Next Generation Software Defined Services and the Global Research Platform: A Software Defined Distributed Environment For High Performance Large Scale Data Intensive Science

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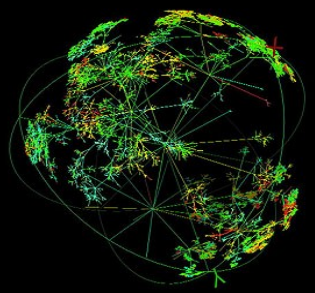
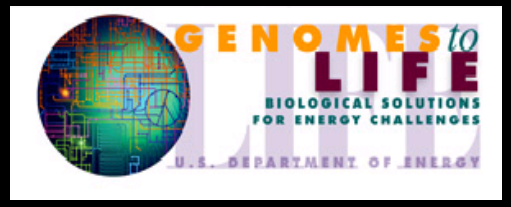
Northwestern University
Director, Metropolitan Research and Education Network (www.mren.org)
Director, StarLight, PI StarLight IRNC SDX,Co-PI Chameleon, PI-iGENI, PI-OMNINet (www.startap.net/starlight)

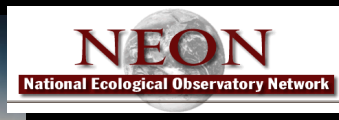
LHCOPN/LHCONE
March 6-7, 2018
Abingdon, Great Britain

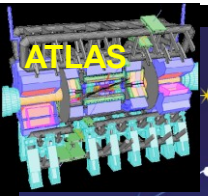


iCAIR

STARLIGHT℠



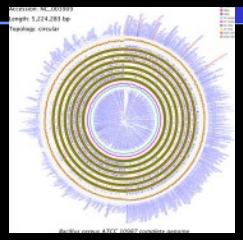




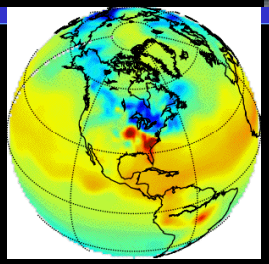
ALMA: Atacama Large Millimeter Array

ANDRILL: Antarctic Geological Drilling
www.andrill.org

BIRN: Biomedical Informatics Research Network
www.nbirn.net



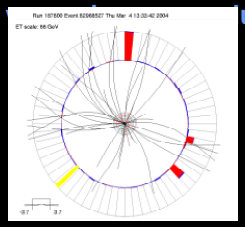
CAMERA metagenomics
camera.calit2.net



Carbon Tracker
www.esrl.noaa.gov/gmd/ccgg/carbontracker

CineGrid
www.cinegrid.org

LHCONE
www.lhcone.net



DØ (DZero)
www-d0.fnal.gov

GEON: Geosciences Network
www.geongrid.org

GLEON: Global Lake Ecological Observatory Network

OOI-CI
ci.oceanobservatories.org

ISS: International Space Station
www.nasa.gov/station

Comprehensive Large-Array Stewardship System
www.class.noaa.gov

LIGO
www.ligo.org

WLCG
lcg.web.cern.ch/LCG/public/

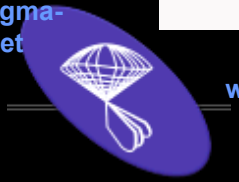
Pacific Rim Applications and Grid Middleware Assembly
www.pragma-grid.net

IVOA: International Virtual Observatory
www.ivoa.net

OSG
www.opensciencegrid.org

Globus Alliance
www.globus.org

SKA
www.skatelescope.org



Sloan Digital Sky Survey
www.sdss.org

TeraGrid
www.teragrid.org

XSEDE
www.xsede.org

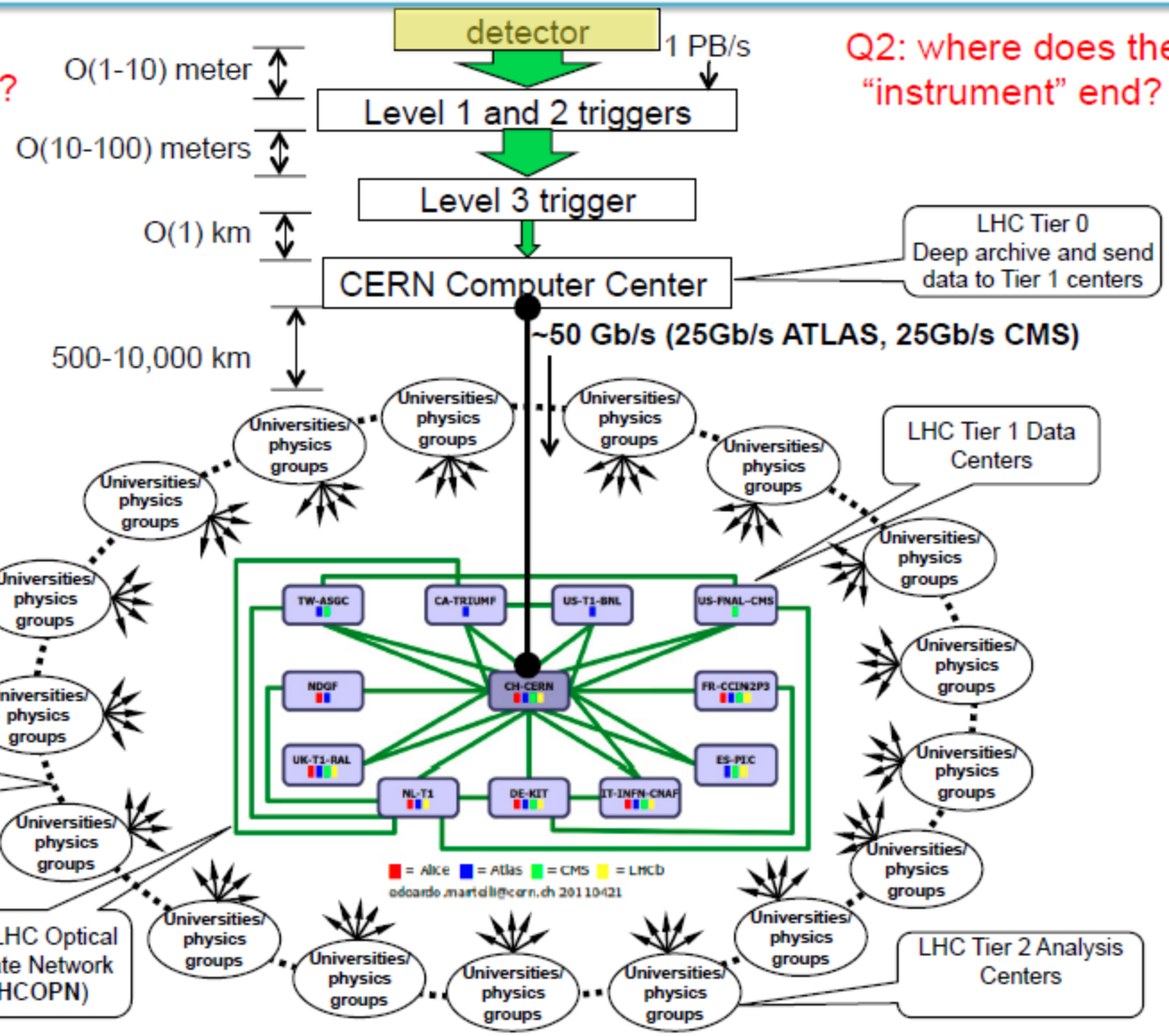
Compilation By Maxine Brown

STARLIGHT SM

Network-Centric View of Large Hadron Collider (@CERN)

Q1: where does "discovery" occur?

