CENIC
CONNECTING CALIFORNIA

CENIC NGI Project

CIBERTIC 2025

Josh Dickman | AD, Network Services | jdickman@cenic.org

CENIC is a 501(c)(3) **with the mission to advance education and research statewide by providing the world-class network essential for innovation, collaboration, and economic growth.**

California State University System

University of California System

California Community Colleges

Stanford University

University of Southern California System

California K-12 System

Naval Postgraduate School

California Public Libraries

California Institute of Technology

CENIC's CalREN Serves 20 million+ Californians

University of California
541,573
Students, Faculty & Staff connected to CENIC's CalREN (spring 2024)

Independent Universities
128,472
Students, Faculty, & Staff connected to CENIC's CalREN (spring 2024)

California State Univ.
517,997
Students, Faculty & Staff connected to CENIC's CalREN (fall 2023)

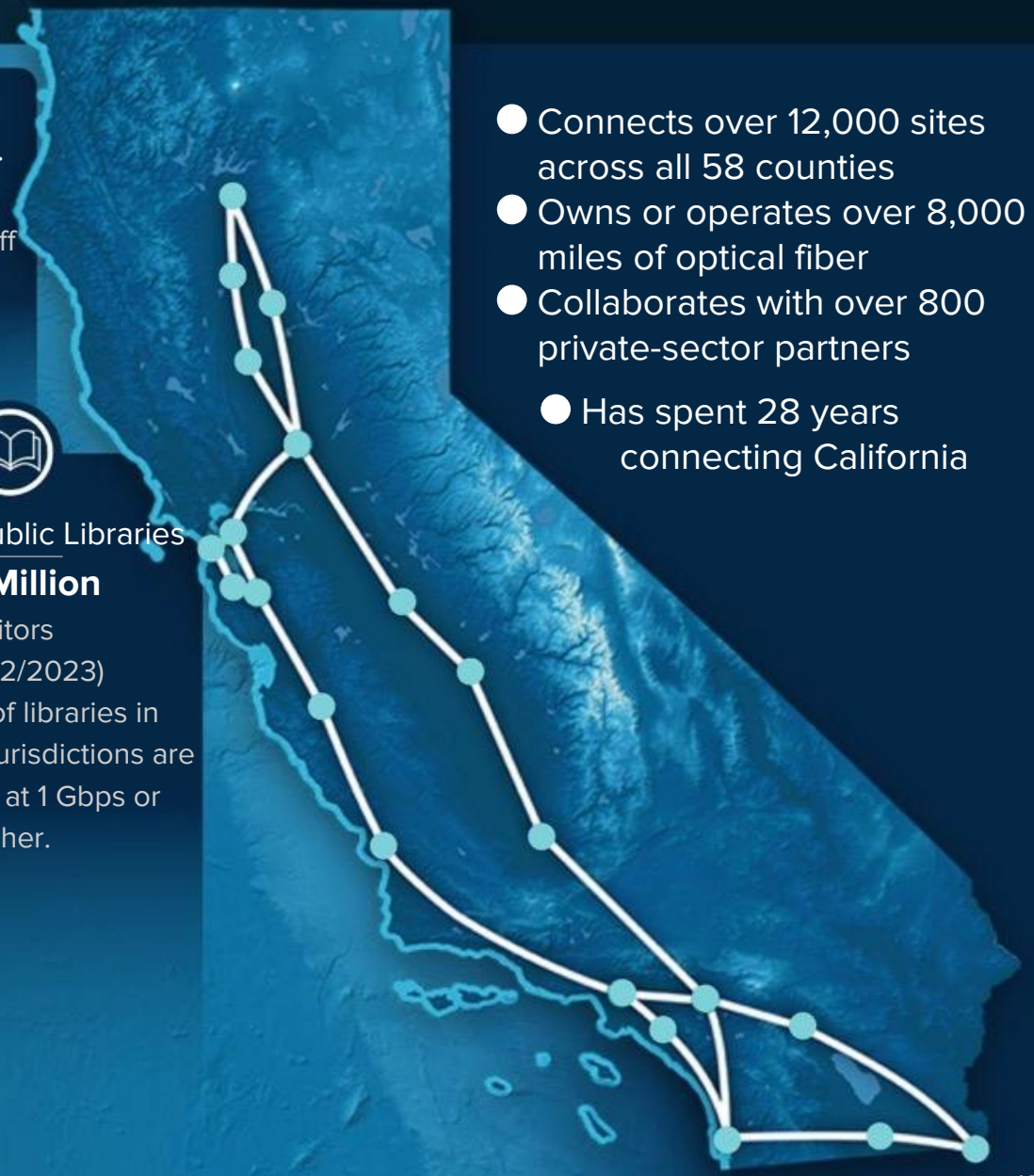
California Community Colleges
1.9 Million
on 116 campuses (fall 2023)
One of five CC students in US attends a CCC connected to CENIC's CalREN

California K-12 Schools
5.8 Million
Students, Faculty, & Staff
58 counties, 1,018 districts
10,010 schools (2022/2023)

California Public Libraries
74.1 Million
Visitors
(in 2022/2023)
Over 85% of libraries in participating jurisdictions are connecting at 1 Gbps or higher.

Hospitals & Health Care
9 hospitals
Over 10 million outpatient visits and 2 million inpatient days
Over 50,000 employees served

Tribal Nation Partners
12 Tribal Nations
17 Reservations
13 Libraries
~550 homes
105 Tribal municipalities



- Connects over 12,000 sites across all 58 counties
- Owns or operates over 8,000 miles of optical fiber
- Collaborates with over 800 private-sector partners
- Has spent 28 years connecting California

