robert Grossman, Piers Nash, Alison Heath, Renuka Arya, Stuti Agrawal, Zhenyu Zhang
Center for Data Intensive Science
University of Chicago
Chicago, Illinois, USA

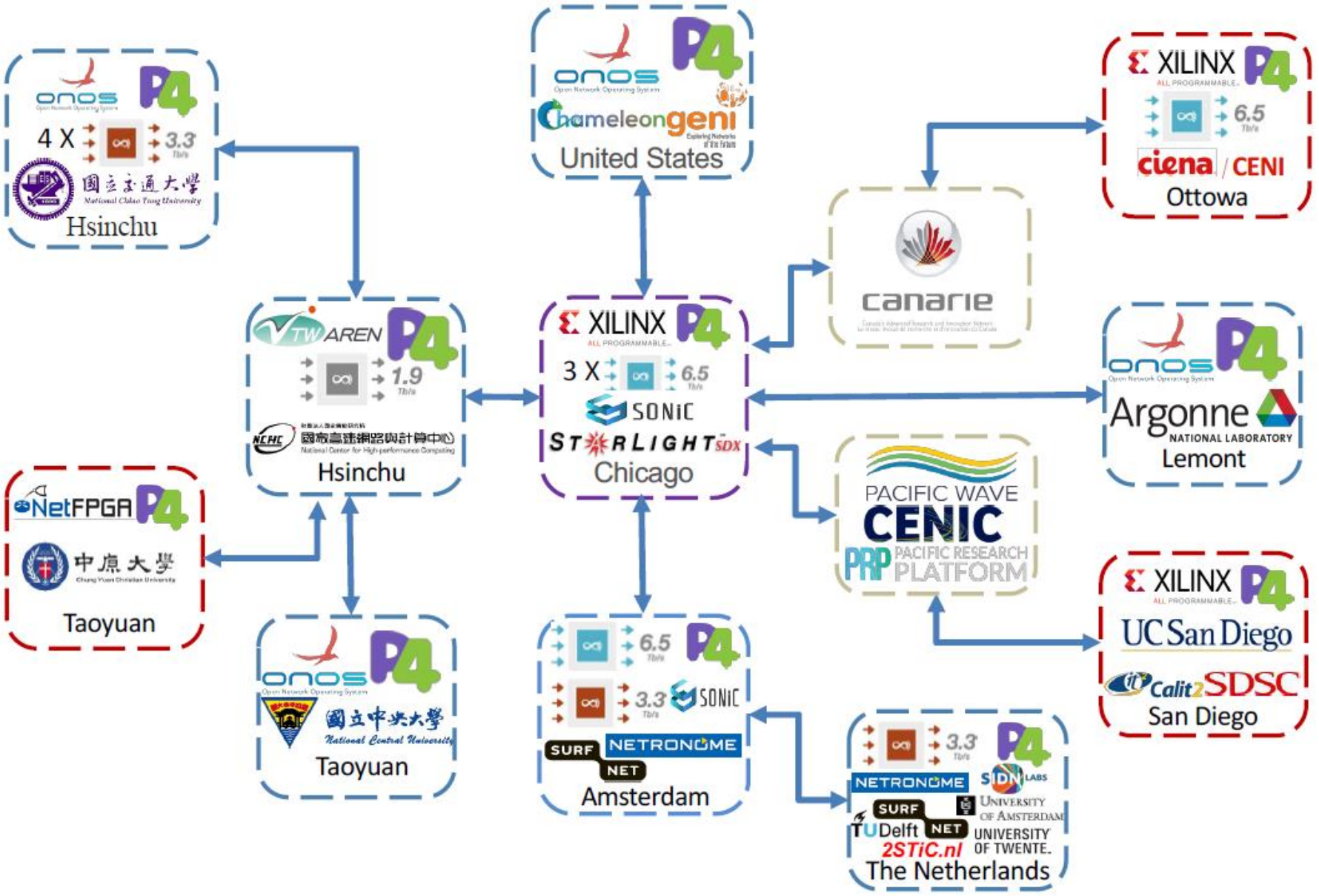
iCAIR

STARLIGHT℠

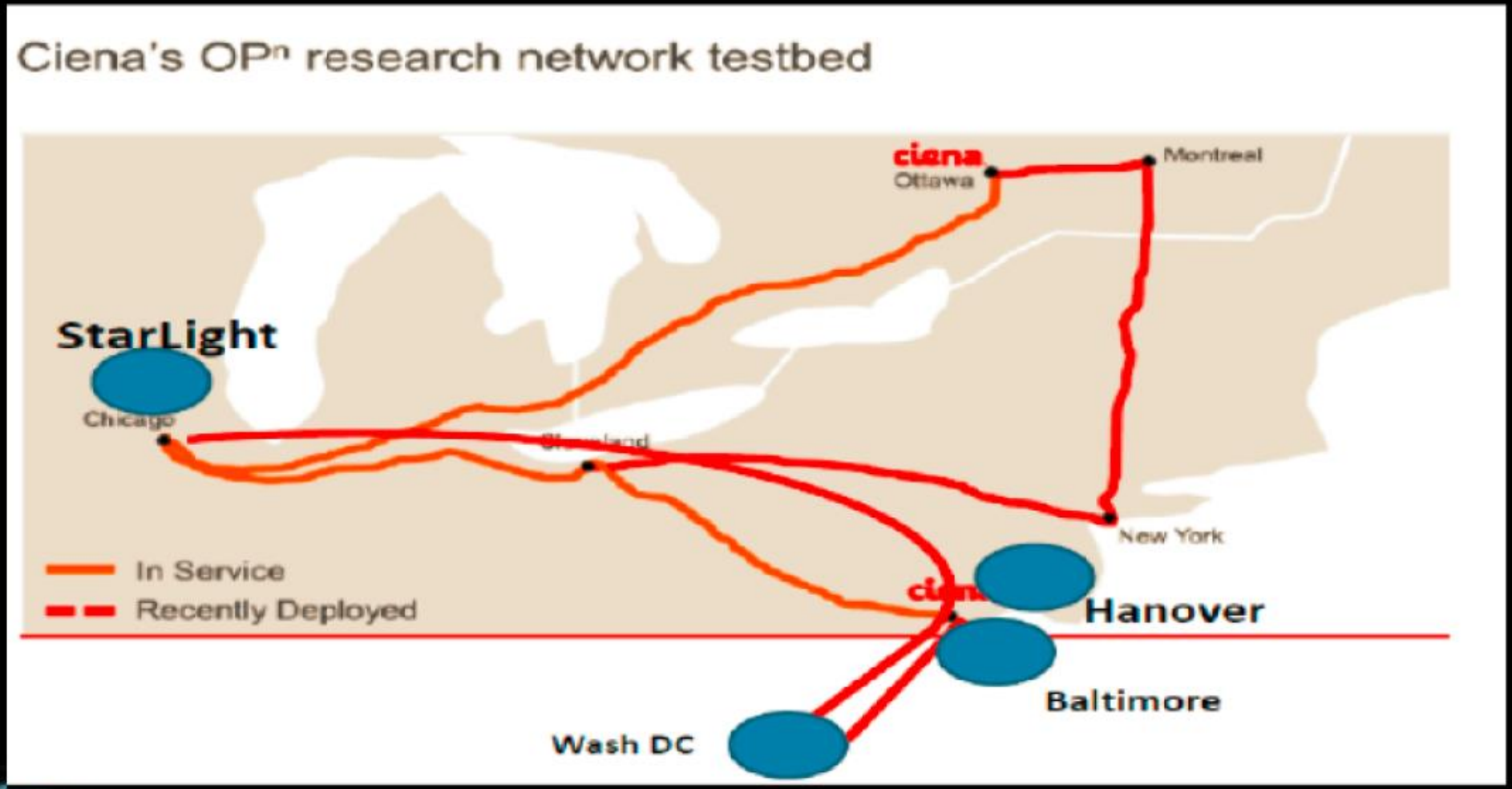
2016 Bioinformatics SDXs Network

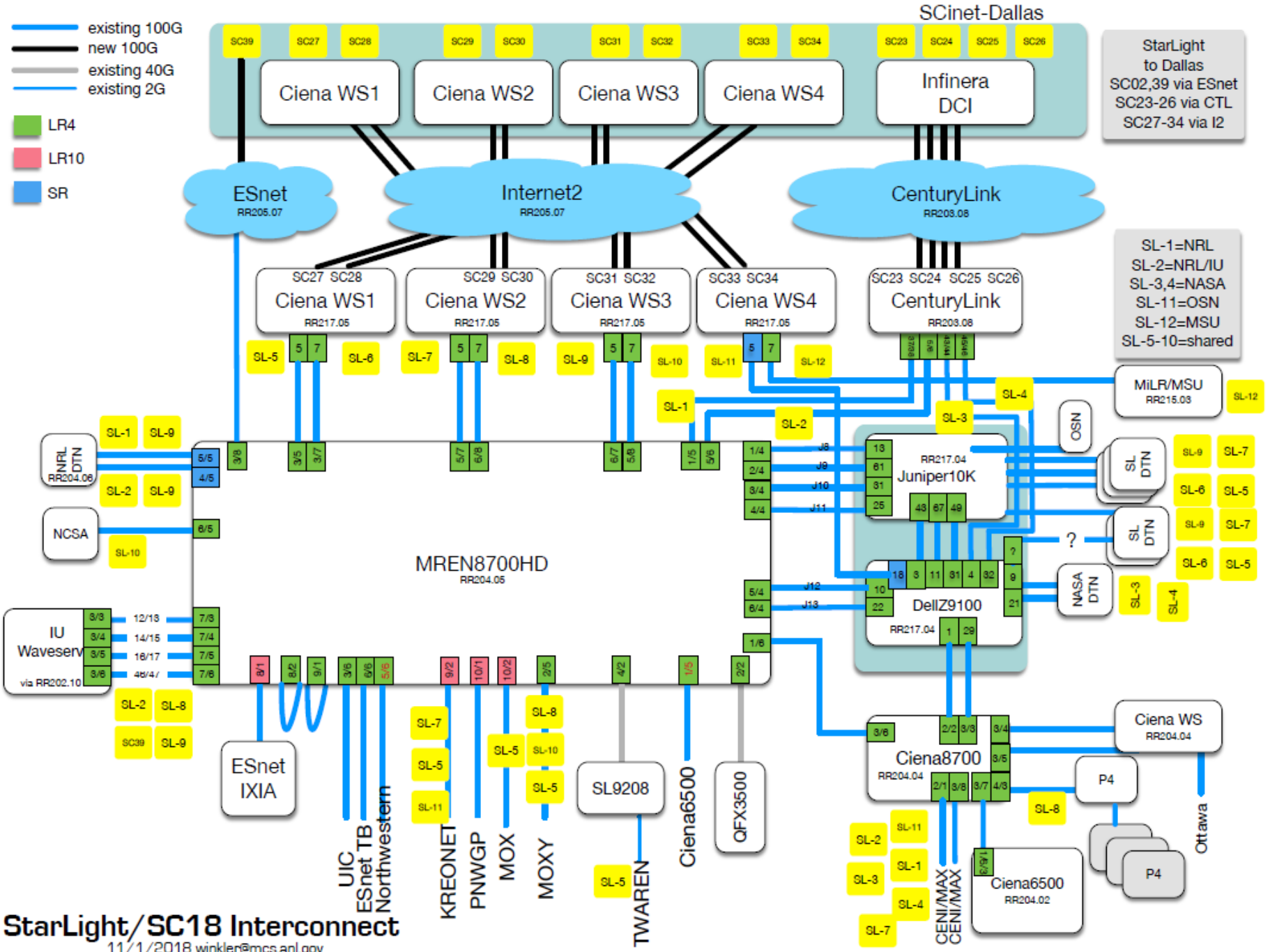


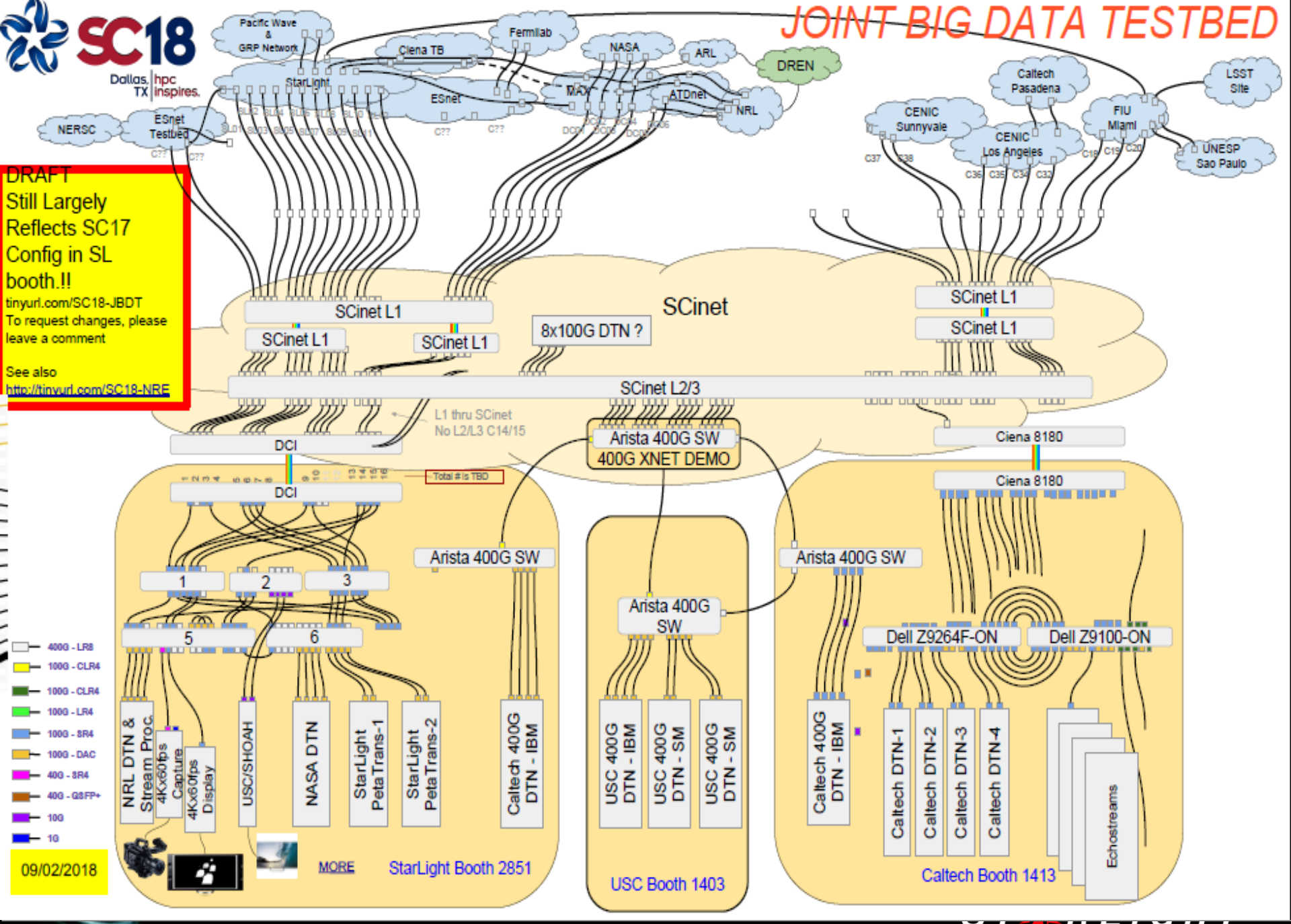
International P4 Experimental Networks (i-P4EN)

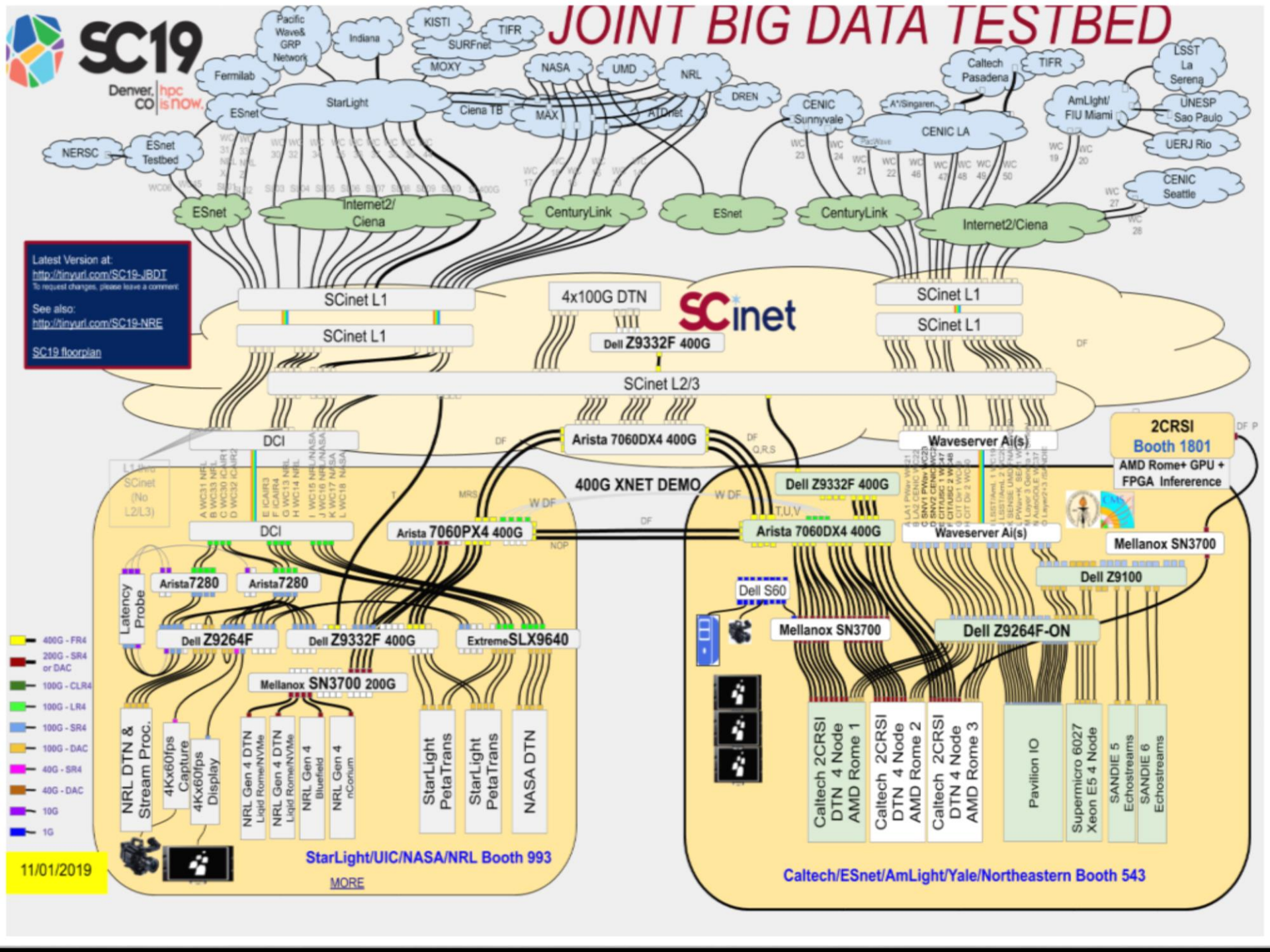


100 Gbps DTN Optical Testbed




existing 100G
new 100G
existing 40G
existing 2G
LR4
LR10
SR
SCinet-Dallas
SC39 SC27 SC28 SC29 SC30 SC31 SC32 SC33 SC34 SC23 SC24 SC25 SC26
Ciena WS1
Ciena WS2
Ciena WS3
Ciena WS4
Infinera DCI
StarLight to Dallas
