Internet2 & NA-REX Update

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Matt Zekauskas, matt@internet2.edu
Senior Researcher

ABOUT INTERNET2

NETWORK

SECURITY

Internet2 is a non-profit, member-driven advanced technology community providing a secure high-speed national network, eduroam global Wi-Fi access service, cloud solutions, research support, and services and training tailored for research and education (R&E). Our community includes higher education, research institutions, government entities, corporations, and cultural organizations.

Through InCommon, Internet2 provides security, privacy, and identity and access management tools built for R&E.

CLOUD

COMMUNITY

BY THE NUMBERS

330+
HIGHER EDUCATION MEMBERS

100+
COUNTRIES & RESEARCH NETWORKS CONNECTIONS

80,000+
COMMUNITY ANCHOR INSTITUTIONS

500+
NET+ SUBSCRIBERS

50+
AFFILIATE & GOVERNMENT MEMBERS

800G+
WAVELENGTHS OF NETWORK CAPABILITY

1000+
INCOMMON PARTICIPANTS

50+
INDUSTRY MEMBERS

1100+
EDUROAM SUBSCRIBERS

50+
COMMUNITY GROUPS SHAPING PRIORITIES

50+
CLOUD SCORECARD PARTICIPANTS

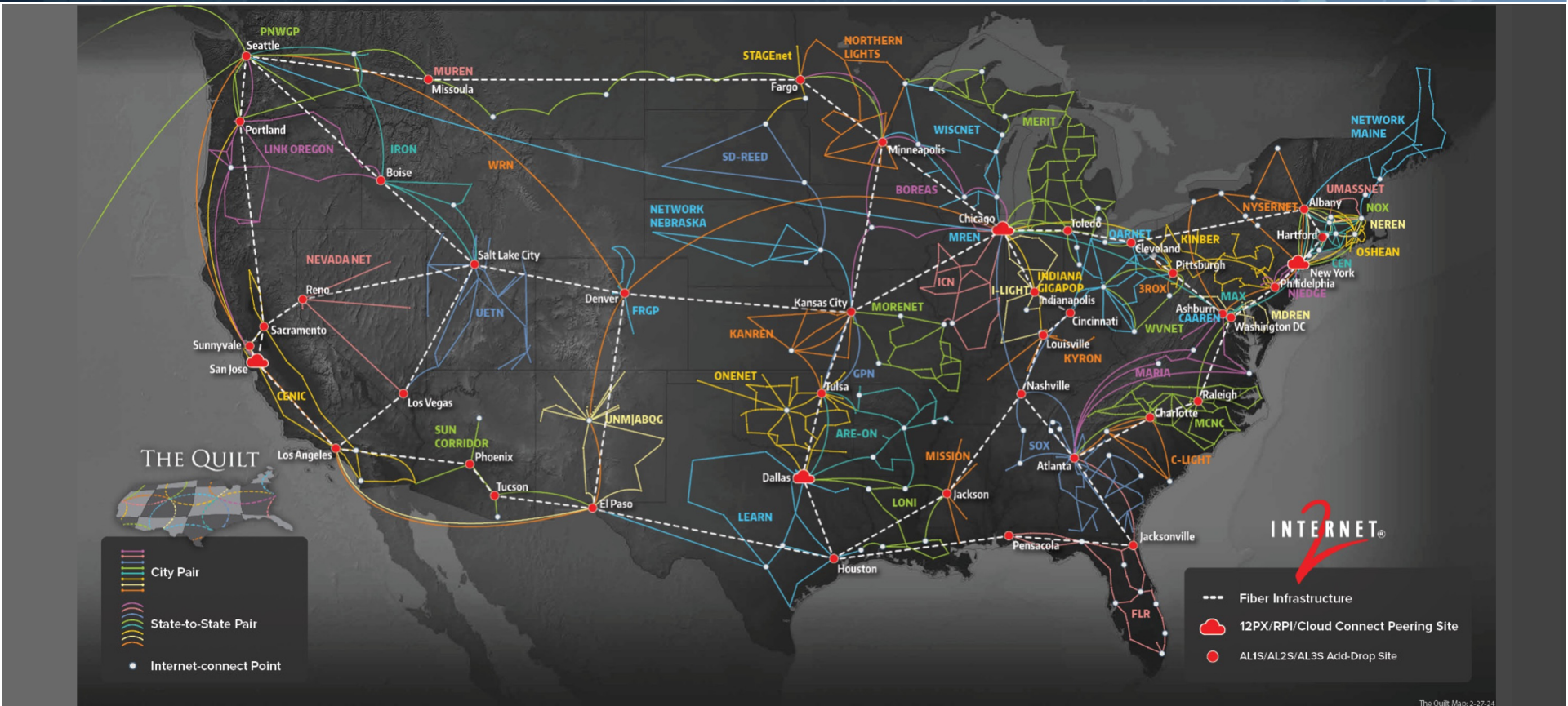
750+
NET+ CLOUD CONTRACTS

46
REGIONAL & STATE NETWORKS

20+
NET+ SERVICE OFFERINGS

32Tbps
CAPACITY PER LINK

Internet2 National Research & Education Network (NREN) + US Regional Research & Education Networks (RENs)



A Brief Technical History

Abilene	NG Abilene	Internet2 Network	BTOP	MPLS	NGI	NGI+
1999	2002	2007	2011	2016	2021	2025
622 Mbps, 2.4 Gbps	10 Gbps	10 x 10 Gbps	Native 100 Gbps (high density)	Native 100 Gbps (high density)	Native 400 Gbps	**Native 800 Gbps ?**
Cisco 12008 GSR	Juniper T640	Juniper T640 Ciena CoreDirector	Juniper T1600 Brocade MLXe-16 Juniper MX960	Juniper MX960 Juniper MX10003	Cisco 8201 Cisco 8202 Cisco NCS55A1	**Core Vendor ?**
IPv4, IPv6	IPv4, IPv6	IPv4, IPv6	Openflow IPv4, IPv6	MPLS IPv4, IPv6	SR-MPLS IPv4, IPv6	SR-MPLS IPv4, IPv6
Qwest DS-3 OC-3c OC-12 OC-48	Qwest OC-192 (2003)	Infinera DTN	Ciena 6500 50 Ghz Ciena OCI/OCLD Ciena OTR	Ciena 6500 50 Ghz Ciena OCI/OCLD Ciena OTR	Ciena 6500 Flex Grid Ciena Waveserver 5	Ciena 6500 Flex Grid **Optical Overlay ?** **Coherent Optics ?**

Hardware

Terabit-Scale Cloud Edge
8202, NCS55A1
(NCS57D2 Coming Soon)

Flex-Grid Open Line System
6500, EDFA-only

Fiber Optic Cable
SMF28-Ultra (plus some LEAF and…)

2x100 Community Test Point
Dell R6515, Mellanox ConnectX-5
R6525, Mellanox ConnectX-6