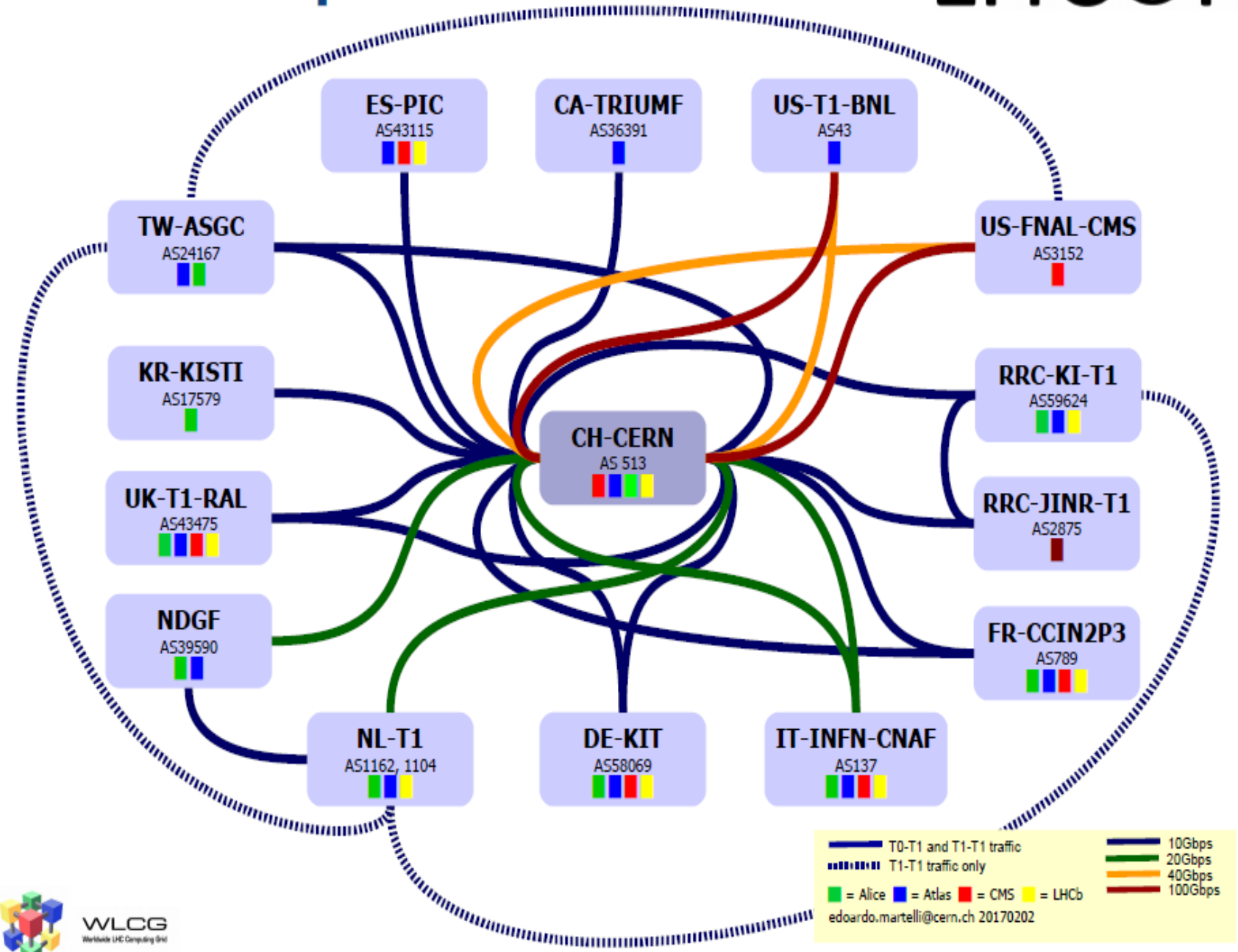
CERN →T1	miles	kms
France	350	565
Italy	570	920
UK	625	1000
Netherlands	625	1000
Germany	700	1185
Spain	850	1400
Nordic	1300	2100
USA – New York	3900	6300
USA - Chicago	4400	7100
Canada – BC	5200	8400
Taiwan	6100	9850



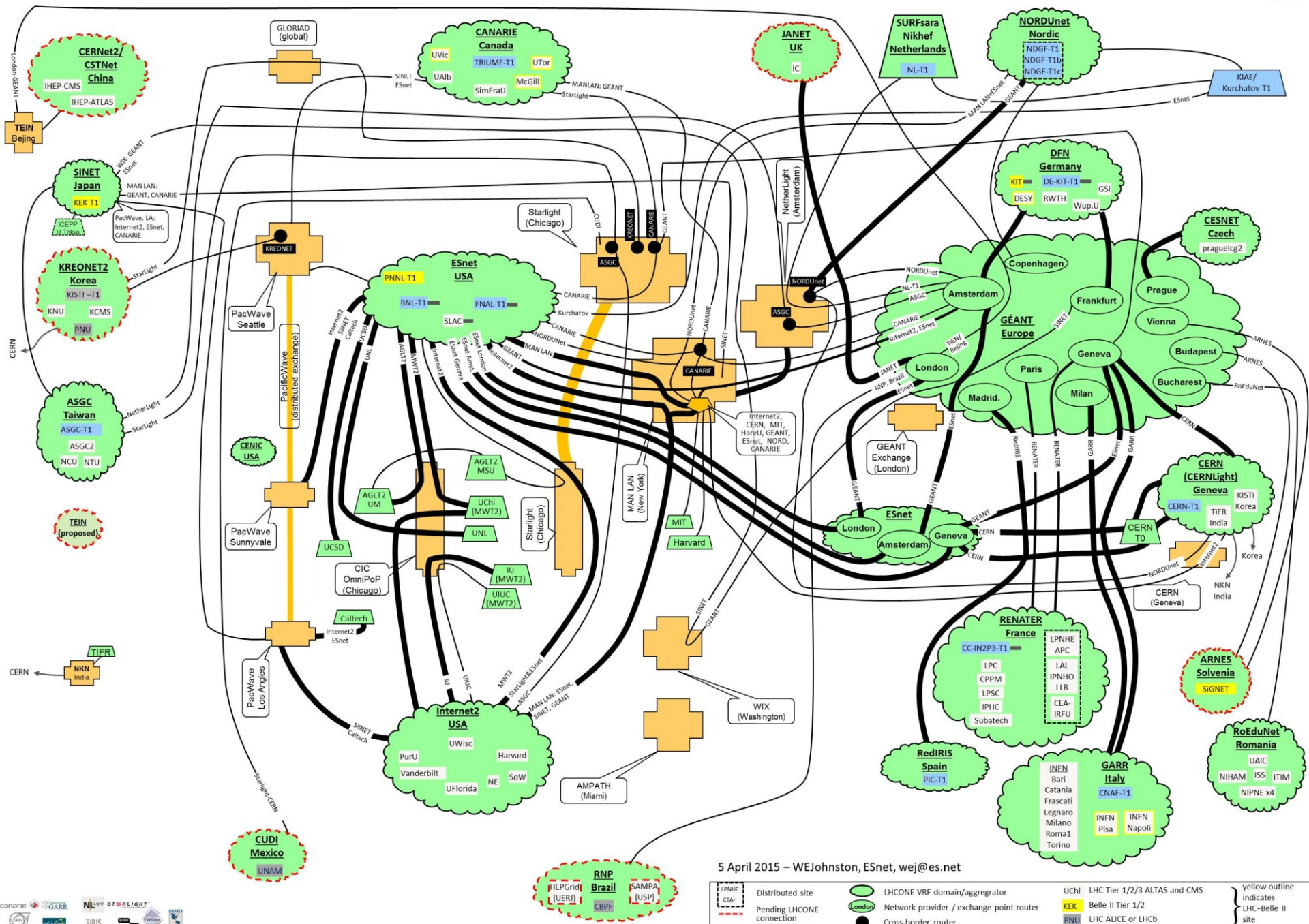
Q2: where does the "instrument" end?

Source: Bill Johnston

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

LHCONE: A global infrastructure for the High Energy Physics (LHC and Belle II) data management



5 April 2015 – WEJohnston, ESnet, wej@es.net

Also see http://lhcone.net for details.

Distributed site
Pending LHCONE connection
Sites connected at 40G-100G
Broadcast VLAN
LHCONE VRF domain/aggregator
Network provider / exchange point router
Cross-border router
Regional R&E communication nexus w/ switch providing VLAN connections
UChi LHC Tier 1/2/3 ALTAS and CMS
KEK Belle II Tier 1/2
PNU LHC ALICE or LHCb
UNL Sites that are standalone VRFs,
yellow outline indicates LHC+Belle II site
Communication links: 1/10, 20/30/40, and 100Gb/s

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.
- ProtoNuma…Nutrino Research