SC02,39 via ESnet
SC23-26 via CTL
SC27-34 via I2
ESnet
RR205.07
Internet2
RR205.07
CenturyLink
RR208.08
SC27 SC28 Ciena WS1 RR217.05
SC29 SC30 Ciena WS2 RR217.05
SC31 SC32 Ciena WS3 RR217.05
SC33 SC34 Ciena WS4 RR217.05
SC23 SC24 SC25 SC26 CenturyLink RR208.08
SL-1=NRL
SL-2=NRL/IU
SL-3,4=NASA
SL-11=OSN
SL-12=MSU
SL-5-10=shared
MiLR/MSU RR215.03
OSN
SL DTN
NASA DTN
NRL DTN RR204.06
NCSA
MREN8700HD RR204.05
RR217.04 Juniper10K
DellZ9100 RR217.04
IU Waveserv via RR202.10
ESnet IXIA
UIC
ESnet TB
Northwestern
KREONET
PNWGP
MOX
MOXY
SL9208
TWAREN
Ciena6500
QFX3500
Ciena8700 RR204.04
Ciena WS RR204.04
P4
Ottawa
Ciena6500 RR204.02
CENI/MAX
CENI/MAX
StarLight/SC18 Interconnect
11/1/2018 winkler@mcs.anl.gov
Linda Winkler