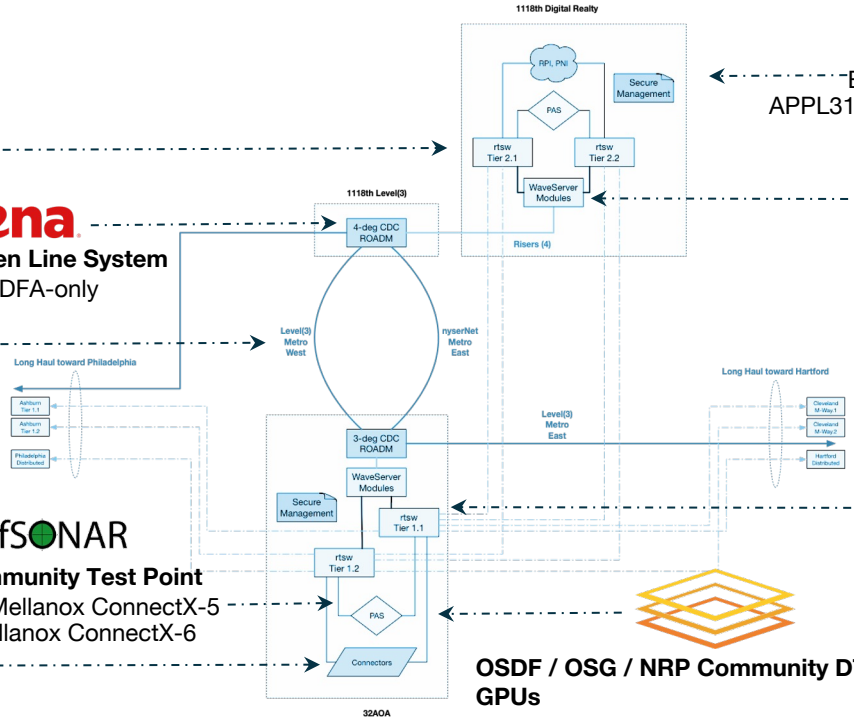
400G Global Exchange
7280PR3K

Management Network
EX4600, SRX1500, SRX 345
APPL3100 IM7232, OM2216

400G - 800G Transponders
WaveServer 5

Core Transport and Access Layer
8201

OSDF / OSG / NRP Community DTN GPUs



Spectrum, Transponders, and Pluggables

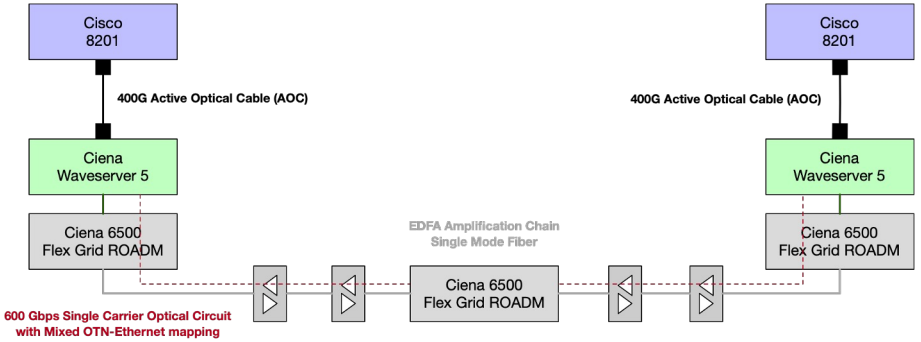
NGI was designed based on a traditional “transponder” model using Waveserver 5 Modules, each module delivering 400G backbone links on 112.5 Ghz

Advantages:

- can achieve up to 800G line rate
- provides additional capacity beyond baseline backbone demands
- mixed-mode capacity for 400G GE, 100G GE, and OTL 4.4
- high launch power (-9 to +4 dBm) and SNR margins to maximize distances achieved

Disadvantages:

- space and power are required for chassis, modules
- high current utilization required for launch power, DSPs ~ 330 W per module



Spectrum, Transponders, and Pluggables

In early-2022 Acacia brought to market "bright" 400G QSFP-DD Pluggable Coherent Optical Modules (PCOM) based on their Greylock 7nm Digital Signal Processor (DSP).

Marked the first commercial DWDM QSFP-DD pluggable with enough power and DSP processing to cross ROADM boundaries for both metro and shorter-long haul distances.

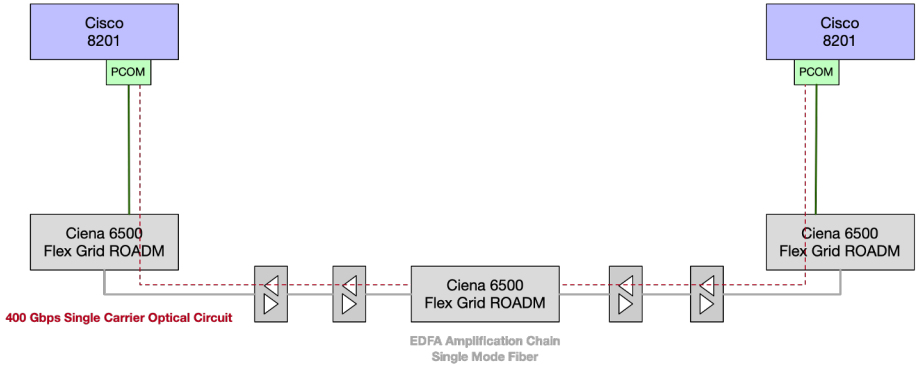
Tested by a variety of community members, including CENIC.

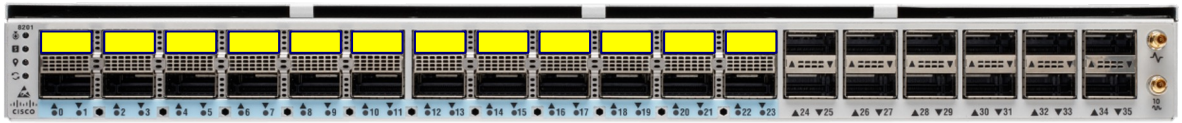
Advantages:

- Lower power envelope 22.5 watts vs 330 watts (WS5)
- Reduces the number of components needed for a 400G link

Disadvantages:

- Limited to router-to-router connections; no muxponding option
- Distances are limited due to launch power and DSP complexity (likely sub 1000 km)
- Wattage may impose limitations on cooling and electrical bus on older devices



