Open Storage Network

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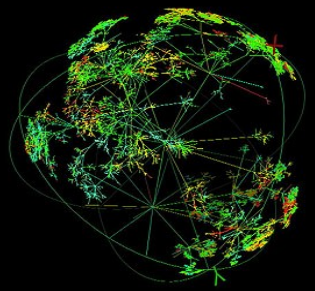
Alexander Szalay, Bloomberg Distinguished Professor, the Alumni Centennial Professor of Astronomy, and Professor, Department of Computer Science, Johns Hopkins University. Director, Institute for Data Intensive Science, Fellow of the American Academy of Arts and Sciences, PI Open Storage Network Project

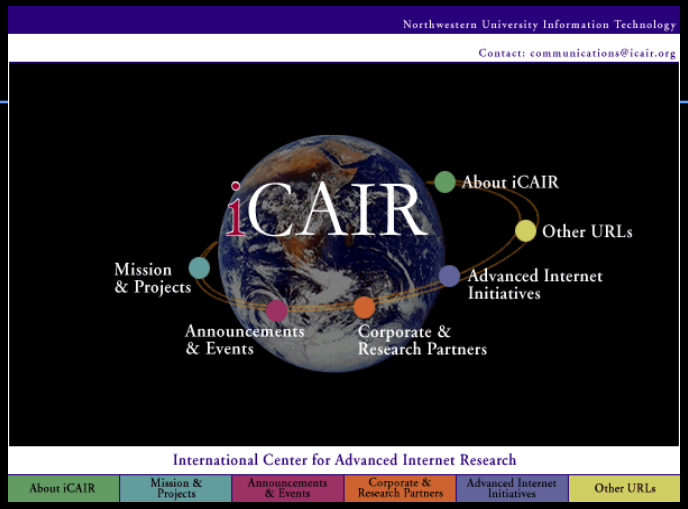


Juniper R&E Networking Symposium (J-RENS) 2018
DePaul University
Chicago, Illinois
October 10, 2018

iCAIR

STARLIGHT℠

Introduction to iCAIR:

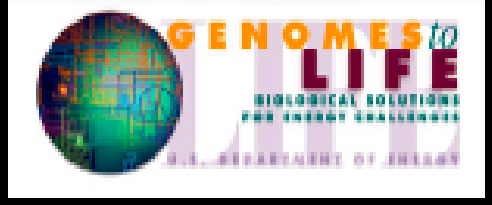


Accelerating Leading Edge Innovation and Enhanced Global Communications through Advanced Internet Technologies, in Partnership with the Global Community

- **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 (e.g., StarLight, Specialized Science Networks)**

Emerging Topics In Advanced Networking

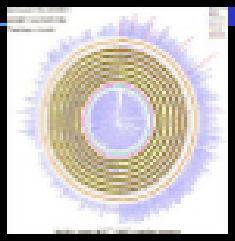
- Transition From Legacy Networks To Networks That Take Full Advantage of IT Architecture and Technology
- Extremely Large Capacity (Multi-Tbps Streams)
- Specialized Network Services, Architecture and Technologies for Data Intensive Science
- High Degrees of Communication Services Customization
- Highly 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/SDI/OCX/SDC/SDE



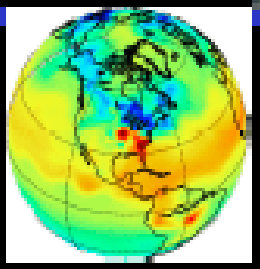
ALMA: Atacama Large Millimeter Array

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

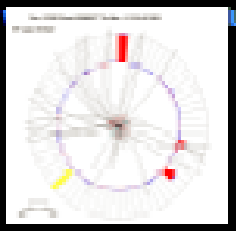
LHCONE
www.lhcone.net

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



DØ (DZero)
www-d0.fnal.gov

LIGO
www.ligo.org

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

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

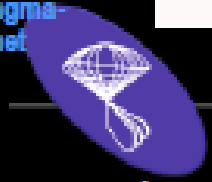
TeraGrid
www.teragrid.org

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

XSEDE
www.xsede.org

Compilation By Maxine Brown

STARLIGHT SM

Petascale Computational Science

For Decades, Computational Science
Has Driven Network Innovation
Today –
Petascale Computational Science

BLUE WATERS
SUSTAINED PETASCALE COMPUTING

National Center for Supercomputing Applications, UIUC

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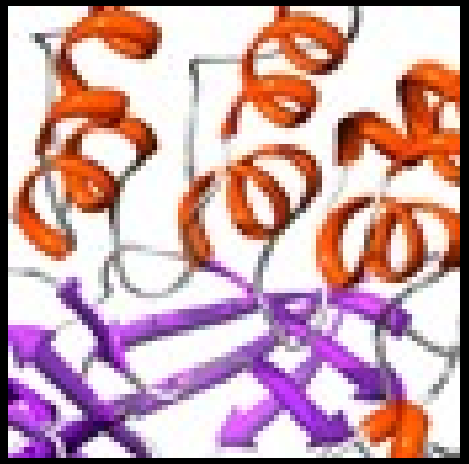
XSEDE

- Extreme Science and Engineering Discovery Environment (XSEDE)
- Goal: Create a Distributed Computational Science Infrastructure to Enable Distributed Data Sharing and High-Speed Computing for Data Analysis and Numerical Simulations
- Builds on Prior Distributed TeraGrid

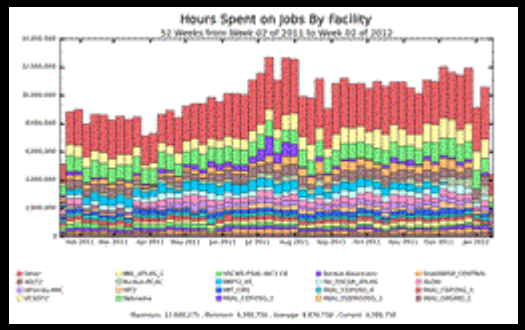
Open Science Grid: Selected Investigations



DNA Modeling

Gravity Wave Modeling

Nutrino Studies

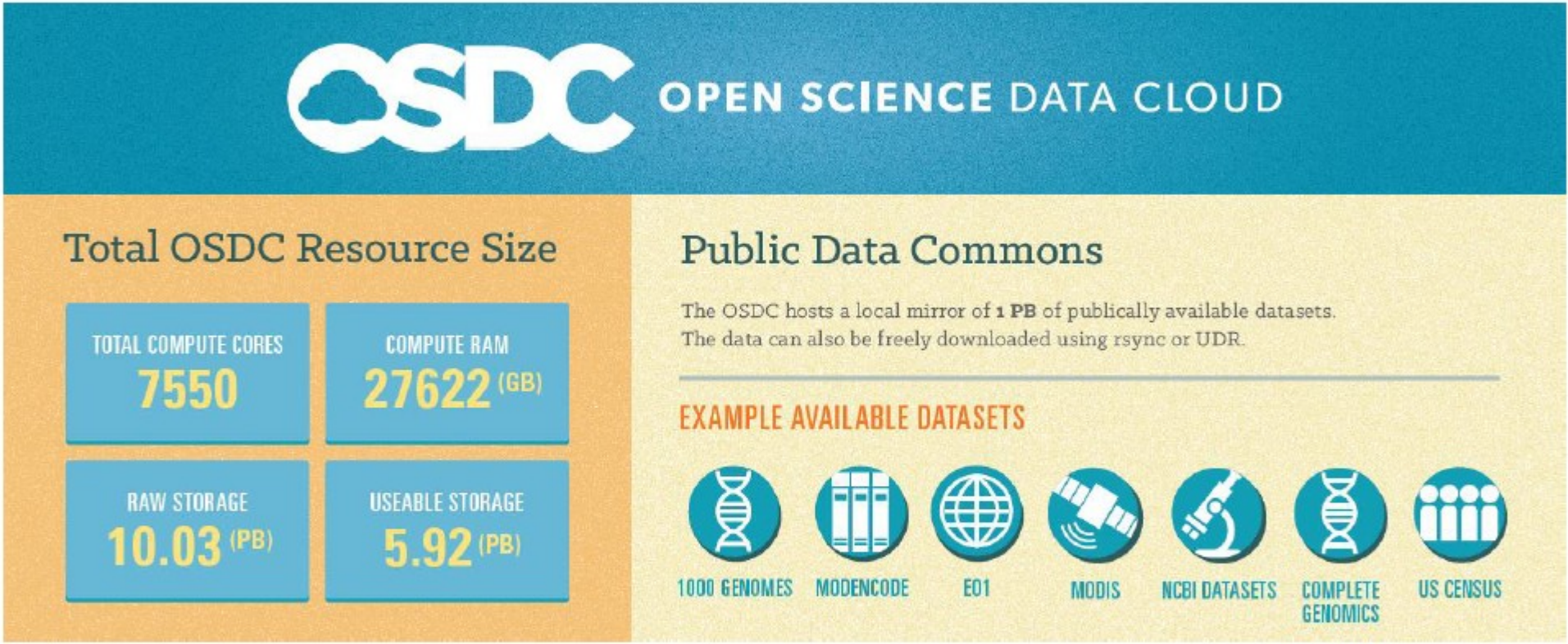


Usage

Open Science Grid

This Distributed Facility
Supports Many Sciences

The Open Science Data Cloud (OSDC) is an **open-source**, **cloud-based** infrastructure that allows scientists to manage, share, and analyze medium to large size scientific datasets.