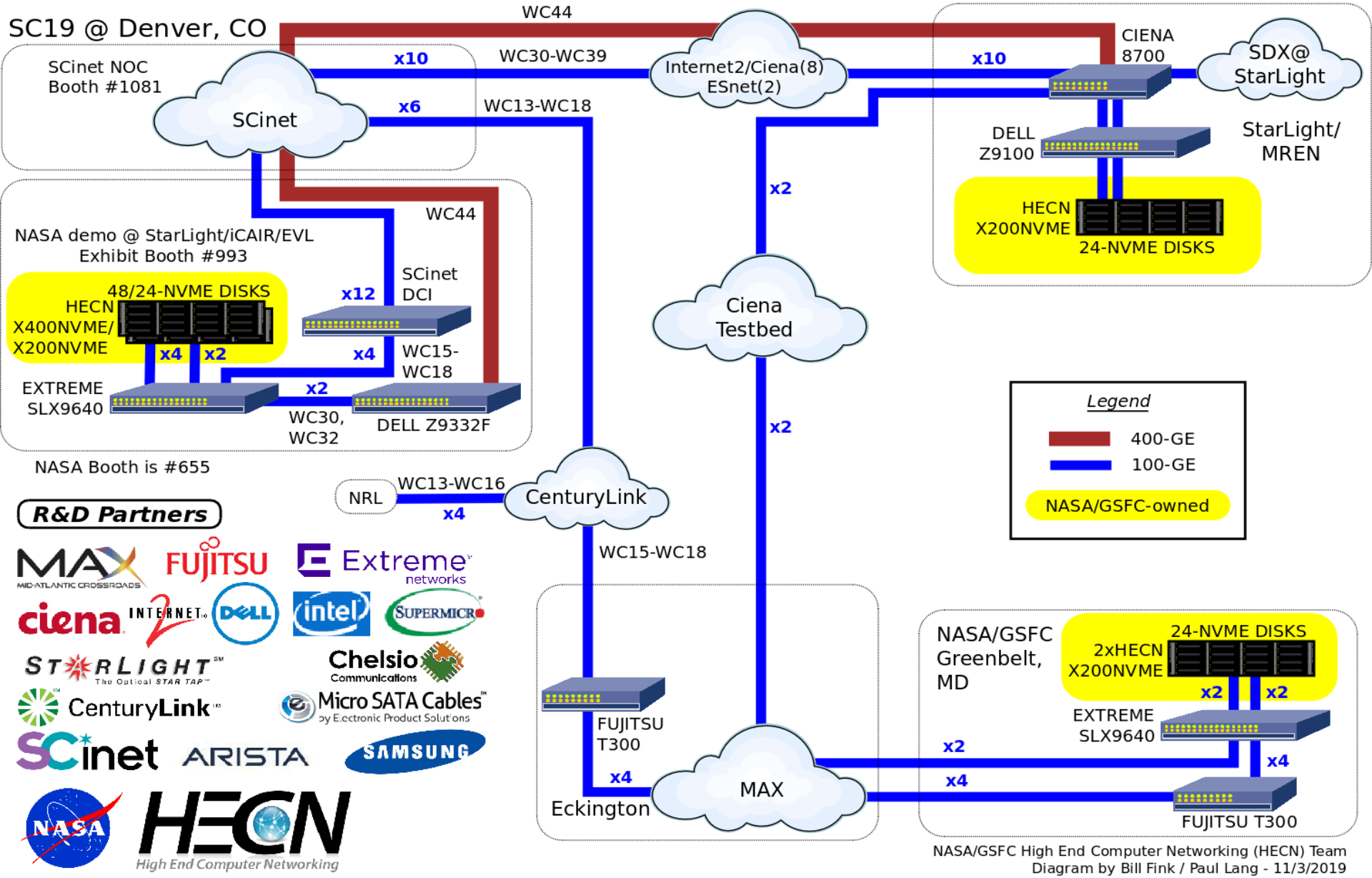

SC18
Dallas, TX | hpc inspires.
JOINT BIG DATA TESTBED
DRAFT
Still Largely Reflects SC17 Config in SL booth.!!
tinyurl.com/SC18-JBDT
To request changes, please leave a comment
See also http://tinyurl.com/SC18-NRE
Pacific Wave & GRP Network
Ciena TB
Fermilab
NASA
ARL
DREN
StarLight
ESnet
MAX
ATDnet
NRL
NERSC
ESnet Testbed
Caltech Pasadena
LSST Site
CENIC Sunnyvale
CENIC Los Angeles
FIU Miami
UNESP Sao Paulo
SCinet
SCinet L1
SCinet L2/3
8x100G DTN ?
L1 thru SCinet
No L2/L3 C14/15
DCI
Total #'s TBD
Arista 400G SW
400G XNET DEMO
Ciena 8180
Arista 400G SW
Dell Z9264F-ON
Dell Z9100-ON
NRL DTN & Stream Proc.
4Kx60fps Capture
4Kx60fps Display
USC/SHOAH
NASA DTN
StarLight Peta Trans-1
StarLight Peta Trans-2
Caltech 400G DTN - IBM
USC 400G DTN - IBM
USC 400G DTN - SM
Caltech DTN-1
Caltech DTN-2
Caltech DTN-3
Caltech DTN-4
Echostreams
MORE
StarLight Booth 2851
USC Booth 1403
Caltech Booth 1413
400G - LR8
100G - CLR4
100G - CLR4
100G - LR4
100G - SR4
100G - DAC
40G - SR4
40G - QSFP+
10G
1G
09/02/2018


SC19
Denver, CO | hpc is now.
JOINT BIG DATA TESTBED
Pacific Wave& GRP Network
Indiana
KISTI
TIFR
SURFnet
MOXY
Fermilab
ESnet
StarLight
Ciena TB
NASA
UMD
NRL
MAX
ATDnet
DREN
Caltech Pasadena
TIFR
LSST La Serena
CENIC Sunnyvale
A*/Singaren
CENIC LA
AmLight/ FIU Miami
UNESP Sao Paulo
UERJ Rio
NERSC
ESnet Testbed
CENIC Seattle
ESnet
Internet2/ Ciena
CenturyLink
ESnet
CenturyLink
Internet2/Ciena
Latest Version at:
http://tinyurl.com/SC19-JBDT
To request changes, please leave a comment
See also:
http://tinyurl.com/SC19-NRE
SC19 floorplan
SCinet L1
SCinet L1
4x100G DTN
SCinet
Dell Z9332F 400G
SCinet L1
SCinet L1
SCinet L2/3
DCI
Arista 7060DX4 400G
Waveserver Ai(s)
2CRSI
Booth 1801
AMD Rome+ GPU + FPGA Infererence
400G XNET DEMO
DCI
Arista 7060PX4 400G
Dell Z9332F 400G
Arista 7060DX4 400G
Waveserver Ai(s)
Mellanox SN3700
Dell Z9100
Arista7280
Arista7280
Latency Probe
Dell S60
Dell Z9264F
Dell Z9332F 400G
ExtremeSLX9640
Mellanox SN3700
Dell Z9264F-ON
Mellanox SN3700 200G
NRL DTN & Stream Proc.
4Kx60fps Capture
4Kx60fps Display
NRL Gen 4 DTN Liqid Rome/NVMe
NRL Gen 4 DTN Liqid Rome/NVMe
NRL Gen 4 Bluefield
NRL Gen 4 nConium
StarLight PetaTrans
StarLight PetaTrans
NASA DTN
Caltech 2CRSI DTN 4 Node AMD Rome 1
Caltech 2CRSI DTN 4 Node AMD Rome 2
Caltech 2CRSI DTN 4 Node AMD Rome 3
Pavilion IO
Supermicro 6027 Xeon E5 4 Node
SANDIE 5 Echostreams
SANDIE 6 Echostreams
400G - FR4
200G - SR4 or DAC
100G - CLR4
100G - LR4
100G - SR4
100G - DAC
40G - SR4
40G - DAC
10G
1G
11/01/2019
StarLight/UIC/NASA/NRL Booth 993
MORE
Caltech/ESnet/AmLight/Yale/Northeastern Booth 543

SC19

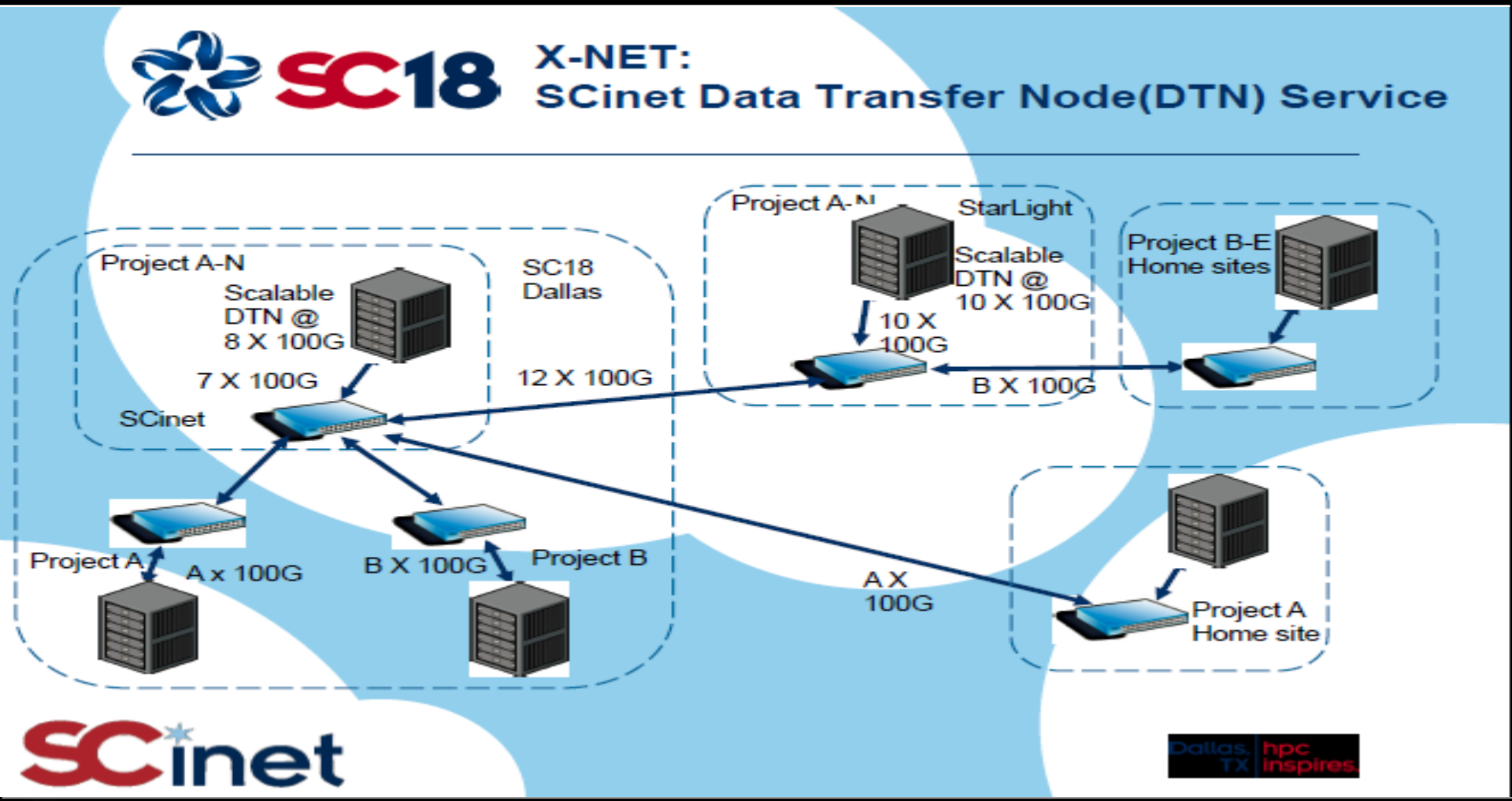
Demonstrations of 400 Gbps Disk-to-Disk WAN File Transfers using RDMA and NVMe Drives