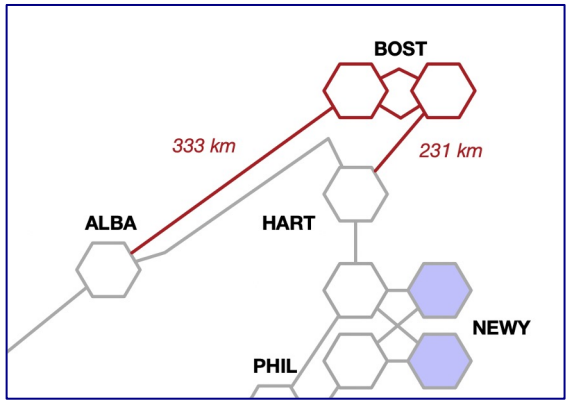


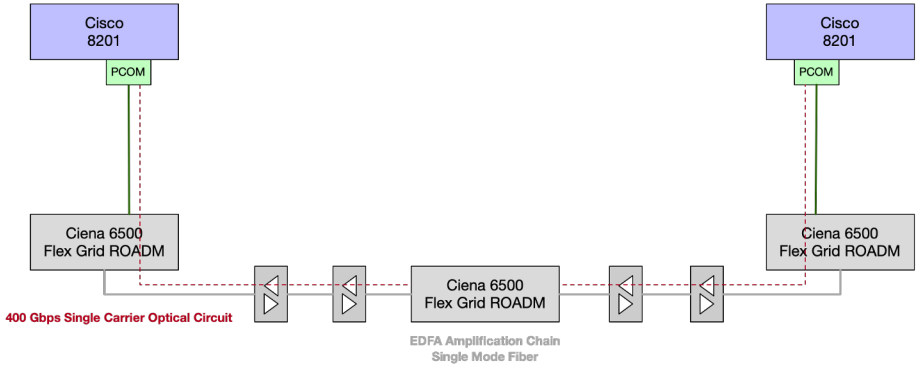
```
Optics Type:  QDD 400G BRT ZRP

DWDM carrier Info: C BAND, MSA ITU Channel=Non-ITU, Frequency=193.6812THz,
Wavelength=1547.866nm
...
Actual TX Power = -2.98 dBm
Actual TX Power(mW) = 0.50 mW
RX Power = -4.52 dBm
RX Power(mW) = 0.35 mW
RX Signal Power = -10.31 dBm
...
Baud Rate =  60.1385459900 GBd
Modulation Type: 16QAM
Chromatic Dispersion 2408 ps/nm
Configured CD-MIN -2400 ps/nm  CD-MAX 2400 ps/nm
Second Order Polarization Mode Dispersion = 49.00 ps^2
Optical Signal to Noise Ratio = 23.90 dB
SNR = 15.30 dB
...
Temperature = 58.00 Celsius
Voltage = 3.27 V
...
Name                    : CISCO-ACACIA
OUI Number              : 7c.b2.5c
Part Number             : DP04QSDD-HE0-190
...
```

550 km Test Link

Spectrum, Transponders, and Pluggables





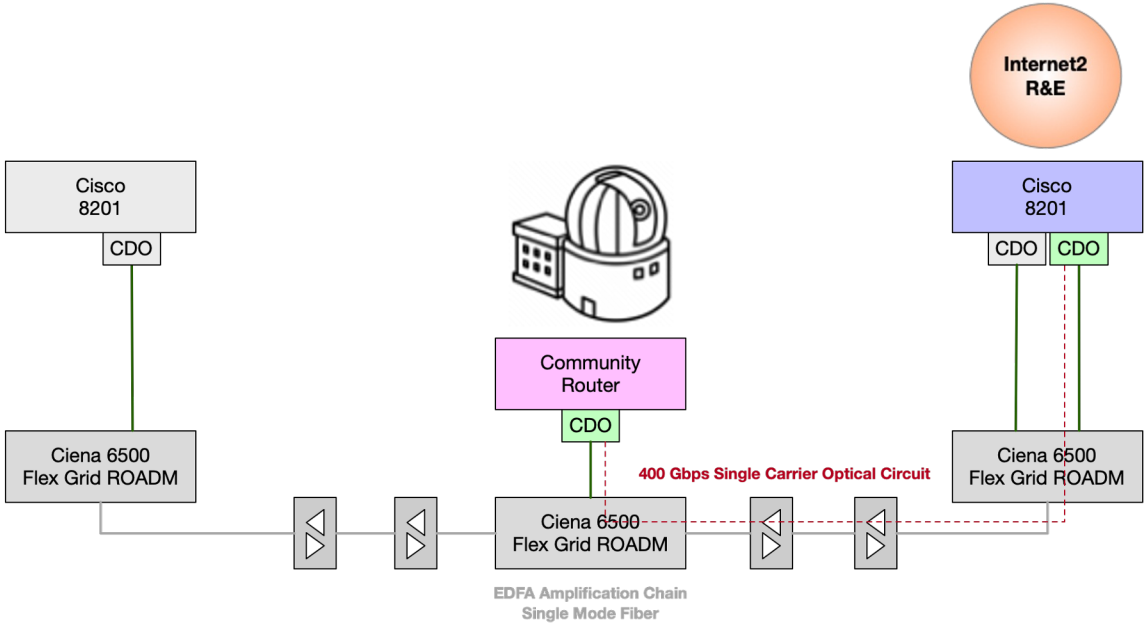
In December 2023, Internet2 placed its first coherent pluggables online in the northeast, fully deploying a new site with no WaveServer 5 devices.

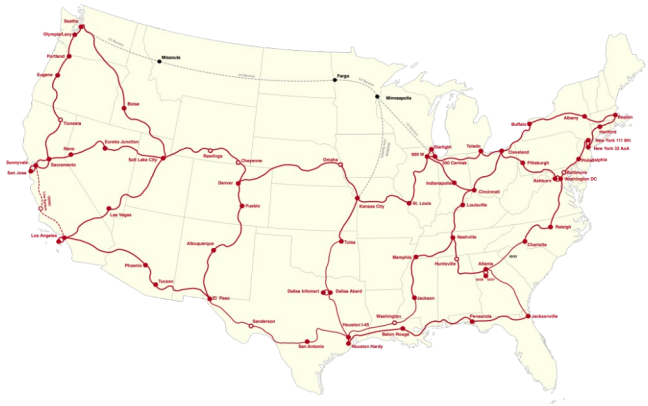
Two sites in boston BOST (300 Bent) and BOST2 (1 Summer) are:

- Linked to each other by two channels (E and W)
- Also linked to adjacent sites:
  - Albany (ALBA) 333 km
  - Hartford (HART) 231 km

Use Case: Coherent Onramp

- Provides a potential solution for a community partner who is not near a router location; also may allow fewer routers on the overall platform
- Community partner can launch from their own gear - even using coherent digital optics
- May accommodate a small metro dark-fiber segment between ROADM and community partner





Services

LAYER 1 SERVICE

Point-to-point 10, 100 & 400G links and flexible grid spectrum to support private network needs.

LAYER 2 SERVICE

Effective and efficient wide area 100 gigabit Ethernet technology.

LAYER 3 SERVICE

For IP network and peer exchange needs.

PEER EXCHANGE

Provides institutions with access to commercial peers across the national footprint.

RAPID PRIVATE INTERCONNECT

Allows Internet2 connectors to present themselves for private peering at selected national peering locations.

R&E

Provides institutions with access to each other across the national footprint.