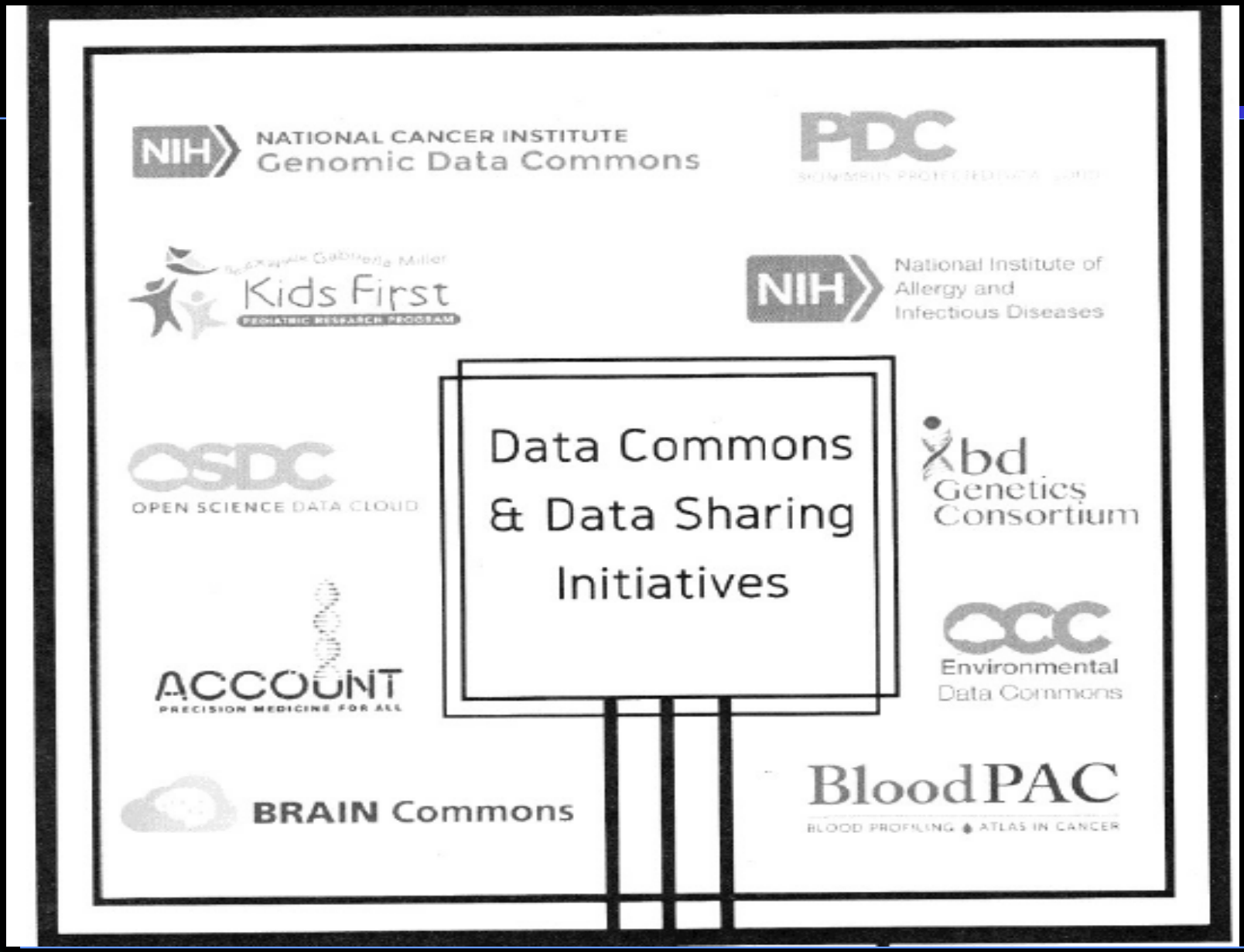


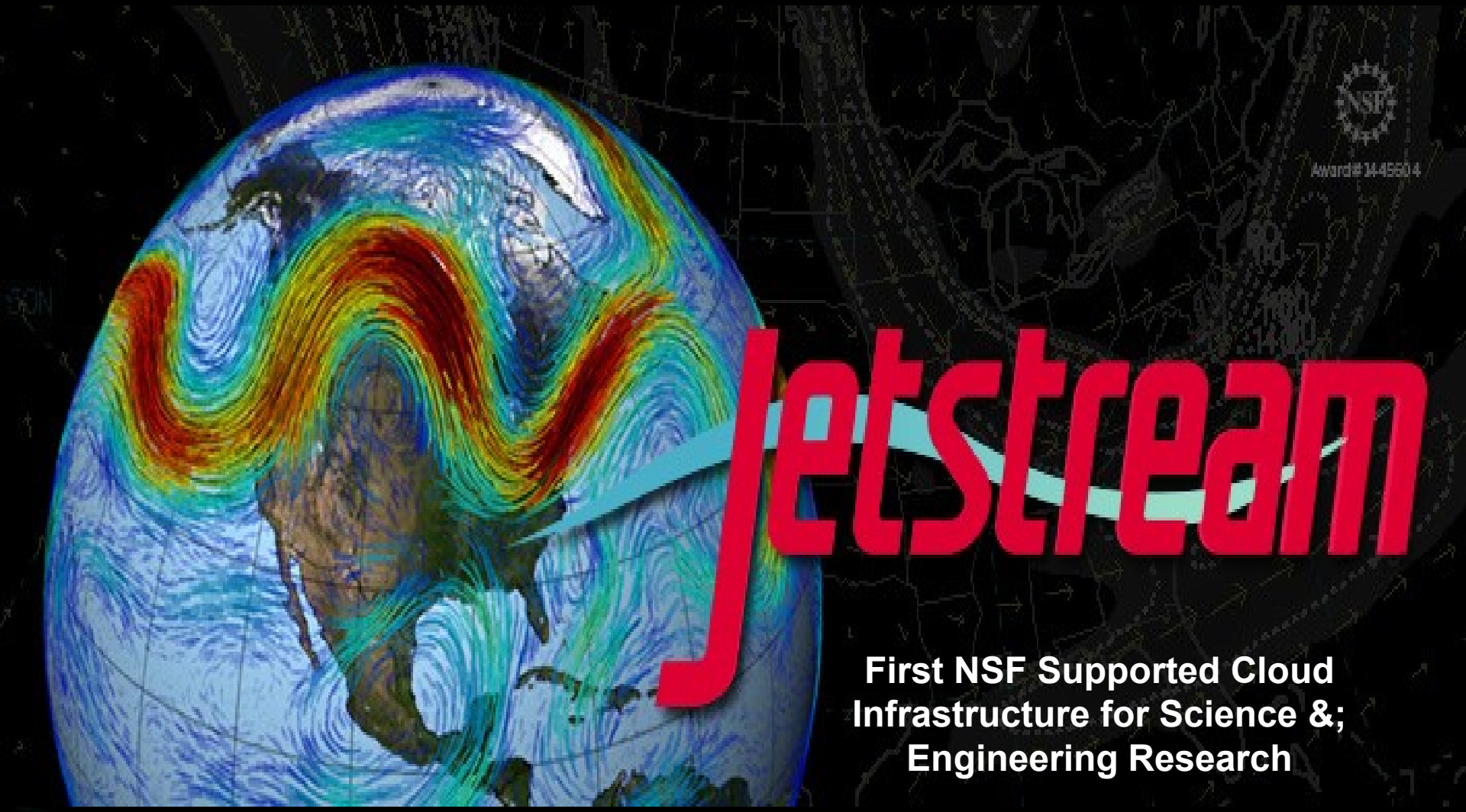
Application for resources available to anyone doing scientific research:

Open Commons Consortium

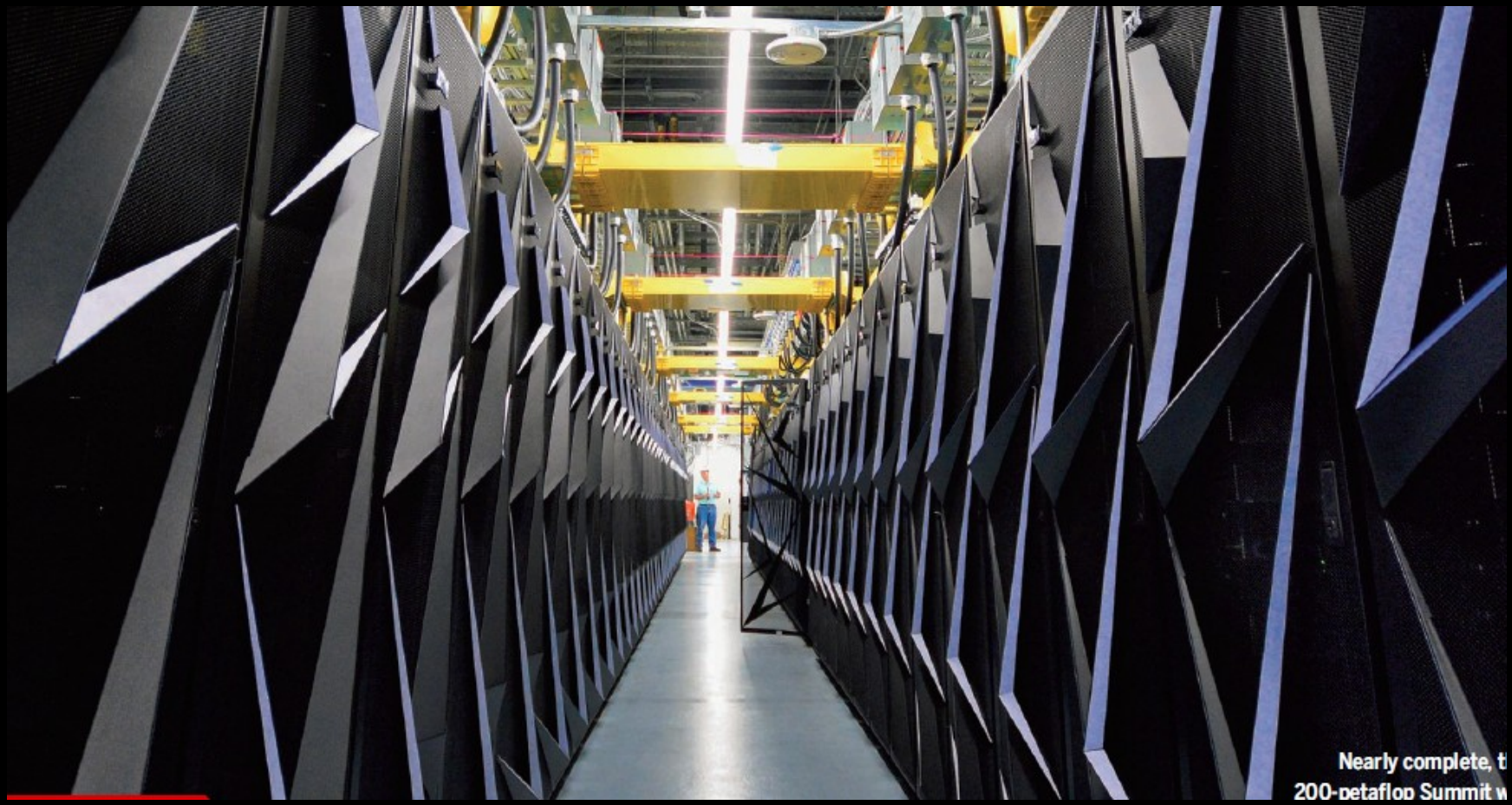
www.opensciencedatacloud.org

Maria Patterson (mtpatter@uchicago.edu) *Center for Data Intensive Science, University of Chicago*


NIH
NATIONAL CANCER INSTITUTE
Genomic Data Commons
PDC
Kids First
PEDIATRIC RESEARCH PROGRAM
NIH
National Institute of
Allergy and
Infectious Diseases
Data Commons
& Data Sharing
Initiatives
OSDC
OPEN SCIENCE DATA CLOUD
bd
Genetics
Consortium
ACCOUNT
PRECISION MEDICINE FOR ALL
CCC
Environmental
Data Commons
BRAIN Commons
BloodPAC
BLOOD PROFILING ATLAS IN CANCER


Award# 1445604
Jetstream
First NSF Supported Cloud Infrastructure for Science &; Engineering Research

Summit At Oak Ridge National Laboratory – A Step To A21 Exescale Computer at Argonne National Laboratory (2021)



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HEP = Staggering Amounts of Data

BaBar 0.3 PetaByte/year (2001)

CDF or D0 Run II

0.5 PetaByte/year (2003)

LHC Mock Data Challenge
1 PetaByte/year (~2005)

CMS or ATLAS

2 PetaBytes/year (~2008)

KTeV 50 TeraBytes /year (1999)

SLD 3 TB /year (1998)

Run I (CDF or D0) 20 TB /year (1995)

L3 5 TB /year (1993)

E791 50 TB /year (1991)

