



# NEXT GENERATION INFRASTRUCTURE

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## Internet2 Next Generation Infrastructure: The I2 Network Footprint



AL2S

# Data Intensive Transport

R&E

#### Internet2 Layer 3 R&E Services (AS11537)

Provides Layer 3 connectivity between endpoints within a common, restricted routing table. Includes select fednet and international routes.

## Internet2 Layer 2 VLAN Services

Provides point-to-point and multipoint Layer 2 connectivity between endpoints

## Internet2 and PacificWave International Connectivity

**AP-REX** 

Simplify operations, coordination and service activities across Atlantic and Pacific Exchange Points. Align operations, capabilities and services at MANLAN, WIX and PacificWave.

Internet2 Wave Services

Waves

Provides traditional managed "lit services" with transponders located in Internet2 shelves.

# **Cloud Access**

I2PX

**I2RPI** 

#### Internet2 Peer Exchange (AS11164)

Use of > 3Tbps of peering capabilities to major cloud providers for access to cloud SaaS services (e.g., Zoom or Office 365)

# Internet2 Cloud Connect

I2CC

"Direct-connect" private Layer 2 and Layer 3 access to Microsoft, Amazon and Google cloud platforms.

# Internet2 Rapid Private Interconnect



Private 10G interconnections at major peering points to reach cloud providers for dedicated access or improved resiliency. Used to connect to any commercial provider located at the peering point

## Internet2 Next Generation Infrastructure: Services

# Security and Connectivity

## Internet2 Spectrum Services



Supports the construction of overlay networks on the Internet2 footprint with spectrum allotments. Assumes transponders are outside Internet2 shelves.

#### Internet2 Last Resort Full Internet Access

rlPcord

Access to a full set of commercial routes on demand. Intended for emergency use in extended outage situations.

#### Internet2 Global DDoS Protection

DDoS

Radware-based cloud solution allowing for selective filtration of DDoS attacks and delivery of "clean" traffic to the community via Internet2.



## Internet2 Next Generation Infrastructure: Framing



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March 2007 2 PB - 10G network March 2012 22 PB - 100G network March 2021 260 PB -> 800G network

# Internet2 Next Generation Infrastructure: Framing





The Next Generation Infrastructure Program is a full set of activities to review and update the services, value and supporting technology of the Internet2 infrastructure portfolio (and relationships in the larger ecosystem)

- Includes the services and service models through which the community adopts Internet2 infrastructure services
- Includes new features, primarily driven by software, automation and systems virtualization to allow the infrastructure to be more readily integrated in to the broader campus, regional and cloud environment around us.
- Includes a number of infrastructure upgrade projects

## Internet2 Next Generation Infrastructure: Framing

Data-Intensive Research

**Enhanced Cloud Access** 

Software-Driven Infrastructure

Infrastructure Sharing

Sustainable Economics

New software orchestration layer for building dynamic research and administrative networks

New capacity, scalability, and consistency for cloud research

Improved support for overlays, including: L2 VPNs, L3 VPNs, and waves

Updated connector agreements with modernized mutual service goals

Updated infrastructure sharing agreements

Generational n x 400G-based capacity backbone and simplified protocol stack

New optical underlay

Substantial overall reduction in network operating costs by spring (helps close gap)



# Internet2 Next Generation Infrastructure: Optical Selection



12-month RFI/RFP/BAFO completed Sept 2019

Ciena C6500 Flex-grid System

Lumen SMF-28 Fiber

Ciena WaveServer 5: 400-800G wavelengths

Ciena MCP will replace OneControl / Site Manager

Significantly greater reach (and lower cost) for community 100G wavelengths

Substantially greener profile (space, power)





# blueplanet<sup>-</sup>

PROFESSIONAL SERVICES FIELD SERVICES DEDICATED ENGINEER

# LUMEN



PROJECT MANAGEMENT FIELD SERVICES PROFESSIONAL SERVICES LOGISTICS



# Internet2 Next Generation Infrastructure: Optical Selection

Chassis

- 2RU chassis supporting 4-8 modules
- 19" rack mount
- Redundant and in-service field replaceable PSU and fan modules
- In-service field replaceable control processor (CP)

Traffic Module (double width)

- 2x WL5e modems
- 16x QSFP28 / 4x QSFP-DD client ports
- Supports 200G-800G per wavelength
- Enables 3.2T per RU; 6.4T per 2RU chassis

Q-DD	Q-28	Q-28	Q-28	Q-28	Q-28	Q-28	Q-DD
Q-DD	Q-28	Q-28	Q-28	Q-28	Q-28	Q-28	Q-DD



# Internet2 Next Generation Infrastructure: Packet Selection

18-month RFI/RFP/BAFO process completed Sept 30,2020

New Cisco 8201/8202 based platform selected

Higher-speed 400G backbone & member connections

Enable modern cloud & research services via new Cisco NSO programmability platform

Enable modern fine-grained telemetry

Increased resiliency and load balancing with new node topologies

Segment Routing with path computation will allow more efficient load-balancing in new topology