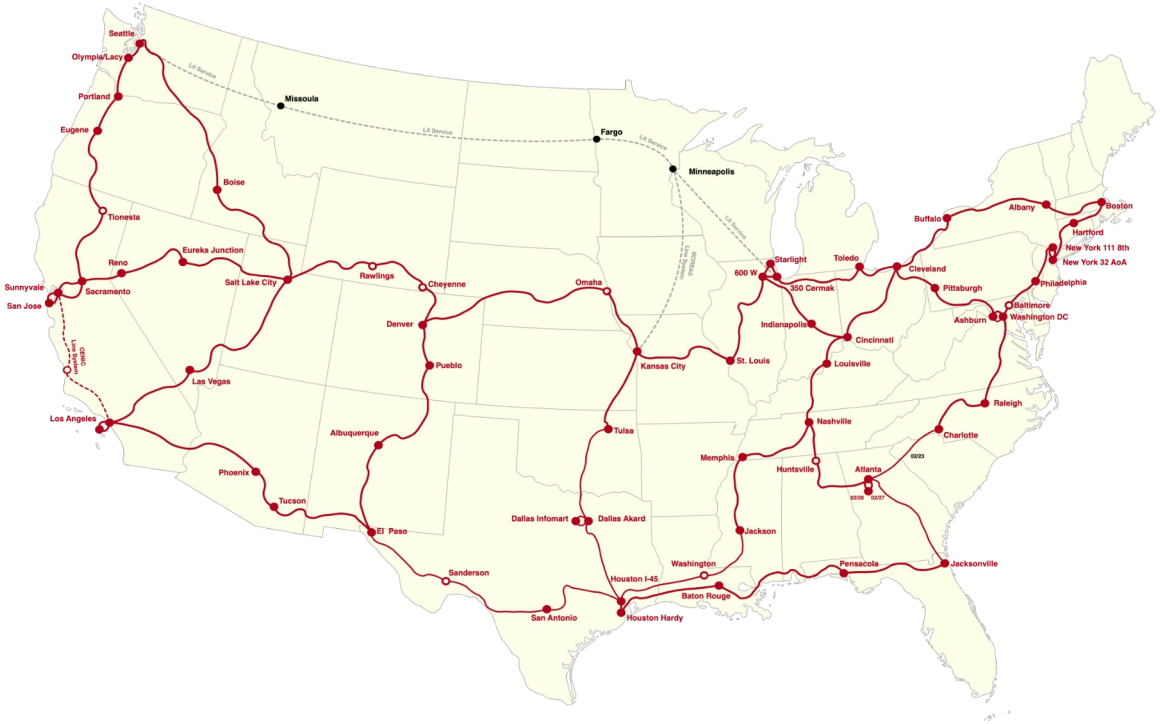
CLOUD CONNECT

Uses regional's infrastructure in conjunction with the Internet2 Network to reach cloud resources.

GLOBAL DDoS PROTECTION

Our cloud-based, volumetric DDoS mitigation service was procured on behalf of the community.

Layer 1 Services



Stats

- 26,000 kilometers of optical fiber
- Ultra SMF28 + a little eLEAF
- Flexible with 74+ add/drop sites
- Open line system, (not locked to a single vendor)

Backbone Waves (400G)

- **96** 400 Gbps Backbone Circuits (WaveServer 5)
- **5** 400 Gbps Backbone Coherent Pluggables

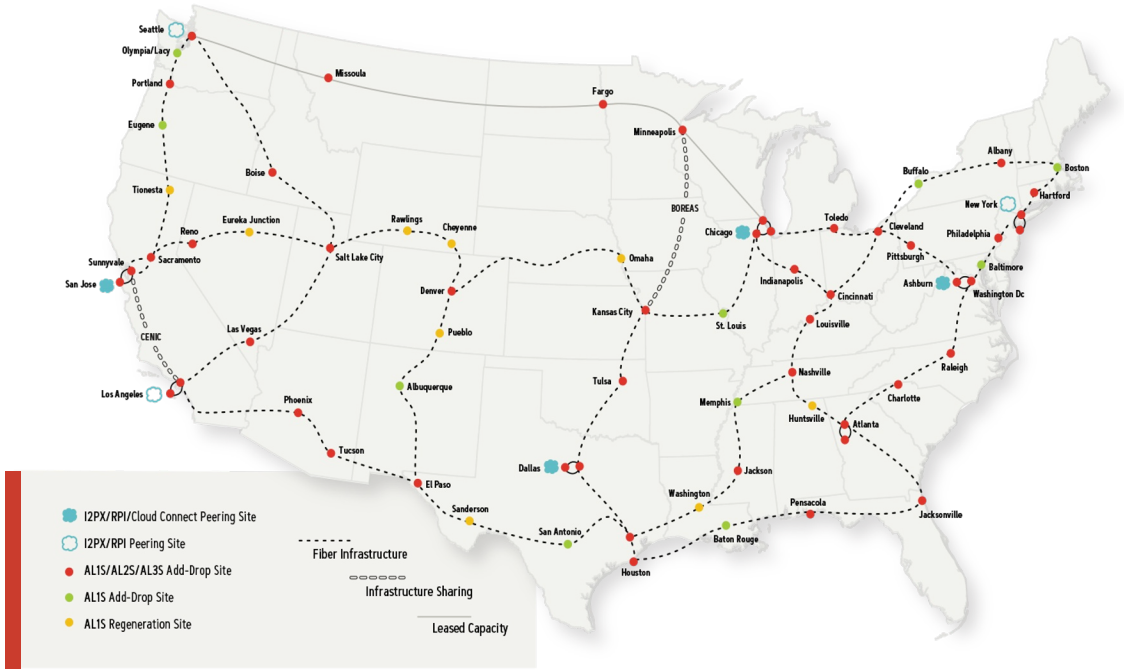
Foreign Waves

- **6** point-to-point alien waves

Customer Services

- **10** 400 Gbps Circuits
- **50** 100 Gbps Circuits
- **60** 10 Gbps Circuits
- **7** Managed Spectrum (Community) 600-800 Gbps

Layer 2 and Layer 3 Services



I2 Cloud Connect

605 Connections

I2 RPI

67 10G Interfaces
2 100G Interfaces

I2 DDOS

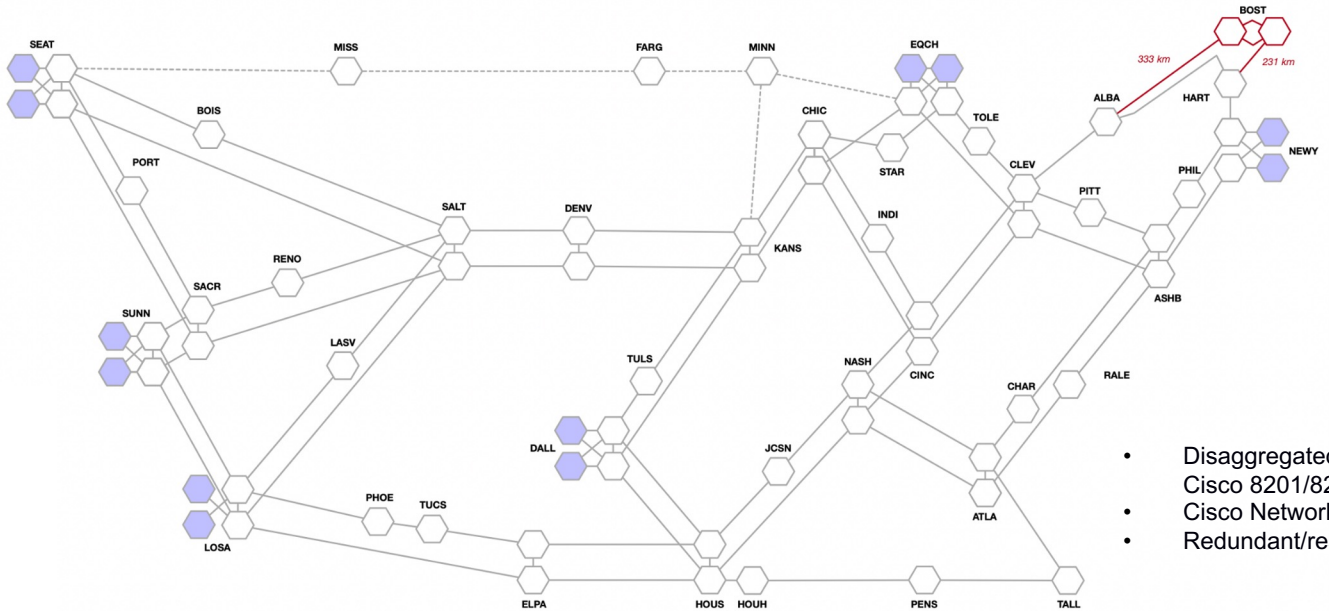
14 Subscribers
95 Tenants

I2 Insight Console (November 2023 - February 2024)