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

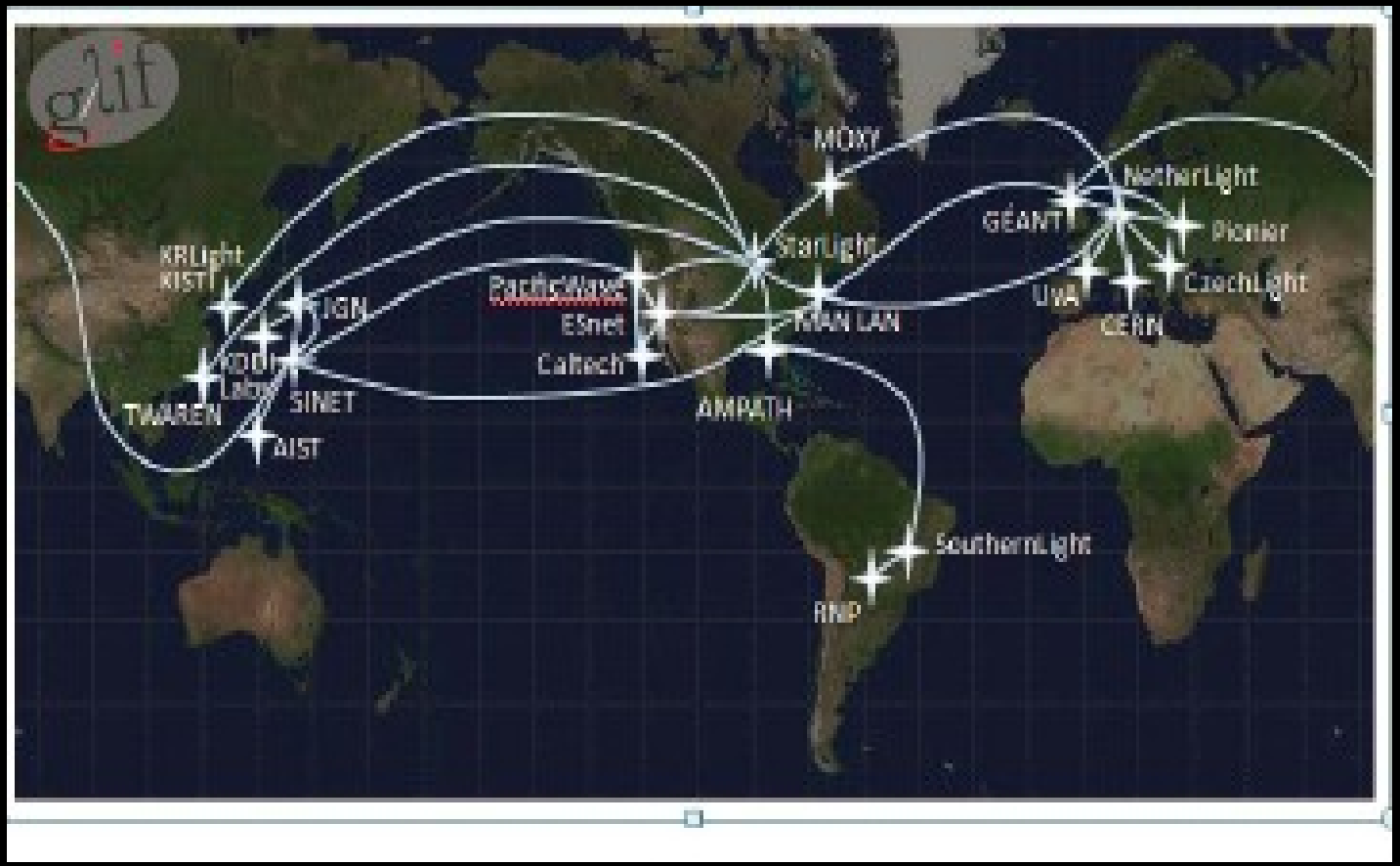
Visualization courtesy of Bob Patterson, NCSA; data compilation by Maxine Brown, UIC.

www.glif.is

iCAIR

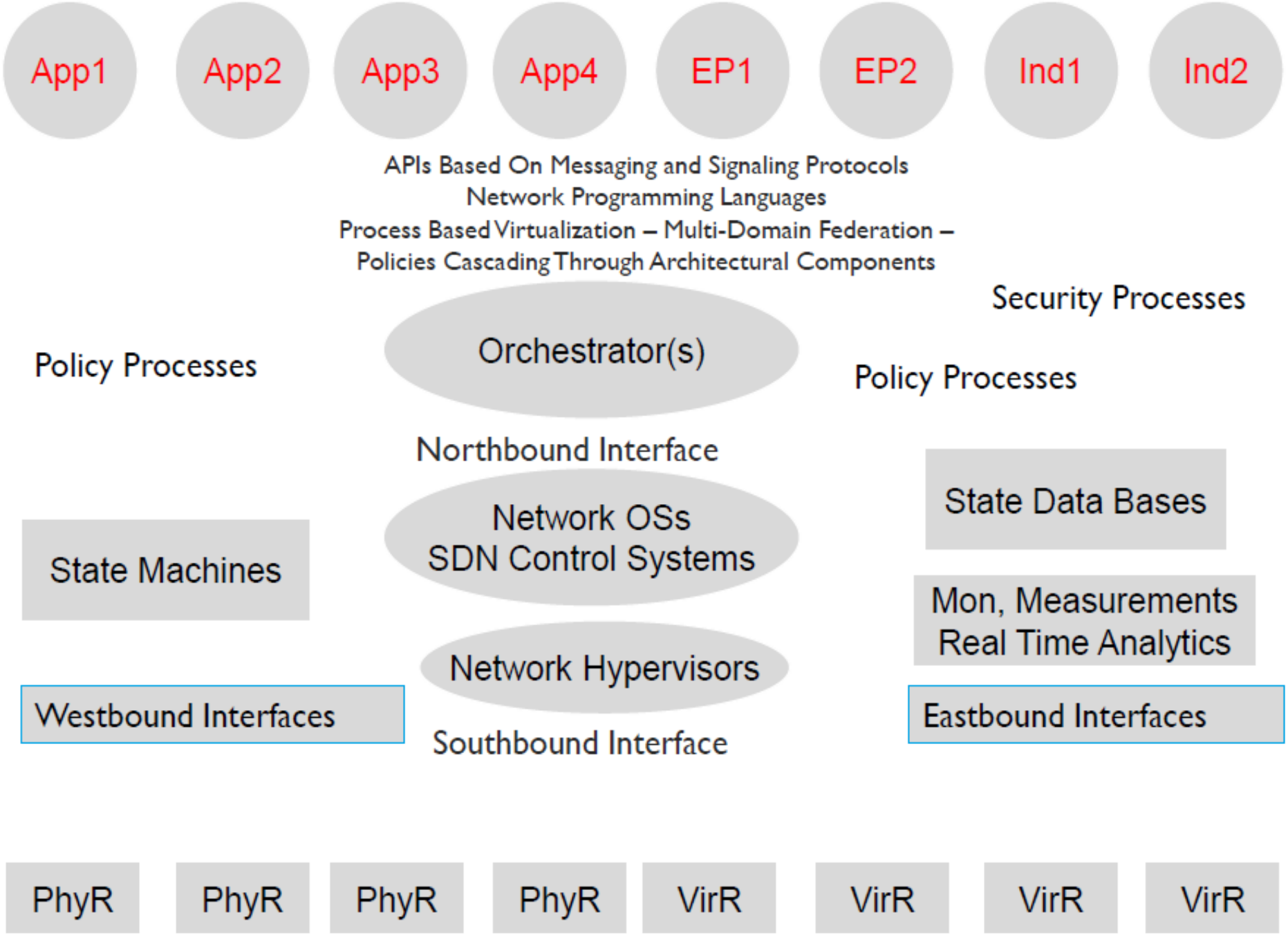
STARLIGHT℠

AutoGOLE


glif
MOXY
NetherLight
GÉANT
Pionier
StarLight
KRLight
KISTI
SURFnet
CzechLight
PacificWave
ESnet
MAN LAN
UvA
CERN
Caltech
TWAREN
SINET
AMPATH
AIST
SouthernLight
RNP

International Multi-Domain Provisioning Using AutoGOLE Based Network Service Interface (NSI 2.0)

* Network Service Interface (NSI 2.0)
* An Architectural Standard Developed By the *Open Grid Forum (OGF)
* OGF Pioneered Programmable Networking (Initially Termed "Grid Networking")
Techniques That Made Networks 'First Class Citizens" in Grid Environments – Programmable With Grid Middleware
* Currently Being Placed Into Production By R&E Networks Around the World


App1
App2
App3
App4
EP1
EP2
Ind1
Ind2
APIs Based On Messaging and Signaling Protocols
Network Programming Languages
Process Based Virtualization – Multi-Domain Federation –
Policies Cascading Through Architectural Components
Security Processes
Orchestrator(s)
Policy Processes
Policy Processes
Northbound Interface
State Data Bases
Network OSs
SDN Control Systems
State Machines
Mon, Measurements
Real Time Analytics
Network Hypervisors
Westbound Interfaces
Eastbound Interfaces
Southbound Interface
PhyR
PhyR
PhyR
PhyR
VirR
VirR
VirR
VirR

IRNC: RXP: StarLight SDX A Software Defined Networking Exchange for Global Science Research and Education

