

# Software Defined Network Exchanges (SDXs): Services, Architecture, Technology, and Future Directions

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Director, Metropolitan Research and Education Network ([www.mren.org](http://www.mren.org))

Director, StarLight, PI- StarLight SDX, Co-PI Chameleon, PI-iGENI, PI-  
OMNINet, ([www.startap.net/starlight](http://www.startap.net/starlight))

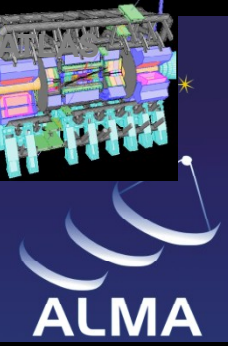
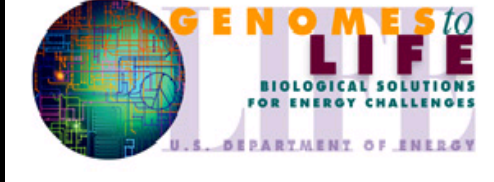
GENI Engineering Conference (GEC24)

Arizona State University

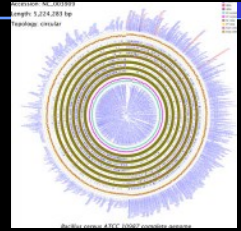
Tempe, Arizona

March 8-9, 2016

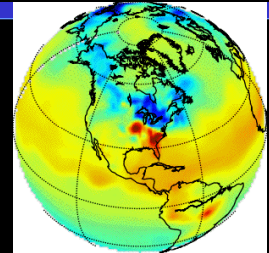




BIRN: Biomedical Informatics Research Network  
[www.nbirn.net](http://www.nbirn.net)



CAMERA metagenomics  
[camera.calit2.net](http://camera.calit2.net)



Carbon Tracker  
[www.esrl.noaa.gov/gmd/ccgg/carbontrack](http://www.esrl.noaa.gov/gmd/ccgg/carbontrack)



CineGrid  
[www.cinegrid.org](http://www.cinegrid.org)



LHCONE  
[www.lhccone.net](http://www.lhccone.net)

ALMA: Atacama Large Millimeter Array

ANDRILL: Antarctic Geological Drilling  
[www.andrill.org](http://www.andrill.org)



GLEON: Global Lake Ecological Observatory Network



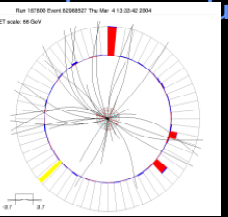
OOI-CI  
[ci.oceanobservatories.org](http://ci.oceanobservatories.org)



ISS: International Space Station  
[www.nasa.gov/station](http://www.nasa.gov/station)



Comprehensive Large-Array Stewardship System  
[www.class.noaa.gov](http://www.class.noaa.gov)



DØ (DZero)  
[www-d0.fnal.gov](http://www-d0.fnal.gov)



GEON: Geosciences Network  
[www.geongrid.org](http://www.geongrid.org)



LIGO  
[www.ligo.org](http://www.ligo.org)



WLCG  
[lcg.web.cern.ch/LCG/public/](http://lcg.web.cern.ch/LCG/public/)



PRAGMA  
Pacific Rim Applications and Grid Middleware Assembly  
[www.pragma-grid.net](http://www.pragma-grid.net)



TeraGrid  
[www.teragrid.org](http://www.teragrid.org)



IVOA: International Virtual Observatory  
[www.ivoa.net](http://www.ivoa.net)



OSG  
[www.opensciencegrid.org](http://www.opensciencegrid.org)



Globus Alliance  
[www.globus.org](http://www.globus.org)



SKA  
[www.skatelescope.org](http://www.skatelescope.org)



Sloan Digital Sky Survey  
[www.sdss.org](http://www.sdss.org)



XSEDE  
[www.xsede.org](http://www.xsede.org)



Compilation By Maxine Brown

# StarLight – “By Researchers For Researchers”

**StarLight: An Experimental  
Optically Based Infrastructure  
& Proving Ground For Next  
Gen Network Services** Optimized  
for  
High-Performance Data Intensive  
Science Applications  
Multiple  
10GE+100 Gbps  
StarWave  
Multiple 100 Gbps  
Over Optics –  
World’s “Largest”  
10G/100G Exchange  
Enabling Interoperability  
At L1, L2, L3