217 Layer 2 Connections Created or Updated
90 Layer 3 Connections Created or Updated
48,000 Looking Glass Queries Executed

Packet Network Topology

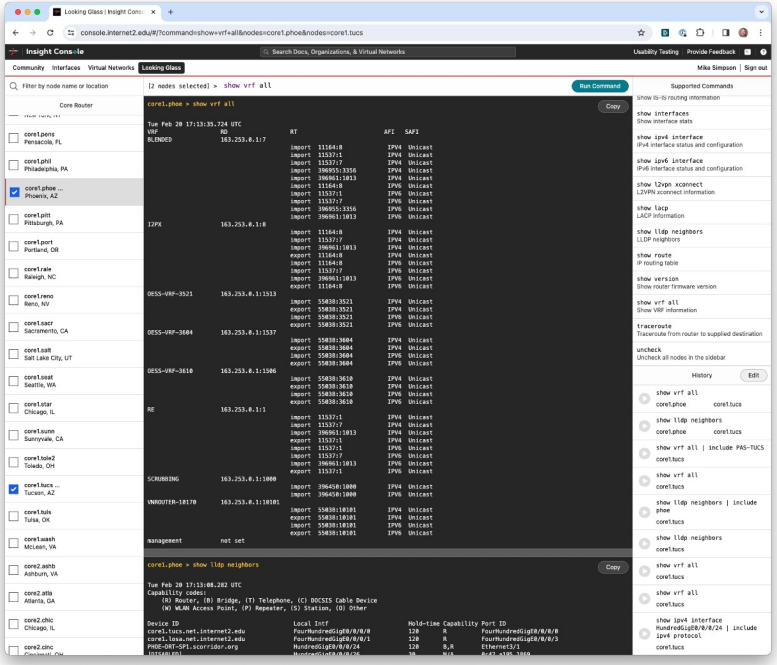
- Fifth generation of the Internet2 backbone
- Ninety-four 400 Gbps Backbone links
- 27,600 Tbps of deployed capacity
- 1.6 Tbps available contiguously coast to coast
- Each link is on non-regenerated wave



- Disaggregated Switching/Routing Platform
  Cisco 8201/8202 - 77 Routers, 47 Sites
- Cisco Network Services Orchestrator (NSO)
- Redundant/resilient routers, dual-connected cloud peers

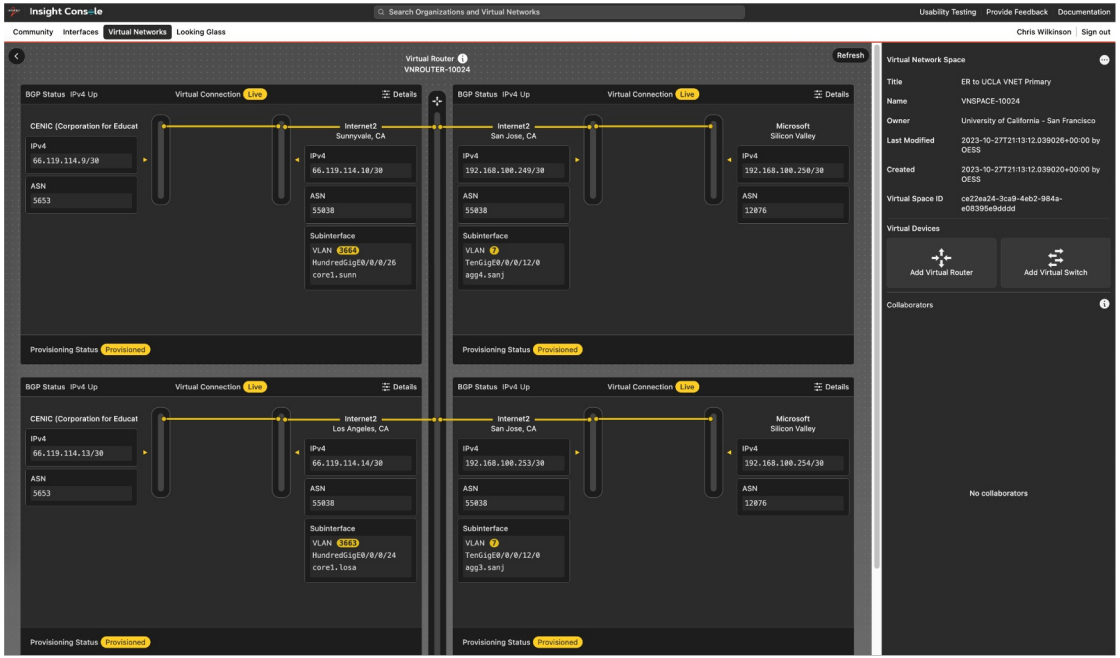
Insight Console

- A web-based tool for **visualizing**, **managing**, and **troubleshooting** all Internet2 **network services**.
- The most visible part of the **Insight** architecture.
- Authentication and authorization integrated with **Internet2 Identity Services** (a.k.a. “InCommon SSO”).
- Functions delivered in 2023:
    - **Looking Glass**: Run commands (in a safe and secure environment) against our production devices and get live results.
    - **Community**: Self-management of organizations, people, and roles.
    - **Interfaces**: Visualization of network ports and services.
    - **Virtual Networks**: Creation and management of L2 and L3 overlay networks, including CloudConnect.
- In 2024:
    - **Full Cloud Connect Automation.**
    - **Evolve interface and API**
    - **Cloud Router development**



Virtual Networks

- **Visualization**, **management**, and **troubleshooting** for L2 and L3 **overlay networks**; a re-implementation and enhancement of similar functionality previously delivered via OESS/CloudConnect.
- **Virtual spaces** provide a canvas within which different organizations can **collaborate** on building overlays.
- **Virtual devices** (switches and routers) can be added to spaces to **establish** L2 and L3 overlays.
- **Virtual connections** can be added to devices to **connect** the overlays to interesting places: other Internet2 members or downstream sponsored parties, government and industry partners, cloud partners (AWS, Azure, GCP, OCI), etc.
- Provisioning of the overlay networks on Internet2's production network is handled via **Insight API** calls, with backend automation provided through **NTC Nautobot**, **Cisco NSO,** and other supporting tools.



What can be controlled?