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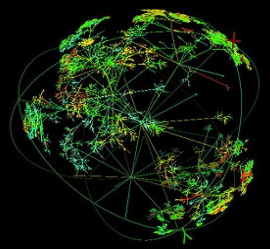
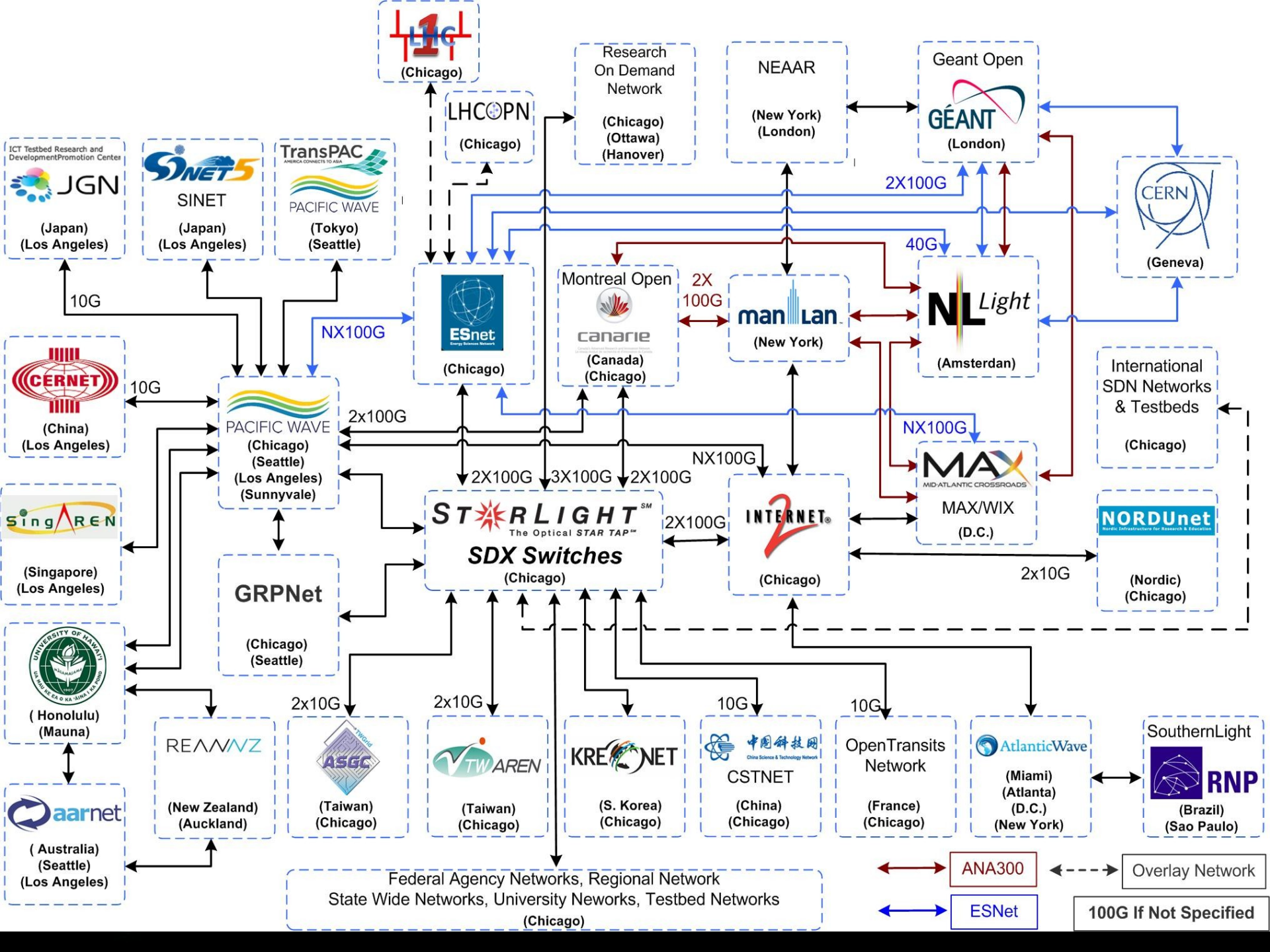
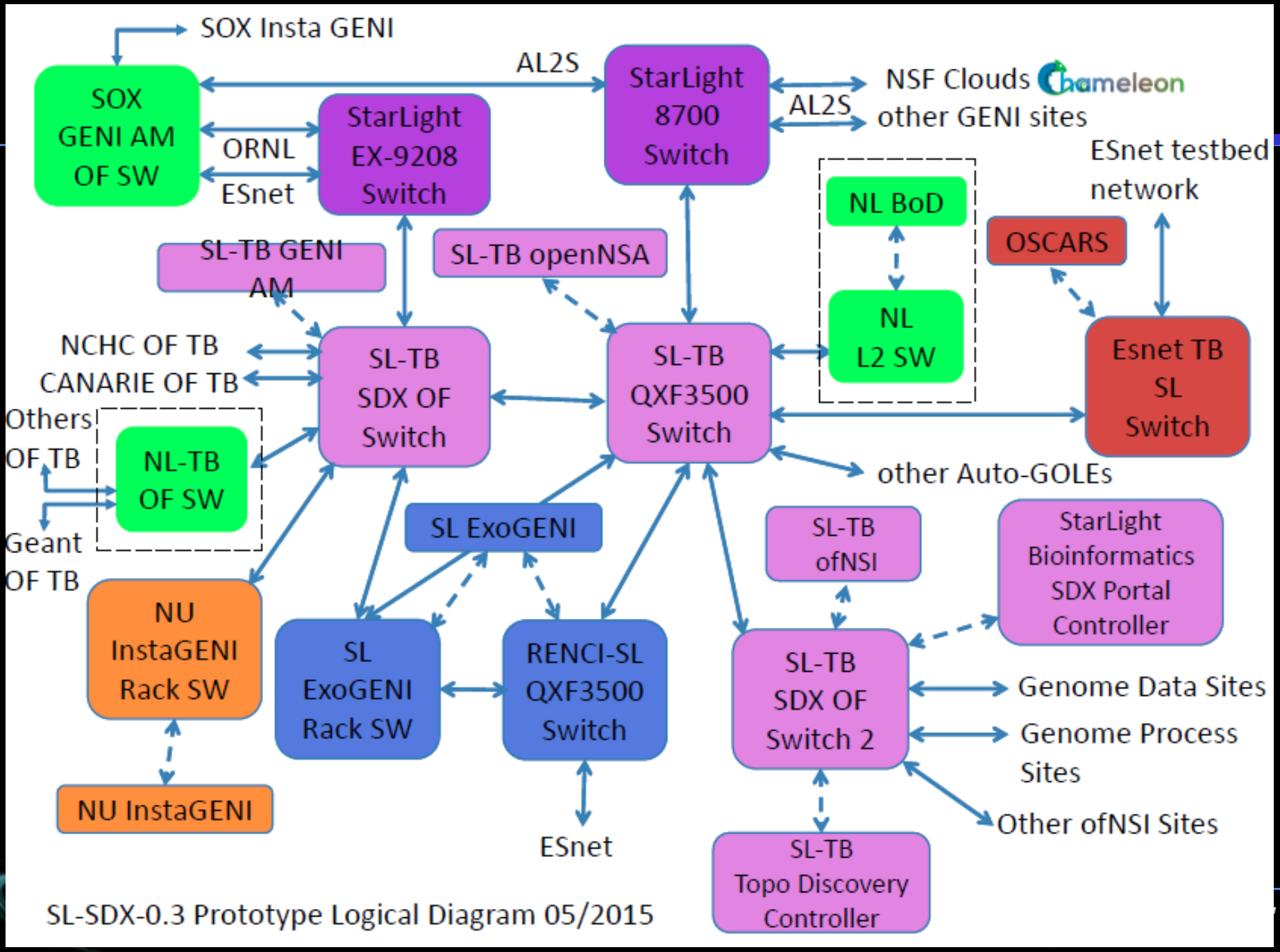
International Center for Advanced Internet Research (www.icair.org)
Northwestern University
Director, Metropolitan Research and Education Network (www.mren.org)
Co-Director, StarLight (www.startap.net/starlight)
PI IRNC: RXP: StarLight SDX
Co-PI Tom DeFanti, Research Scientist, (tdefanti@soe.ucsd.edu)
California Institute for Telecommunications and Information Technology (Calit2),
University of California, San Diego
Co-Director, StarLight
Co-PI Maxine Brown, Director, (maxine@uic.edu)
Electronic Visualization Laboratory, University of Illinois at Chicago
Co-Director, StarLight
Jim Chen, Associate Director, International Center for Advanced Internet Research, Northwestern University