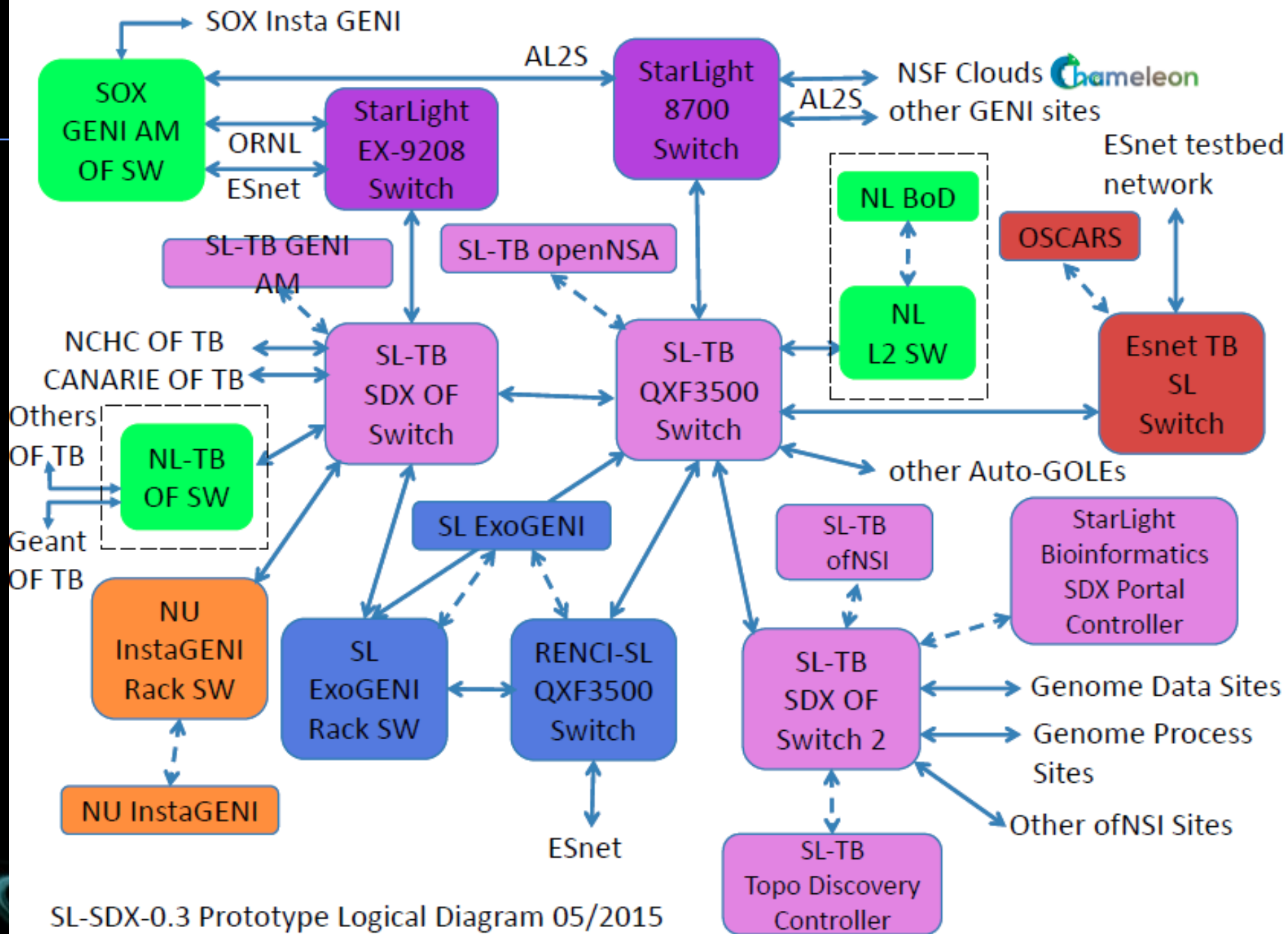


View from StarLight



Abbott Hall, Northwestern University's  
Chicago Campus





SL-SDX-0.3 Prototype Logical Diagram 05/2015

# iCAIR: Founding Partner of the Global Lambda Integrated Facility Available Advanced Network Resources



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

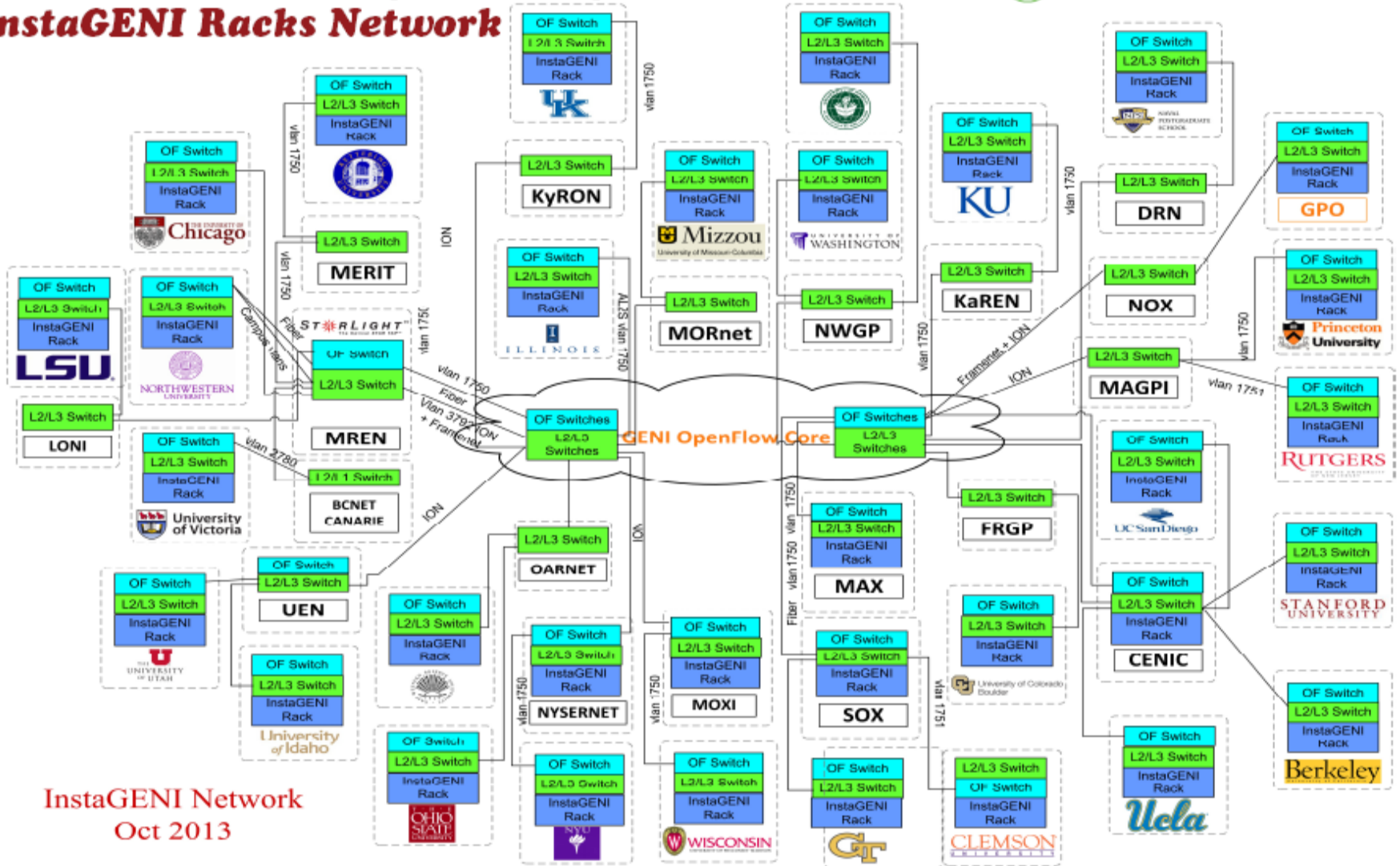


[www.glif.is](http://www.glif.is)