GDT

3rd PARTY OPTICS PROJECT MANAGEMENT FIELD SERVICES PROFESSIONAL SERVICES LOGISTICS

PROFESSIONAL SERVICES DEDICATED ENGINEERS





1 RU 24 x 400G QSFP56-DD ports 12 x 100G QSFP28 ports

# Internet2 Next Generation Infrastructure: Transport Design



# **Performance Assurance Service Upgrade**

- NGI Deployment will include a complete upgrade to the Internet2 performance assurance services (PAS).
- Every Internet2 core node (47 PoPs) will have multiple perfSONAR testpoints deployed:
  - 1 x 100G internal testpoint for Internet2 testing, monitoring, and alerting;
  - 2 x 10G internal testpoints for Internet2 disaggregation testing;
  - 1 x 100G external testpoint to support community ad hoc testing.
- PerfSONAR testpoints will be deployed using Docker containers:
  - Isolate internal and external usage to prevent false-positive alerting;
  - Containerization simplifies OS dependencies, upgrades;
  - Testing indicates negligible overhead incurred from containerization;
  - Systems support spare cpu/ram/storage capacity for future needs.





# **Performance Assurance Service Upgrade**



[ 15 ]

# Internet2 Next Generation Infrastructure: Software Architecture

- Supervision (high-level composed views into other components) is in early prototype development:
  - Dashboard for packet backbone provisioning and management;
  - Sessions providing unified SSO and authorization via Internet2 Collaboration Platform.
- Orchestration (structured configuration management) is in pre-production rollout:
  - Ciena BluePlanet MCP for management of optical gear;
  - Cisco NSO for management of packet configuration.
- Provisioning (controlled creation and maintenance of configuration objects) will involve:
  - Training in the NSO CLI interface;
  - Retrofitting of existing tools (OESS, CloudConnect) to use NSO;
  - Creation of new API interfaces, tools, and services.
- Assurance (validation of network functionality) relies upon an existing and expanding toolkit:
  - GlobalNOC DB, AlertMon, and other tools.
  - perfSONAR





# Internet2 Next Generation Infrastructure: SMF28 Fiber Upgrade, Open Line System, MCP

#### **Deployment Highlights**

Ciena flex-grid line-system which supports wider channels at lower operating cost

Replaced ~ 80% I2-IRU nationwide fiber with single mode fiber (through 2042)

Infrastructure sharing activities developing with regional networks

- CENIC/PNWGP (Pacific Wave)
- Florida LambdaRail (FLR)
- Wisconsin/Iowa/Minnesota (BOREAS and Wiscnet)

All planned segments completed on schedule: February 2021.





# Internet2 Next Generation Infrastructure: Packet, perfSONAR, Secure Management

#### **Program Highlights**

Cisco 8200 Packet platform with underlying Ciena Waveserver 5 transport. Native 400G at all network layers.

Installation contact awarded to Cisco and GDT in September 2020. Also included installation of:

- Juniper Secure Management Platform
- perfSONAR Nodes by ADS (Dell)

>100 site visits, including remediation work

• Optics, cables, etc





## Internet2 Next Generation Infrastructure: Optical + Packet Implementation



# Internet2 Next Generation Infrastructure: Transponder Provisioning



## Internet2 Next Generation Infrastructure: Transponder Provisioning



# Internet2 Next Generation Infrastructure: Transponder Performance



# Internet2 Next Generation Infrastructure: Packet IS-IS Provisioning



## Internet2 Next Generation Infrastructure: Packet IS-IS Provisioning

Up

cwilkinson@nso.bldc# devices device core1.losa live-status exec any "show isis adj" result Tue Apr 13 15:17:59.491 UTC

\*PtoP\*

\*PtoP\*

\*PtoP\*

\*PtoP\*

\*PtoP\*

\*PtoP\*

\*PtoP\*

IS-IS INTERNET2 Level-2 adjacencies: System Id SNPA Interface core1.phoe FH0/0/0/3.4079 \*PtoP\*

core1.sunn FH0/0/0/4.4079 agg1.losa2 FH0/0/0/1.4079 core2.losa Hu0/0/0/19.4079 core2.losa Hu0/0/0/20.4079 core2.losa Hu0/0/0/21.4079 core2.salt FH0/0/0/2.4079 FH0/0/0/0.4079 agg2.losa2

Total adjacency count: 8 RP/0/RP0/CPU0:core1.losa#

cwilkinson@nso.bldc# devices device core2.losa live-status exec any "show isis adj" result Tue Apr 13 15:17:34.509 UTC