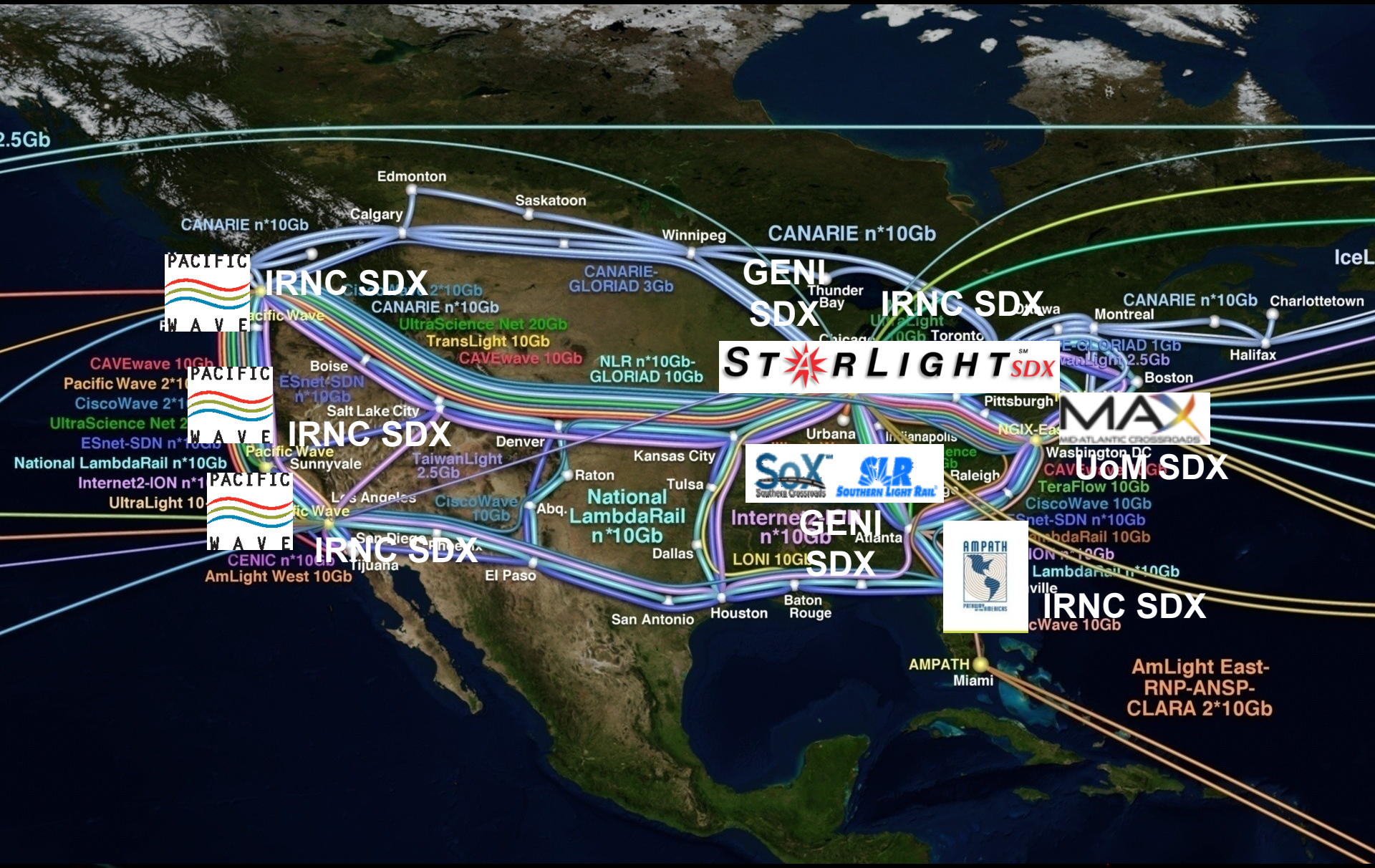


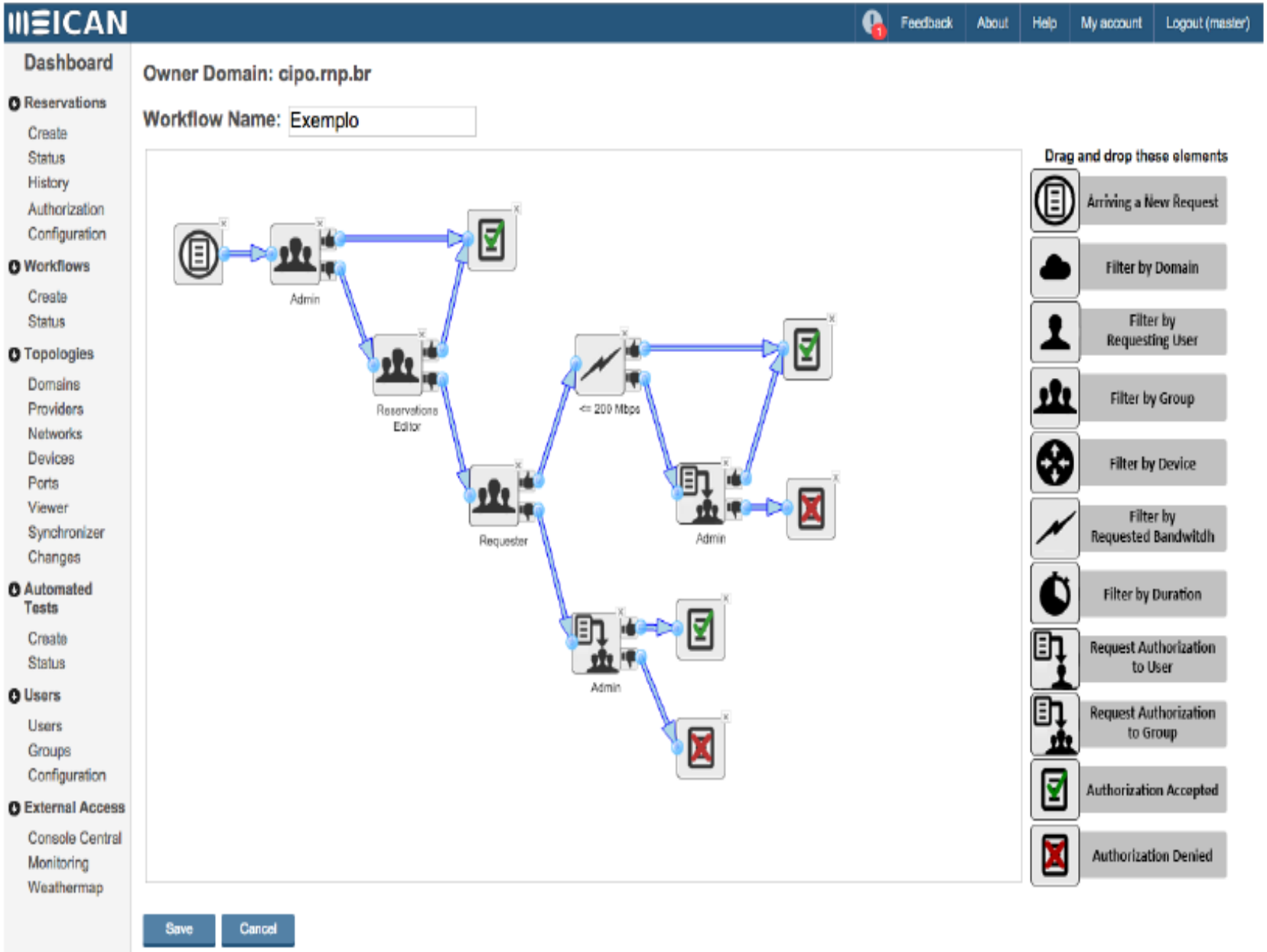
National Science Foundation
International Research Network Connections Program
Workshop
Chicago, Illinois
May 15, 2015


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.)
2X100G
3X100G
2X100G
NX100G
SingAREN
(Singapore)
(Los Angeles)
STARLIGHT
The Optical STAR TAP
SDX Switches
(Chicago)
2X100G
INTERNET2
(Chicago)
2x10G
NORDUnet
(Nordic)
(Chicago)
GRPNet
(Chicago)
(Seattle)
UNIVERSITY OF HAWAI'I
(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
Overlay Network
ESnet
100G If Not Specified