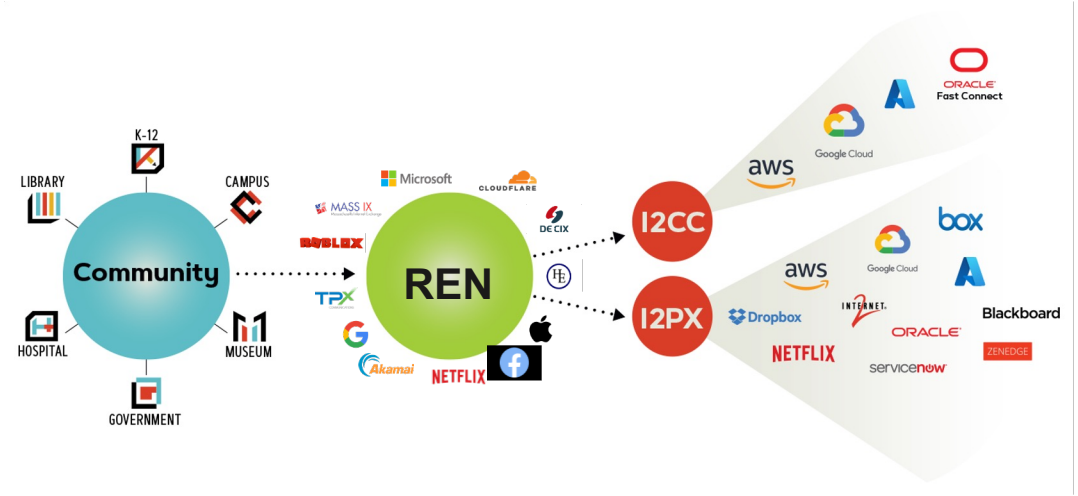
- Within Internet2
  - From any connection point to another you can
    - Create a VRF (routing instance, virtual router, VPN)
    - Create a point to point or multipoint Layer 2 path (virtual switch)
  - And you can add direct connections to cloud service providers
    - AWS Direct Connect
    - Google Cloud Partner Interconnect
    - Microsoft Azure ExpressRoute
    - Oracle FastConnect
  - Yes, there's an API
- Outside of Internet2, through regional and school networks
  - Varies.
  - You can always plumb a set of VLANs to connect your project to one of the connection points

Research using Virtual Networks

- Large projects like SENSE (DoE) and facilities, like FABRIC and ACCESS (NSF)
  - (We do not carry the FABRIC backbone today, but can be a part of a school connecting to FABRIC and did carry backbone traffic prior to the dedicated circuits being created; we do carry commercial cloud traffic for FABRIC)
- Tie together sites that can't or don't want to use IP via a layer 2 network
  - Wireless testbeds
  - Weather data distribution experiment
- Integrating commercial cloud into research projects
  - Need to get to specific hardware (usually particular GPUs)
  - E.g.:NSF IceCube - use GPUs to perform an experiment and then use direct cloud attach to return data (in particular to examine cost structure)

Use Case: I2 Peer eXchange & Cloud Connect

- Community members leverage their existing Internet2 Network investments
- Directly augments commercial services demand
- Provides high-speed access to network-intensive off-net applications, such as social networking and high-definition video
- I2PX provides high performance, low latency, and efficient (often 1 hop) access to some of the top content destinations in the world including: Google, Zoom, Netflix, and other commercial content providers. The service supports IPv4 and IPv6. Transit between subscribers is not permitted.
- Individual community members can also use Cloud Connect for private connections to Amazon Direct Connect, Google Cloud Partner Interconnect, Microsoft Azure Express Route or Oracle Fast Connect services.



Use Case: Cloud Workflow

- Multiple paths may exist for data to flow down to a PI or student from a given resource
- Dedicated connections may exist from commercial cloud to Researchers via Cloud Connect (at one of our exchange point sites, using 10 and 100G connections)

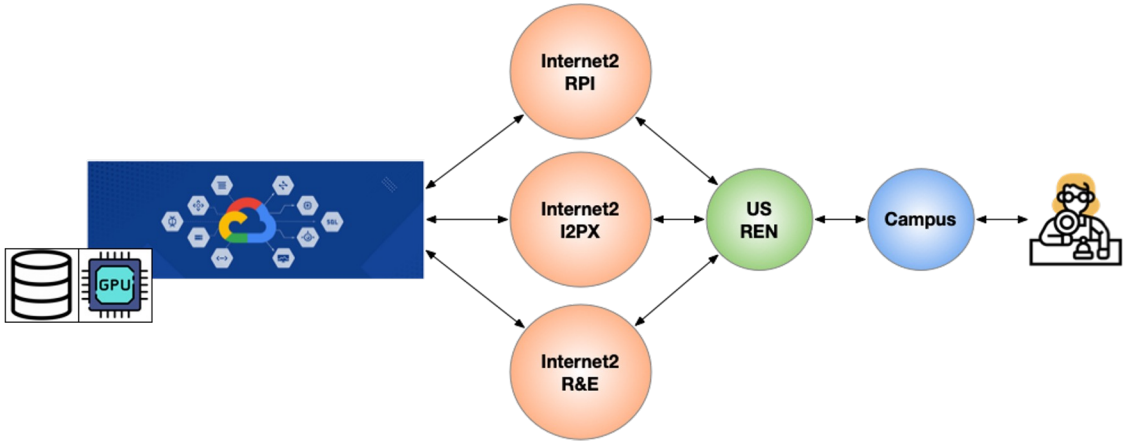
  …or…

- Dedicated connections can be built from commercial cloud via Internet2 RPI ports (anywhere on our footprint) at 10 or 100G

  …or…

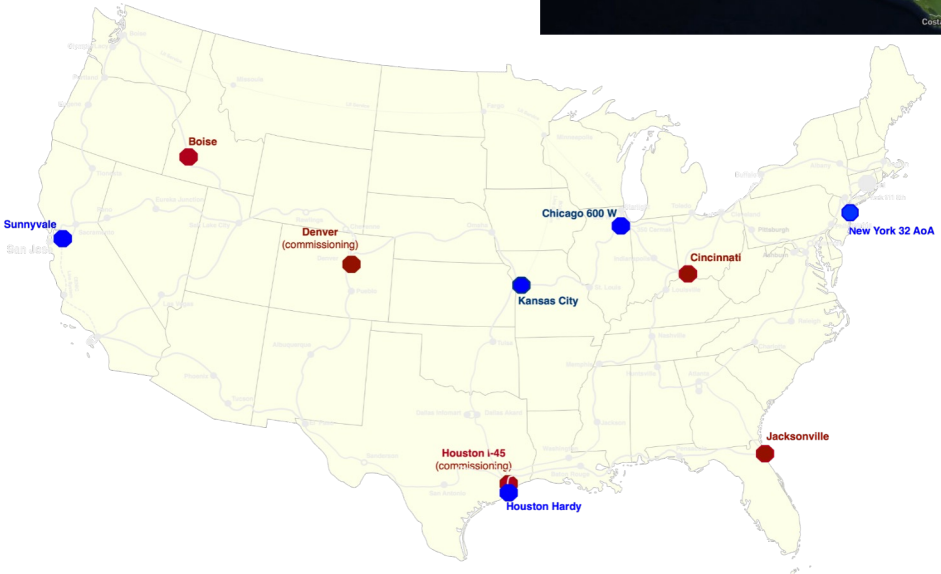
- General commercial cloud access may be made available through I2PX

- All through existing 100 or 400G connections US RENs have to support campuses.

