

### Internet2 Update

South American – African Astronomy Coordination Committee (SA3CC) Meeting May 2025

> **Chris Wilkinson** Sr Director, Network Infrastructure and Operations

#### **Internet2: A Member Consortium**



# 

Internet2 is a non-profit consortium providing research support, cloud solutions and custom services tailored for Research & Education.

A trusted, adaptable, secure network that empowers higher education, research institutions, government entities and cultural organizations. 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

50+ INDUSTRY MEMBERS

750 +

**NET+ CLOUD CONTRACTS** 

1100+ EDUROAM SUBSCRIBERS

INCOMMON PARTICIPANTS

1000 +

50+ COMMUNITY GROUPS SHAPING PRIORITIES

50+ CLOUD SCORECARD PARTICIPANTS





**BY THE NUMBERS** 



330+ HIGHER EDUCATION MEMBERS 100 +COUNTRIES & RESEARCH NETWORKS CONNECTIONS 80,000+ COMMUNITY ANCHOR INSTITUTIONS

50+ **AFFILIATE & GOVERNMENT MEMBERS**  1600G 800G+ WAVELENGTHS OF NETWORK CAPABILITY 500 +**NET+ SUBSCRIBERS** 

50+ INDUSTRY MEMBERS

1100 +EDUROAM SUBSCRIBERS

46

INCOMMON PARTICIPANTS

1000+

50 +

COMMUNITY GROUPS SHAPING PRIORITIES

50+CLOUD SCORECARD PARTICIPANTS

50-74 Tbps 27-JZIDDS CAPACITY PER LINK

750 +

NET+ CLOUD CONTRACTS





**BY THE NUMBERS** 

#### Internet2 National Research & Education Network (NREN)





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



#### North America Research & Education eXchange (NA-REX) Collaboration



#### **Research & Education Global Connectivity**



## **Current Network**

### **Current Services**

#### LAYER 1 SERVICE

Point-to-point 10, 100 & 400G links and flexible grid spectrum to support private network needs. Also serves the I2 backbone.

#### LAYER 2 SERVICE

Effective and efficient wide area Ethernet technology.

#### LAYER 3 SERVICE

For IP network and peer exchange needs.

#### PEER EXCHANGE

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

R&E

Provides community 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.

#### **RAPID PRIVATE INTERCONNECT**

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

#### Global Exchange

Provides community with access to international partners, ESnet, and other assets.

#### GLOBAL DDoS PROTECTION

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

### **Current Hardware Families**



### **Packet Network Topology**

- 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



### **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.
- Functions planned for 2024:
  - **Routing Intentions**: Visualization and management of I2RE and I2PX routes and routing policy.