An SC19 Collaborative Initiative Among NASA and Several Partners



NASA/GSFC High End Computer Networking (HECN) Team
Diagram by Bill Fink / Paul Lang - 11/3/2019

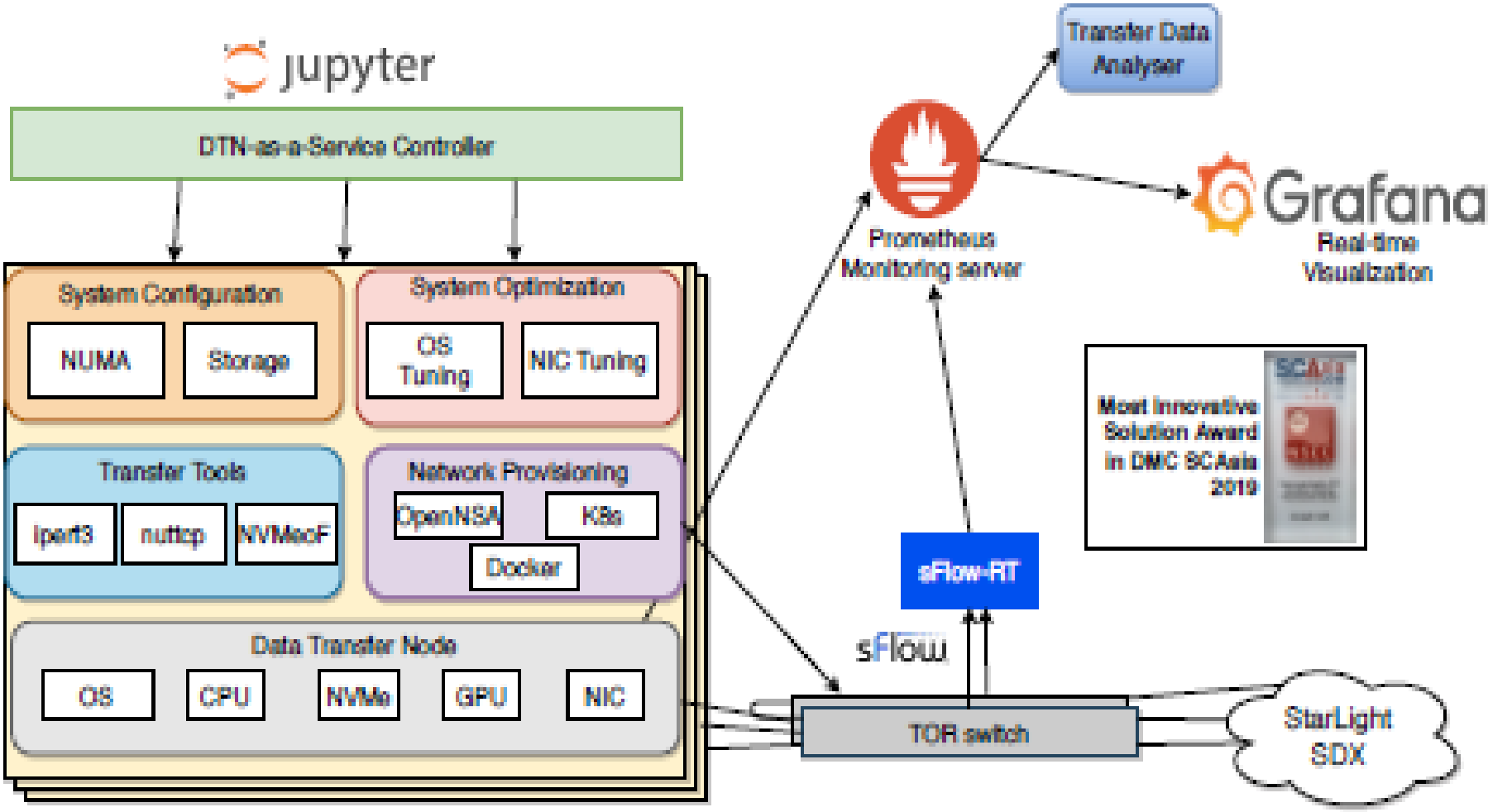
Implementing a SCinet DTN (DTN-as-a-Service, DaaS)



Source; Jim Chen, iCAIR

STARLIGHT SM

STARLIGHT SDX DTN-as-a-Service



BigData Express: Toward Predictable, Schedulable, High-performance Data Transfer

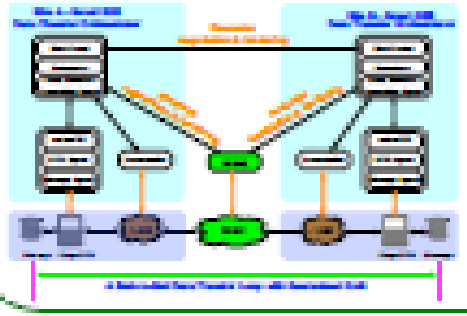
Fermilab

ENERGY

What Is BigData Express?

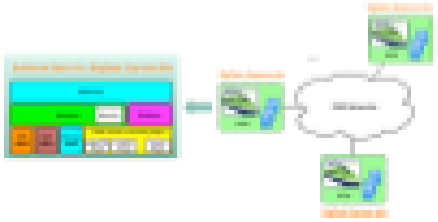
- A schedulable, predictable, and high-performance data transfer service
  - Peer-to-peer, scalable, and extensible data transfer model
  - Visually appealing, easy-to-use web portal
  - High-performance data transfer engine
  - On-demand provisioning of network paths with guaranteed QoS
  - Robust and flexible error handling
  - CILogon-based security
  - A rich set of REST APIs to support scientific workflows
- Project web site: http://bigdataexpress.fnal.gov

End-to-End Transfer Loop

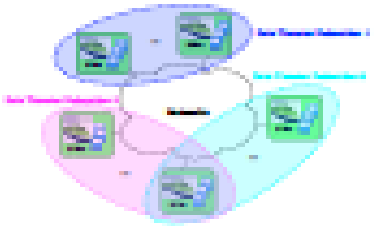


- Application-aware network service
  - On-demand programming
- Fast-provisioning of end-to-end network paths with guaranteed QoS
- Distributed resource negotiation & brokering

Distributed, Peer-to-Peer Model

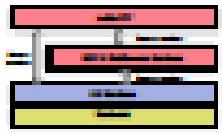


Each site independently provides data transfer service



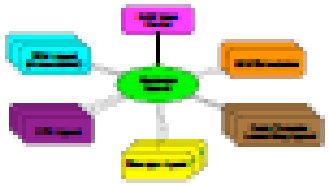
Flexible data transfer federations

A High-performance Data Transfer Engine – mdtmFTP

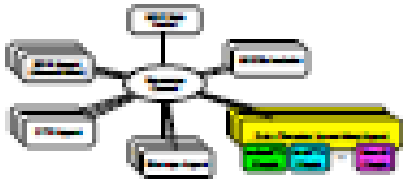


- A pipelined I/O centric design to streamline data transfer
- Multicore-aware data transfer middleware optimizes use of underlying hardware
- Extremely efficient in transferring of Lots Of Small Files

Scalable & Extensible Design



- Scheduler manages site resources through agents
- Use MQTT as message bus



- Extensible Plugin framework to support various data transfer protocols
  - mdtmFTP, GridFTP, XrootD