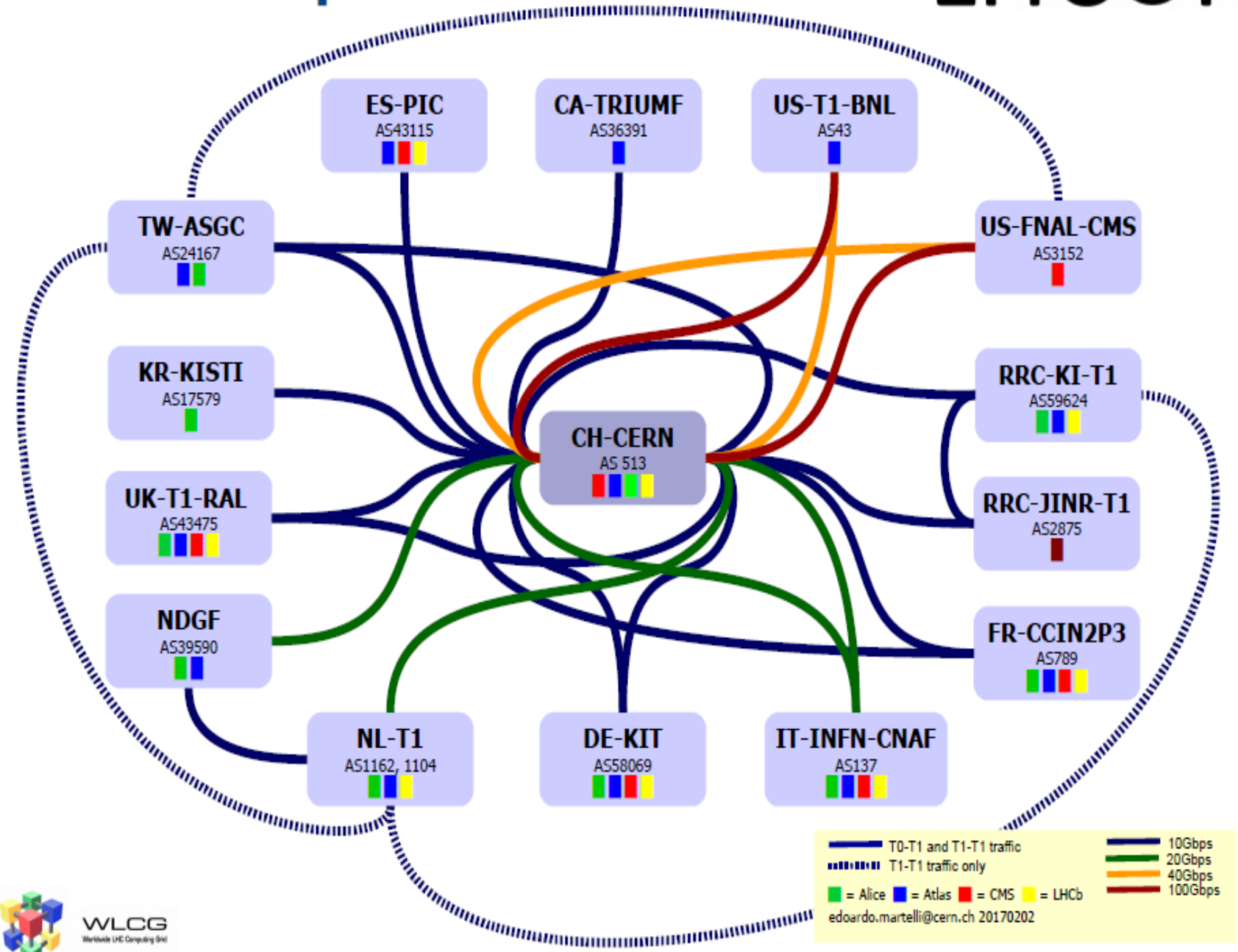
EMC 400GB /year (1981)

In 1977 the Upsilon (bottom quark) was discovered at Fermilab by experiment E288 led by now Nobel laureate Leon Lederman

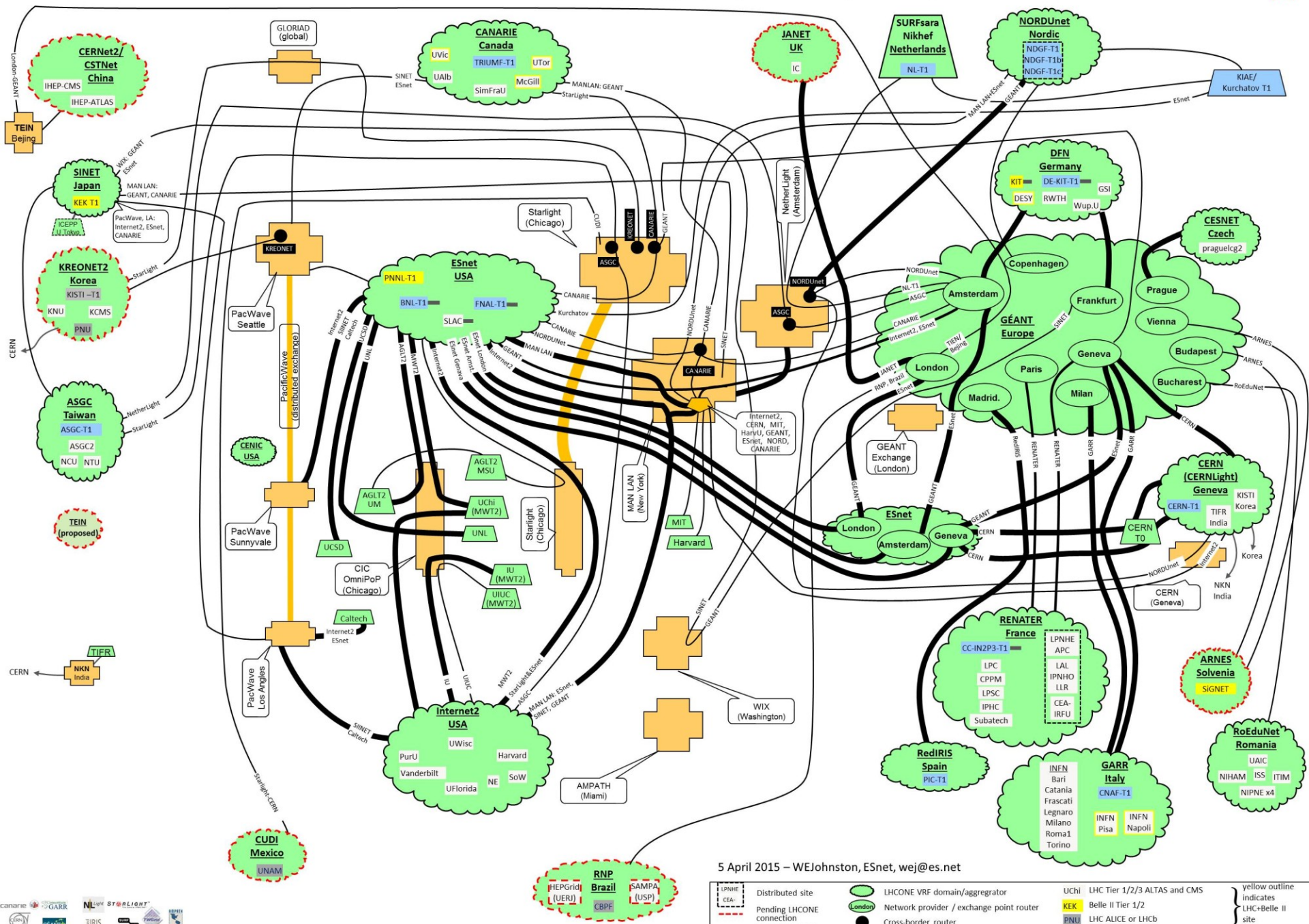
The experiment took about 1 million events and recorded the raw data on ~ 300 magnetic tapes for about 6 GB of raw data

Source: Fermi Lab

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

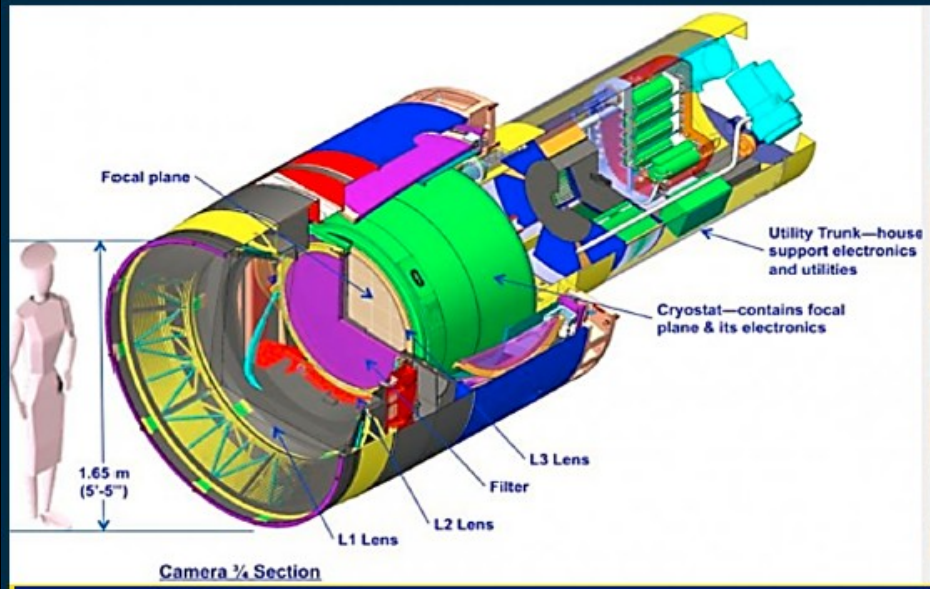
New Science Communities Using LHCONE

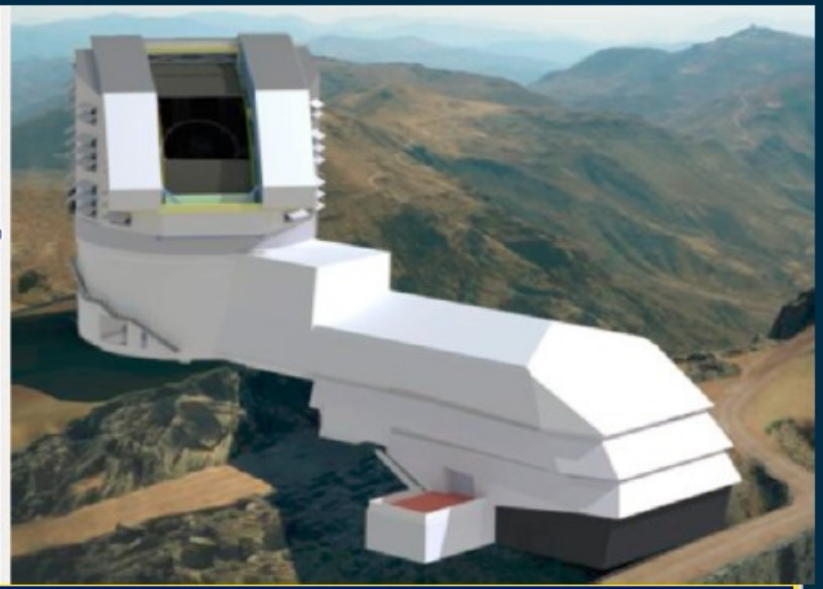
- Belle II Experiment, Particle Physics Experiment Designed To Study Properties of B Mesons (Heavy Particles Containing a Bottom Quark).
- Pierre Auger Observatory, Studying Ultra-High Energy Cosmic Rays, the Most Energetic and Rarest of Particles In the Universe.
- In August 2017 the PAO, LIGO and Virgo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

Argonne National Laboratory Advanced Photon Source

Square Kilometer Array

LSST Data Movement
Upcoming challenges for Astronomy





- 3.2 Gigapixel Camera with calibrated exposures at (10 Bytes / pixel)
- Planned Networks: Dedicated 100G for image data, Second 100G for other traffic, and 40G for diverse path
- Lossless compressed Image size = 2.7GB (~5 images transferred in parallel over a 100 Gbps link)
- UDP based custom image transfer protocols

Current Storage Landscape

- Storage Is Isolated, Difficult To Access
  - Multiple Isolated Facility, Campus, instrument Systems
  - Incompatibilities, Inefficiencies
  - Especially Problematic for Petabytes – Exebytes Are Also Required
- Commercial Clouds Not A Solution
  - Cost Model Makes Collaborative Distribution Prohibitive
  - Operations Prevent Detailed Performance Analytics
  - Limited Data Tools