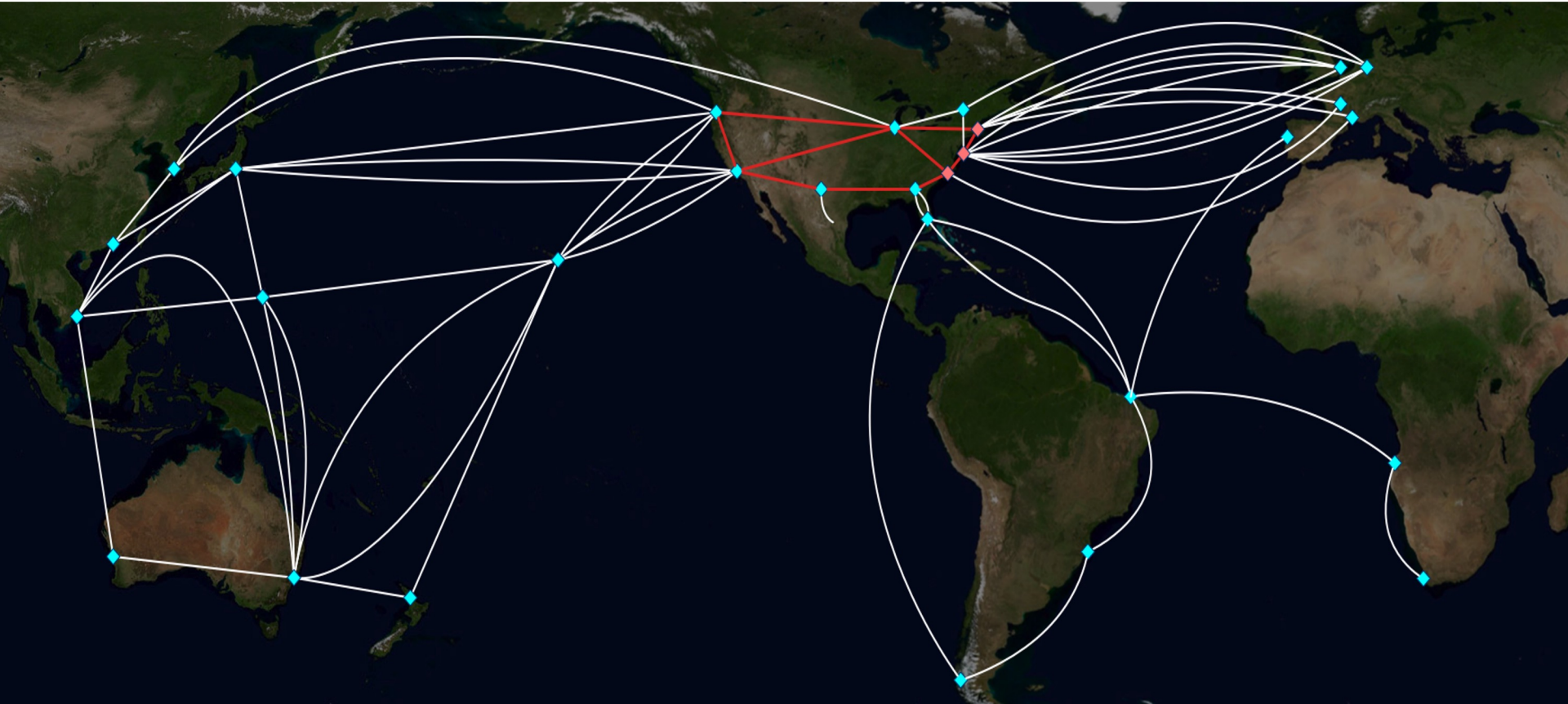


Open Science Data Federation (OSDF)

- Provides Distributed high-throughput computing (dHTC) in support of open science
- Internet2 hosts 10 cache / compute nodes
- 100G connections to the backbone
- Chicago, Kansas City and New York nodes being refreshed
- Filling key latency and location gaps



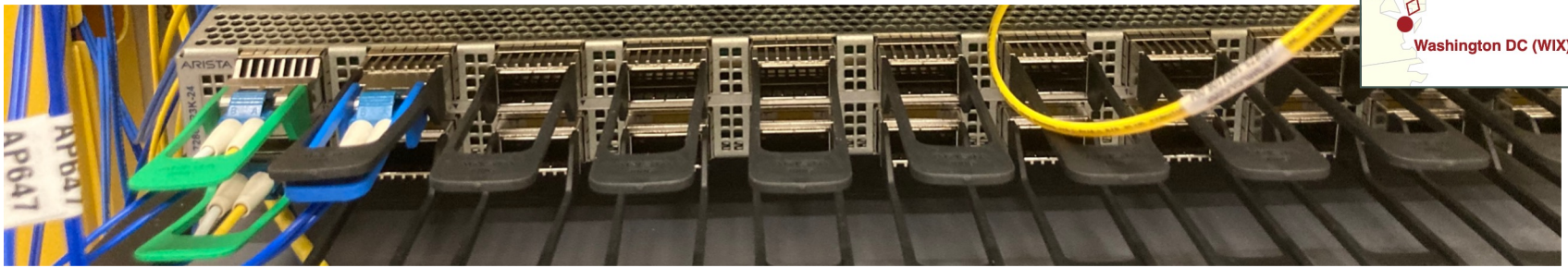
International Connectivity (NREN to NREN) via multiple partnerships and consortiums



400G Global Exchange Points

Deployment of Arista DCS-7280PR3K-24 Switches

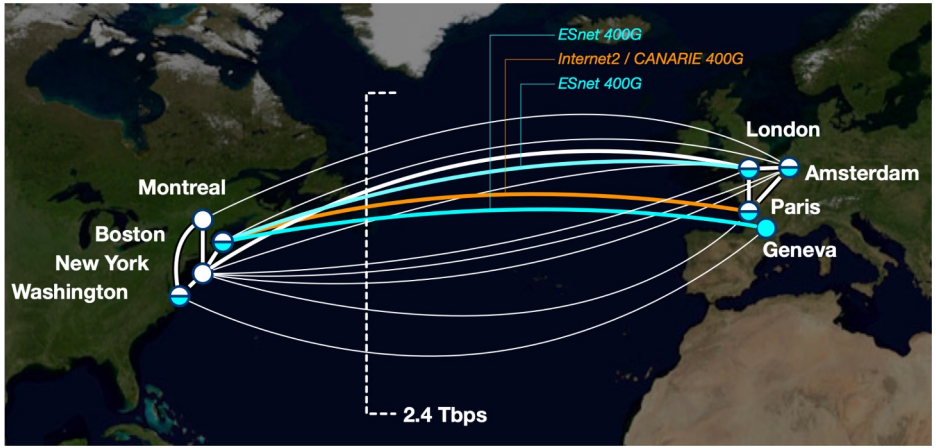
- Global Exchange Points are currently Layer 2
- Now installed and operating at Boston (BIX), New York (MAN LAN), and Washington (WIX)
- In the process of fully integrating them into the core backbone, NSO, and Insight Console (Virtual Networks, APIs)
  - Intend to integrate into AutoGOLE/SENSE
- First 400G links are online!
- **Inter-GXP links will likely be pluggables - just waiting for the release of “bright” OSFP**