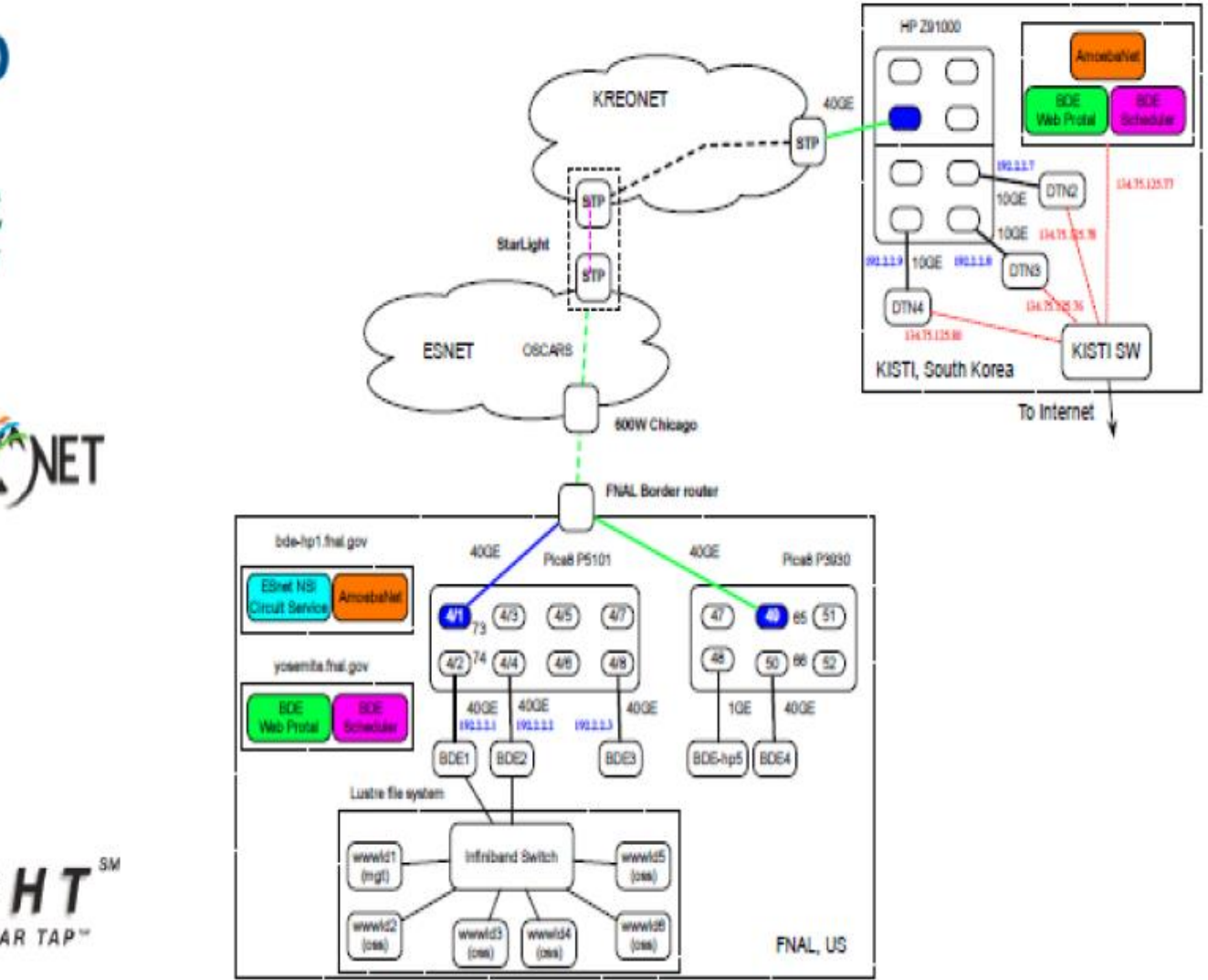
Miscellaneous

- Apache 2.0 License
- Docker release is available at publicregistry.fnal.gov
- Manuals:
  - Admin: https://bigdataexpress.fnal.gov/admin_manual/index.html
  - Web portal user: https://bigdataexpress.fnal.gov/portal_manual/index.html
- Deployment and collaborations

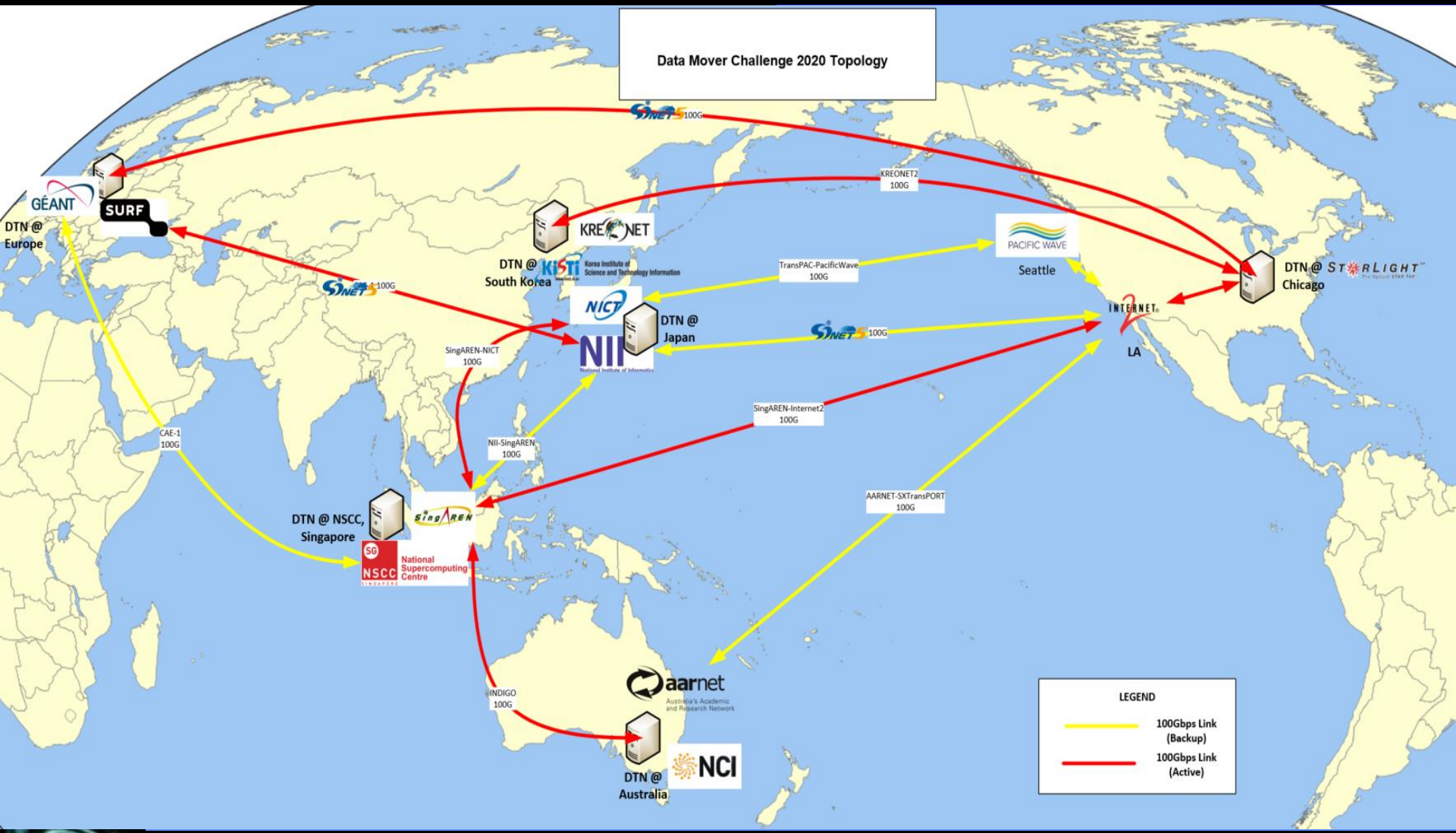
KISTI KREONET MAX ciena AutoLight KSTAR STARLIGHT NCI

STARLIGHT℠

A Cross-Pacific SDN Testbed



Supercomputing Asia Data Mover Challenge 2020



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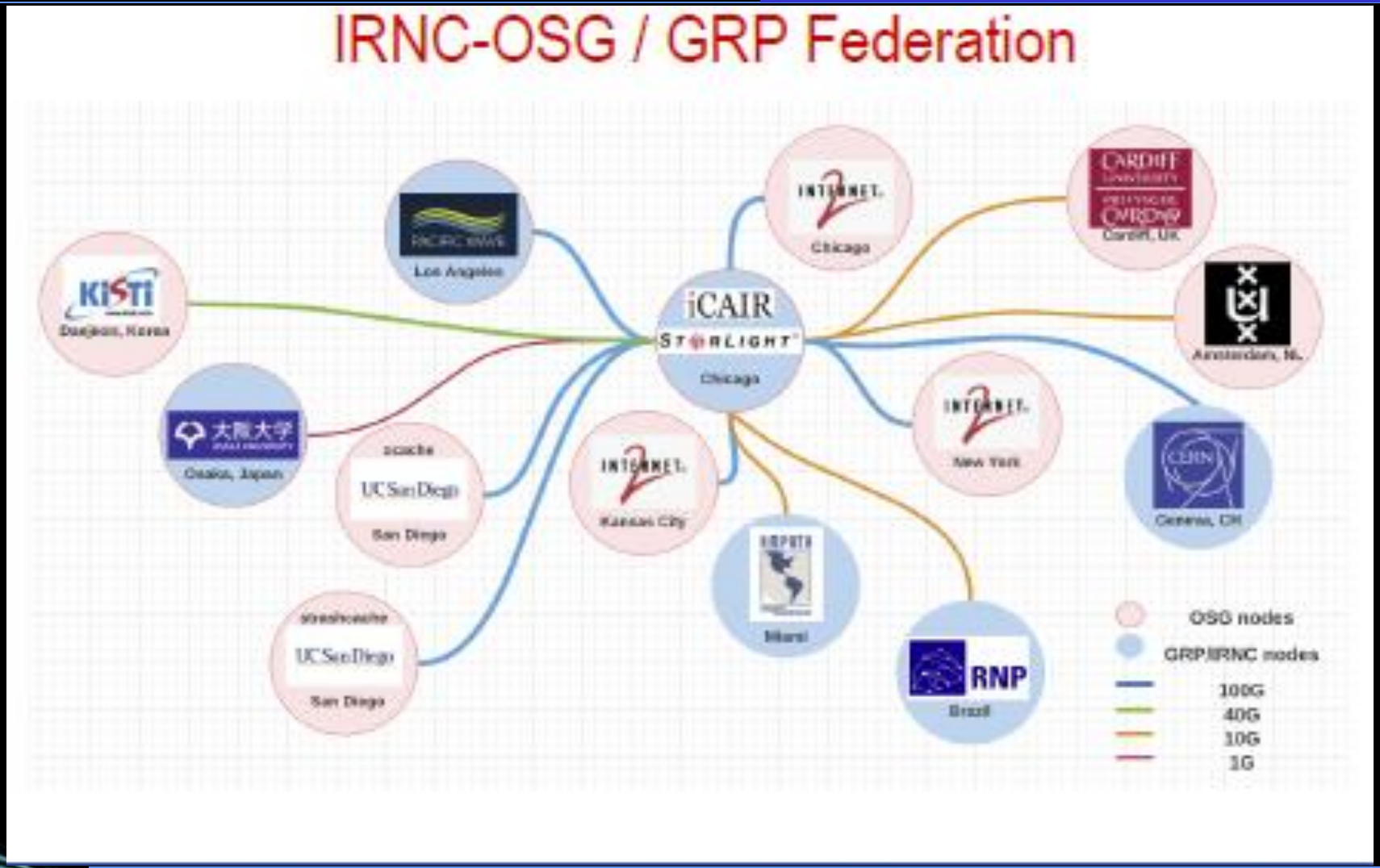
IRNC-OSG Global Fabric



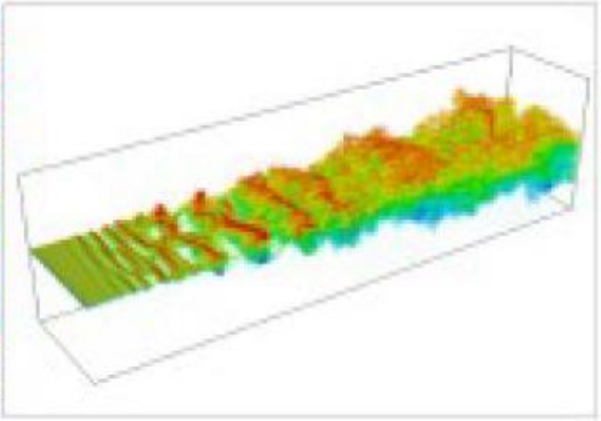
Composable Platform as a Service

Instrument for Deep Learning & Visualization (COMPaaS DLV)

Using the *Liqid* Composable Infrastructure System to Demonstrate...