# National Science Foundation Global Environment for Network innovations

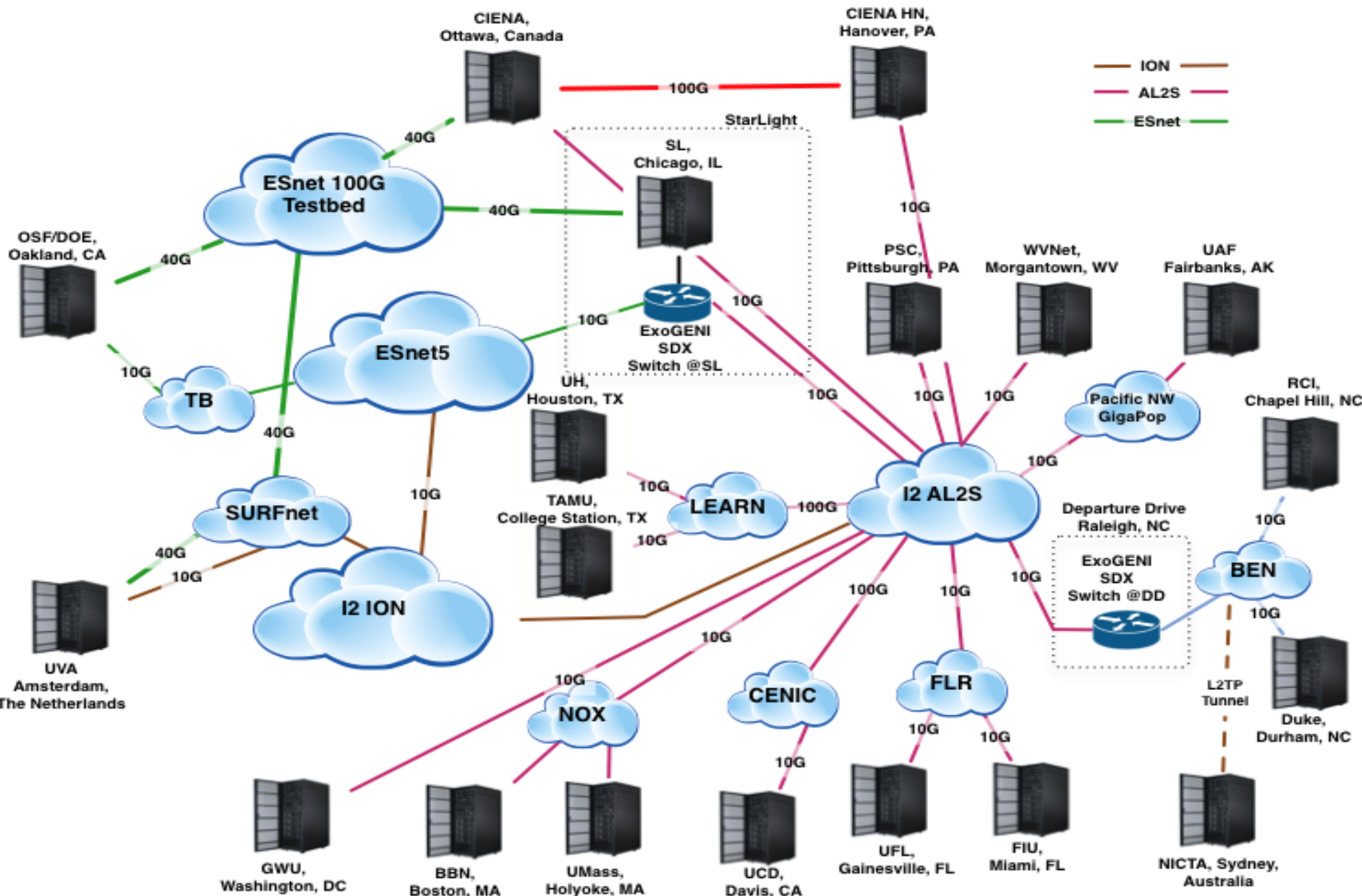
## InstaGENI Racks Network

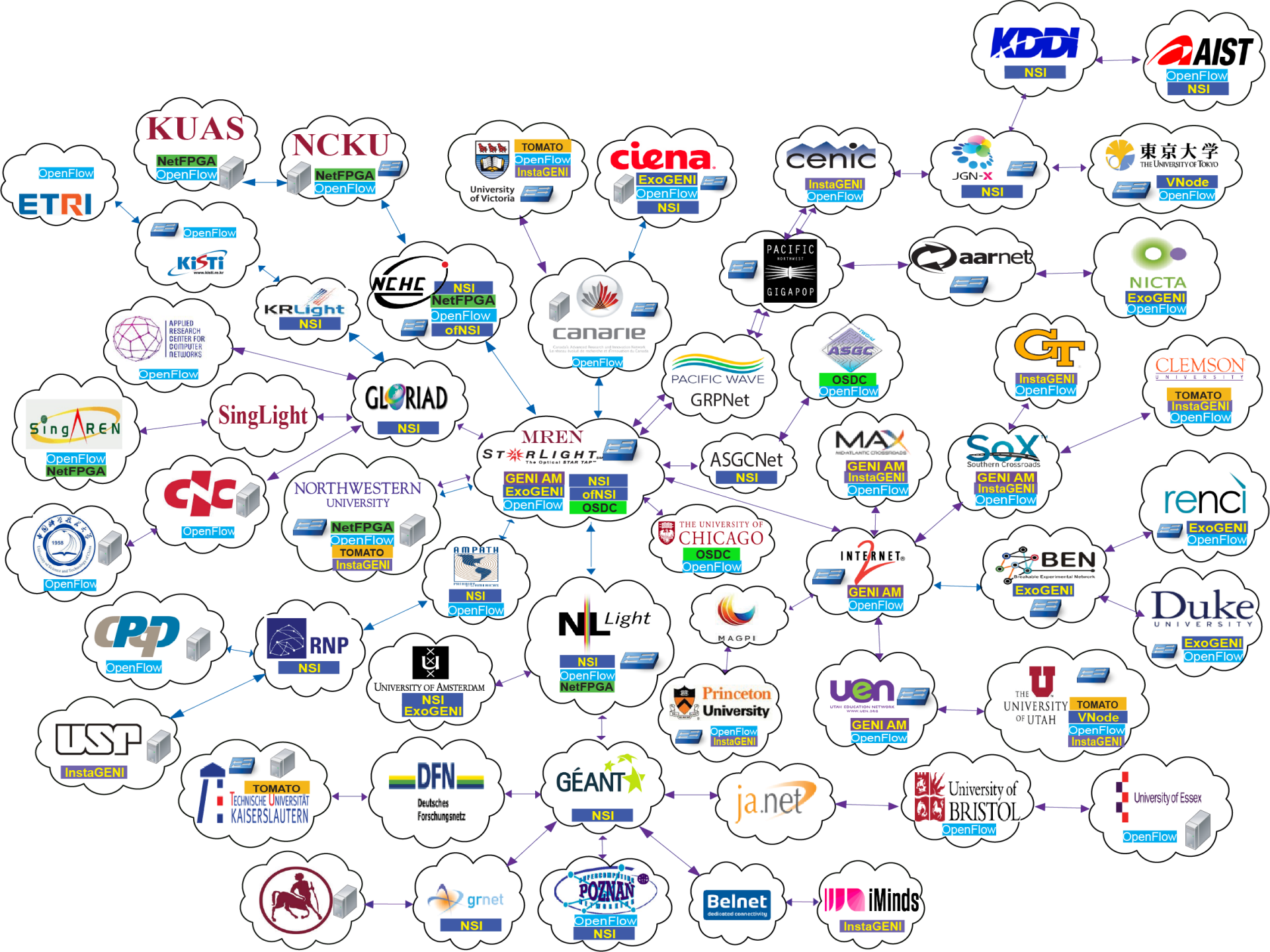


InstaGENI Network  
Oct 2013



# International 40G and 100 G ExoGENI Testbed





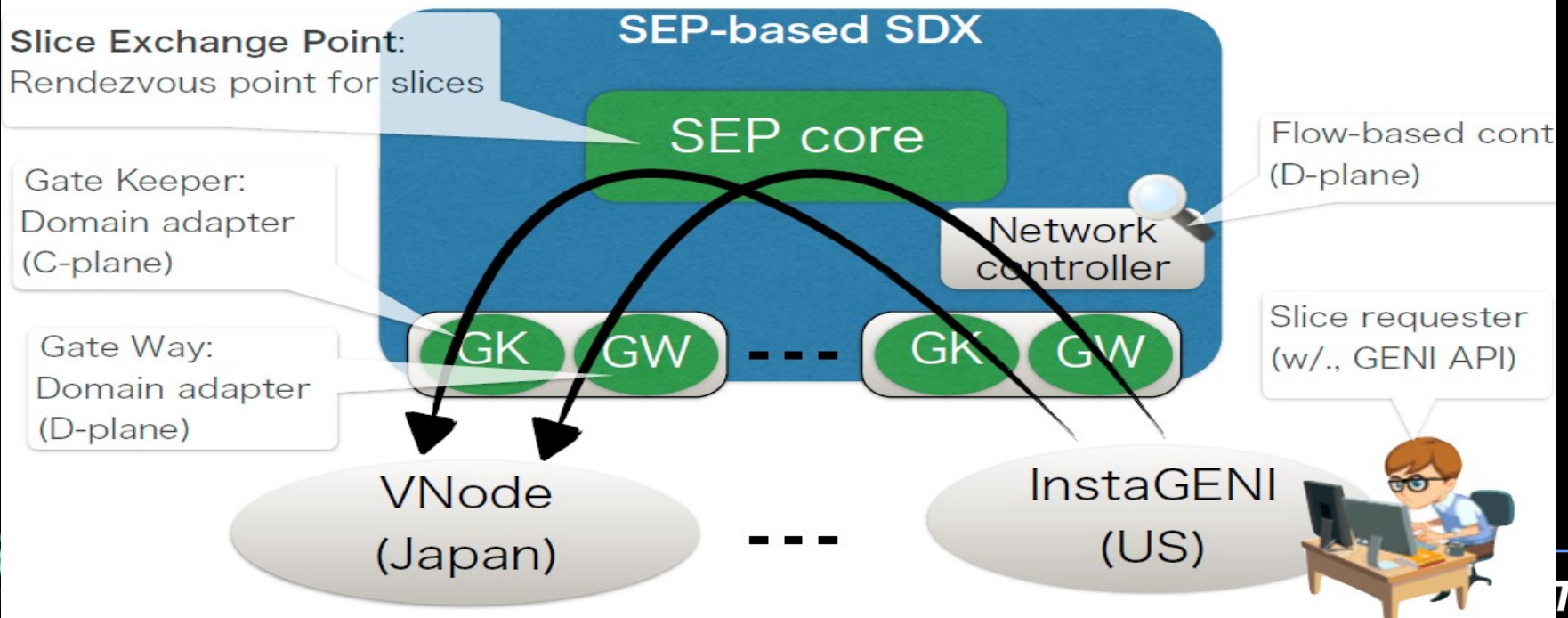


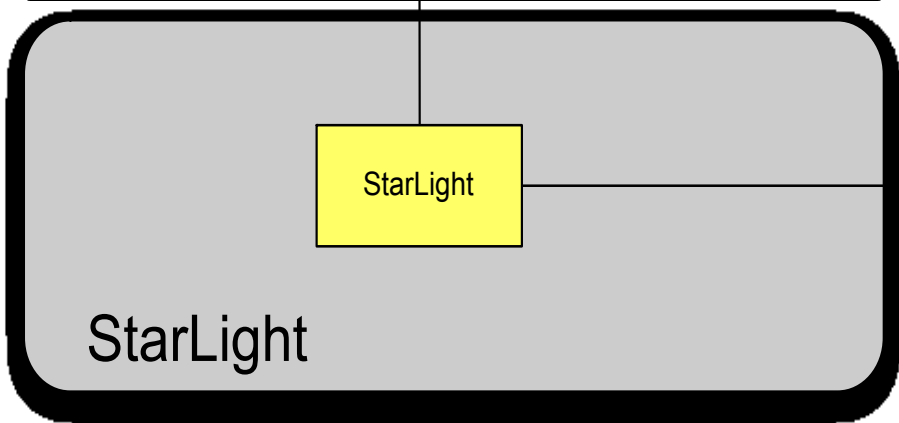
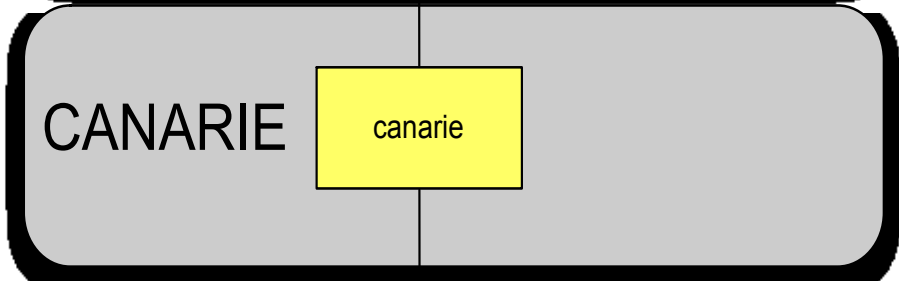
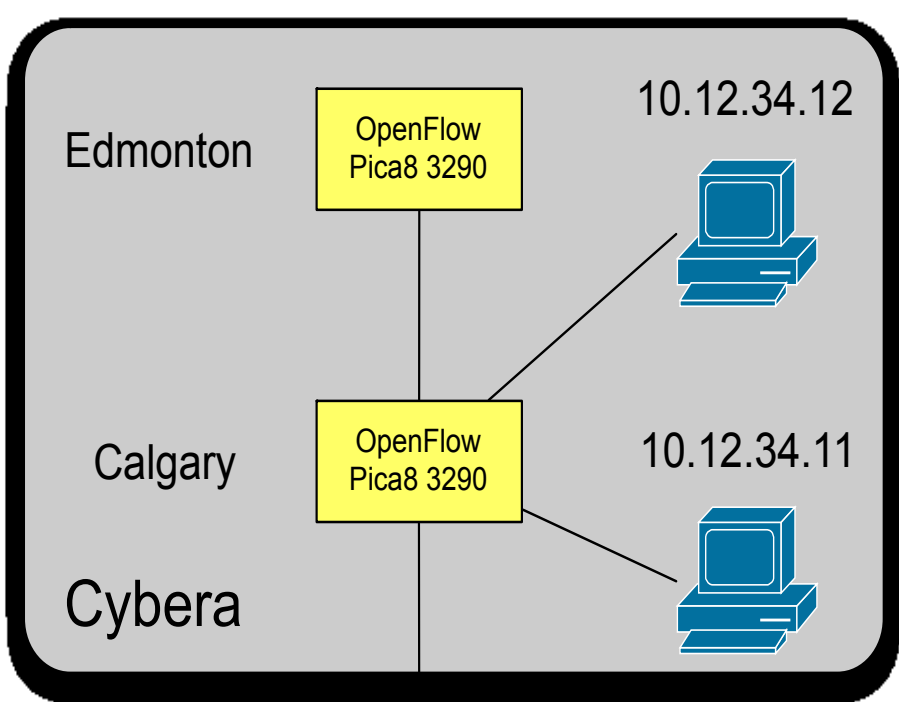
# Slice Exchange Showcase: Special Thanks To Aki Nakao