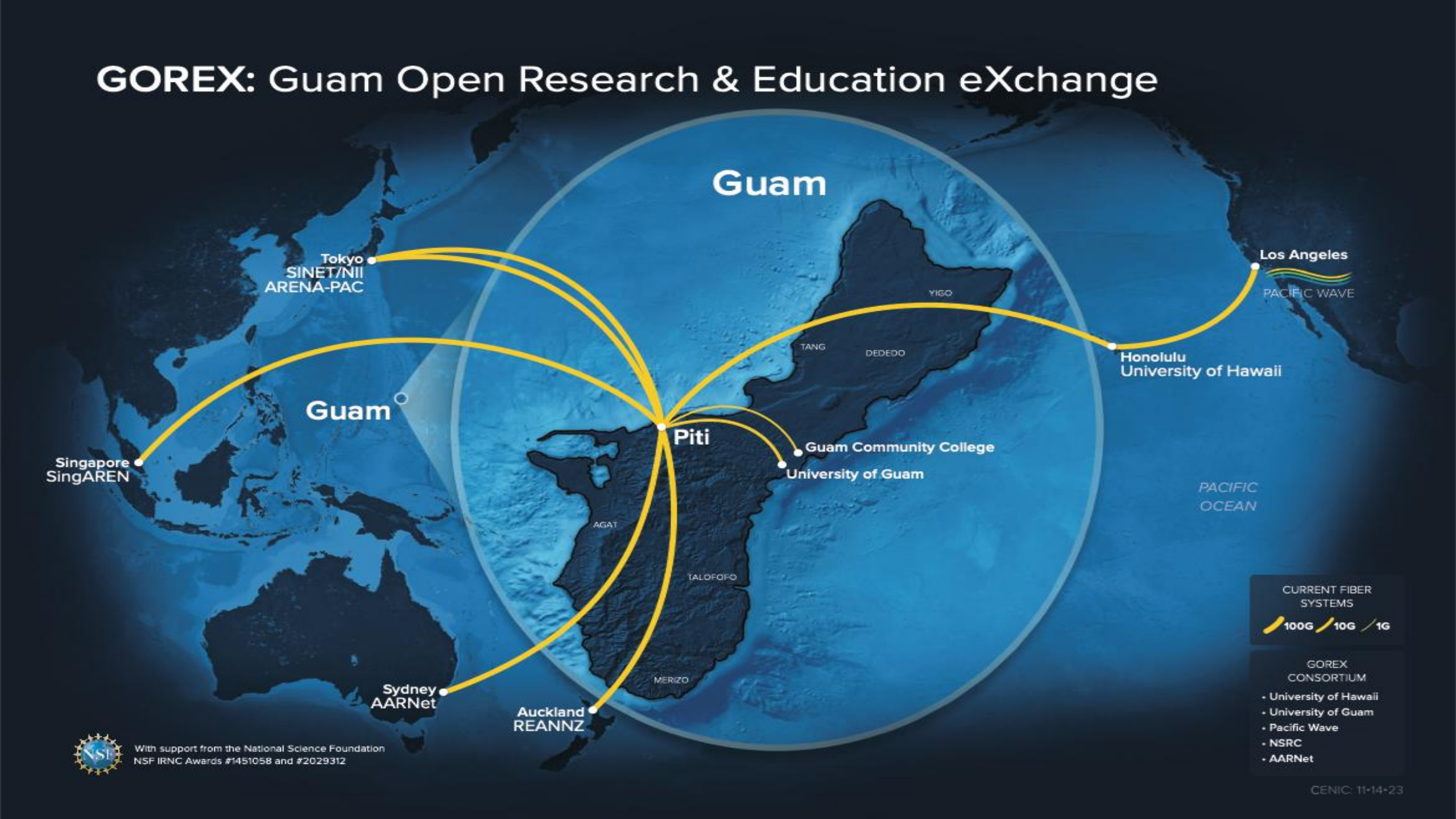
10/25/24

California Research & Education Network (CalREN)


PACIFIC WAVE
NATIONAL & INTERNATIONAL PEERING EXCHANGE
Pacific Wave is a project of CENIC & PNWGP
Fairbanks
PACIFIC WAVE
Vancouver
Seattle
PACIFIC WAVE
Tokyo
PACIFIC WAVE
Korea
Japan
China
Hong Kong
Taiwan
Guam
PACIFIC WAVE
Philippines
Singapore
Oahu
Hawaii
Sunnyvale
PACIFIC WAVE
Los Angeles
PACIFIC WAVE
Tijuana
Los Nettos
Albuquerque
Denver
Chicago
StarLight
Montreal
MOXY
Boston
BIX
New York
MAN/LAN
DC Area
WIX
Atlanta
AMPATH
Miami
AMPATH
El Paso
Flō Networks
Australia
New Zealand
CSTNET
KISTI/KREONET
JGN (Seattle & Tokyo
TransPAC/Pacific Wave
WIDE
ARENA-PAC
JGA
SINET
PIREN
REANNZ
AARNET
UH
JGN/SingAREN
TWAREN/TANET
CERNET
PREGINET
CANARIE
PNWGP
FABRIC
ESnet
Internet2
DREN
NA-REX
FRGP
CENIC
NREN
(NASA Ames)
UltraLight
(Caltech)
ABQG
CUDI
ANA
GÉANT
NORDUnet
SURF
CERN
With Support from the National Science Foundation Award #2029306
Pacifc Wave Backbone
Pacific Wave Participant Links
Partner Exchange Links
Prospective Links
Pacific Wave PoP
Partner Exchange
CENIC-AIR (AI Resource)
AutoGOLE/SENSE
Commercial Peering Points
(Amazon, Google, & Microsoft)
Western Regional Network
States served by WRN members:
• ABQG: New Mexico
• CENIC: California
• FRGP: Colorado, & Wyoming
• PNWGP: Washington, Montana, Alaska, Oregon, & Idaho
• UH: Hawaii
CENIC 06-08-24

WRN Western Regional Network

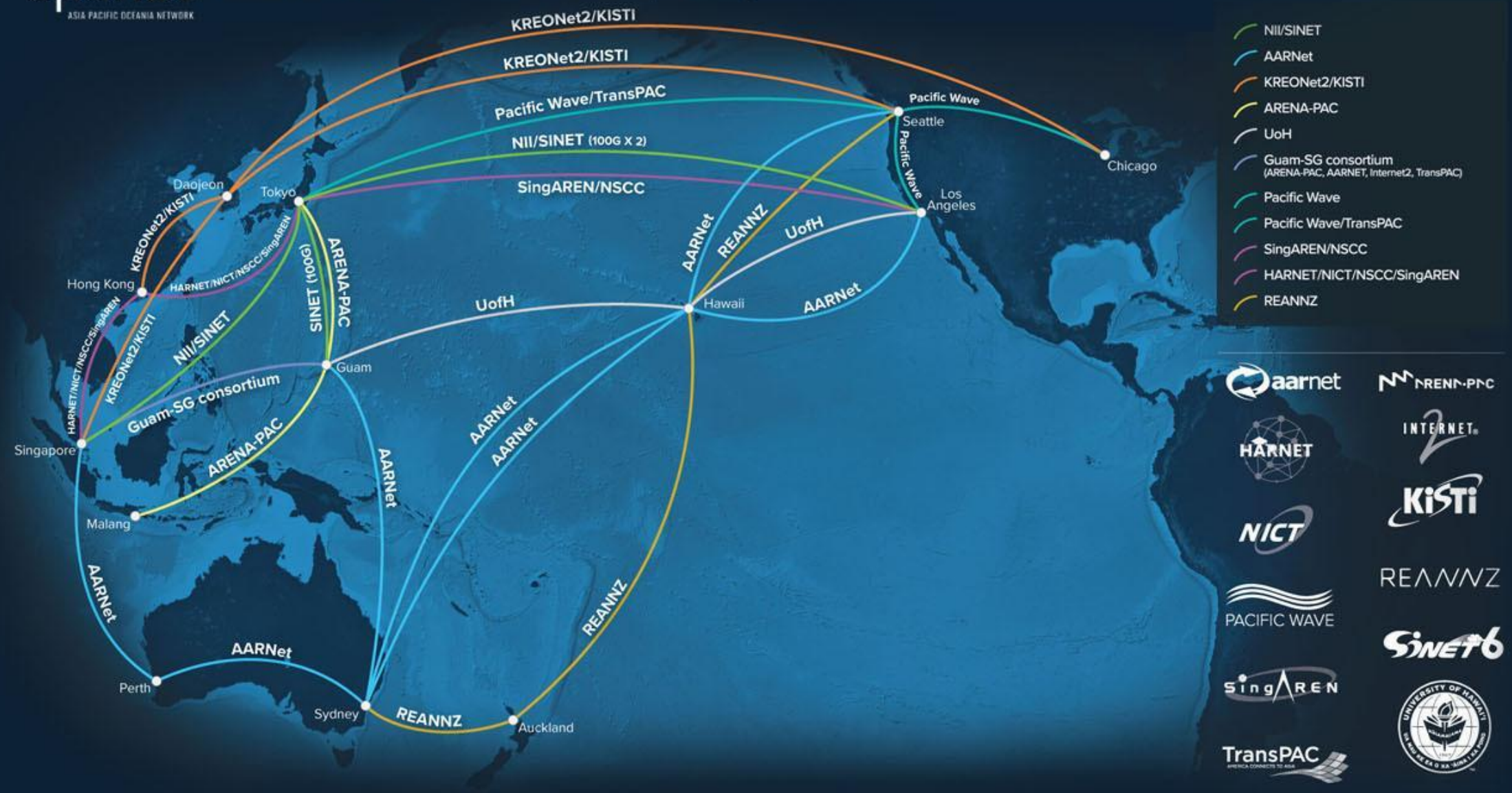
GOREX: Guam Open Research & Education eXchange



With support from the National Science Foundation
NSF IRNC Awards #1451058 and #2029312