...interoperable Science DMZs and Data Transfer Nodes (DTNs) at a national/ international scale, using best strategies from the Pacific Research Platform (PRP) over the GLIF infrastructure.

...SAGE2™, the *de facto* operating system for managing Big Data on tiled-display walls, enabling local and remote collaborators to access, share and interact with a variety of digital media.



...on-demand post-processing and visualization of a UIC Mechanical Engineering high-fidelity CFD simulation that, on a supercomputer, generates ~11TB worth of data for four simulations.

evl

Electronic Visualization Laboratory
University of Illinois at Chicago
https://www.evl.uic.edu

NSF award CNS-1828265 to UIC/EVL for COMPaaS DLV
https://www.evl.uic.edu/compaas-dlv

SAGE2 is trademark of the University of Illinois Board of Trustees

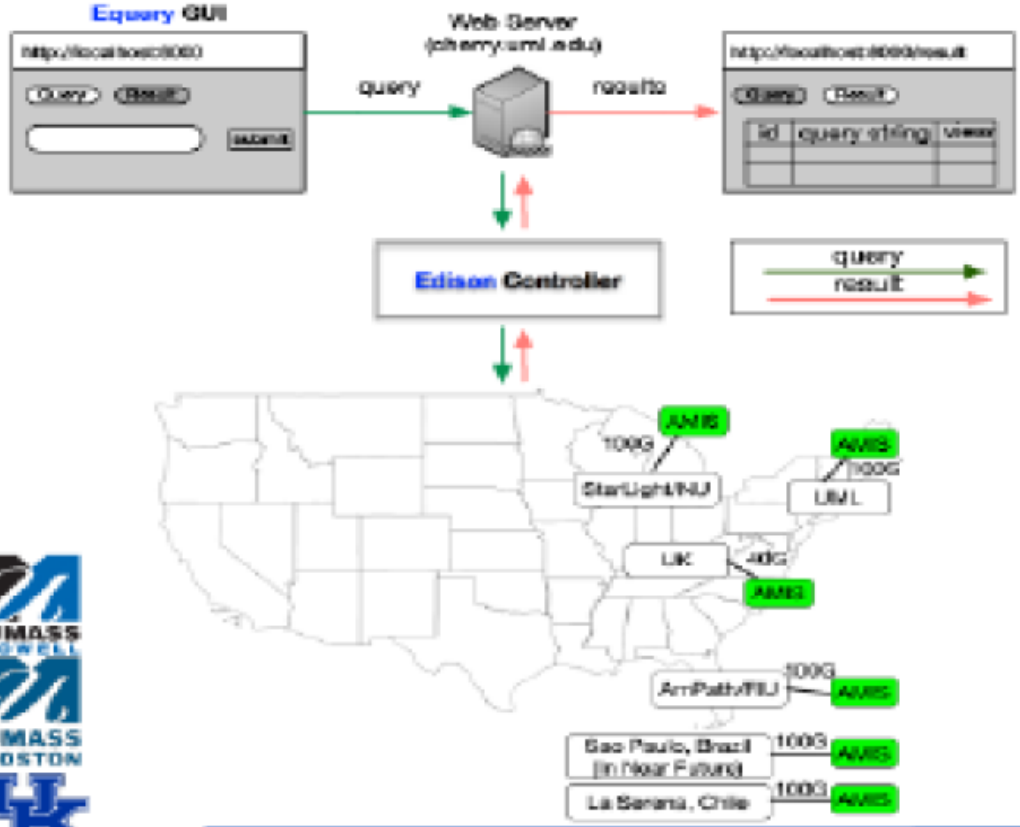
Liqid: https://www.liqid.com/
PRP: https://prp.ucsd.edu
GLIF: https://www.glif.is
SAGE2: http://sage2.sagecommons.org/
CFD simulation: https://cmtl.uic.edu

Global P4 Experiment Network(G-P4EN)

AMIS: Advanced Measurement Instrument and Services for Programmable Network Measurement of Data Intensive Flows

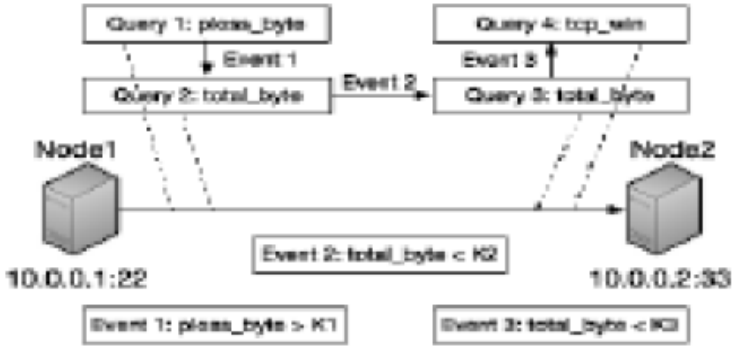
Yan Luo, U. of Massachusetts Lowell; Gabriel Ghinita, U. of Massachusetts Boston;
Cody Bumgardner, U. of Kentucky; Michael McGarry, U. of Texas El Paso

AMIS framework for programmable measurement



Equery: event driven measu

- q1: select ploss_byte where src_addr=10.0.0.1, dst_addr=10.0.0.2, src_port=22, dst_port=33, protocol=TCP, node_id=Node1;
- q2: select total_byte where src_addr=10.0.0.1, dst_addr=10.0.0.2, src_port=22, dst_port=33, protocol=TCP, node_id=Node1 when q1.ploss_byte > K1;
- q3: select total_byte where src_addr=10.0.0.1, dst_addr=10.0.0.2, src_port=22, dst_port=33, protocol=TCP, node_id=Node2 when q2.total_byte < K2;
- q4: select tcp_win where src_addr=10.0.0.1, dst_addr=10.0.0.2, src_port=22, dst_port=33, protocol=TCP, node_id=Node2 when q3.total_byte < K3;



This project is supported by US National Science Foundation (No. 1450937,1450975,1450996,1450997)
Collaborators: Joe Mambretti, Jim Chen and Fei Yeh, StarLight/iCAIR/Northwestern University;
Jeronimo Bezerra, Julio Ibarra, AMPATH/Florida International University

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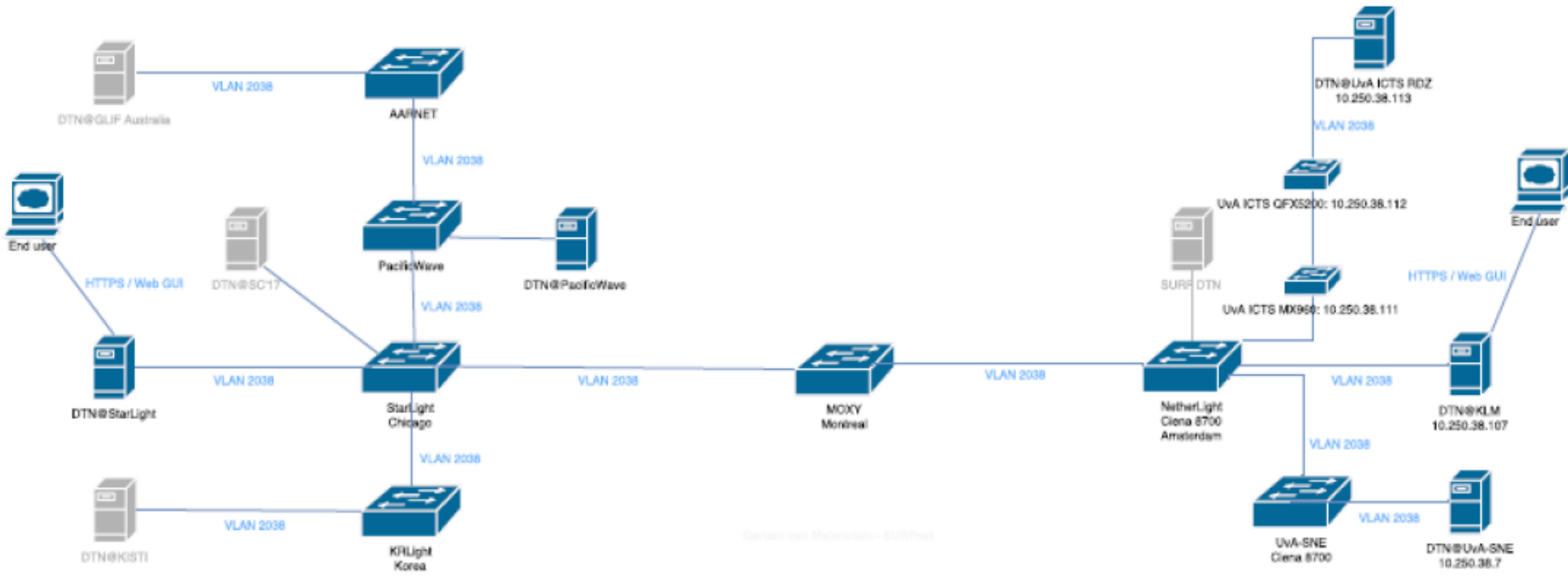
Transferring LargeScale Airline Data E2E Across WANs Using DTNs