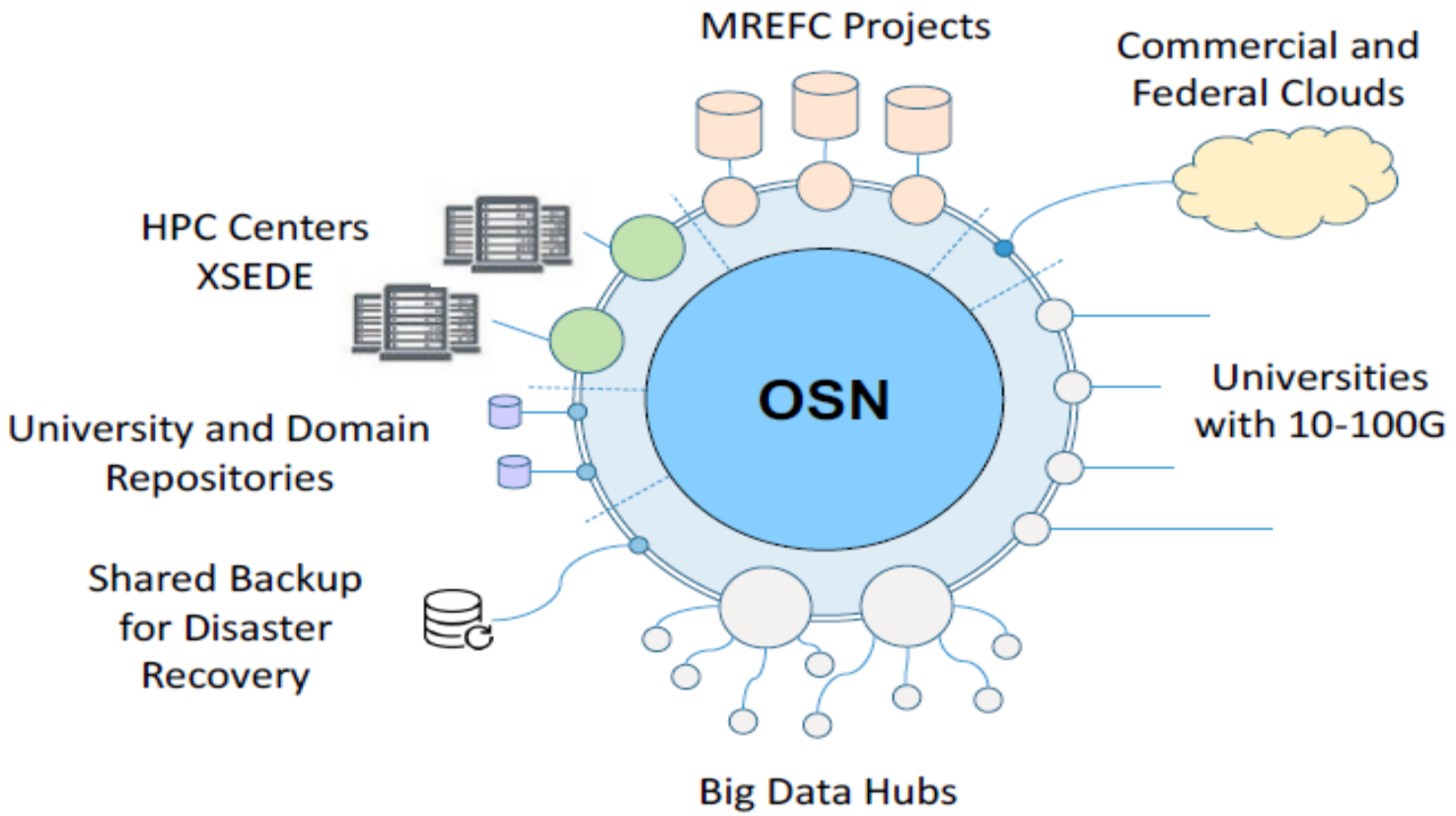
Opportunity: Next Gen Storage For Science

- **Large National Distributed Storage System:**
- ***– Perhaps 1-2PB Storage Rack On Each CC* Campus (~200PB)***
- ***– Create Redundant Interconnected Storage Substrate***
- ***Using Industrial Strength Erasure Code Storage***
- **– Provide *High Capcity Aggregate Bandwidth, Easy Data Flow Among Sites (100 Gbps Channels)***
- ***– Potential For Acting As Gateways To Cloud Providers***
- ***– Automatic Compatibility, Simple Standard API (S3)***
- ***– Implement a Set of Simple Policies***
- ***– Enable Sites To Add Additional Storage Locally Funded***
- ***– Provide Variety of Services Built By Communities***

Transformational Impact

- **Potentiual To Totally Change Landscape For Academic Big Data Research (Even At Petabyte Scale)**
- ***– Create Homogeneous, Uniform Storage Tier For Science***
- ***– Liberate Communities To Focus On Science, Discovery, Analytics Collaboration, and Preservation***
- ***– Amplify NSF CC* Investment***
- ***– Very Rapidly Spread Best Practices Nationwide***
- ***– Links to Large Science Instruments, Compute Facilities, Data Facilities (Including Big Data Hubs), Analytics Sites, et al***
- ***– Big Data Projects Can Use It For Data Distribution***
- ***– Small Projects Can Build On Existing Infrastructure***
- ***– Enablibg Whole Ecosystem of Specialized Services to Flourish***
- ***<u>Major Opportunities for Novel Interdisciplinary Research</u>***

Connections



Many Issues

- Architecture
- Technologies
- Services
- Mechanisms For Integration With Instruments, Compute Facilities, Data Hubs, Analytic Centers, etc
- Policies
- Communications/Education
- Security
- Financial Models
- Mechanisms For Innovation and On-Going Extensions and Enhancements
- Governance/Management of Data and Facilities
- Long vs Short Term Repositories
- Etc

Building Blocks

- Scalable element (SE)
  - *500TB of storage+ single server*
  - *Support 40G interface for sequential read/write*
  - *Should saturate 40G for read, about half for write*
- Stack of multiple SEs
  - *Aggregated to 100G on a fast TOR switch, now becoming quite inexpensive (<$20K)*
- These can also exist inside the university firewall
  - *But purchased on local funds, storing local data*
- Software stack to be discussed
  - *ZFS, Ceph, Mero,…*
  - *Integrated with Globus "Lite", with streamlined stack*

Building Blocks 2

- E2E Services (e.g., BigData Express, SENSE)
- APIs
- Workflow Managers (e.g., Jupyter)
- Data Transfer Nodes
- Performance Monitoring/Measurement/Analytics Instrumentation
- Ultra High Performance File Systems
- Piplines Based On Direct Connections Between HP File Systems and High Performance Optical Channels (e.g., Lightpaths)
- Interdomain Services

Management

- Who owns it?
  - *OSN storage should remain in a common namespace*
  - *This would enable uniform policies and interfaces*
- Software management
  - *Central management of software stack (push)*
  - *Central monitoring of system state*
- Hardware management
  - *Local management of disk health*
  - *Universities should provide management personnel*
- Policy management
  - *This is **hard** and requires a lot more discussion*
- Monitoring
  - *Two tier, store all events and logs locally, send only alerts up*
  - *Try to predict disk failures, preventive maintainance*
- Establish metrics for success

Initial OSN Faciltity Sites

- Johns Hopkins University, Baltimore Maryland
- StarLight International/National Communications Exchange Facility, Chicago, Illinois
- University of California At San Diego Supercomputing Center, La Jolla, California
- Future Sites Under Discussion
- International Extensions Possible

StarLight – "By Researchers For Researchers"

StarLight is an experimental optical infrastructure and proving ground for network services optimized for high-performance applications

Multiple 10GE+100 Gbps StarWave

Multiple 10GEs Over Optics – World's "Largest" 10G/100G Exchange

First of a Kind Enabling Interoperability At L1, L2, L3

View from StarLight

Abbott Hall, Northwestern University's Chicago Campus

iCAIR

STARLIGHT℠

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

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

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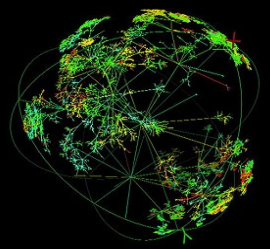
Electronic Visualization Laboratory, University of Illinois at Chicago
Co-Director, StarLight
Jim Chen, Associate Director, International Center for Advanced Internet Research, Northwestern University