CENIC: 11•14•23

aponet ASIA PACIFIC OCEANIA NETWORK (APOnet)



November 2023

NA-REX North America Research & Education Exchange Collaboration

AMPATH PATHWAY TO THE AMERICAS

canarie

ESnet ENERGY SCIENCES NETWORK

INTERNET2

International Networks at Indiana University

STARLIGHT The Optical STAR TAP

CENIC

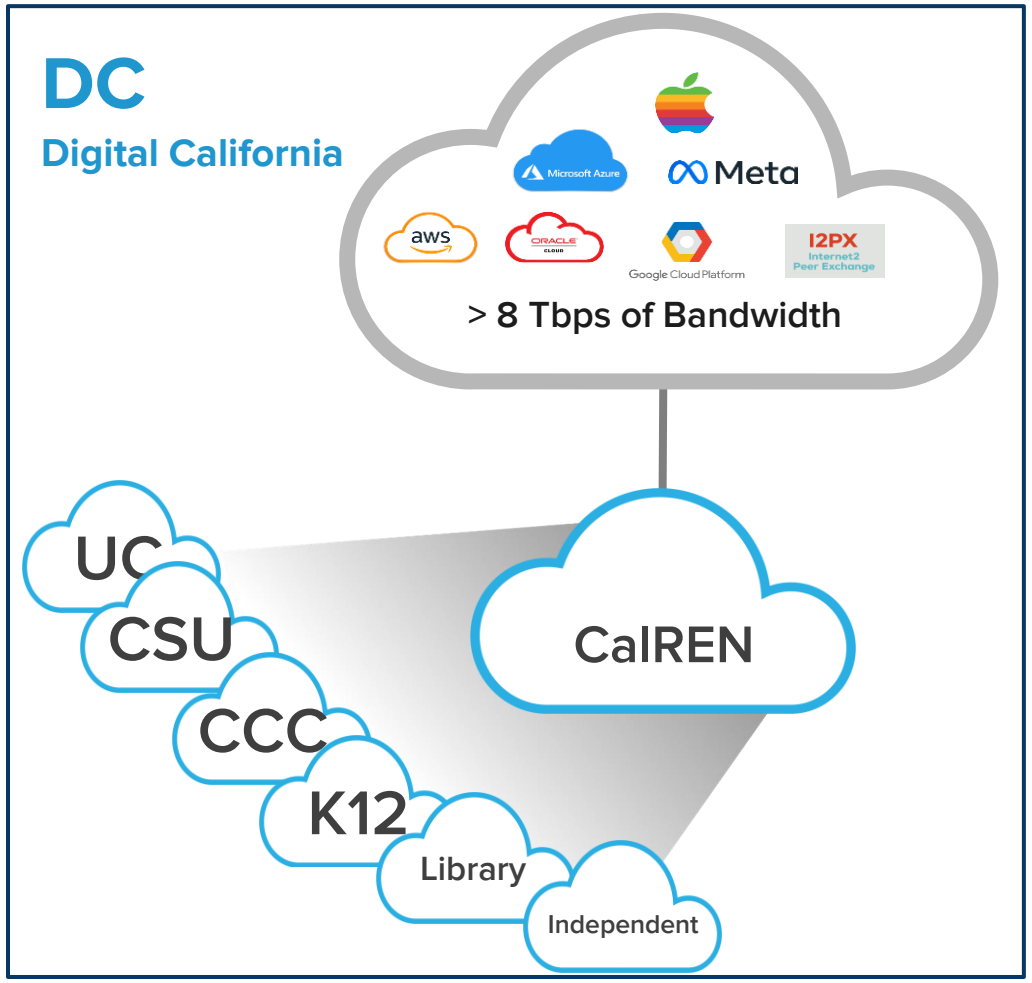
PACIFIC NORTHWEST GIGAPOP

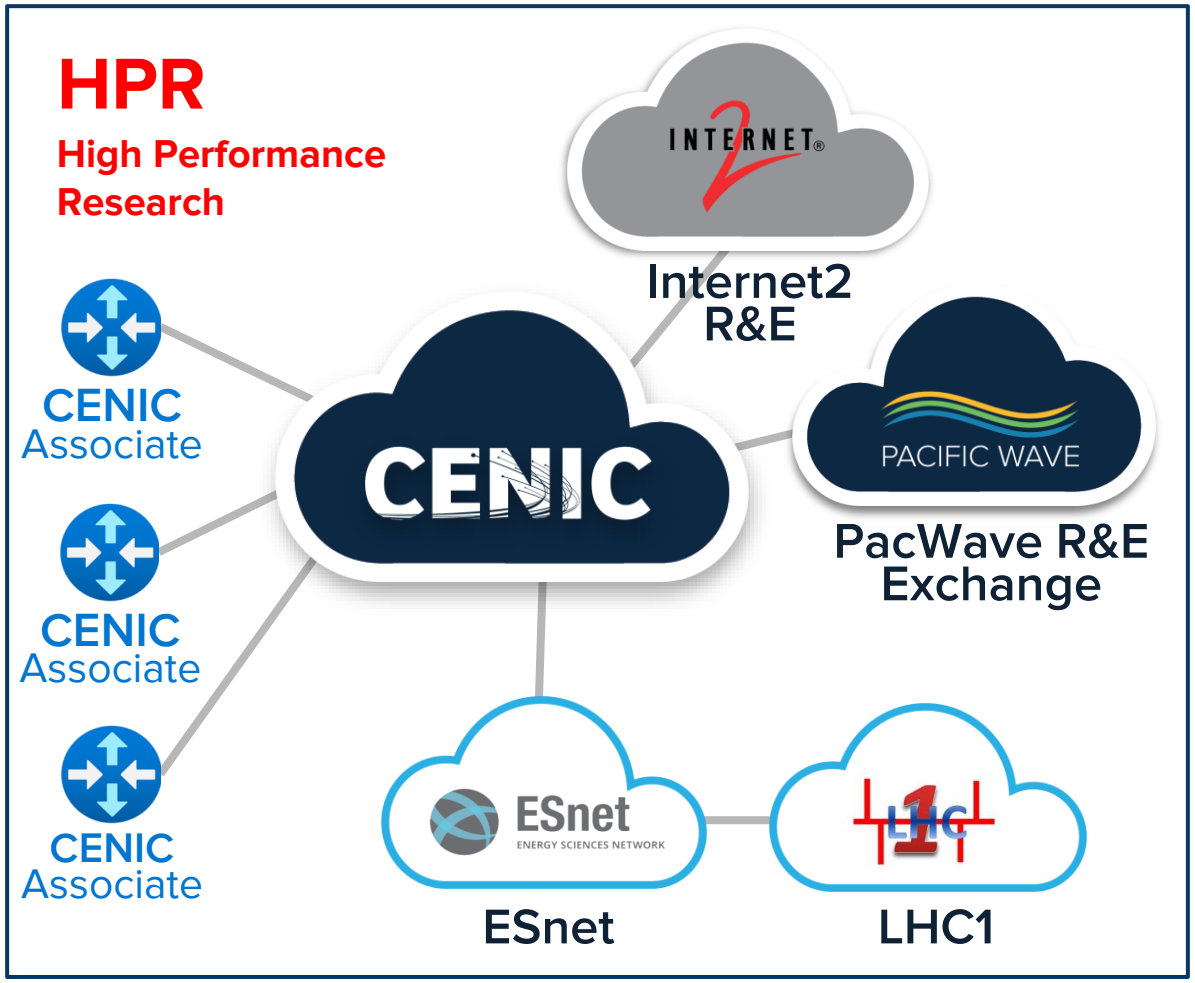
PACIFIC WAVE

October 2024

CalREN NGI
2018 - 2025

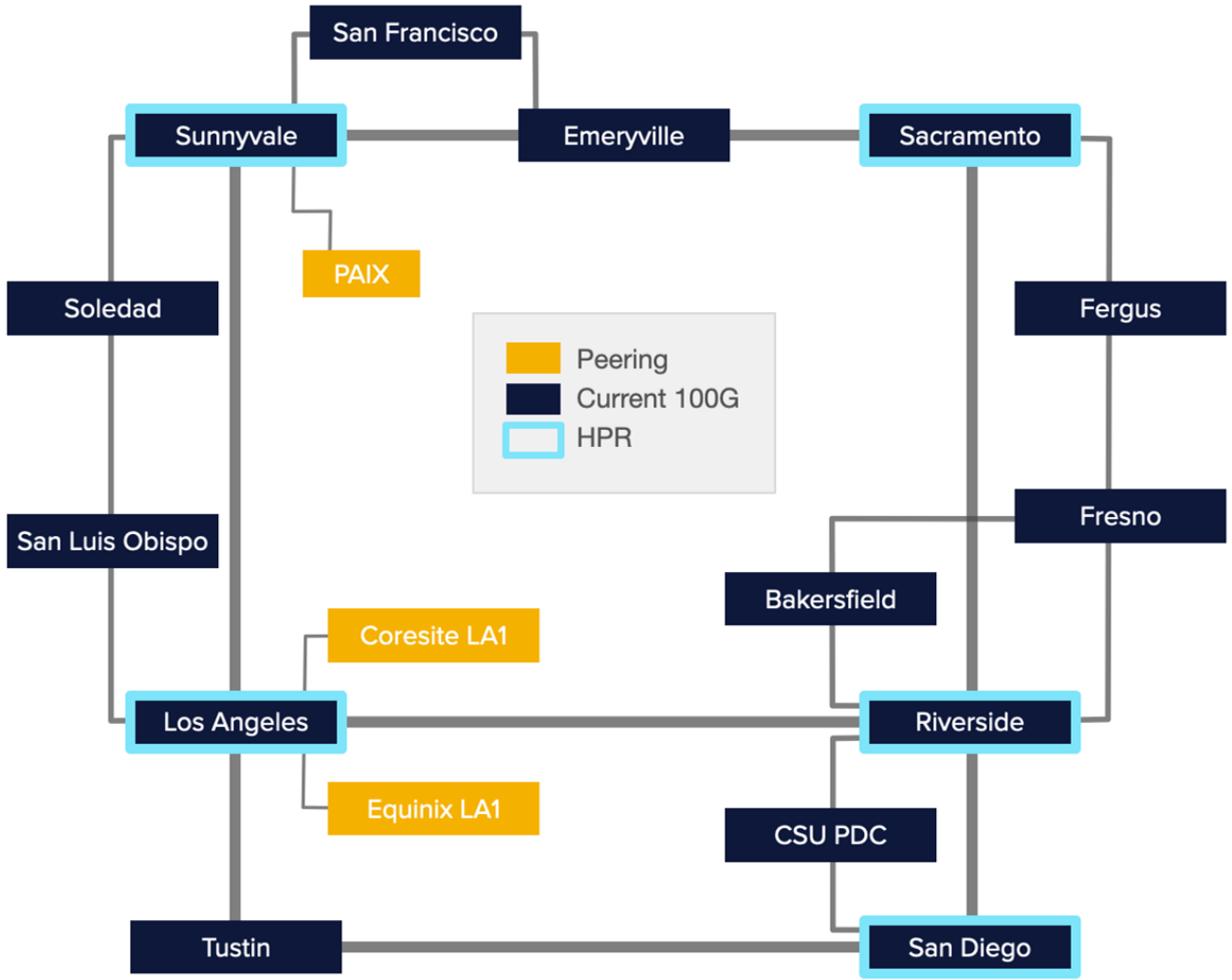
CalREN DC and HPR Networks





CalREN in 2018

- Native IPv4 and IPv6 Only
- IS-IS and BGP for IP Services
- Separate Ethernet Infrastructure for R&E and Layer 2 Services
- Limited HPR locations



Next-Gen Goals

Service Offerings

- DC & HPR Everywhere
- L2VPN
  - Dynamic | Explicit
  - Efficient Multicast | mLDP Replication
  - PE-CE Multihoming
  - PE-CE Significant VLANs
- L3VPN | IPVPN
  - Multicast Ready