v5, 21 SEP 2017



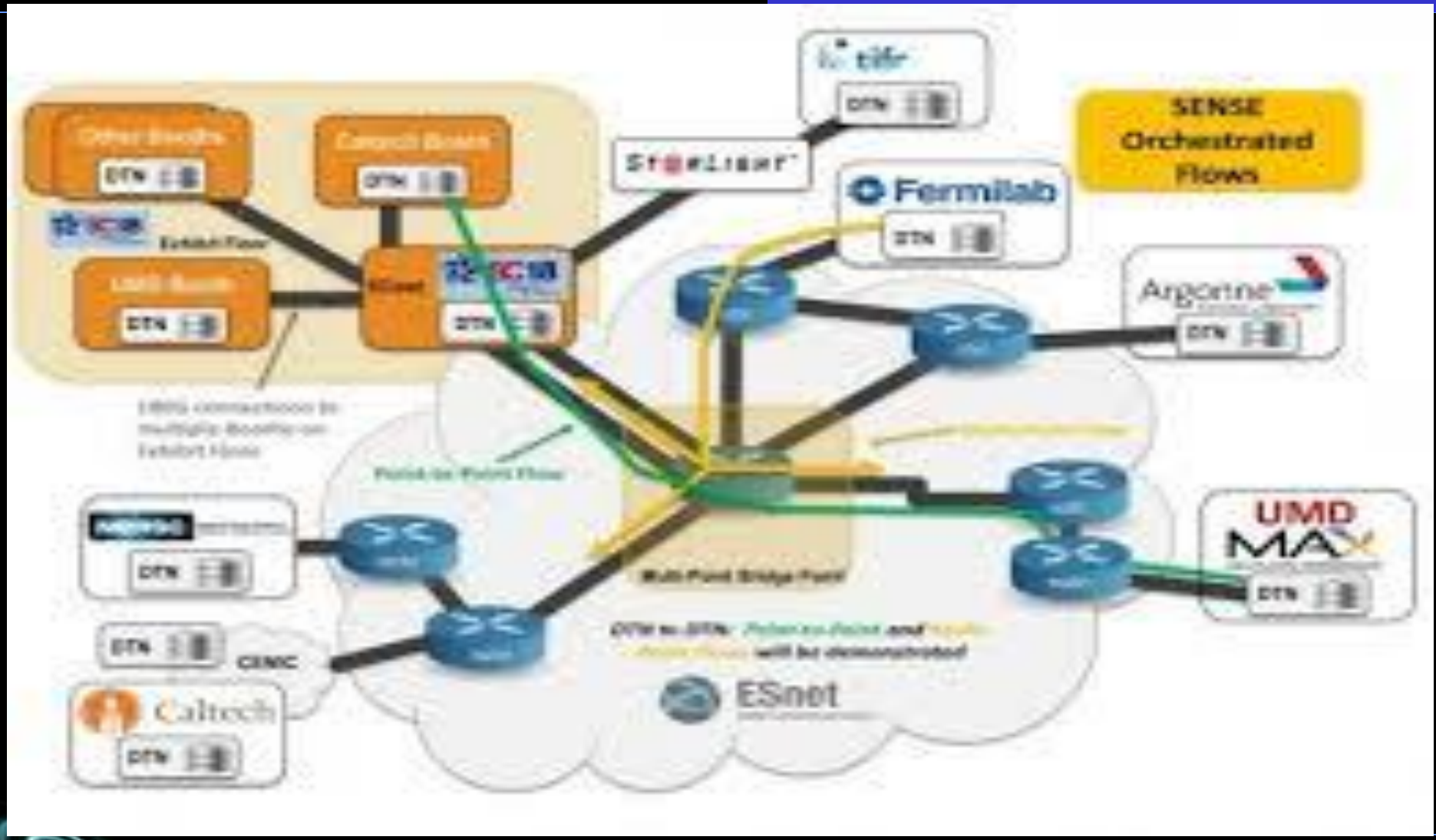
Ingredients
- Using Globus Toolkit (NOT Globus Online)
- Has GridFTP under the hood
- Under Globus license (must be evaluated)
- 40Gbit/s data transfer expected
- VLAN 2038, multipoint/extending
- Including authentication/authorization framework, e.g. SURFconext

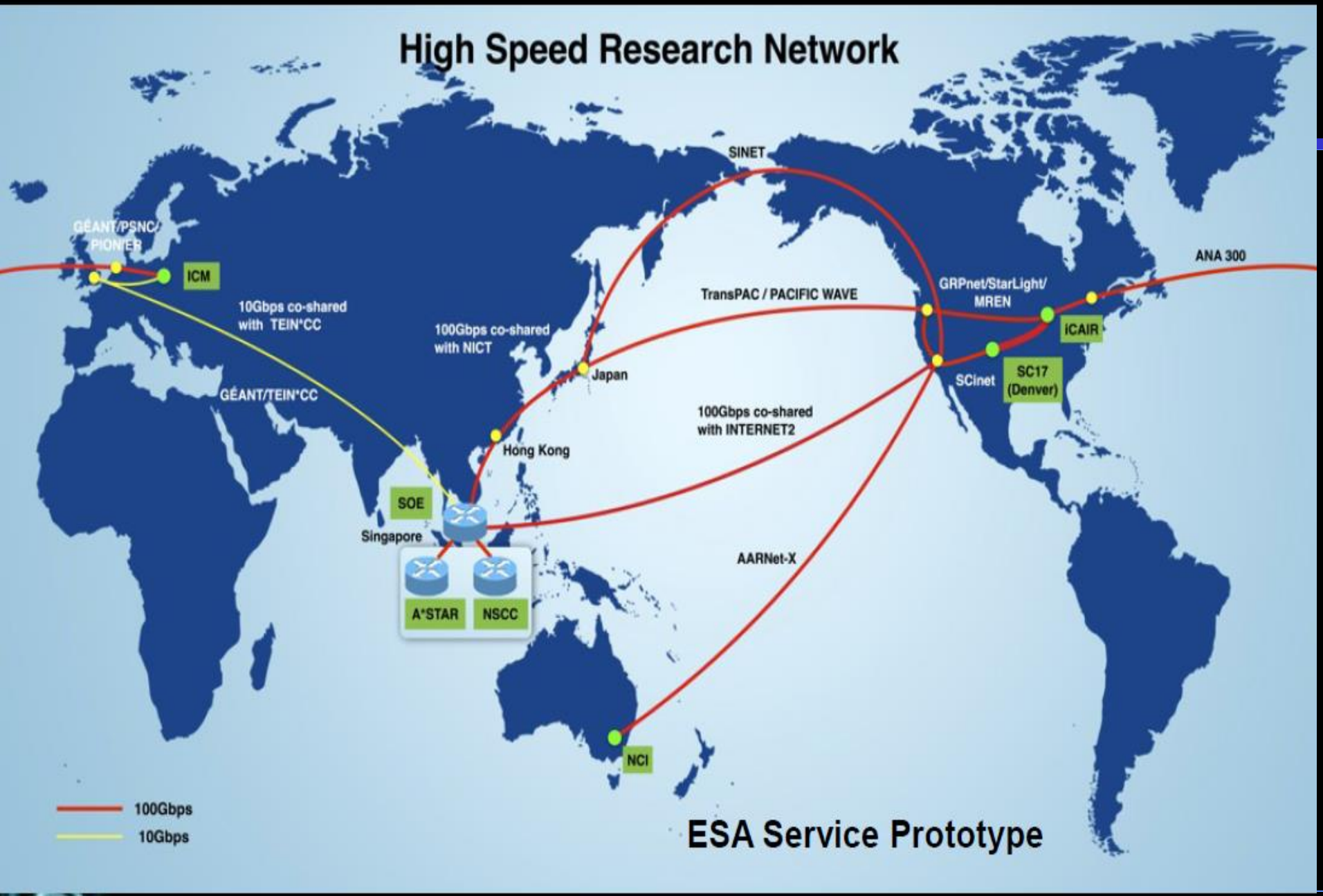
Minimal setup
- Data transfer between DTN@UvA to DTN@StarLight at 40G
- Compare this to IPv4 performance Chicago-Amsterdam

Additional features
- Single Sign-On
- Comparison to IPv6
- Auto-deletion of file when transfer completed
- >40Gbps data transfer
- Expanding sites for GLIF and/or SC