## Japan-US Slice Exchange over SDX

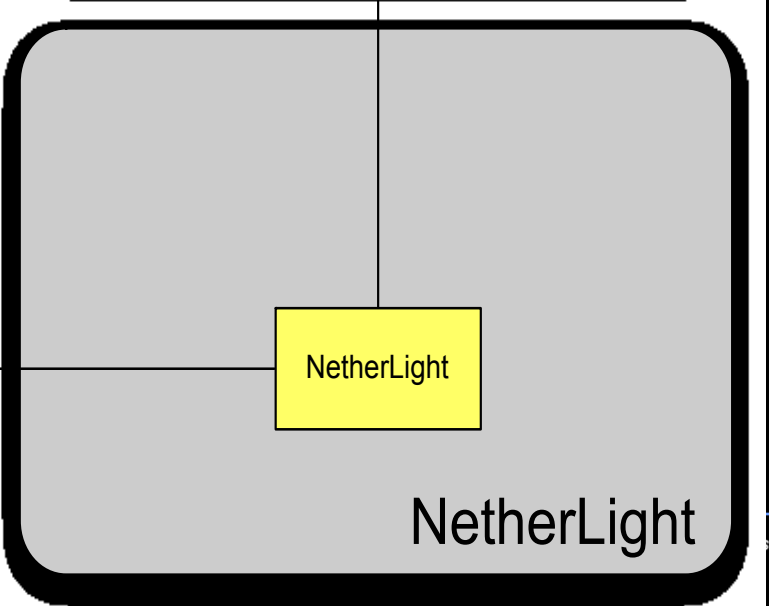
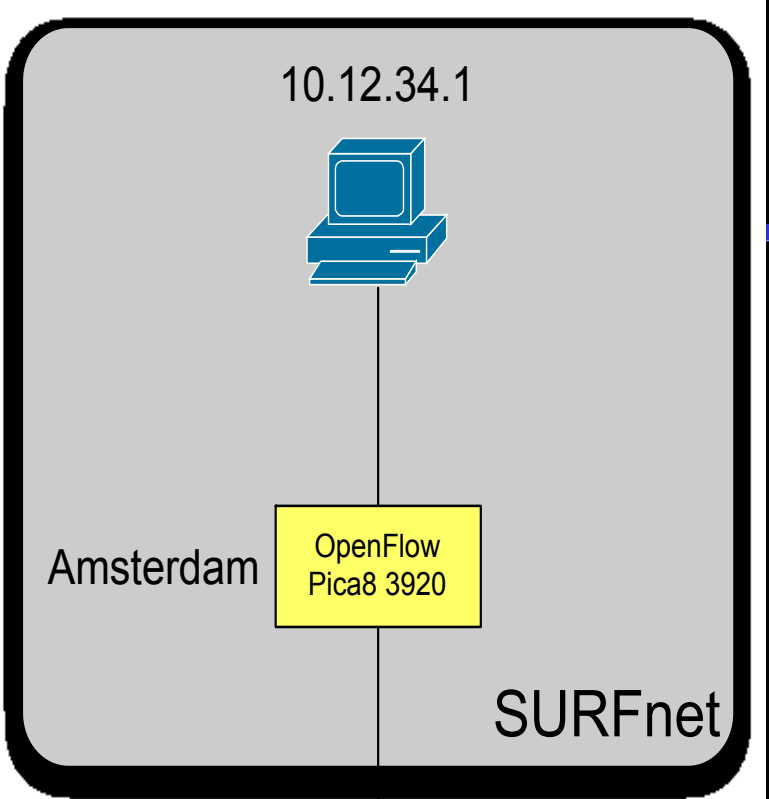


### Slice Exchange Architecture





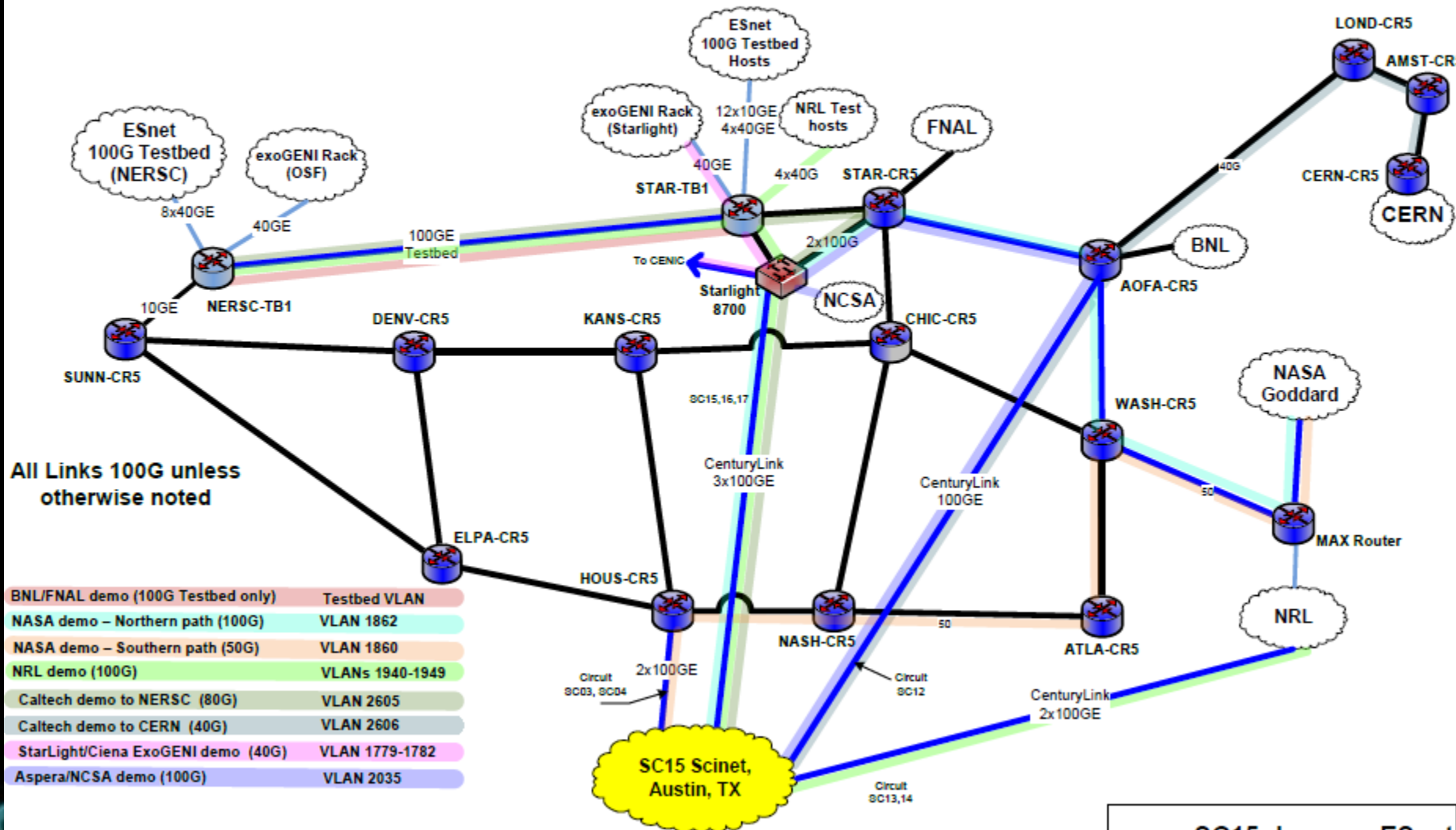
ACE





# ESnet

ENERGY SCIENCES NETWORK



All Links 100G unless otherwise noted

BNL/FNAL demo (100G Testbed only)	Testbed VLAN
NASA demo – Northern path (100G)	VLAN 1862
NASA demo – Southern path (50G)	VLAN 1860
NRL demo (100G)	VLANs 1940-1949
Caltech demo to NERSC (80G)	VLAN 2605
Caltech demo to CERN (40G)	VLAN 2606
StarLight/Ciena ExoGENI demo (40G)	VLAN 1779-1782
Aspera/NCSA demo (100G)	VLAN 2035

Other Demos 10G or Less:

- ESnet/RENCI demo: NERSC to ANL
- ESnet ENOS Demo: WASH, AMST, CERN
- ANL QoS Demo: DENV, ATLA