#### IS-IS INTERNET2 Level-2 adjacencies:

System Id	Interface	SNPA	State	Hold	Changed	NSF	IPv4	IPv6
							BFD	BFD
core2.elpa	FH0/0/0/3.4079	*PtoP*	Up	28	00:07:56	Yes	Up	Up
core2.sunn	FH0/0/0/2.4079	*PtoP*	Up	26	00:07:47	Yes	Up	Up
core1.losa	Hu0/0/0/19.4079	*PtoP*	Up	24	00:08:39	Yes	Up	Up
core1.losa	Hu0/0/0/20.4079	*PtoP*	Up	26	00:08:40	Yes	Up	Up
core1.losa	Hu0/0/0/21.4079	*PtoP*	Up	23	00:08:40	Yes	Up	Up
agg1.losa2	FH0/0/0/1.4079	*PtoP*	Up	24	00:07:57	Yes	Up	Up
agg2.losa2	FH0/0/0/0.4079	*PtoP*	Up	29	00:07:56	Yes	Up	Up

Total adjacency count: 7 RP/0/RP0/CPU0:core2.losa# cwilkinson@nso.bldc#

itus ex	cec ar	iy "snow 19	515 8	adj		Salt Lake City
State Up Up Up Up Up Up Up	Hold 23 22 27 22 28 25 27 22 27 22	Changed M 00:07:43 00:07:51 00:07:43 00:08:29 00:08:30 00:08:30 00:07:50 00:07:52	NSF Yes   Yes   Yes   Yes   Yes   Yes   Yes   Yes	IPv4 BFD Up Up Up Up Up Up	IPv6 BFD Up Up Up Up Up	Sunnyvale Las Vegas El Paso
State Up Up Up Up Up Up	Hold 28 26 24 26 23 24 29	Changed 1 00:07:56 00:07:47 00:08:39 00:08:40 00:08:40 00:08:40 00:07:57 00:07:56	NSF Yes Yes Yes Yes Yes Yes Yes	IPv4 BFD Up Up Up Up Up	IPv6 BFD Up Up Up Up	Packet Packet Packet Packet INTERNET

# Internet2 Next Generation Infrastructure: Transport + Software Implementation

#### Scope:

- Cisco 8200 Platform Commissioned
  MPLS-SR
- Ciena WaveServer 5 Transponders Commissioned
- Orchestration Online Ciena BluePlanet MCP (optical) Cisco NSO (packet).
- Provisioning Integration Complete OESS, CloudConnect
- Quality Assurance Integration Complete GlobalNOC DB, AlertMon perfSONAR Deepfield

#### Complete (...just a sample...):

- Platform interoperation testing
- MPLS-SR proof-of-concept
- WS5 prototyping / testing
- NSO MPLS-SR templating
- perfSONAR + Kubernetes testing and validation
- Ciena MCP Installation

#### <u>Underway (Today!):</u>

- NSO Services Templating
- MPLS-SR and VRF design work
- Ciena MCP Migration to Operational Status
- C6500 Platform Software upgrade underway







Original Schedule Q3 2020	Plan of Record Schedule	Project Deliverable
February 29	Completed	Optical program: Lumen single mode fiber + Ciena 6500 amps and ROADMs + Ciena MCP
March 24	Completed	Packet program: Cisco 8200 packet + Ciena Waveserver 5 transponders + perfSONAR + Juniper Management Network + Cisco NSO
March 31	Completed	Cisco software delivered for routers (go/no go decision)
(new)	May 10	Target to complete base platform testing
<del>July 31</del>	Sept 30	Target to complete "migration" of services from MX to 8200 platform
Sept 30	Oct 15	Target to complete power down of legacy equipment (packet/optical)
Fall 2021	Dec 15	Target to complete legacy hardware removal

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# Internet2 Next Generation Infrastructure: Packet Capabilities

AP-REX

#### Internet2 Layer 3 R&E Services (AS11537)

AL2S

R&E

Internet2 Layer 2 VLAN Services

Internet2 and PacificWave International Connectivity

# • 400G - 3.2 Tbps of intra-node Capability (day 1)

- 400G member-facing connection capability
- 100G performance assurance mesh at all sites
- Better visibility of system performance (telemetry)
- Additional Self-Service, API and Software Access to provision/maintain
- Expanded performance assurance testing w/ ad hoc
- Predictive Failure analysis (planned)



# Internet2 Next Generation Infrastructure: Optical Capabilities



- Complete upgrade and optimization of nationwide footprint
- Improved system performance due to SMF28 fiber
- Support for flexible spectrum width (media channel) system-wide
- Improved vendor support for spectrum (foreign wave) services
- Consistent topologies in all locations, including interconnect
- Better visibility of system and service performance
- Provide 10G, 100G, and 400G wave services





# Internet2 Next Generation Infrastructure: Interconnection Capabilities

Internet2 Last Resort Full Internet Access

rlPcord

Internet2 Peer Exchange (AS11164)

I2PX

Internet2 Cloud Connect

Internet2 Rapid Private Interconnect



Capabilities update:

• Consistent architecture at all interconnect sites

**12CC** 

- Consistent load-balancing at all interconnect sites
- Highly scalable interconnect architecture
- Terabit-scale between edge and core network elements
- Large peer-facing port counts
- Improved service self-provisioning by APIs and Portals (OESS + CC)
- Prefix list management / verification (new interface planned)



# **Questions?**



INTERNET