  - Flexible PE-CE Protocols | eBGP and iBGP
- Traffic Class Specific Topologies
  - i.e. Flex-Algo - Least Delay
- HQoS

MPLS

- Segment Routing

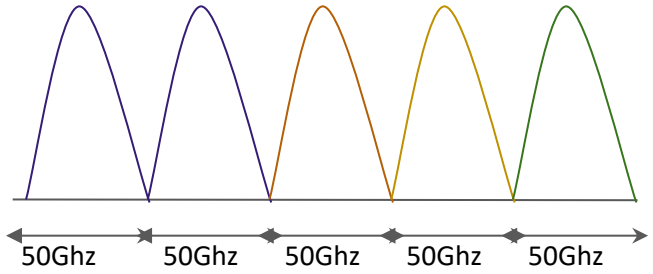
Additional Features

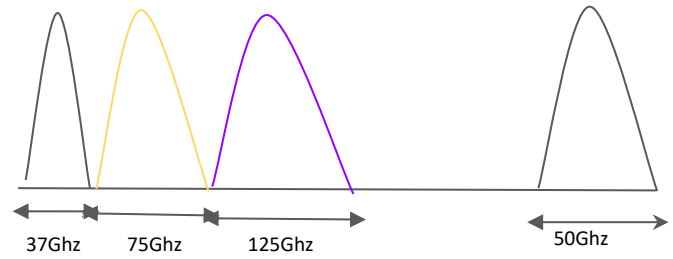
- Resiliency:
  - BFD | Micro BFD
  - LFA | TI-LFA
  - BGP-PIC Edge & Core
- Service Assurance:
  - CFM (Connectivity Fault Management)
- Forwarding Flexibility:
  - Shared Services Model
  - Stateless TE
  - Traffic Class-based Topologies
  - Extension of Services via PWHE
  - Logical Tunnels
- Security
  - BCP38 (Anti-Spoofing)

DWDM Background

- To support services above **200G**, we needed to first upgrade to a **flex-grid** optical network
  - Legacy DWDM has fixed 50Ghz channel spacing, while flex-grid is ‘flexible’
- Secondly, optical hardware for above 200G requires **coherent** optics
  - Legacy optics modulate with ‘on-off keying’, while coherent optics modulate phase / amplitude