**SC15 demos – ESnet**  
 Brian Tierney, ESnet 11/6/2015

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FILENAME SC15-DEMOS-V9.VSD



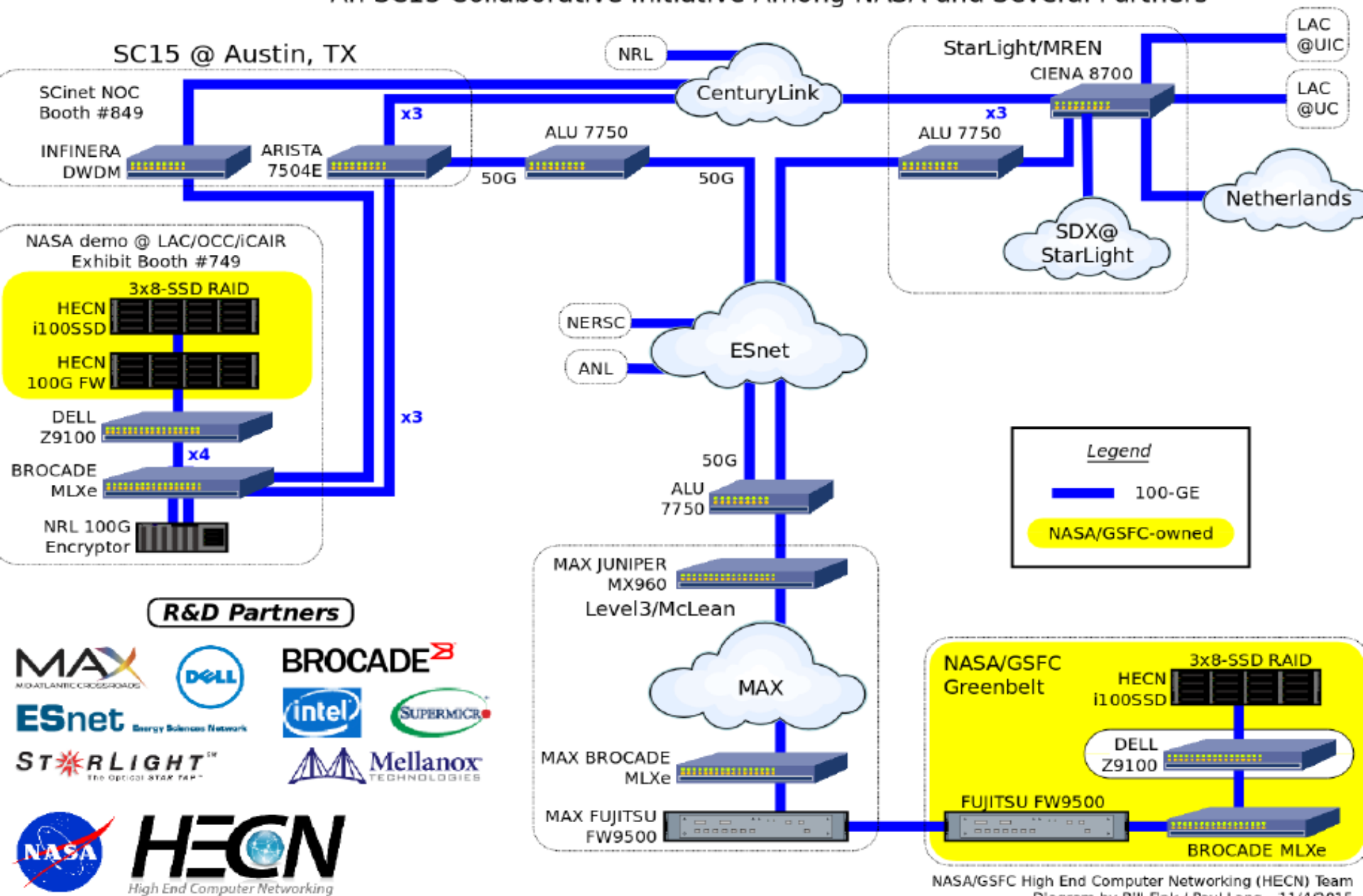
WAN providers

- ESNet
- CENIC
- CenturyLink
- NetherLight
- GEANT
- DFN
- RNP
- ANESP

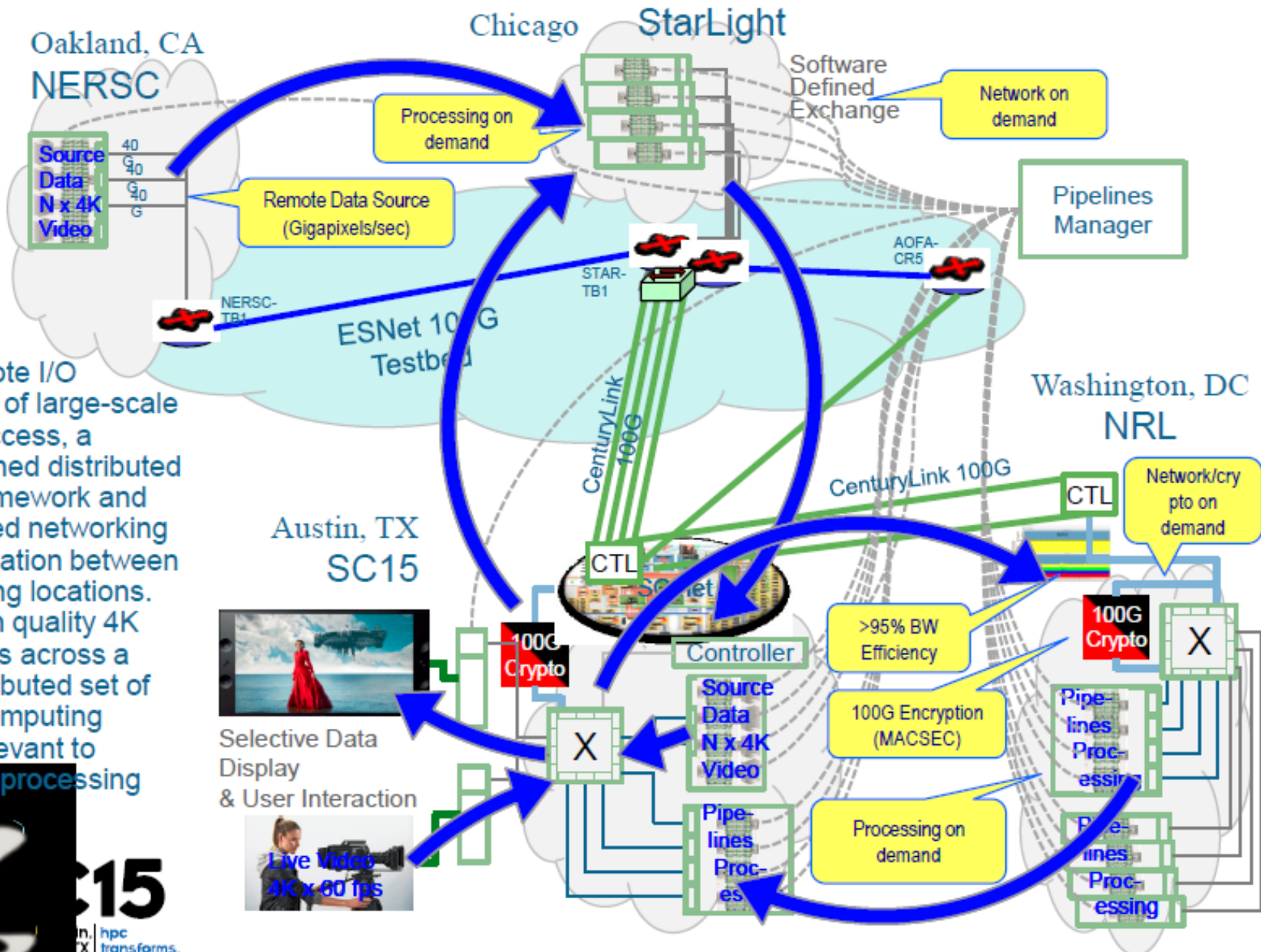
# SC15

## Demonstrations of 100 Gbps Disk-to-Disk WAN File Transfer Performance via SDX and 100G FW

An SC15 Collaborative Initiative Among NASA and Several Partners

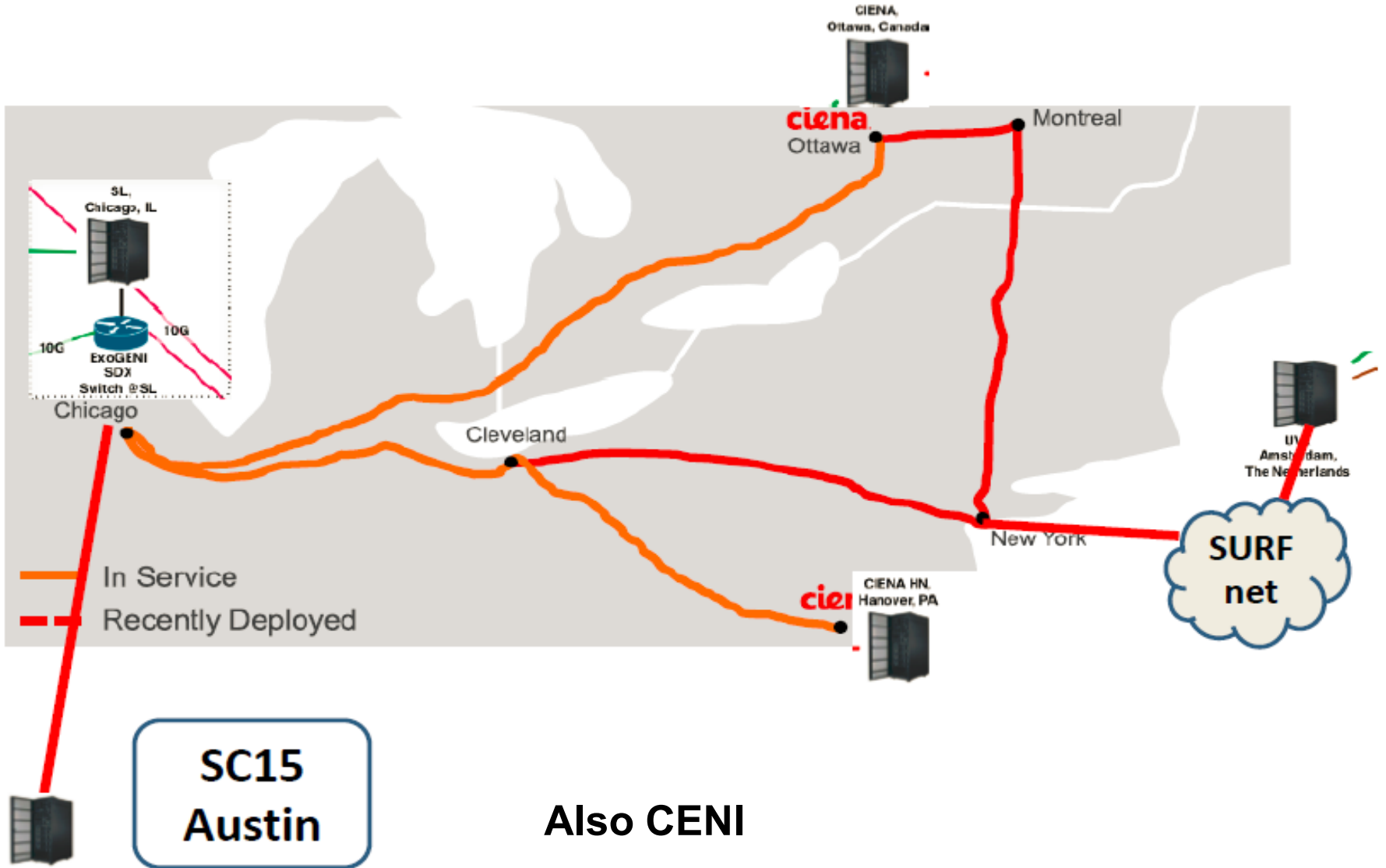