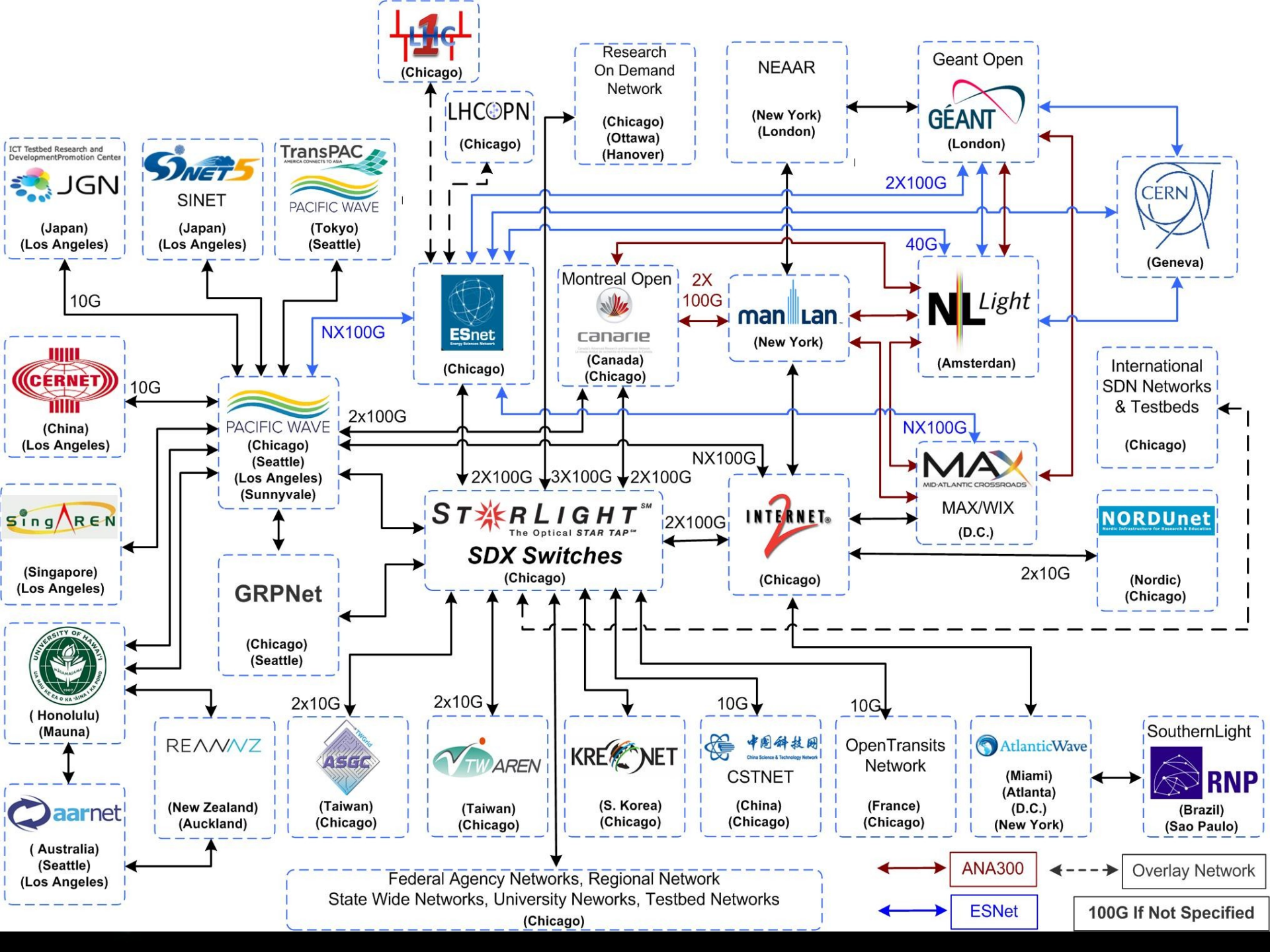


National Science Foundation
International Research Network Connections Program

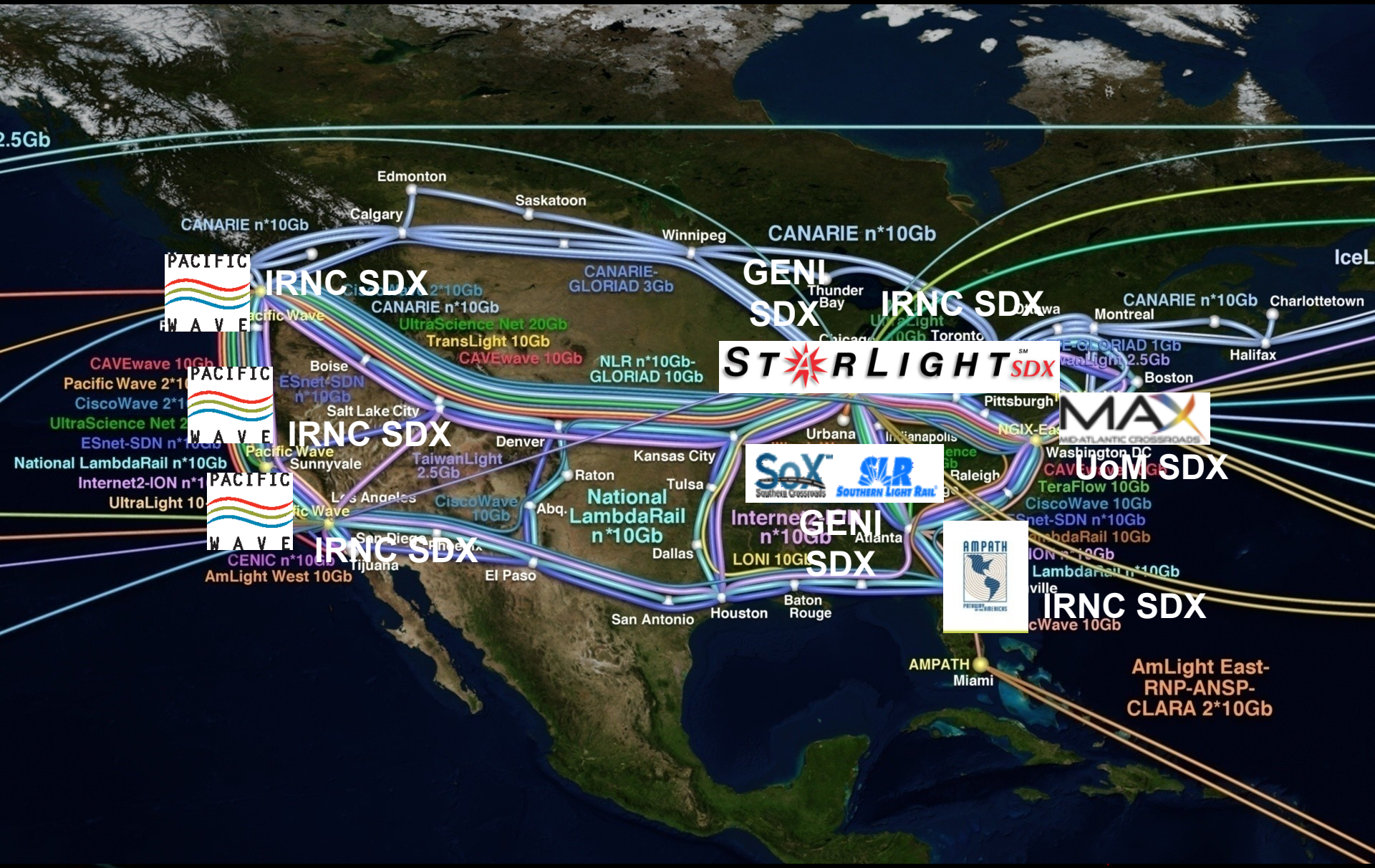
NSF

iCAIR

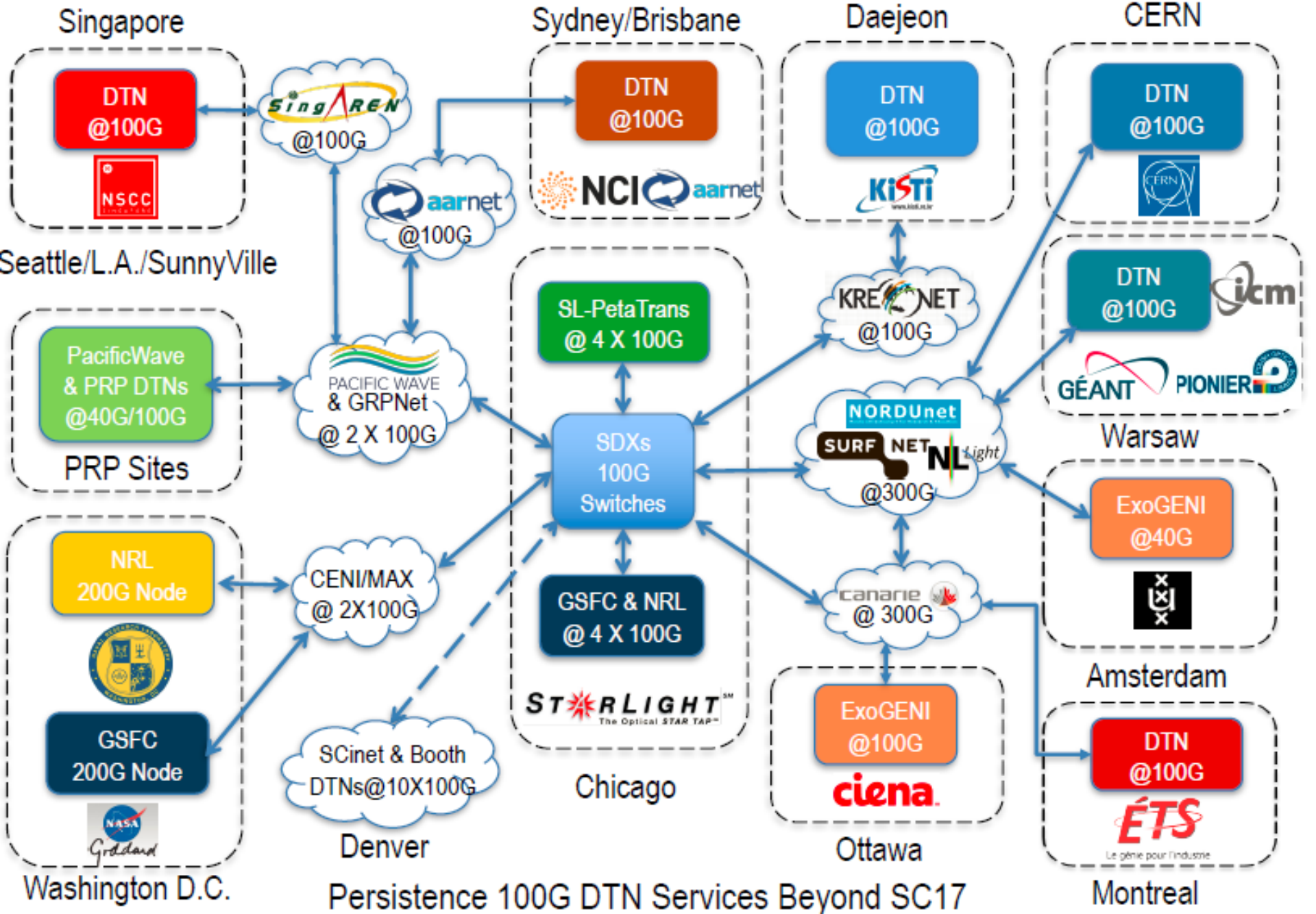
STARLIGHT SDX


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

Emerging US SDX Interoperable Fabric



PetaTrans: Petascale Sciences Data Transfer



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

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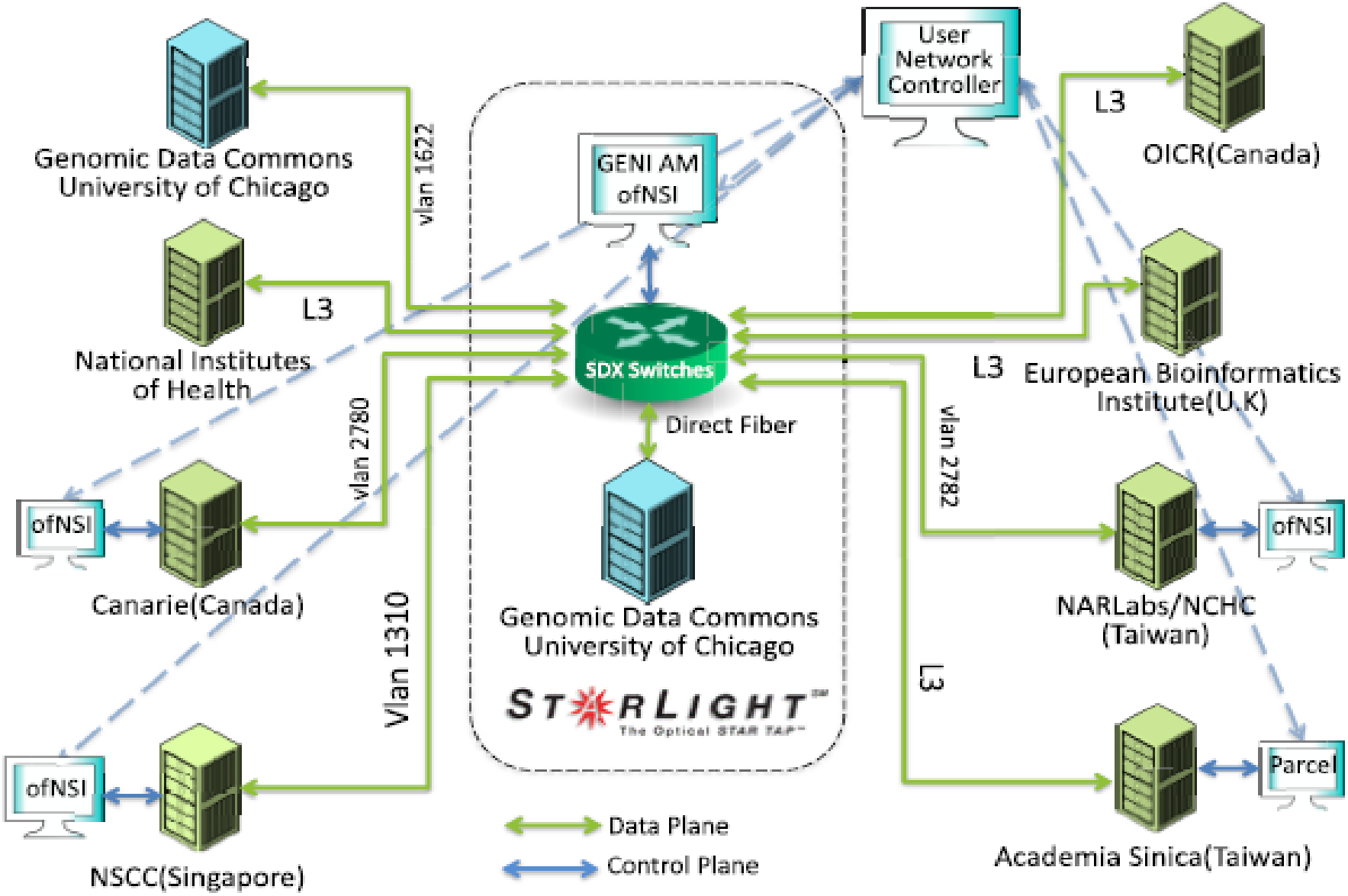
International Center for Advanced Internet Research
Northwestern University
Robert Grossman, Piers Nash, Alison Heath, Renuka Arya, Stuti Agrawal, Zhenyu Zhang
Center for Data Intensive Science
University of Chicago
Chicago, Illinois, USA