🗧 😑 🧧 Looking Glass   Insight	Conso × +					·	Commu	nity	Interfaces Virtual Netw
C is console.interne	at2.edu/#/?command=sho	w+vrf+all&nodes=core1	phoe&nodes=core1.tucs			🖈 🛛 🔍 🖸 🔍 🗄 🗎			Organizations
Insight Consele		Q Sea	rch Does, Organizations, & Virtu	al Networks		Usability Testing Provide Feedback 🕤 😌			organizations
community interfaces Virtual Networ	ks Looking Glass					Mike Simpson   Sign out	4.1	CE	NIC (Corporation for Educ
Filter by node name or location	[2 nodes selected]	> show vrf all			Run Command	Supported Commands			the (corporation for Edde.
Core Router	core1,phoe > show					show interfaces		.1	h Albumun Cinnen
	Tue Feb 20 17:13:3 VRF	5.724 UTC RD	RT	AFI SAFI		Show interface stats		*	<ul> <li>Albuquerque Gigapop</li> </ul>
Pensacola, FL	BLENDED	163.253.0.1:7	import 11164:8	IPV4 Unicast		show ipv4 interface IPv4 interface status and configuration			
core1.phil Philadelphia, PA			import 11537:1 import 11537:7 import 396955:3356	IPV4 Unicast IPV4 Unicast IPV4 Unicast		show ipv6 interface IPv6 interface status and configuration		١	California Internet2 Mem
core1,phoe Phoenix, AZ			import 11164:8 import 11537:1 import 11537:7	IPV6 Unicast IPV6 Unicast IPV6 Unicast		show U2vpn xconnect L2VPN xconnect information		\$	California Maritime Acad
core1.pitt Pittsburgh PA	1707	143 343 4 3.4	import 396955:3356 import 396961:1013	IPV6 Unicast IPV6 Unicast		show tacp LACP information			
corel.port	474	100.233.0.1.0	import 11164:8 import 11537:7	IPV4 Unicast IPV4 Unicast IPV4 Unicast		show lldp neighbors LLDP neighbors		*	California State Polytech
Portland, OK			export 11164:8 import 11164:8	IPV4 Unicast IPV6 Unicast		show route IP routing table			
Raleigh, NC			import 11537:7 import 356961:1013 export 11164:8	IPVG Unicast IPVG Unicast IPVG Unicast		show version Show router firmware version		*	California State Universit
core1.reno Reno, NV	OESS-VRF-3521	163.253.0.1:1513	import 55638:3521 export 55838:3521	IPV4 Unicast IPV4 Unicast		show vrf all Show VRF information		*	California State Universit
core1.sacr Sacramento, CA	CE55-VRF-3684	163.253.0.1:1537	import 55038:3521 export 55038:3521	IPV6 Unicast IPV6 Unicast		traceroute Traceroute from router to supplied destination		-	California State Oniversi
core1.salt Salt Lake City, UT			import 55838:3684 export 55838:3684 import 55838:3684 export 55838:3684	IPV4 Unicast IPV4 Unicast IPV6 Unicast IPV6 Unicast		uncheck Uncheck all nodes in the sidebar		\$	California State Universi
core1.seat Seattle, WA	OESS-VRF-3610	163.253.0.1:1506	import 55038:3010 export 55038:3610	IPV4 Unicast IPV4 Unicast		History Edit		•	Colifornio State Universit
Core1.star Chicago, IL	RÉ		import 55838:3610 export 55838:3610	IPV6 Unicast IPV6 Unicast		oret,phoe corettucs			California State Oniversi
coret.sum			import 11537:1 import 11537:7 import 356961:1013	IPV4 Unicast IPV4 Unicast IPV4 Unicast		show lldp neighbors corel.phoe corel.tucs		8	California State Universi
core1tole2			import 11537:1 import 11537:1 import 11537:7	IPV4 Unicast IPV6 Unicast IPV6 Unicast		<pre>show vrf all   include PAS-TUCS coret.tucs</pre>			
core1.tucs	SCRUBBING	163.253.0.1:1000	export 11537:1	IPV6 Unicast		show wrf all			California State Universi
Tucson, AZ	WROUTER-10178	163.253.0.1:10101	import 396458:1000	IPV6 Unicast		show lldp neighbors   include		-	
Core1.tuis Tuisa, OK			import 55038:10101 export 55038:10101 import 55038:10101	IPV4 Unicast IPV4 Unicast IPV6 Unicast		core1.tucs		ie i	California State Universit
core1.wash McLean, VA	management	not set	export 55838:10101	IPV6 Unicast		show 11dp neighbors coret.tucs		*	California State Universit
core2.ashb Ashburn, VA	corel,phoe > show	lldp neighbors			Сару	show wrf all			
core2.atla Atlanta, GA	Tue Feb 20 17:13:0 Capability codes: (R) Router, (B)	8.282 UTC ) Bridge, (T) Te <u>leoho</u>	ne, (C) DDCSIS Cabl <u>e Devi</u> s			Show wrf all		¢	California State Universi
core2.chic	(W) WLAN Acces Device ID	s Point, (P) Repeater	, (S) Station, (O) Other Local Intf	Hold-time Capability Port ID		show ipv4 interface		÷	California State Universit
<ul> <li>corregulation</li> <li>correducing</li> </ul>	corel.tucs.net.int corel.losa.net.int PHDE-DRT-SP1.score	ernet2.edu ernet2.edu idor.org	FourHundredGigE8/8/8/8 FourHundredGigE8/8/8/1 HundredGigE8/8/8/24	128 R FourHundredG 128 R FourHundredG 128 BJR Ethernet3/1	1gE8/8/8/8 1gE8/8/8/3	ipv4 protocol coreltucs			
Contracti Oli	INTERNI EN1		Hundram (att 1979) 25		50				California State Universit
								*	California State Universi

High Energy Physi

#### Global Exchange Points Boston, New York, Washington

R&E Open Exchange on East Coast of US

Boston (BIX), New York (MAN LAN), and Washington (WIX)

- Operate <u>independently</u> from Internet2 network
- Currently Layer 2 only
- Currently working to enable AutoGOLE/SENSE via NSI / SuPA (SURF ultimate Provider Agent)
- Based on Arista 7280PR3K-24 switches (OSFP)

moving to Arista 7280DR3K-24 switches (QSFP28-DD)