# Dynamic Remote I/O Network



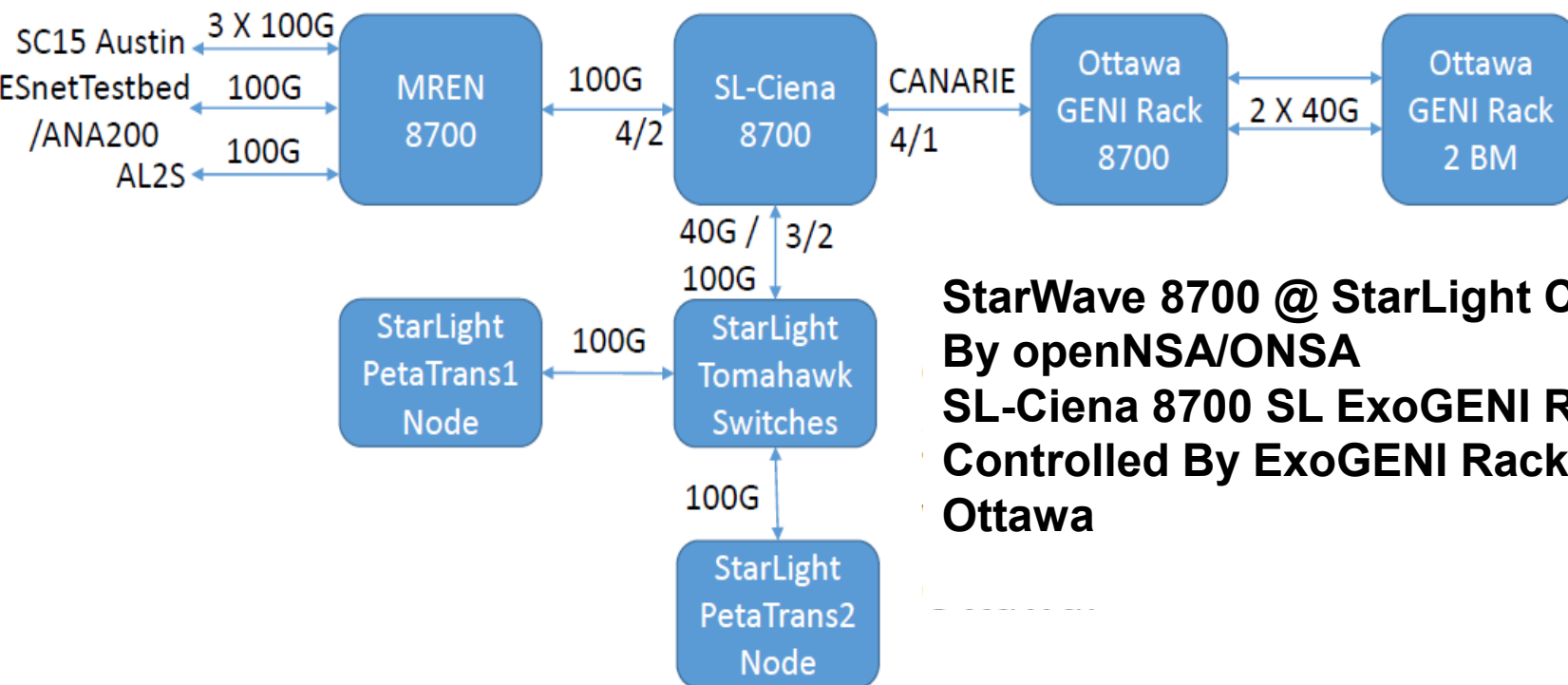
Dynamic Remote I/O Demonstration of large-scale remote data access, a dynamic pipelined distributed processing framework and software defined networking enabled automation between distant operating locations. Live production quality 4K video workflows across a nationally distributed set of storage and computing resources - relevant to emerging data processing challenges.





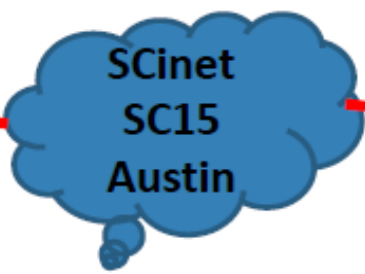
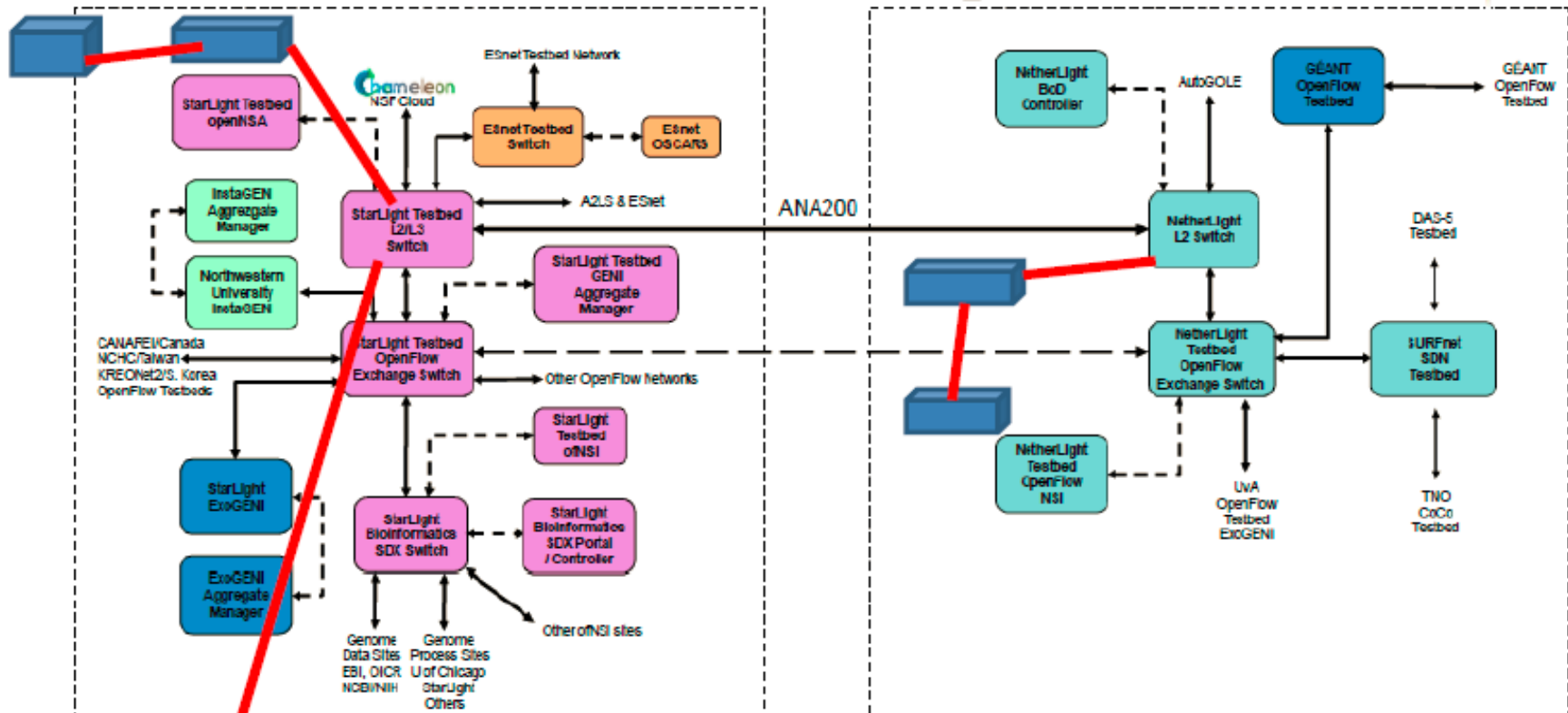
# Multi-Tenant 100 GE SDX