iCAIR

STARLIGHT

2016 Bioinformatics SDXs Network

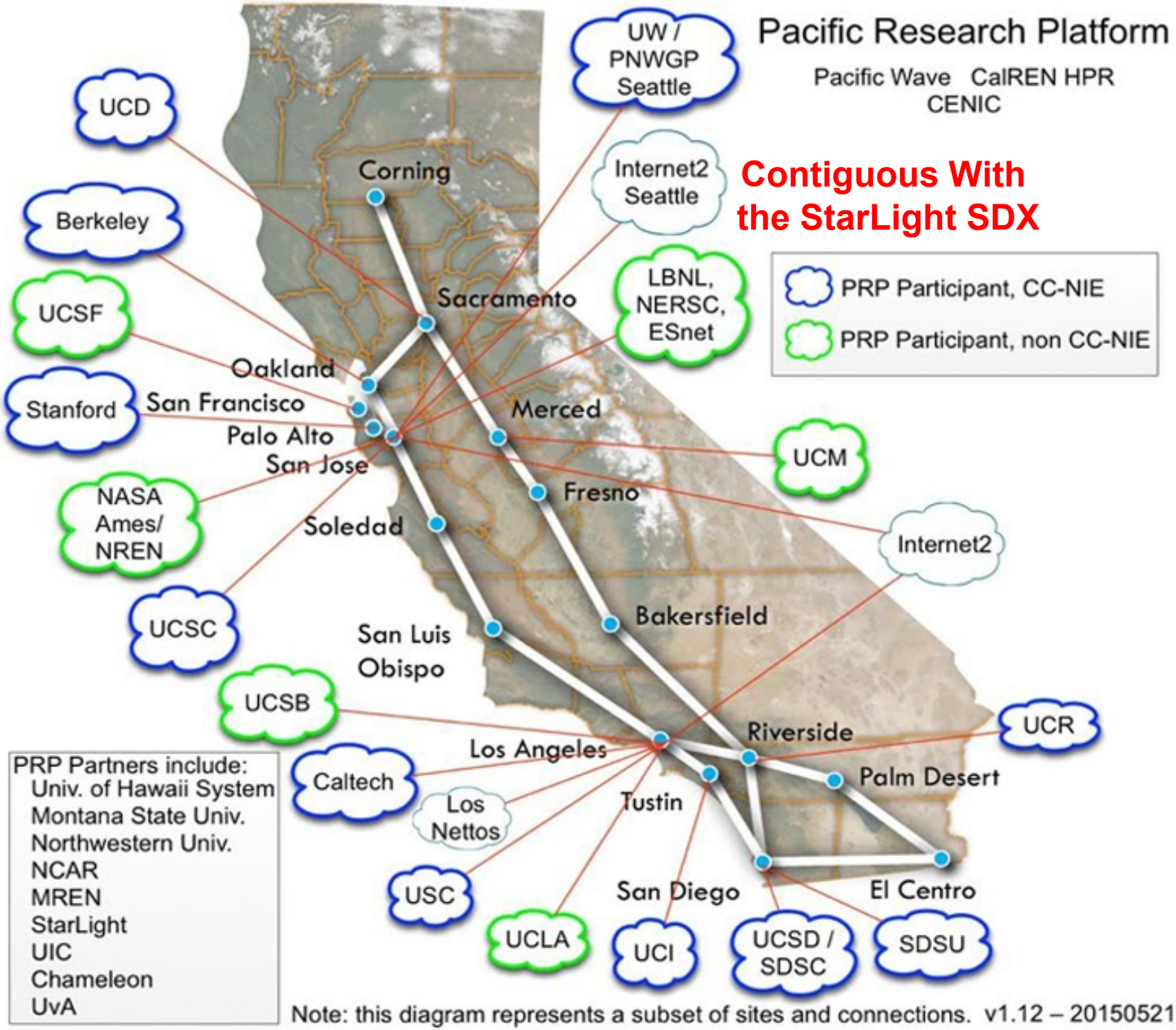


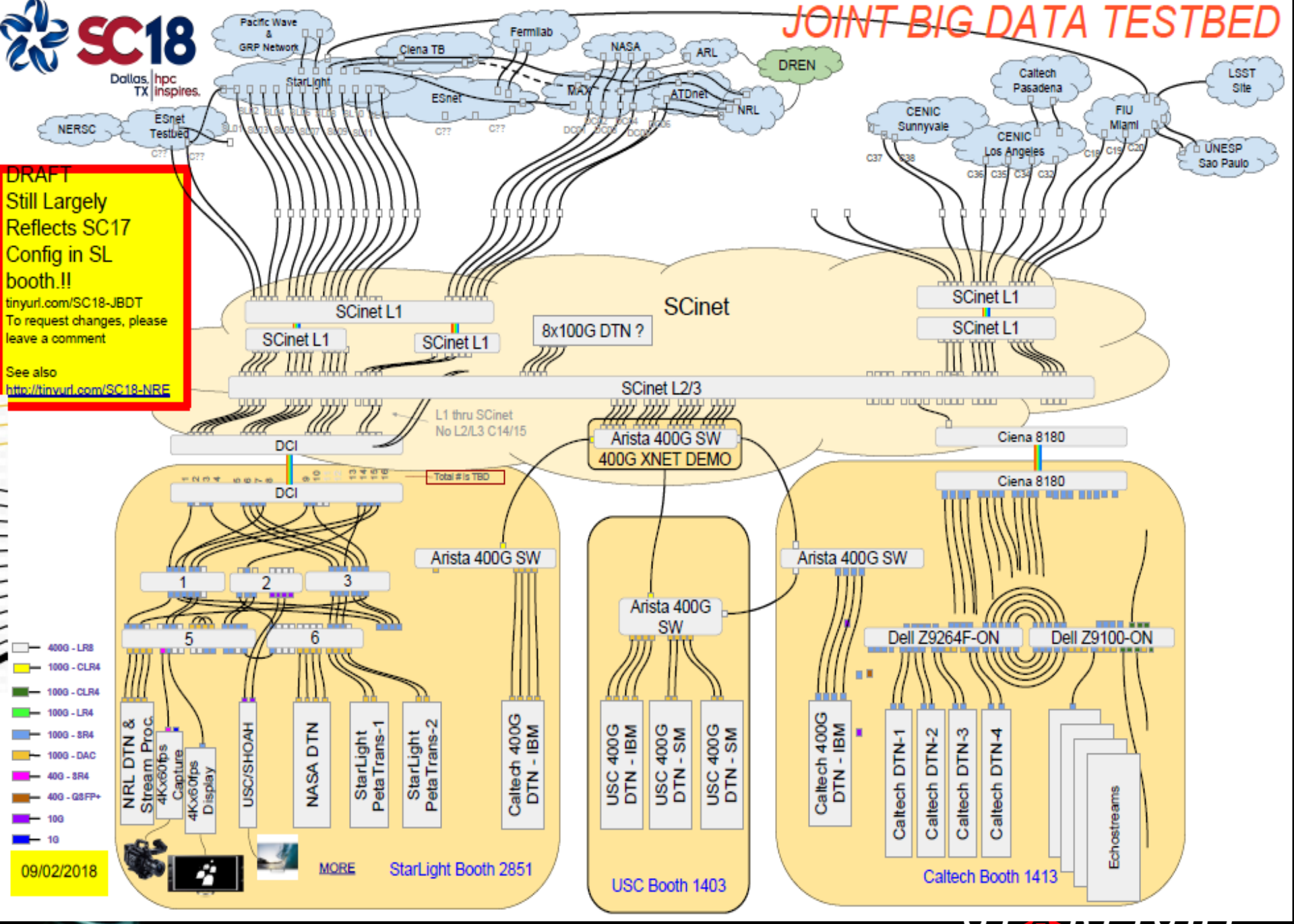
Global Research Platform: Building On CENIC/Pacific Wave, GLIF and GLIF GOLEs (e.g., StarLight et al)

Current International GRP Partners

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
- ***Core Building Blocks Exist Today!***
- 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, Planned Demonstrations for SC18 in Dallas Texas in November

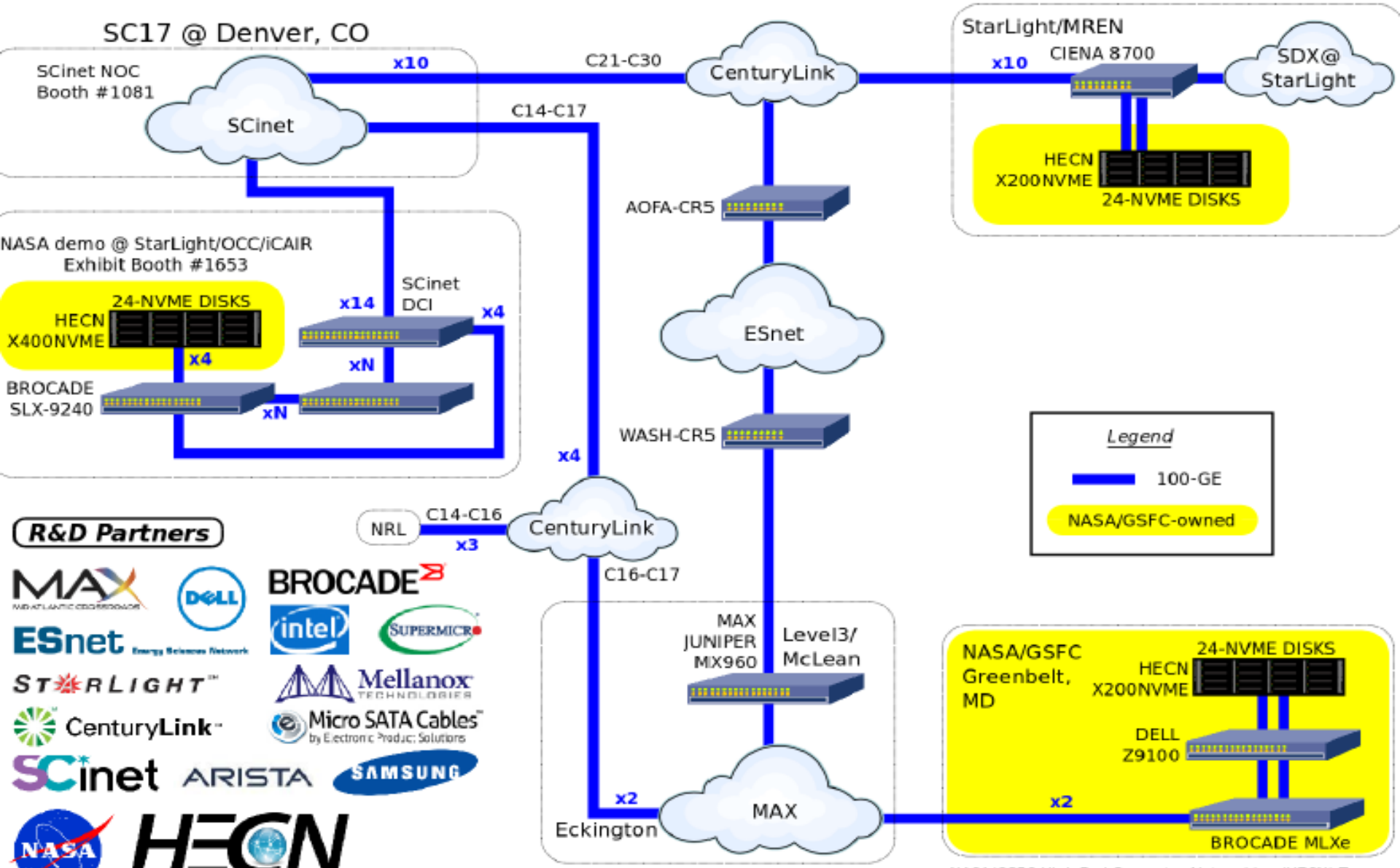

Pacific Research Platform
Pacific Wave CalREN HPR
CENIC
Contiguous With
the StarLight SDX
PRP Participant, CC-NIE
PRP Participant, non CC-NIE
UW / PNWGP Seattle
Internet2 Seattle
LBNL, NERSC, ESnet
UCD
Berkeley
UCSF
Stanford
NASA Ames/ NREN
UCSC
UCSB
Caltech
Los Nettos
USC
UCLA
UCI
UCSD / SDSC
SDSU
UCM
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