Fixed-Grid



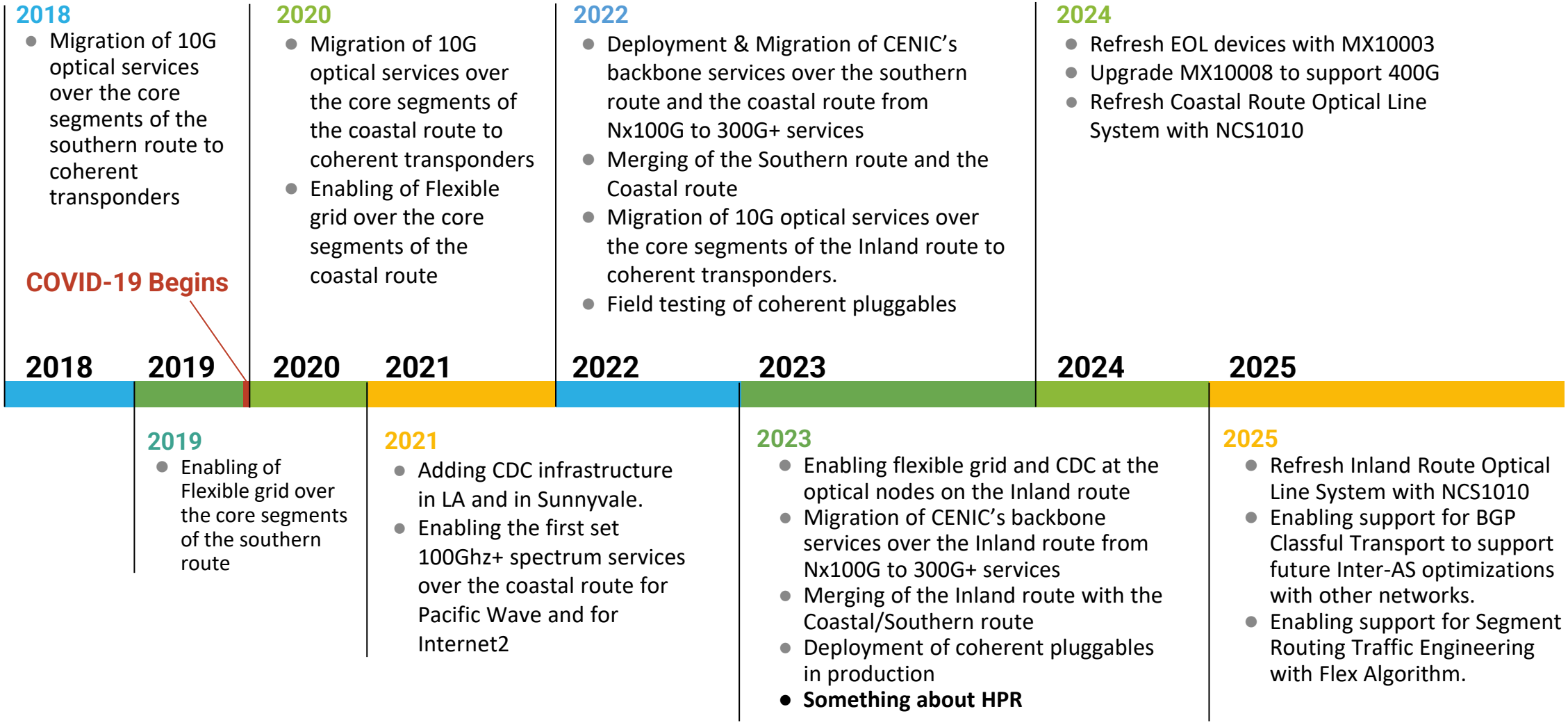


Flex-Grid

Non-Coherent Optics

Coherent Optics

CalREN and Next Generation Infrastructure (NGI) Timeline



CalREN in 2025

Layer 1

- Flex-grid Cisco NCS2Ks
- Cisco NCS1010 upgrades in-progress
- Cisco ONC transition in-progress
- IPoDWDM using 400G ZR+ optics

Layer 2/3

- Juniper MX480/10003/10008s
- DC and HPR on same hardware
- ISIS Segment Routing
- EVPN
  - ELINE
    - Dynamic & Explicit Path
  - ELAN
  - Port- or VLAN-based
- IPVPN

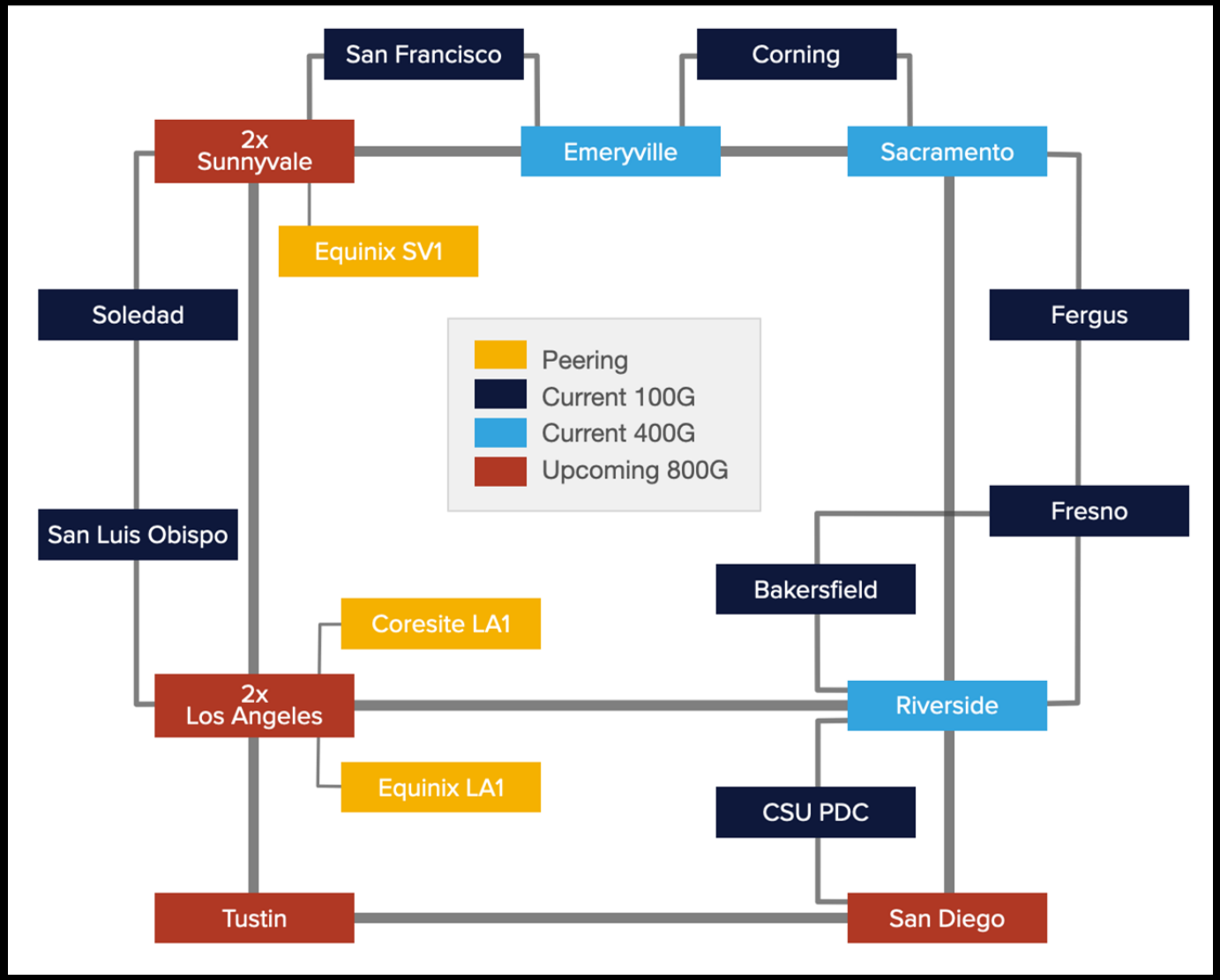
Bandwidth Availability

- 100G support at all Layer 3 locations
- 400G support on all 7 ‘core’ locations
- 800G support in-progress using PTX10002s

Additional Features

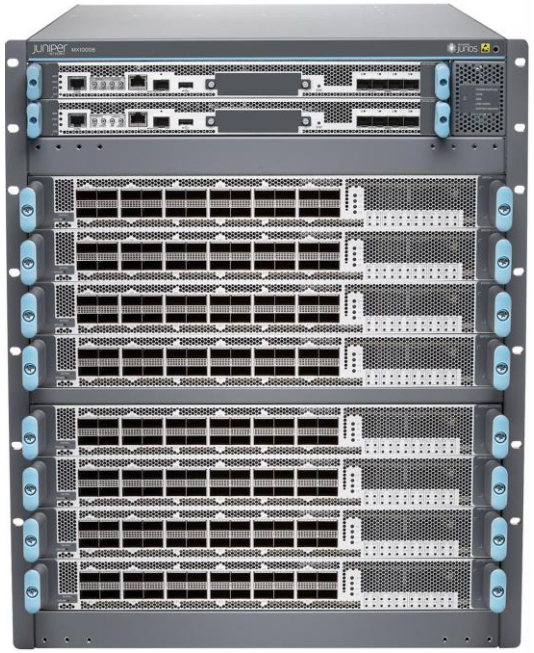
- Resiliency:
  - BFD
  - BGP-PIC Edge & Core
  - TI-LFA
- Security
  - BCP38
  - RPKI