## Multi-Tenant 100GE Science Network Exchange SC15 NRE Testing Phase



**StarWave 8700 @ StarLight Controlled  
By openNSA/ONSA**  
**SL-Ciena 8700 SL ExoGENI Rack  
Controlled By ExoGENI Rack in  
Ottawa**



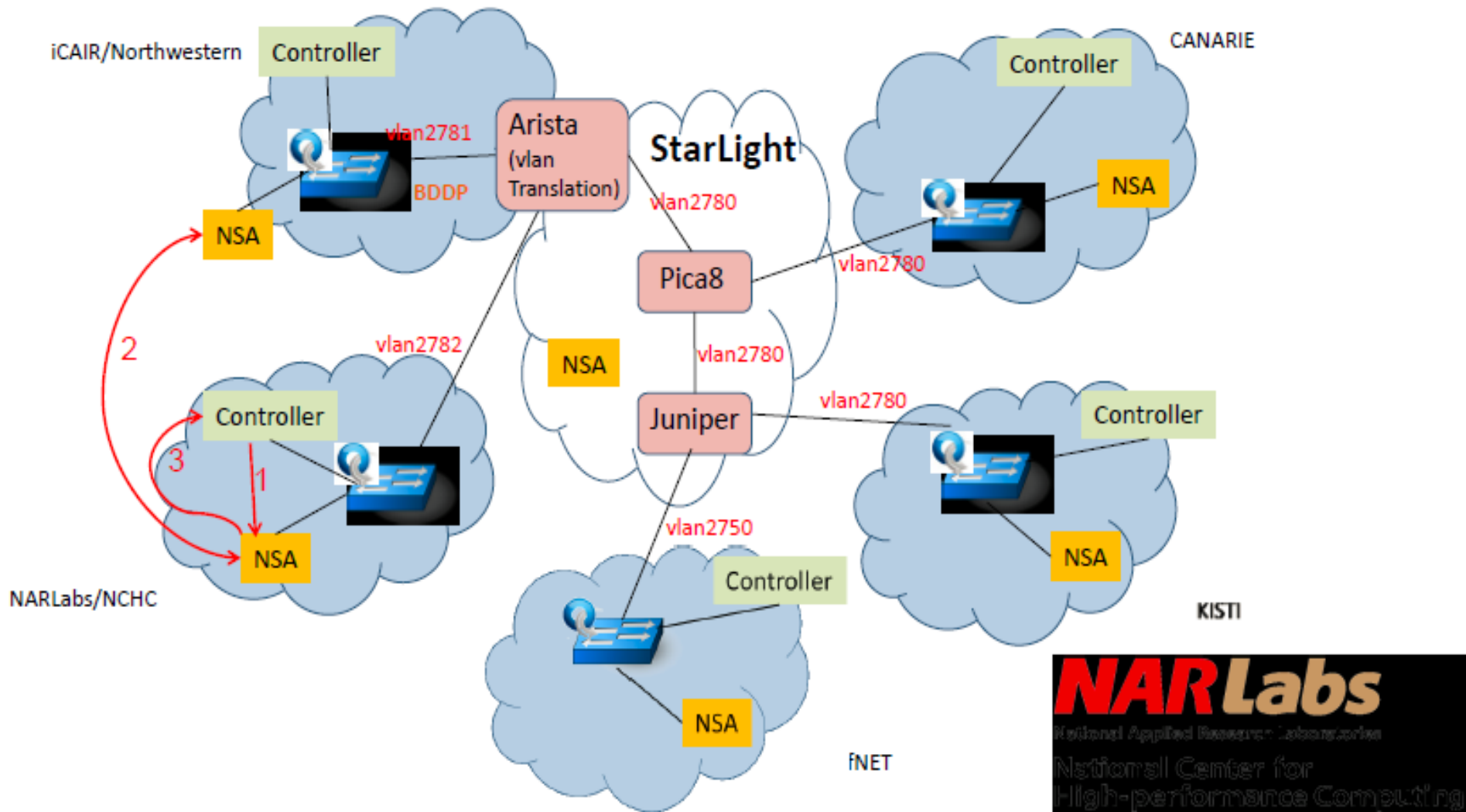


iCAIR Booth SC15



100 Gbps

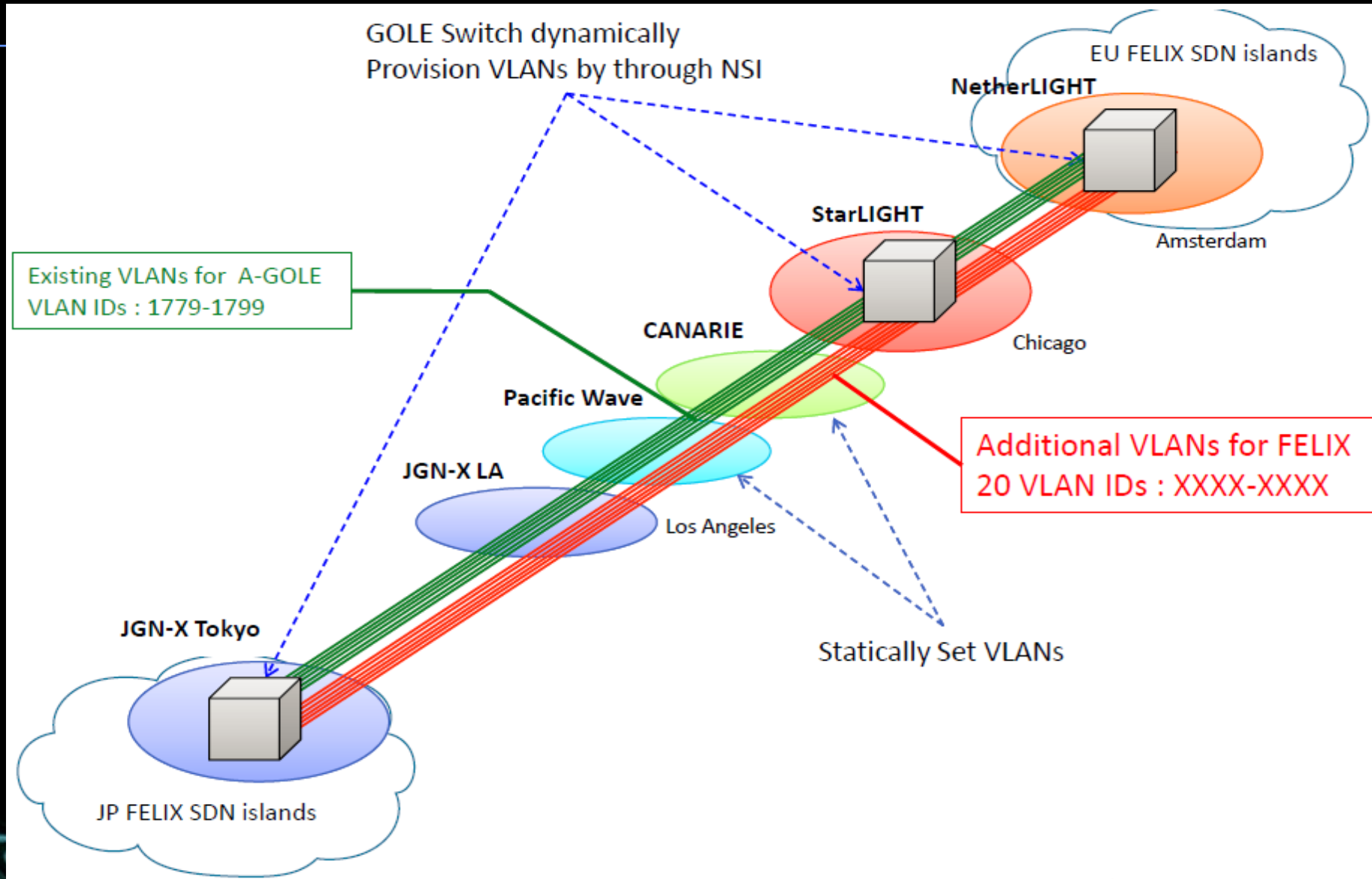
# NSI-OpenFlow Hybrid Topology Exchange



Coming Soon => Taiwan SDX



# FELIX Demonstrations



# **SDX Services For Multiple HPC Cloud Computing Testbeds & Production Cloud Facilities Specifically Designed for Science Research**



⇒ **Open Commons Consortium**

⇒ **Multiple OCC Demonstrations @ SC15**

**At Scale Experimentation**

**The OCC Has Formed a Partnership With The Advanced Networking Community To Create At Scale (Global) Distributed Environments For Data Intensive Scientific Research & Experimentation – Based On a Foundation of (& Integration With) Programmable, Deterministic, Edge Customizable High Performance Large Capacity Networks (e.g., 100 G and 100 G +)**