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

SC17

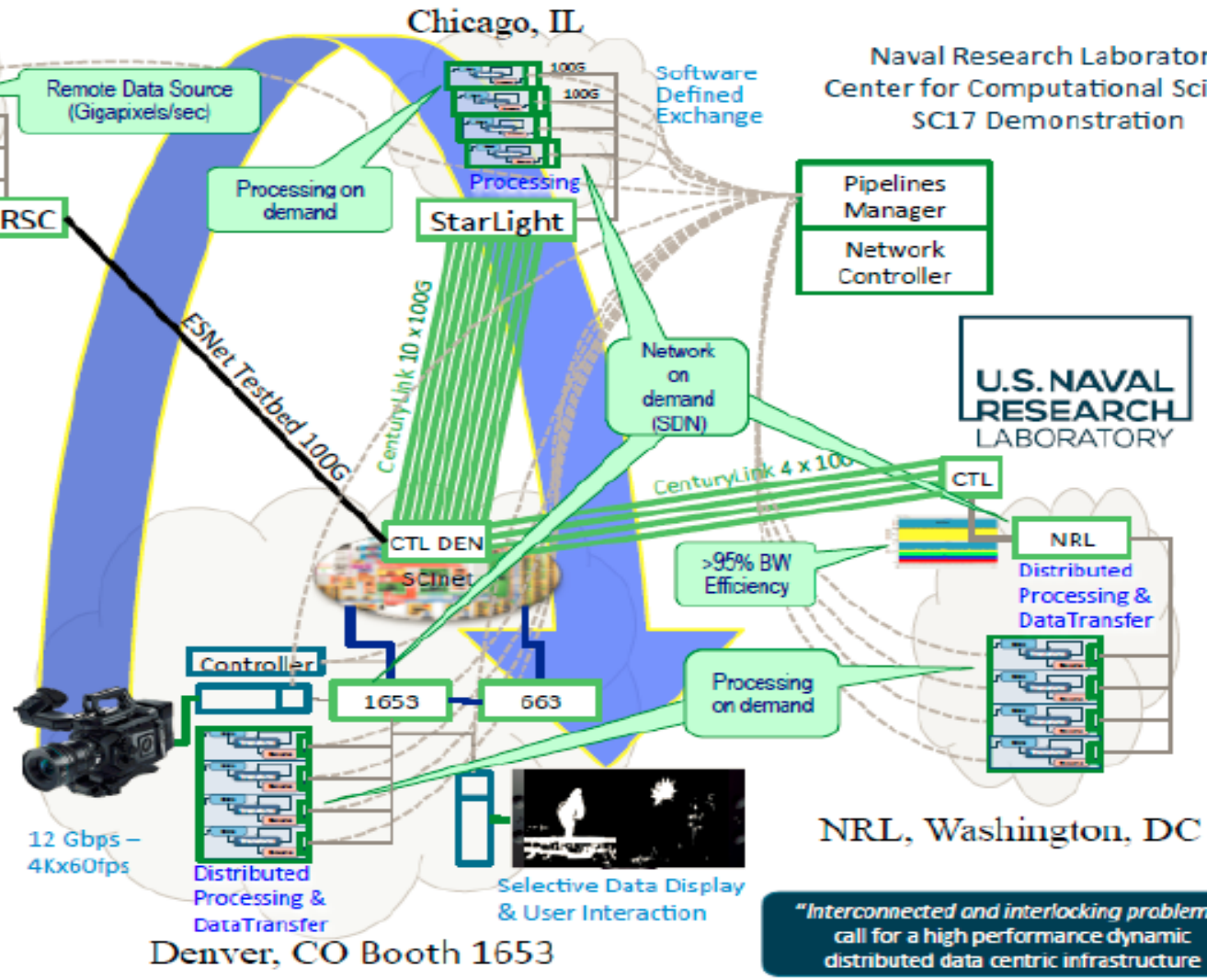
Demonstrations of 400 Gbps Disk-to-Disk WAN File Transfers using iWARP and NVMe Drives

An SC17 Collaborative Initiative Among NASA and Several Partners



NASA/GSFC High End Computer Networking (HECN) Team
Diagram by Bill Fink / Paul Lang - 8/14/2017

Dynamic Distributed Data Processing



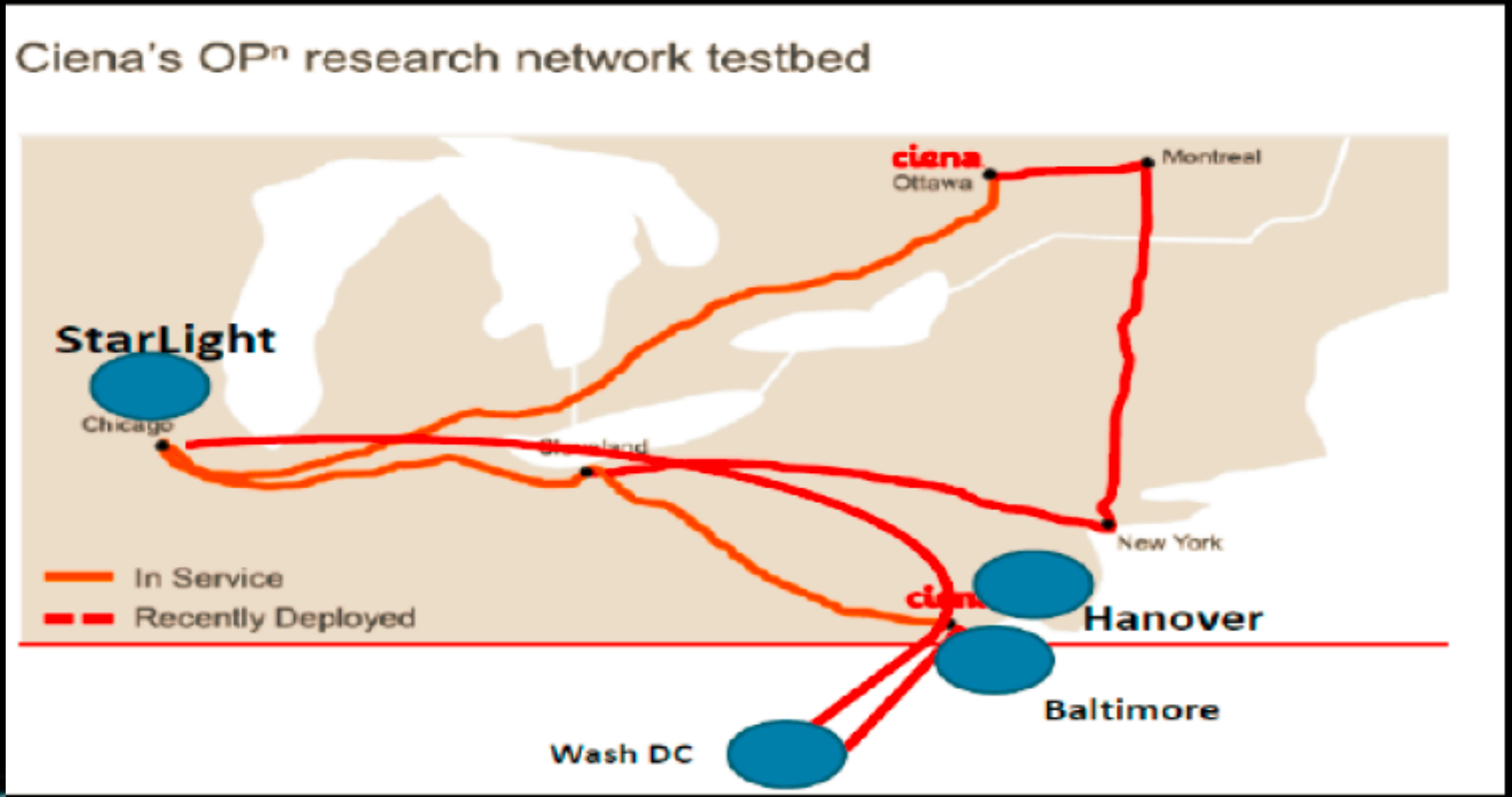
NRL will demonstrate:

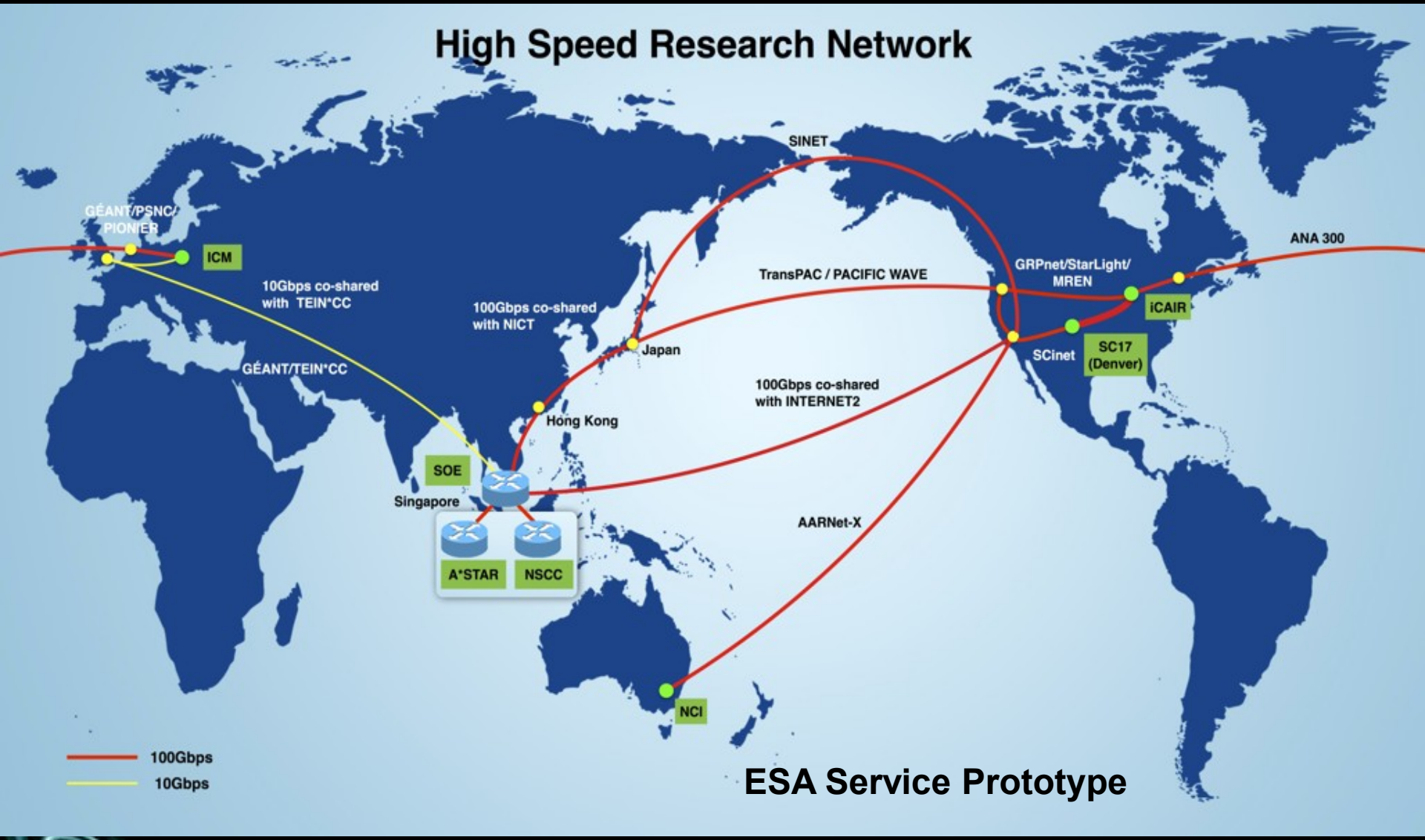
- *Dynamic* distributed processing of *large* volumes of data
- Across *geographically dispersed* HPC and network resources
- Able to *rapidly change resources* to meet application demands.
- Software Defined Networking (SDN)
- Pipelined 12 Gbps real-time video processing workflows coexisting with bulk data transfers between processing nodes.
- 3 – 100 Gbps connections DC-to-SC17 floor plus 100 Gbps connections to Chicago and Oakland