Current CalREN Network



NGI - Hardware

Aggregation Router - Juniper 400G Line Cards



Juniper MX10008

+

LC9600 400G Line Card

Replace 100G Line Cards with High-Capacity 400G Line Cards

High Capacity

400G card supports 9.6T/Slot
vs
100G card supports 2.4T/Slot

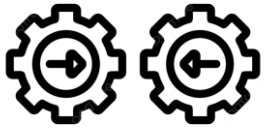
Future Ready

Support 400G ZR+ and 400G grey optics

400G Coherent Optics

Backward Compatibility

Support 100Gs by using break-outs



400G tech 100G tech

Digital Coherent Optics - 400ZR+ Optics

400ZR+ Digital Coherent Optics

OpenZR+ MULTI-SOURCE AGREEMENT

Using IPoWDM, 400ZR+ optics are inserted directly in Aggregation Routers to replace external 100G transponders

Legacy 400G Solution

REPLACED

NCS2006 Shelf

+

4x 100G Transponder

Bulky Cisco NCS2K Shelf(s) with 4x100G Transponder

- Complex
- Expensive
- End-of-Life

400G IPoWDM Solution

400ZR+ Coherent Optics

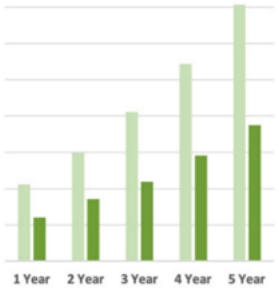
400G QSFP-DD inserted directly in Agg router

- Simpler
- Economical
- Next-Gen Technology

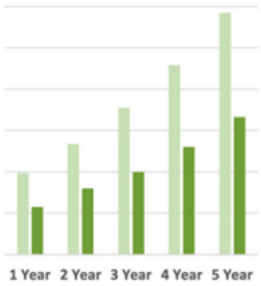
CAPEX and OPEX Savings

TCO Saving Estimates

IPoWDM Solution



Cumulative TCO



Cumulative CAPEX

45% **TCO Saving** compared to Router + Transponder

40% **CAPEX Saving** compared to Router + Transponder

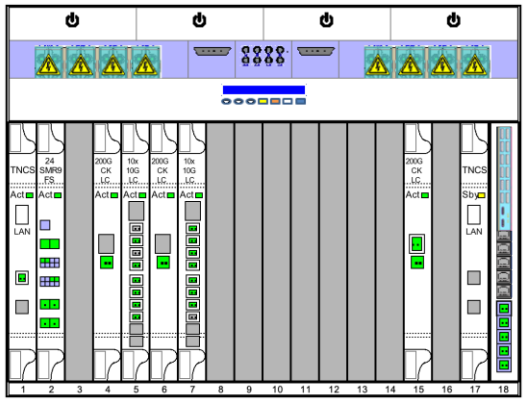
Environmental Efficiency

54% **Power Savings**

77% **Space Savings**

55% **Carbon Footprint Savings**

Greener - Power & Space Saving



Chassis Power Summary

Total Power Consumption: 1743 W

Max Power: 6000 W

Total Consumption: ~1740 Watts

```
CHASSIS LEVEL POWER INFO: 0
   Total output power capacity (Group 0 + Group 1) :    1050W +     1050W
   Total output power required                     :     700W
   Total power input                               :     179W
   Total power output                              :     135W
```

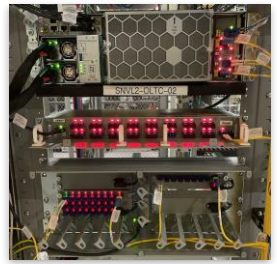
Total Consumption: ~200 Watts

Power Savings of 88.5%

25RU
43.75in

NCS2K Setup

8RU
14in

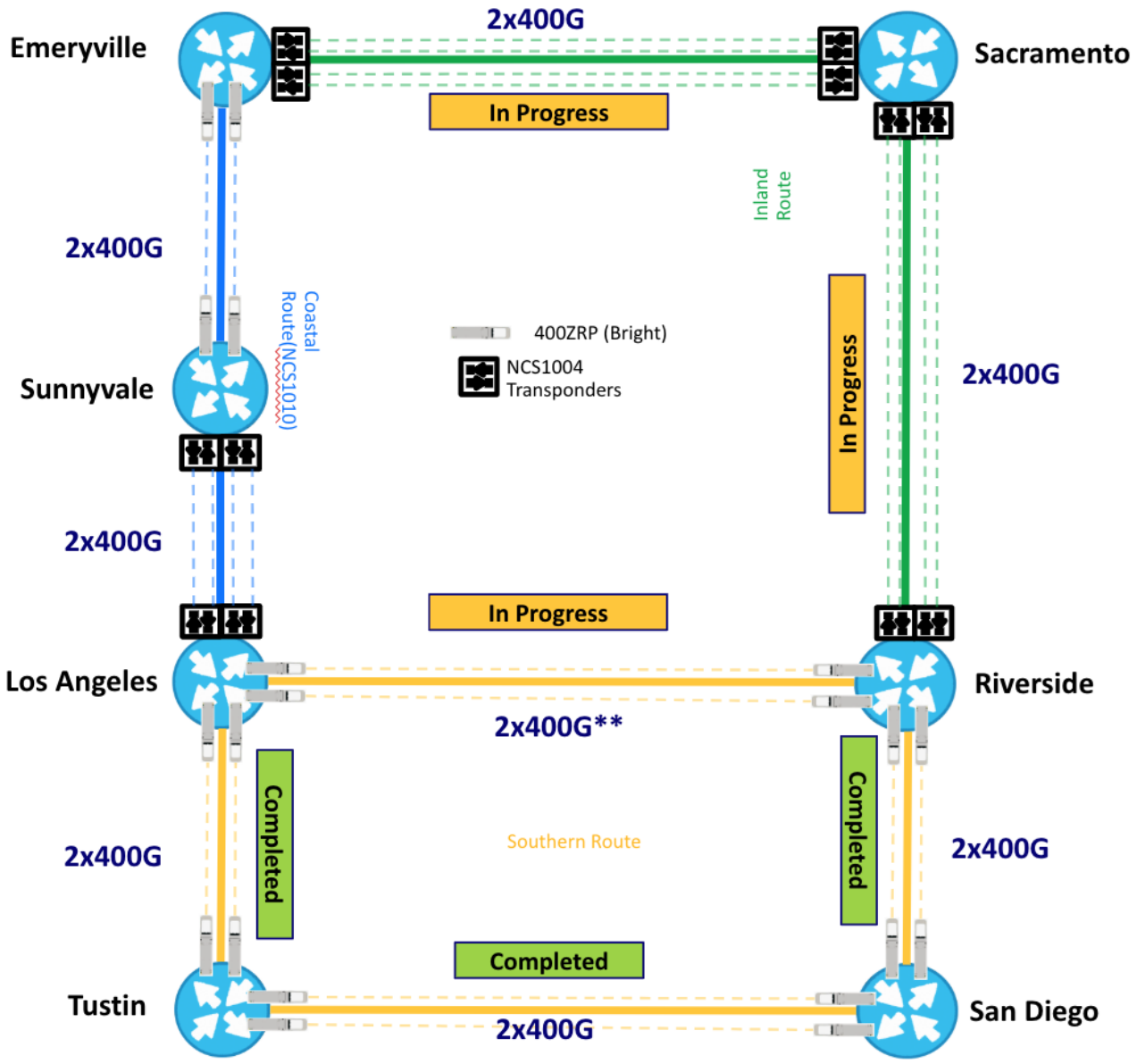


NCS1010 Setup

Space Savings of 68%

CalREN Core Ring 2025

- 400G ZR+ pluggables where possible
- Dedicated transponders for longer spans
- Upcoming 1x400G upgrades to low-demand locations using Juniper ACX7348s