# Beyond Today's Internet Experiencing a Smart Future



## Prototype SDX Bioinformatics Exchange: Demonstrating an Essential Use-Case for Personalized Medicine

Robert Grossman, Piers Nash, Allison  
Heath, Renuka Arya  
University of Chicago

Joe Mambretti, Jim Chen  
Northwestern University

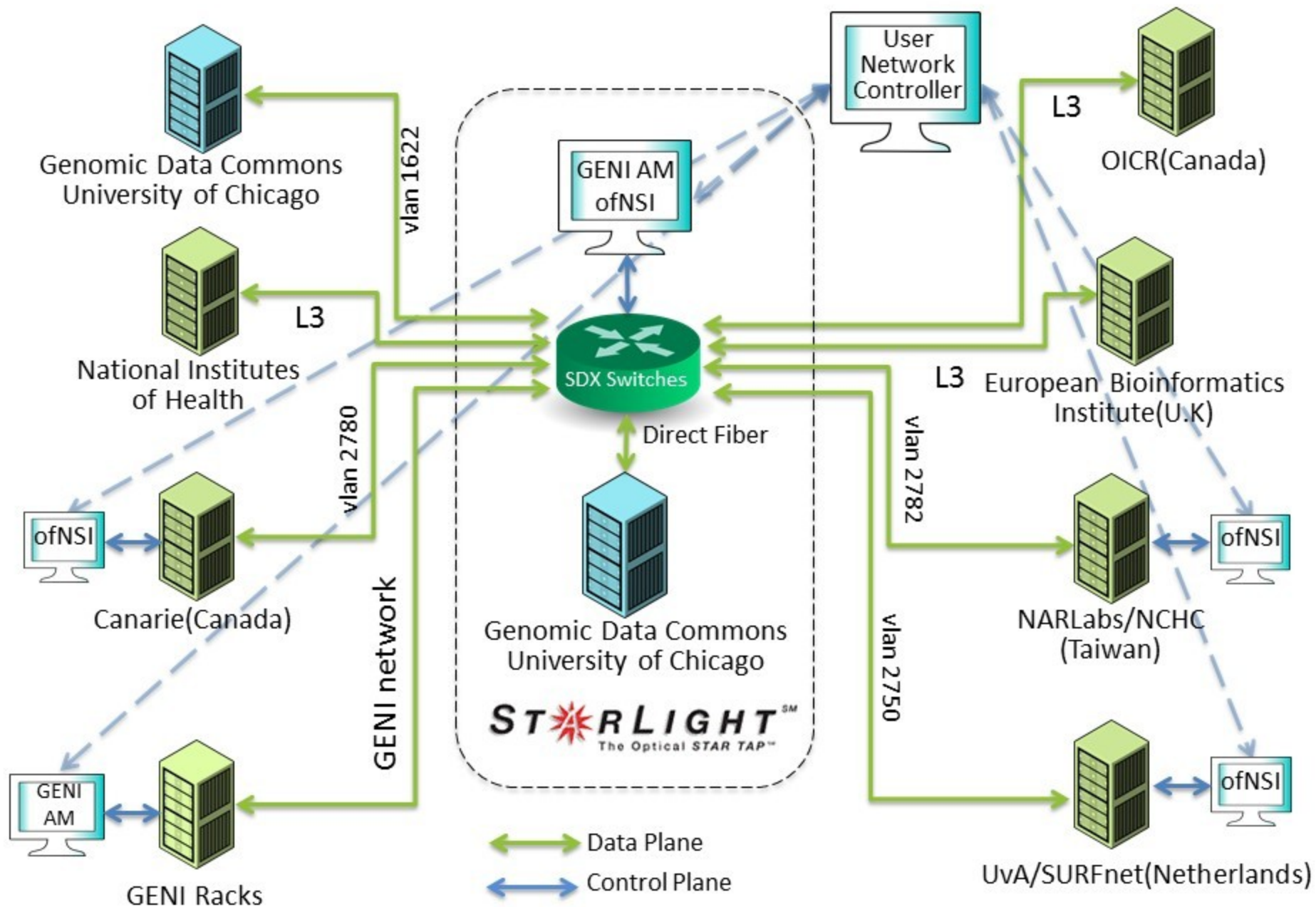


THE UNIVERSITY OF  
**CHICAGO**  
MEDICINE



NORTHWESTERN  
UNIVERSITY

# GEC22 Bioinformatics SDXs Demo Network





# An Experimental Testbed For Computer Science Research

[www.chameleoncloud.org](http://www.chameleoncloud.org)

CHAMELEON:  
A LARGE-SCALE, RECONFIGURABLE EXPERIMENTAL  
ENVIRONMENT FOR CLOUD RESEARCH

Principal Investigator: Kate Keahey

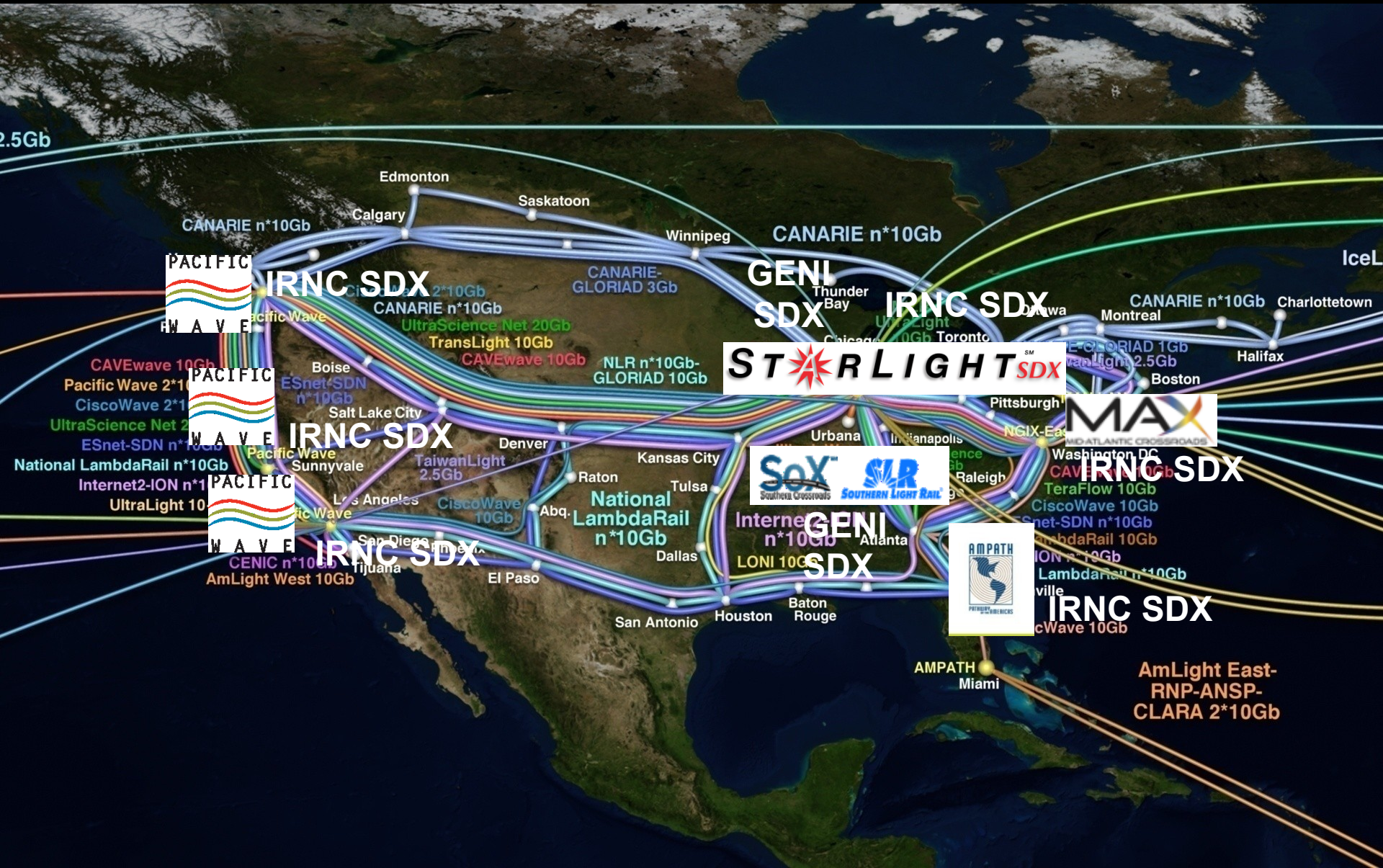
Co-PIs: J. Mambretti, D.K. Panda, P. Rad, W. Smith, D. Stanzione

**Another SDX Opportunity – Especially For Federation!  
SDX=> “Federation As A Service”**

AUGUST 29, 2014



# Planned US SDX Interoperable Fabric





[www.startap.net/starlight](http://www.startap.net/starlight)



Thanks to the NSF, DOE, NIH, USGS,  
DARPA  
NOAA, Universities, National Labs,  
International Partners,  
and Other Supporters