#### Transponders

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 800Gbps line rate (next generation 1600Gbps)
- provides additional capacity beyond baseline backbone demands
- mixed-mode capacity for (800GE) 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





### **Pluggable Coherent Optics!**



OUI Number

Part Number

: 7c.b2.5c : DP040SDD-HE0-190

550 km Test Link

Advantages:

- Lower power envelope 22.5 watts vs 330 watts (WS5)
- Reduces the number of components needed for a 400Gbps link (soon to be 800 Gbps)

Disadvantages:

- Limited to router-to-router connections; no muxponding option
- Distances are limited due to launch power and DSP complexity
- Spectrally inefficient
- Wattage may impose limitations on cooling and electrical bus on older devices



#### Spectrum, Transponders, and Pluggables



### **Coherent Pluggables - 3000 km POC**



### **Coherent Pluggables - Extending the Edge to HPC, Al** !



Internet2 Backbone Node (Community Facility)









53

+

-

÷

741

# NATIONAL RESEARCH

The National Research Platform is a partnership of more than 50 institutions, led by researchers at UC San Diego, University of Nebraska-Lincoln, and Massachusetts Green High Performance Computing Center and includes contributions by the National Science Foundation, the Department of Energy, the Department of Defense, and many research universities and R&E networking organizations in the US and around the world.

Select a site or click on a site in the map

Sites	Nodes
82	412
Sites hosting NRP nodes	Nodes registered in Kubernetes
GPUs	CPU Cores
1,438	27,498
Total GPUs across all nodes	Total CPU cores across all nodes



## What are we working on next?

### **Network Refresh!**

The next refit should strive to ensure the Internet2 platform is relevant and able to provide all the services projected as being needed by the community for the next 5-6 years

#### Trends:

- Service Growth in Packet, both routed (I2PX & R&E) and (Layer 3) and AL2S (Layer 2)
- Service Growth in Cloud Connect and RPI
- Growth in adoption of the Platform: Ports, ports, ports! (RPI, Flex)
- Routing Intentions / Security and automated Route Policy
- Security Applications: DDoS, MACSEC, flowspec, encrypted Layer 1
- 800Gbps+
- Coherent Optics
- Network Research demands, including <u>data-intensive</u> and <u>distributed computing+caching</u> use cases
- Access to emerging AI Facilities, both commercial and community based
- RIPCORD last-resort commodity ISP services
- Multi Vendor
- Overlay Networks
  - Packet: Layer 2, Private VPNs
  - Optical: Foreign Waves, Managed Spectrum, Mission Networks, NA-REX

### **Network Refresh!**

vBNS	Abilene	"Internet2 Network"	втор	MPLS	NGI	FUTURE
1995	2002	2007	2011	2016	2021	2025 - 2027
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	Arista? Cisco? Juniper? Nokia?
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	Flex Grid Coherent Optics

### **Collaborative Infrastructure Development**

#### Fiber and Spectrum:

- MGHPCC community-run regional data center now on-net (community foreign spectrum)
- Four metro areas are under study for expansion to meet community requests (locations currently off-net)
- Planning for 800 Gbps underway along northern tier and BOREAS (community foreign spectrum)

#### **Optical Platform:**

- Additional location added in New Jersey (community collaboration)
- Foreign spectrum on Internet2 platform under study in multiple regions to meet **community** IRU demands

#### Packet Infrastructure:

- Substantial deployment of coherent optics (backbone now 20% coherent links), including on **community** spectrum
- Node added in Boston (in addition to MGHPCC); preparing for node addition in Baton Rouge for LONI

#### CSP, ISP, IX Interconnect:

• Cloud Connect and RPI added to New Jersey, Los Angeles (coherent optics; Seattle, Dallas are next)

#### Global Interconnect:

• All NA-REX community-collaboration overlay links now up; commissioning is underway

### **Connecting Cross-Country!**

Goal 4 x 800 Gbps 3,500 km





### **Collaborative Infrastructure Development**

#### scitags.org

Scientific network tags (scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level.

Identifying and Understanding Scientific Network Flows, CHEP2023, EPJ Web Conf.



### Staff Development

Two key engagements which give us experience with <u>emerging technologies</u>

- SCInet is part of Supercomputing
- OFCnet is part of Optical Fiber Communications Conference and Exhibition



# **Thank You**