"Interconnected and interlocking problems" call for a high performance dynamic distributed data centric infrastructure

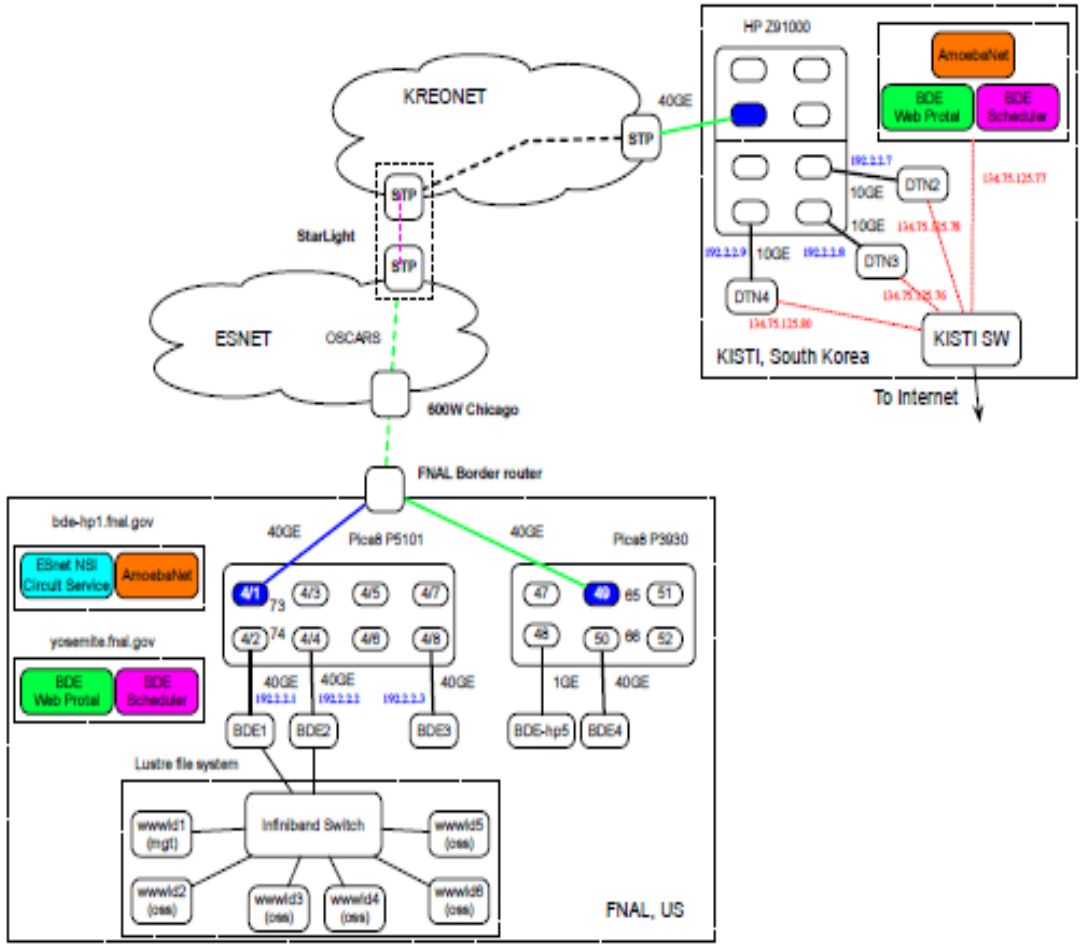
STARLIGHT℠

100 Gbps DTN Optical Testbed




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

A Cross-Pacific SDN Testbed

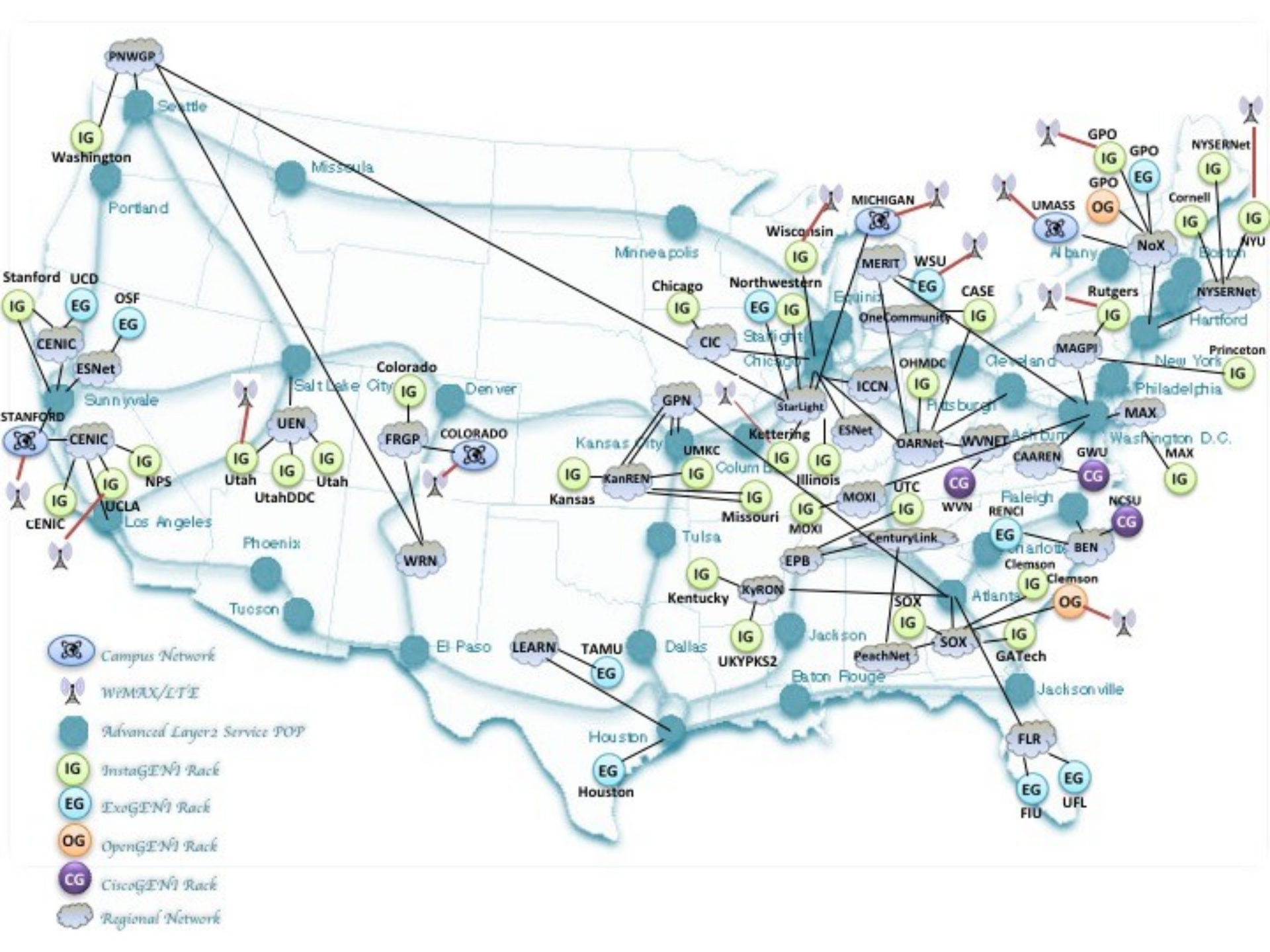


www.chameleoncloud.org

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

Kate Keahey

Joe Mambretti, Pierre Riteau, Paul Ruth, Dan Stanzione


PNWGP
Seattle
IG
Washington
Missoula
Portland
Minneapolis
Stanford
UCD
OSF
IG
EG
EG
CENIC
ESNet
Sunnyvale
STANFORD
CENIC
IG
NPS
IG
UCLA
CENIC
IG
Los Angeles
Phoenix
Tucson
Salt Lake City
UEN
IG
Utah
IG
UtahDDC
IG
Utah
Colorado
IG
FRGP
COLORADO
Denver
WRN
El Paso
LEARN
TAMU
EG
Houston
EG
Houston
Chicago
IG
CIC
Wisconsin
IG
Northwestern
EG
IG
Starlight
Chicago
MICHIGAN
MERIT
WSU
EG
CASE
IG
OneCommunity
ICCN
StarLight
ESNet
GPN
Kettering
IG
IG
Illinois
Kansas City
UMKC
IG
KanREN
IG
Kansas
IG
Missouri
IG
MOXI
MOXI
UTC
IG
OHMDC
IG
OARNet
WVNET
CG
WVN
Pittsburgh
Cleveland
Equinix
Ashburn
CAAREN
GWU
CG
Washington D.C.
MAX
MAX
IG
Raleigh
RENCI
EG
NCSU
CG
BEN
Charlotte
Clemson
IG
Clemson
OG
Atlanta
SOX
IG
SOX
IG
GATech
PeachNet
Jackson
Baton Rouge
Jacksonville
FLR
EG
FIU
EG
UFL
Tulsa
EPB
CenturyLink
IG
Kentucky
KyRON
IG
UKYPKS2
GPO
IG
GPO
EG
GPO
OG
UMASS
NoX
Albany
Cornell
IG
NYSERNet
IG
NYU
Boston
NYSERNet
Hartford
Rutgers
IG
MAGPI
Princeton
IG
New York
Philadelphia
Campus Network
WiMAX/LTE
Advanced Layer2 Service POP
IG InstaGENI Rack
EG ExoGENI Rack
OG OpenGENI Rack
CG CiscoGENI Rack
Regional Network

GENI – iCAIR P4 Testbed – Integrated With GENI StarLight SDX

- In Partnership With The GENI Initiative, iCAIR Is Developing a P4 Testbed for Computer Science Research.
- The Testbed Will Be Integrated With the GENI SDX At StarLight
- P4 (Programming Protocol-Independent Packet Processors).
- An Emerging Networking Programming Language,
- A Domain Specific Language for Network Protocols.
- Highly Flexible In Contrast To OpenFlow
- Testbed Based on Tofino (Barefoot Networks) Switches
- Compiler (V16) Enables Rules To Be Dynamically Implemented In Chip

www.startap.net/starlight

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