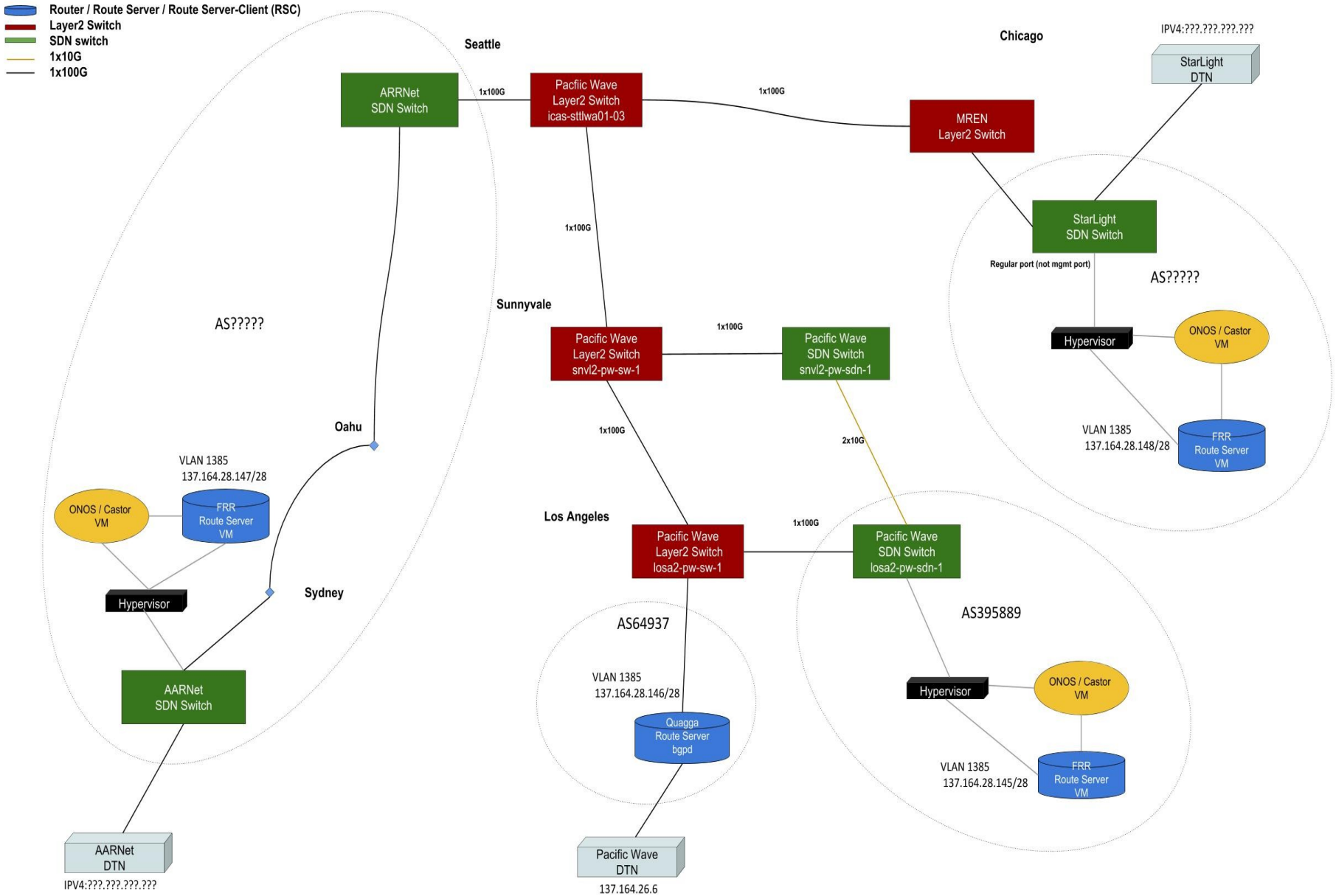

SOX Insta GENI
SOX GENI AM OF SW
AL2S
StarLight 8700 Switch
NSF Clouds
Chameleon
AL2S
other GENI sites
ORNL
ESnet
StarLight EX-9208 Switch
ESnet testbed network
NL BoD
OSCARS
SL-TB GENI AM
SL-TB openNSA
NL L2 SW
NCHC OF TB
CANARIE OF TB
SL-TB SDX OF Switch
SL-TB QXF3500 Switch
Esnet TB SL Switch
Others OF TB
NL-TB OF SW
other Auto-GOLEs
Geant OF TB
SL ExoGENI
SL-TB ofNSI
StarLight Bioinformatics SDX Portal Controller
NU InstaGENI Rack SW
SL ExoGENI Rack SW
RENCI-SL QXF3500 Switch
SL-TB SDX OF Switch 2
Genome Data Sites
Genome Process Sites
Other ofNSI Sites
NU InstaGENI
ESnet
SL-TB Topo Discovery Controller
SL-SDX-0.3 Prototype Logical Diagram 05/2015

Emerging US SDX Interoperable Fabric




MEICAN
Feedback
About
Help
My account
Logout (master)
Dashboard
Reservations
Create
Status
History
Authorization
Configuration
Workflows
Create
Status
Topologies
Domains
Providers
Networks
Devices
Ports
Viewer
Synchronizer
Changes
Automated Tests
Create
Status
Users
Users
Groups
Configuration
External Access
Console Central
Monitoring
Weathermap
Owner Domain: cipo.rnp.br
Workflow Name: Exemplo
Admin
Reservations Editor
Requester
<= 200 Mbps
Admin
Admin
Drag and drop these elements
Arriving a New Request
Filter by Domain
Filter by Requesting User
Filter by Group
Filter by Device
Filter by Requested Bandwitdh
Filter by Duration
Request Authorization to User
Request Authorization to Group
Authorization Accepted
Authorization Denied
Save
Cancel