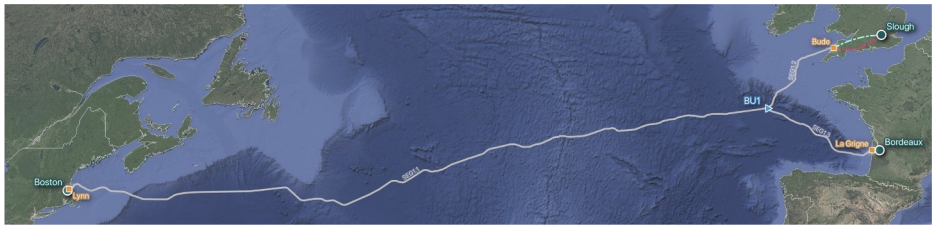


400G in the Atlantic

First General Purpose R&E Circuit Online

- A key part of the global ecosystem for R&E
- Continuity from European 400G networks to North American networks
- Under Final Test and Provisioning
- Amitié cable
- Part of Advanced North Atlantic
- Primarily a collaboration between CANARIE, ESnet, and Internet2; however success depends on all the ANA partners!
- ESnet also has two dedicated links as part of system
- First of Many Expected





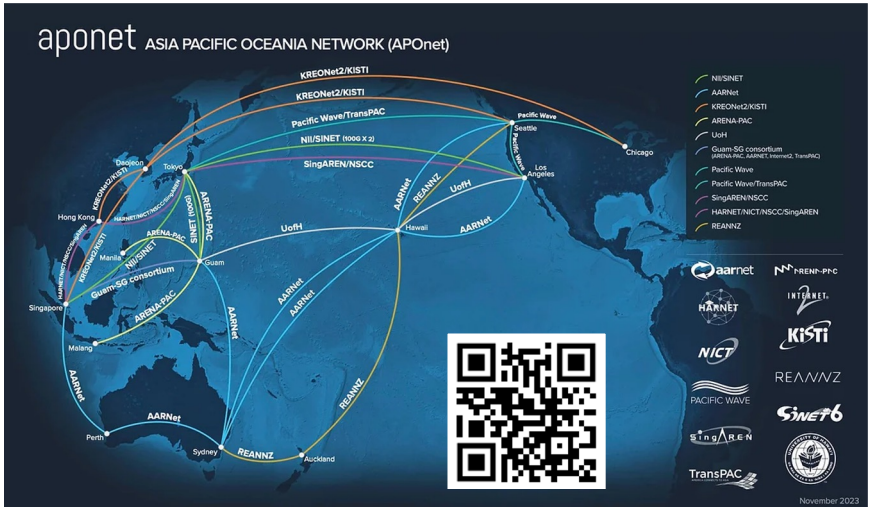
Global Partnerships: ANA & APONET

Advanced North Atlantic (ANA)

- KREONET and NII have joined ANA.
  - KREONET - 100G Chicago to Amsterdam
  - NII - 100G New York to Amsterdam
- New NREN working group formed to advance multi-domain network provisioning and failover. Currently surveying members and exploring potential solutions.
- Massive documentation and operational procedure overhaul.
- ANA specific dashboard created by Indiana University.

Asia Pacific Oceanic Network (APONET)

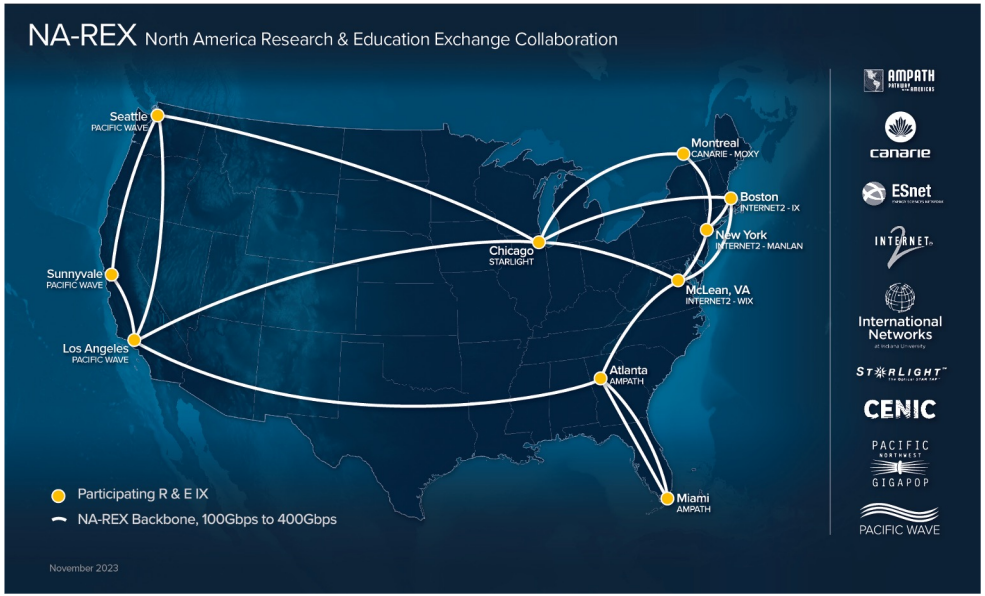
- Internet2 joined in 2021 through the Guam-Singapore Connectivity Consortium.
  - Partners: AARNET, ARENA-PAC, Indiana University, Internet2
  - Exchange providers: GOREX and SingAREN
- Recently supported a dedicated satellite data downloads connection for the ISRO-NOAA Data Exchange and Cooperation (INDEC) with the help of NII, NKN, Pacific Wave, SingaREN and TransPAC.



NA-REX: Collaboration, Overlay

International Collaboration: NA-REX

- North American consortium of Exchange Point Operators, Connectivity Providers, Science Networks
- Improve coordination, establish common operating principles
- Leverage common toolsets, provisioning mechanisms
- Support dedicated links for experimental traffic, network research
- Initial links online:
  - Chicago and Seattle (dedicated)
  - Chicago and Los Angeles (dedicated)
- Links were successfully leveraged by Supercomputing NREs (Network Research Experiments) and OFCnet
- Currently planned for 2024:
  - Deployment of dashboard based on NetSage
  - Bring additional 400G links online
  - Restore API functionality to I2 Exchange Points (Q2) -> 2025Q2



Internet2 NA-REX Participation (as of end 2024)

Questions ?

For further information

- Myself, matt@internet2.edu
- Questions about accessing Internet2 Network services - start with your local networking group, but you can also contact Internet2 network services research support at rs@internet2.edu (but note it is best effort)
- Questions specific to cloud connect: cloudconnect_request@internet2.edu
- Internet2 Website https://www.internet2.edu/
- Internet2 Insight Console (portal for services, you can use the looking glass and read the documentation without logging in but other services require authentication): https://console.internet2.edu/
- API has no detailed explanation today, but you can see it at https://api.ns.internet2.edu/docs/ – contact me or the rs address above if you are interested in using it.
- Internet2 NOC (has statistics): https://noc.net.internet2.edu/