Ideas
- Dutch Research LAN Project

SENSE Orchestration Testbed

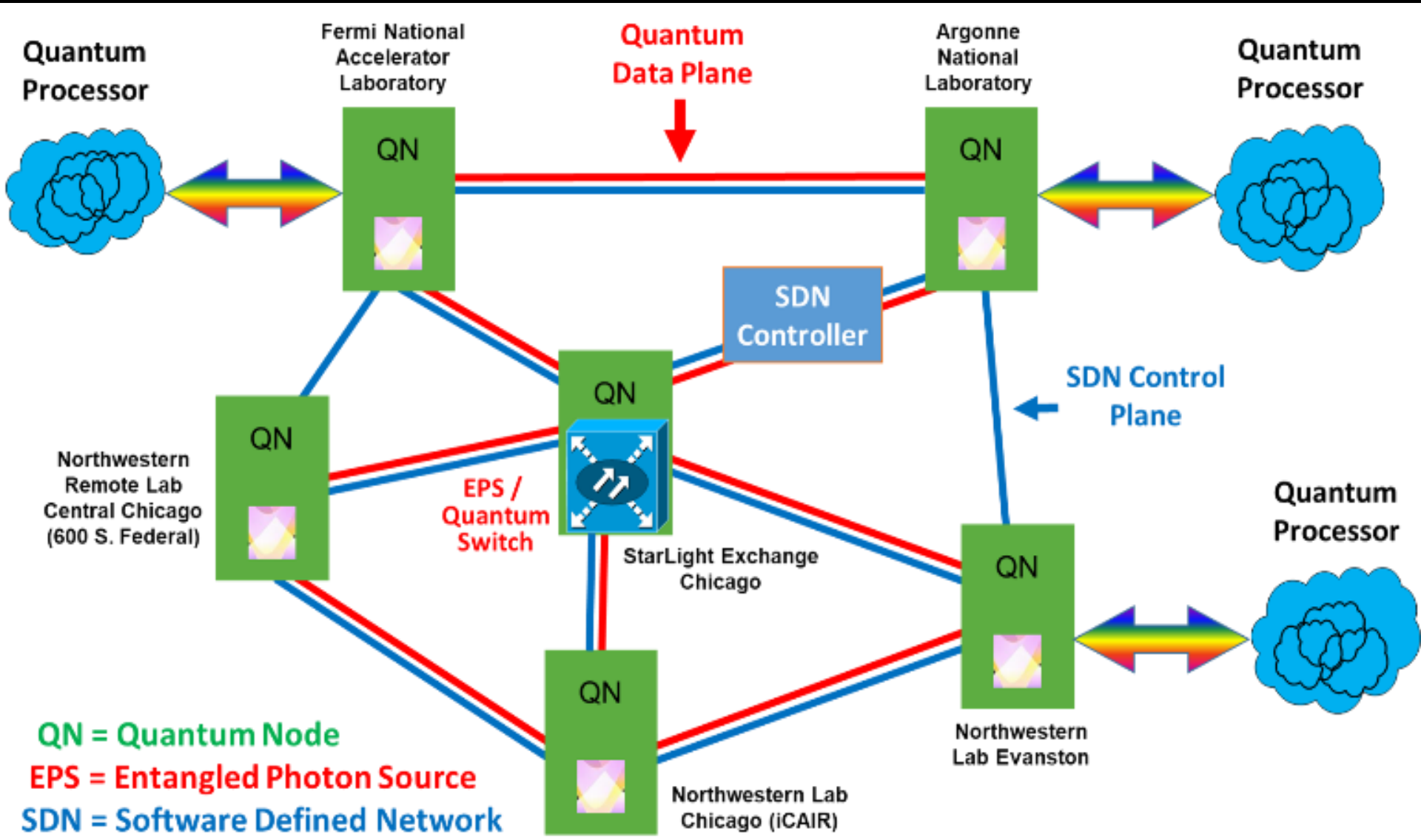



High Speed Research Network
SINET
GÉANT/PSNC/
PIONIER
ICM
10Gbps co-shared
with TEIN*CC
100Gbps co-shared
with NICT
TransPAC / PACIFIC WAVE
GRPnet/StarLight/
MREN
ANA 300
iCAIR
SCinet
SC17
(Denver)
Japan
GÉANT/TEIN*CC
100Gbps co-shared
with INTERNET2
Hong Kong
SOE
Singapore
AARNet-X
A*STAR
NSCC
NCI
100Gbps
10Gbps
ESA Service Prototype

National Quantum Science Initiative

- Multiple Federal Agency Initiatives
- Multiple Consortium Projects
- Multiple Topics
  - Physics
  - Quantum Science
  - Information Theory
  - Information Science
  - Optimization Theory
  - Materials Science
  - Quantum Components
  - Quantum Computing
  - Quantum Communications
  - Quantum Networking
- Multiple Projects: Chicago Quantum Exchange, Illinois Quantum Express Et Al

Planned Chicago Quantum Exchange Testbed



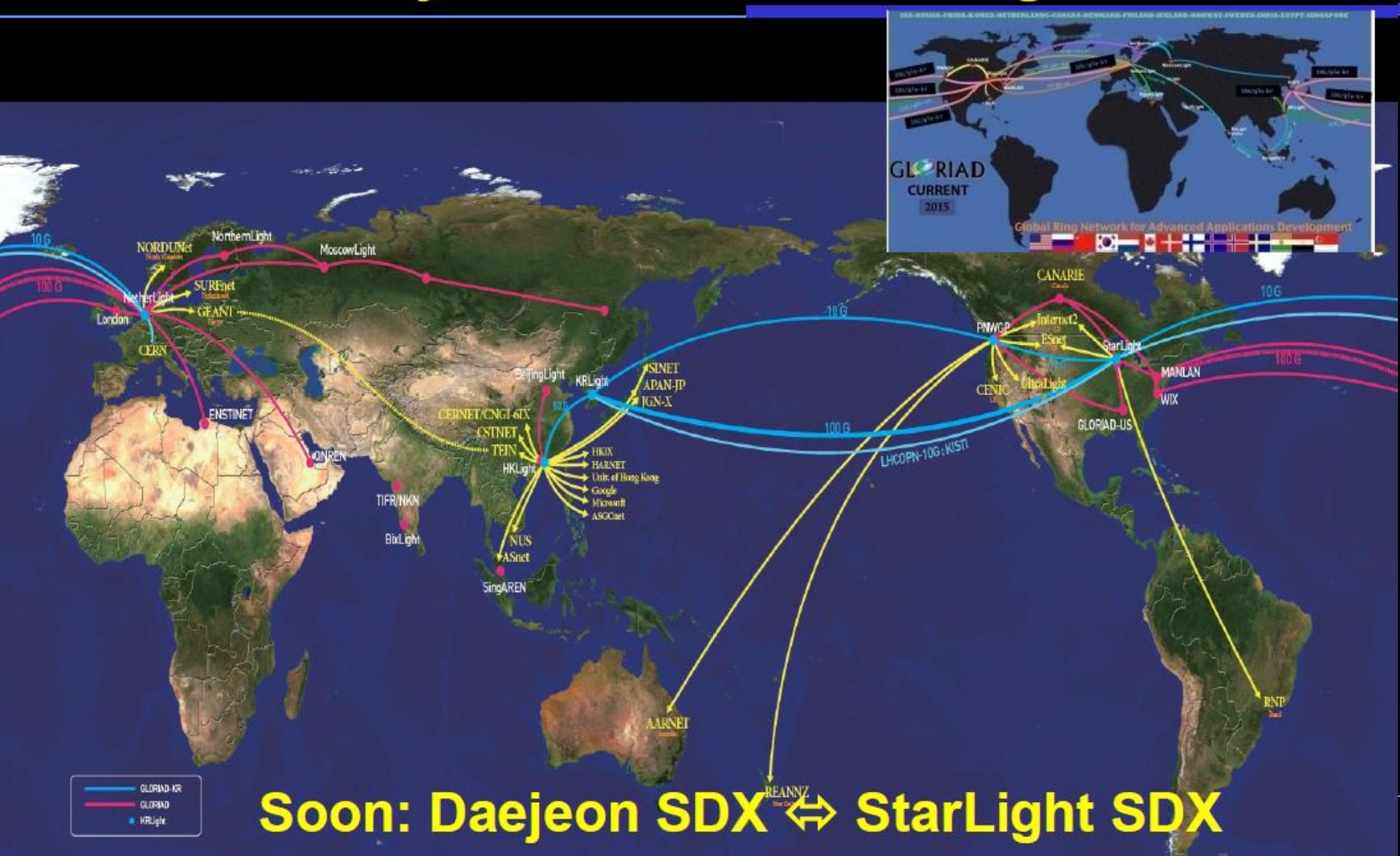
Ilya Baldine PI, RENCI: FABRIC

Next Generation Distributed Enviroment For Global Science

STARLIGHT℠

PACIFIC WAVE
INTERNATIONAL PEERING EXCHANGE
Global Research Platform Network
100 Gbps
StarLight
Global Research Platform

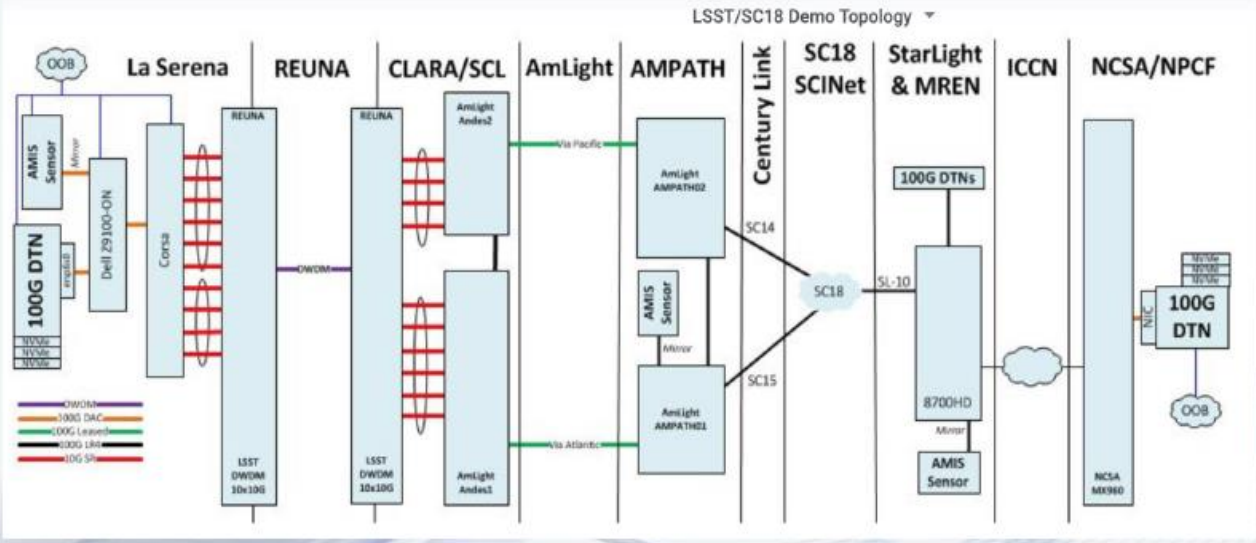
KREONet2 SD-WAN GLORIAD-KR
KISTI Daejeon ⇔ 100 G ⇔ StarLight



Soon: Daejeon SDX ⇔ StarLight SDX

KRLight
KREONET
STARLIGHT SDX
KASI/
KISTI
@Daejeon
100Gbps
100Gbps
SC18@
Dallas
60Gbps
AMLIGHT
LLST Base Site
@La Serena
RØDNA
CLARA

US LUA
ESnet
Fermilab
CERN
INTERNET2
AMLIGHT
YALE
STARLIGHT
The Optical STAR TAP
SURF NET
Argonne
PRP
PACIFIC RESEARCH PLATFORM
BERKELEY LAB
tifr
KISTI
CENIC
PACIFIC WAVE
PACIFIC NORTHWEST GIGAPOP
+ INDUSTRY


LSST/SC18 Demo Topology
OOB
La Serena
REUNA
CLARA/SCL
AmLight
AMPATH
Century Link
SC18 SCINet
StarLight & MREN
ICCN
NCSA/NPCF
AMIS Sensor
Mirror
100G DTN
Dell Z9100-ON
Corsa
REUNA
DWDM
LSST DWDM 10x10G
AmLight Andes2
AmLight Andes1
Via Pacific
Via Atlantic
AmLight AMPATH02
AmLight AMPATH01
SC14
SC15
SC18
SL-10
100G DTNs
8700HD
NCSA MX960
NIC
100G DTN
OOB

www.startap.net/starlight

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