AARNet - Pacific Wave - Starlight
Inter-domain SDX Topology v0.4

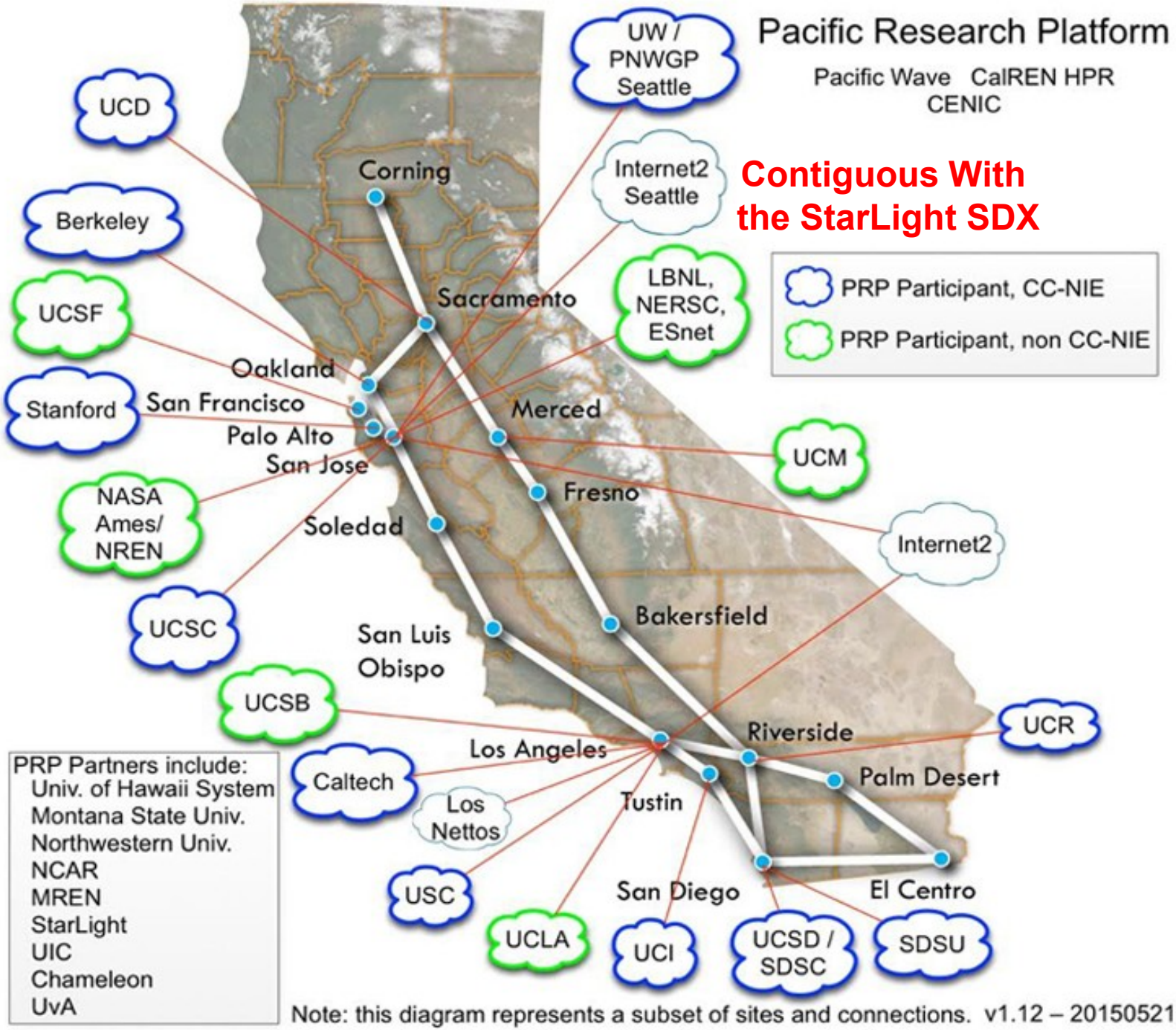


NOTE: this diagram represents a subset of sites, devices, and connections

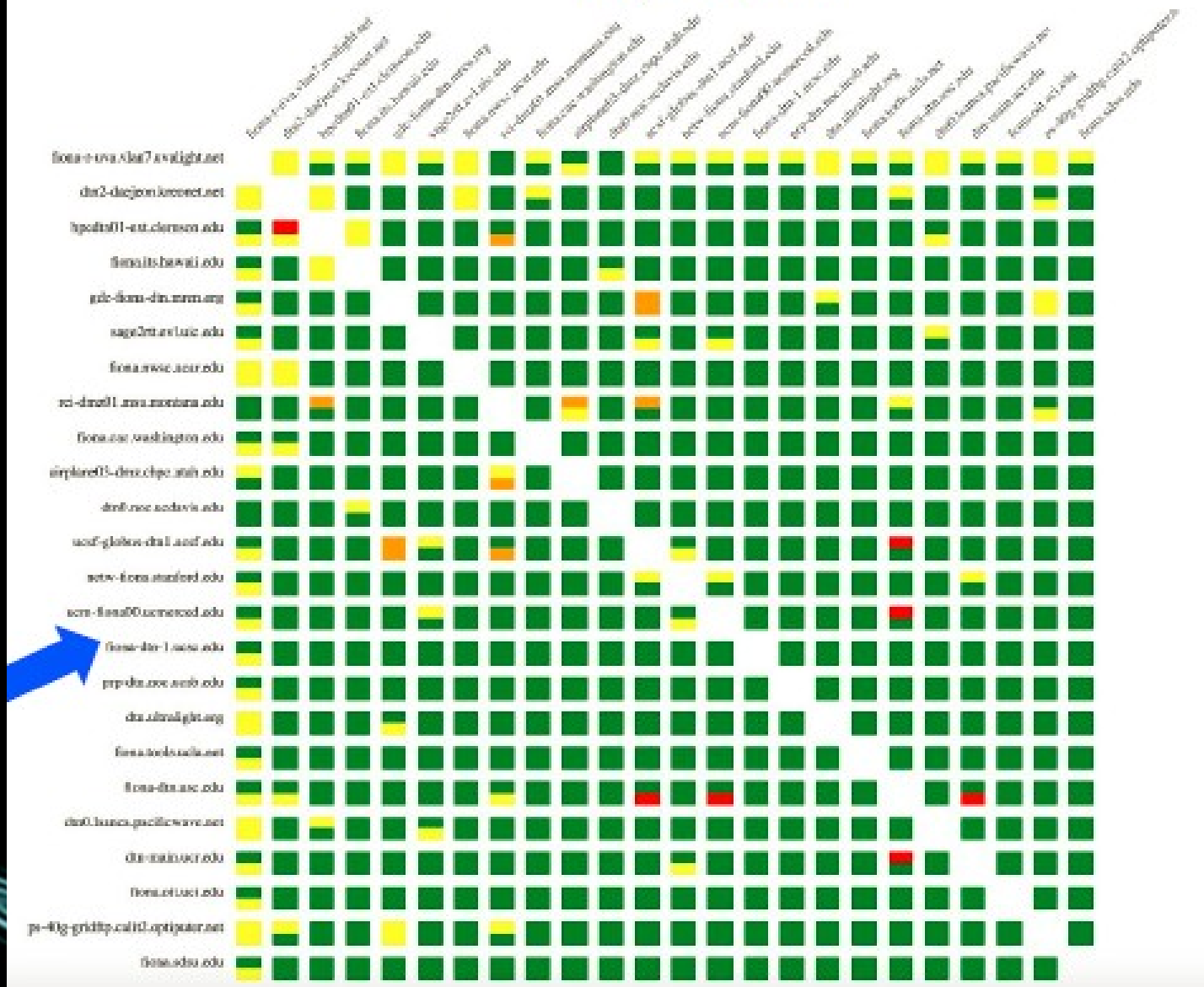
https://docs.google.com/drawings/d/1NIcvdKg8Zy4mFH-uIYmYsJdz5HKpmgjfk1QyBKpntel/edit?usp=sharing
V0.04 20170801

Global Research Platform (GRP)

- A Emerging International Fabric
- A Specialized Globally Distributed Environment/Platform For Science Discovery and Innovation
- Based On State-Of-the-Art-Clouds, Networks, Storage Systems, Data Repositories, etc
- Interconnected With Computational Grids, Supercomputing Centers, Specialized Instruments, et al
- Also, Based On World-Wide 100 Gbps (Soon 100 G+) Networks
- Leveraging Advanced Architectural Concepts, e.g., SDN/SDX/SDI – Science DMZs
- Ref: 1st Demonstrations @ SC15, Austin Texas November 2015
- Subsequent Demonstrations @ SC16 Salt Lake City Utah, November 2016, Global LambdaGrid Workshop 2016 and 2017,
- Major Demonstrations at SC17 in Denver, Colorado


Pacific Research Platform
Pacific Wave CalREN HPR
CENIC
Contiguous With
the StarLight SDX
PRP Participant, CC-NIE
PRP Participant, non CC-NIE
UW / PNWGP Seattle
Internet2 Seattle
LBNL, NERSC, ESnet
UCD
Berkeley
UCSF
Stanford
NASA Ames/ NREN
UCSC
UCSB
Caltech
Los Nettos
USC
UCLA
UCI
UCSD / SDSC
SDSU
UCM
Internet2
UCR
Corning
Sacramento
Oakland
San Francisco
Palo Alto
San Jose
Soledad
Merced
Fresno
Bakersfield
San Luis Obispo
Los Angeles
Riverside
Palm Desert
Tustin
San Diego
El Centro
PRP Partners include:
Univ. of Hawaii System
Montana State Univ.
Northwestern Univ.
NCAR
MREN
StarLight
UIC
Chameleon
UvA
Note: this diagram represents a subset of sites and connections. v1.12 – 20150521

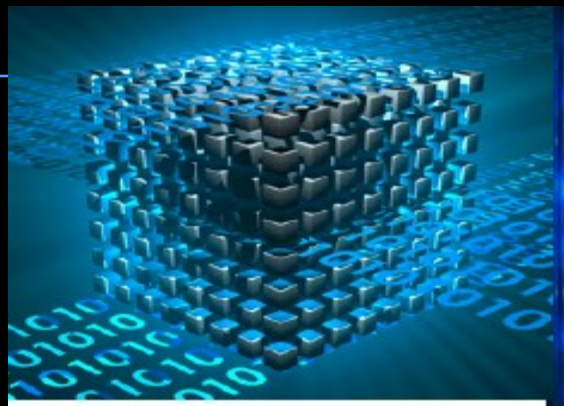
July 21, 2017


fiona-1-ovs.ultralight.net
dtn2-daejeon.kreonet.net
hpcdtn01-ext.clemson.edu
fiona.its.hawaii.edu
gdc-fiona-dtn.mrnn.org
sage2rtt.evl.uic.edu
fiona.nwsc.ucar.edu
sci-dtn01.nrao.manitara.edu
fiona.cse.washington.edu
airplane03-dtn2.chpc.utah.edu
dtn0.nsrc.ucdavis.edu
ucsf-globus-dtn1.ucsf.edu
netw-fiona.stanford.edu
scm-fiona00.uchicago.edu
fiona-dtn-1.nersc.edu
prp-dtn.nrec.ucsb.edu
dtn.ultralight.org
fiona.tools.sacla.net
fiona-dtn.usc.edu
dtn0.hanea.pacificwave.net
dtn-tmin.ucr.edu
fiona.crt.uci.edu
ps-40g-griddtp.calit2.optiputer.net
fiona.sdsu.edu


NSF


it2

Global Research Platform: Building On CENIC/Pacific Wave, GLIF and GLIF GOLEs (e.g., StarLight et al)

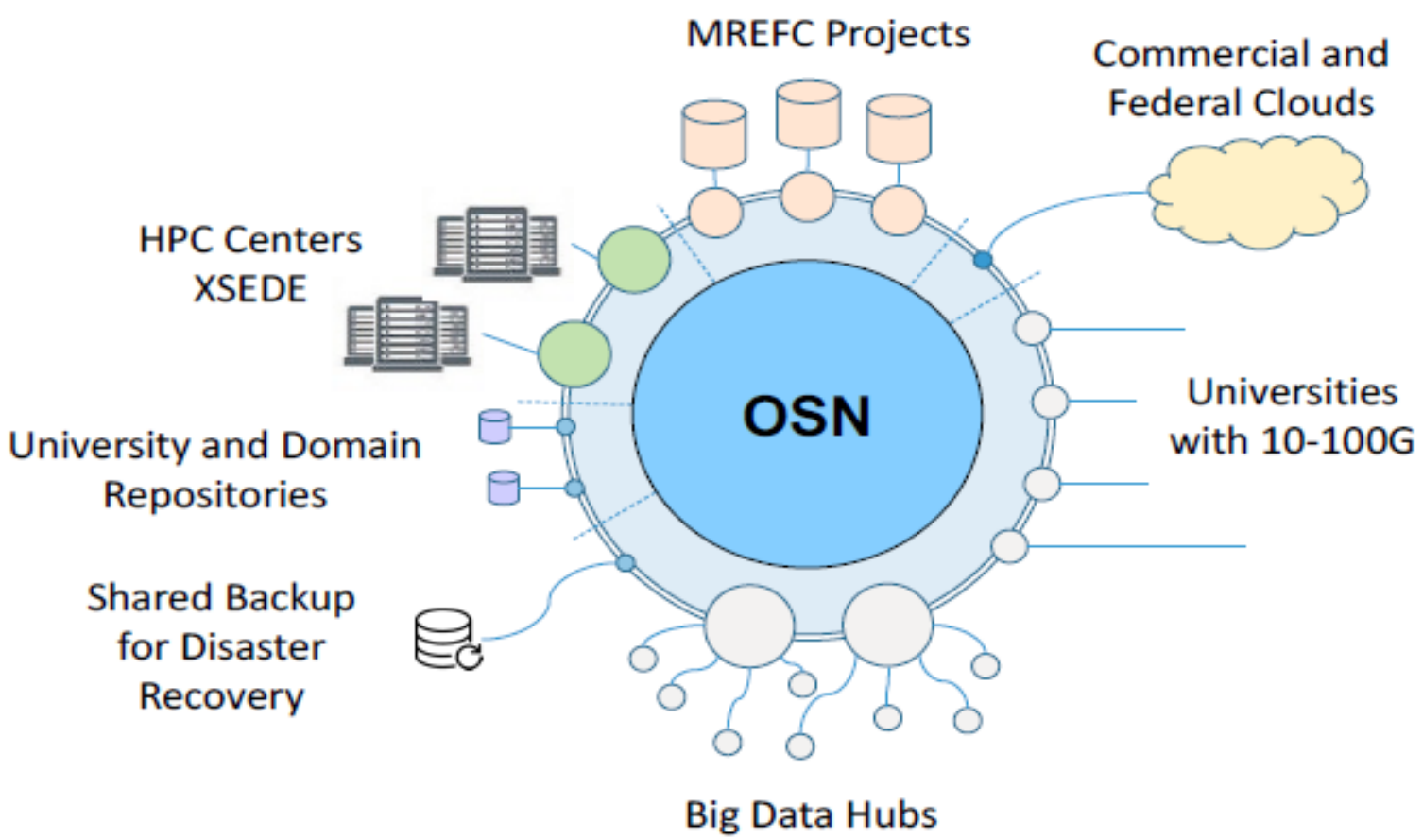


Building the Open Storage Network

Alex Szalay
The Johns Hopkins University

Institute for Data Intensive Engineering and Science
idies

Connections



Cognitive Hardware and Software Ecosystem Community Infrastructure (CHASE-CI)

- Machine Learning Cloud Development Led By UCSD
- Will Leverage The Pacific Research Platform (PRP)
- Will Provide Researchers With Fast GPU Appliances For Machine Learning/Deep Learning Next Generation Cognitive Computingl Investigations - Neural Network Hardware, Software, Architecture etc.
- PRP's High Bandwidth + Big Data + Machine Learning + GPUs
- Already Being Used For Multiple Investigations, Including For Distributed Systems
- ***NRP/GRP Can Be A Foundation Platform for Such "Plug-In' Tsetebeds/Facilities/Instruments***

Nationwide 100 Gbps and Minimized Latency

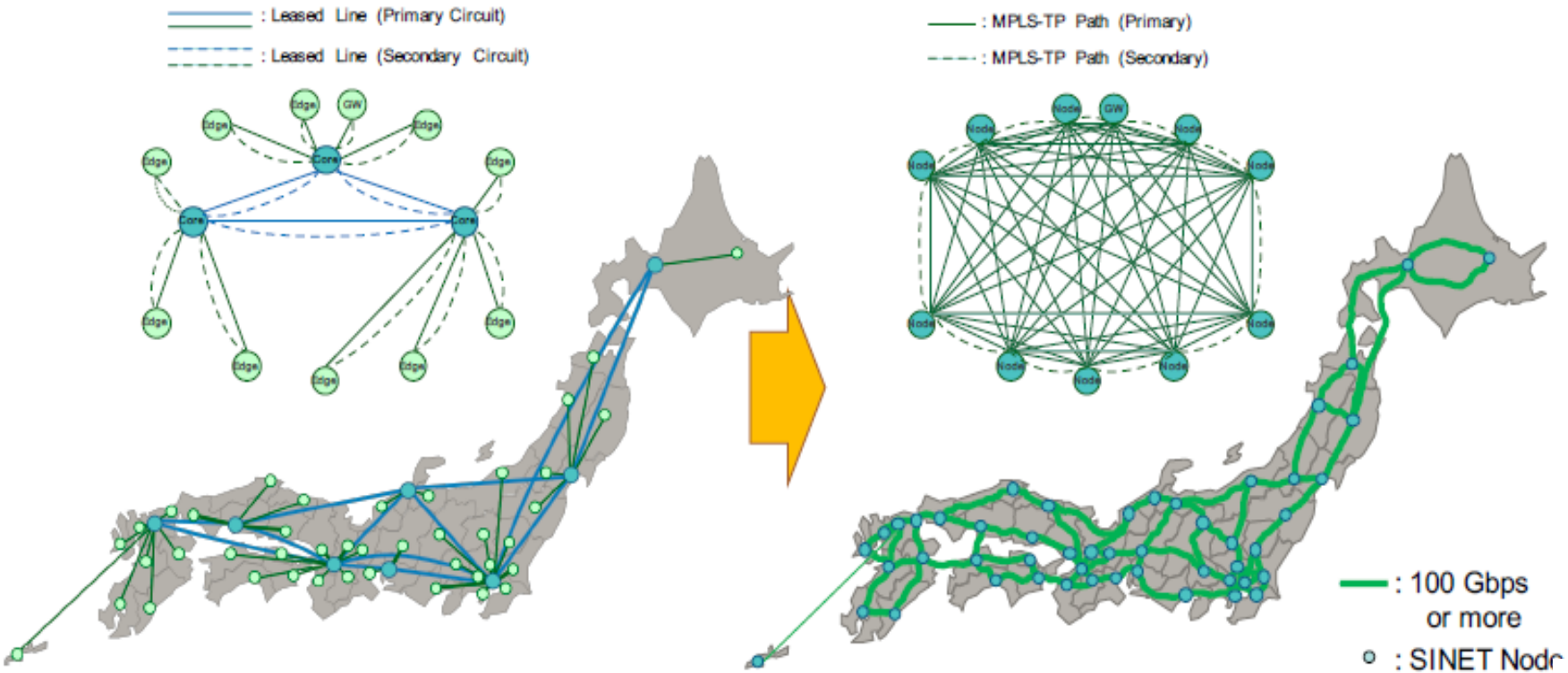
◆ SINET5 will be a nationwide 100-Gbps backbone network using 100-Gigabit Ethernet technology and connect each pair of nodes with a minimized latency.

SINET4

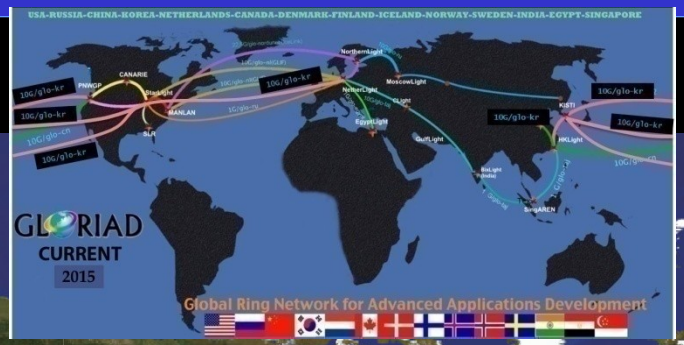
- Star-like topology
- Resource-consuming secondary circuits

SINET5

- Fully-meshed topology with redundancy
- Non-resource-consuming secondary paths



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



Soon: Daejeon SDX ⇔ StarLight SDX

International KREONET-S Connections to StarLight: SD-WAN Federations

www.startap.net/starlight