NGI - Pacific Wave

Pacific Wave - 400Gbps Online

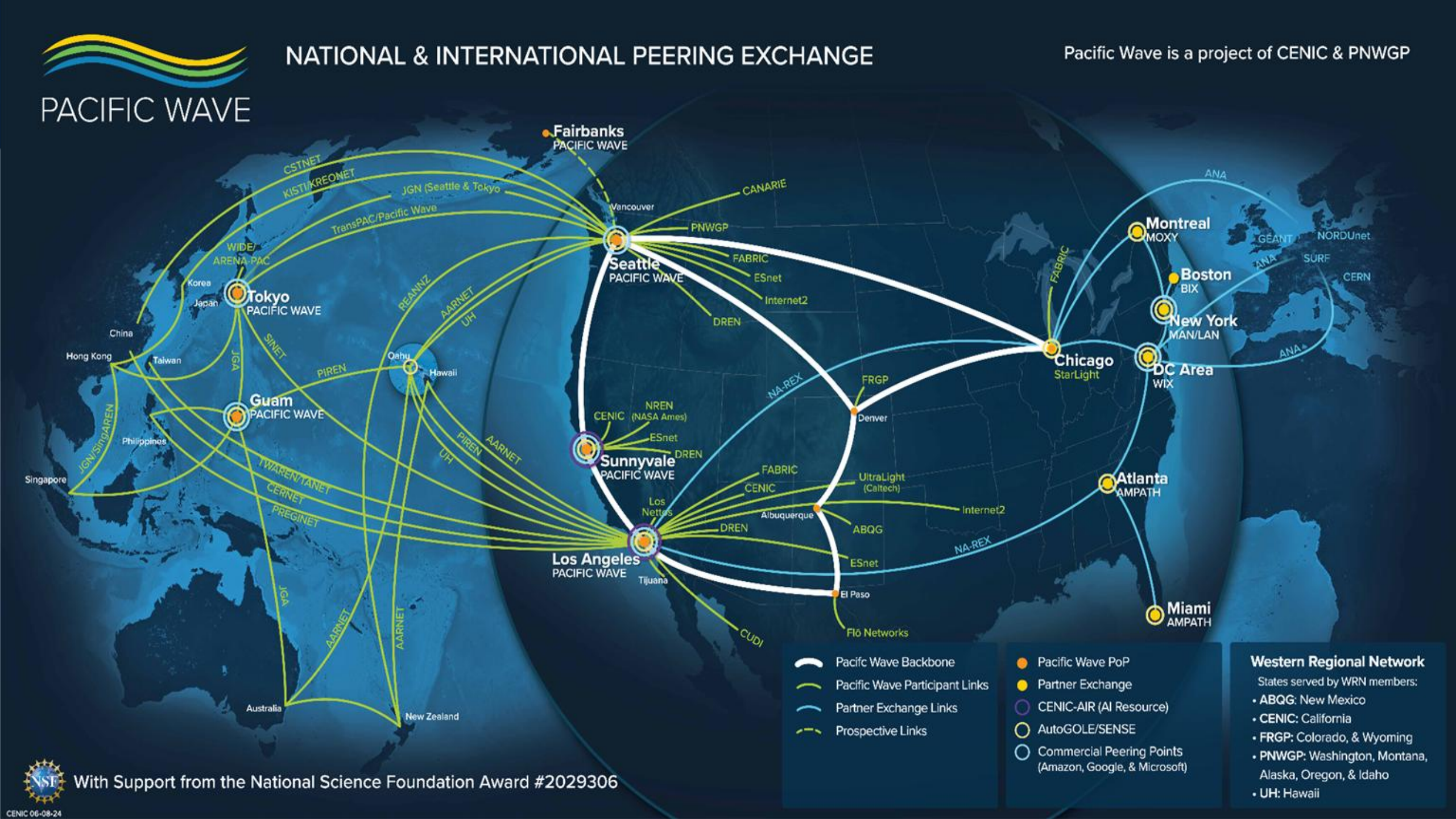
- Juniper PTX10001 deployed in production at all sites

- West Coast 400Gbps backbone upgrade complete
- Participant 400Gbps connections online!
  - SINET
  - PNWGP & CENIC
  - ESnet

PACIFIC WAVE

CENIC

PACIFIC NORTHWEST GIGAPOP


PACIFIC WAVE
NATIONAL & INTERNATIONAL PEERING EXCHANGE
Pacific Wave is a project of CENIC & PNWGP
Fairbanks
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Vancouver
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Tokyo
PACIFIC WAVE
Guam
PACIFIC WAVE
Sunnyvale
PACIFIC WAVE
Los Angeles
PACIFIC WAVE
Tijuana
Qahu
Hawaii
Korea
Japan
China
Hong Kong
Taiwan
Philippines
Singapore
Australia
New Zealand
Albuquerque
Los Nettos
Denver
Chicago
StarLight
Montreal
MOXY
Boston
BIX
New York
MAN/LAN
DC Area
WIX
Atlanta
AMPATH
Miami
AMPATH
El Paso
Flō Networks
CSTNET
KISTI/KREONET
JGN (Seattle & Tokyo
TransPAC/Pacific Wave
WIDE
ARENA-PAC
REANNZ
AARNET
UH
SINET
JGA
PIREN
JGN/SINGAREN
TWAREN/TANET
CERNET
PREGINET
CANARIE
PNWGP
FABRIC
ESnet
Internet2
DREN
NA-REX
FRGP
CENIC
NREN
(NASA Ames)
UltraLight
(Caltech)
ABQG
CUDI
ANA
GÉANT
NORDUnet
SURF
CERN
With Support from the National Science Foundation Award #2029306
Pacifc Wave Backbone
Pacific Wave Participant Links
Partner Exchange Links
Prospective Links
Pacific Wave PoP
Partner Exchange
CENIC-AIR (AI Resource)
AutoGOLE/SENSE
Commercial Peering Points
(Amazon, Google, & Microsoft)
Western Regional Network
States served by WRN members:
• ABQG: New Mexico
• CENIC: California
• FRGP: Colorado, & Wyoming
• PNWGP: Washington, Montana, Alaska, Oregon, & Idaho
• UH: Hawaii
CENIC 06-08-24

Pacific Wave in Alaska

- Node deployment in Fairbanks, AK
- Collaborating with MTA & University of Alaska
- Provide local peering and connectivity

PACIFIC WAVE

CENIC

PACIFIC NORTHWEST GIGAPOP

NGI - CalREN Services

CENIC Service Overview – 2024

Primary Network Services:

- CalREN Digital California (**DC**)
- CalREN High Performance Research (**HPR**)

MPLS VPN Services:

- L2 VPN Network Service – **E-LINE**
- L2 VPN Network Service – **E-LAN**
- L3 VPN Network Service – **IP-VPN**

Layer 1 Services:

- Optical Service
- Optical Spectrum as a Service

Other Network Services:

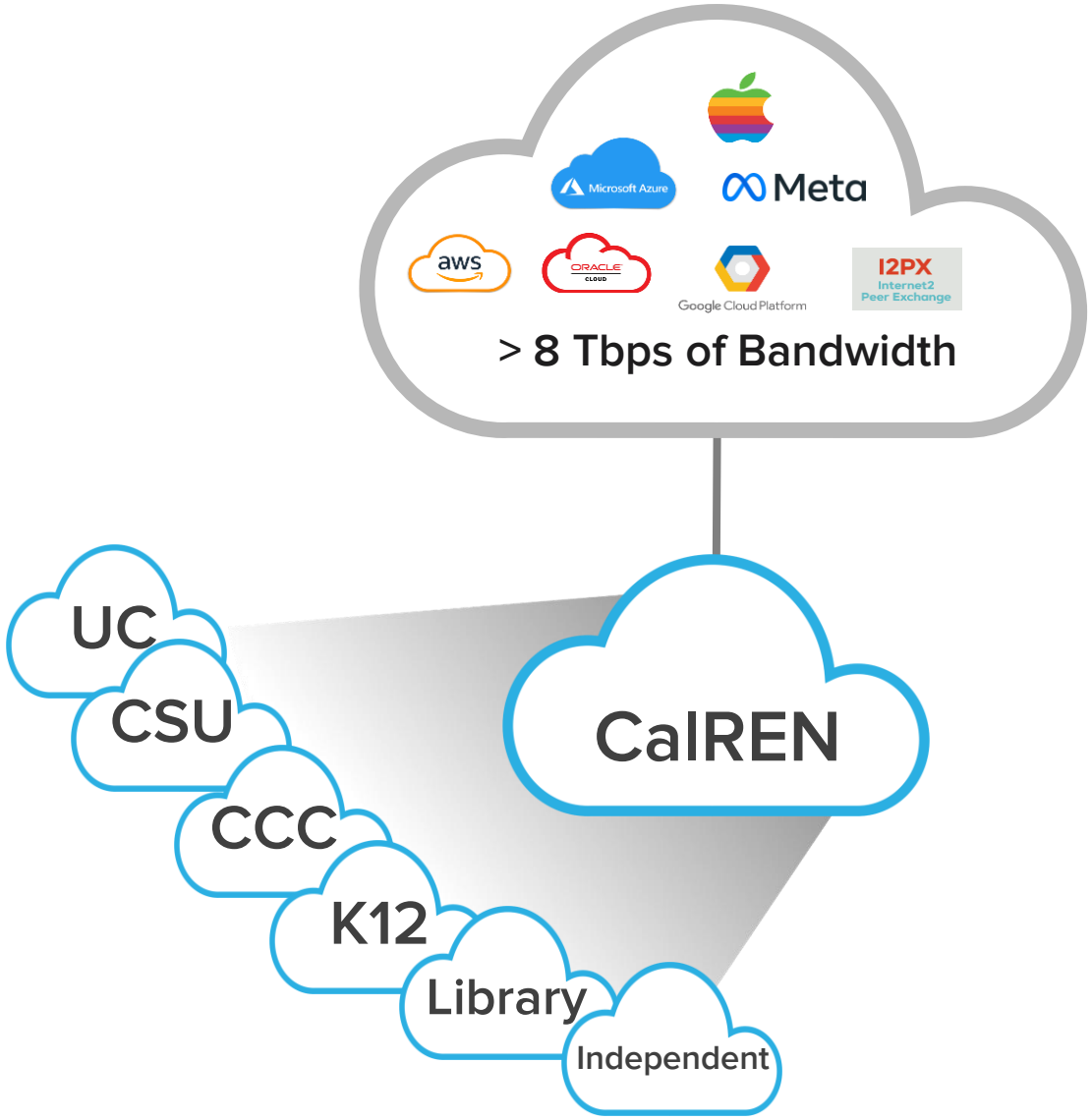
- CENIC Rapid Private Interconnect (RPI)
- CENIC DDoS Mitigation Service (DMS)
- CENIC AIR ScienceDMZ (**New!**)

Internet2 Services available via CENIC:

- Internet2 AL2S
- Internet2 Cloud Connect
- Internet2 RPI
- Internet2 InCommon & Net+ Services

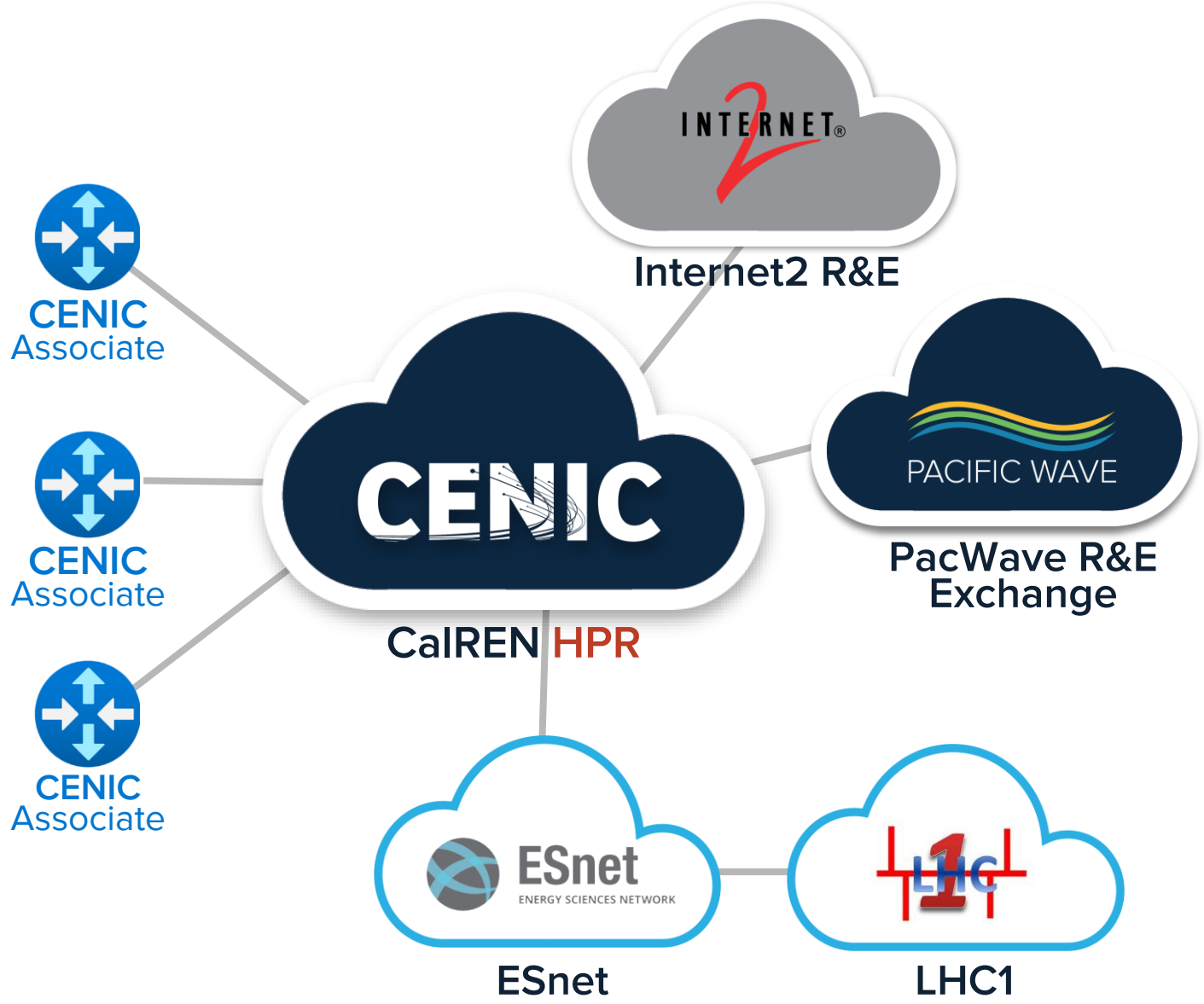
Digital California (DC)

- Used by majority of CENIC members
- Connectivity to general Internet
- Direct connectivity to other CENIC members
- Transit, peering and cloud services built in



High Performance Research (HPR)

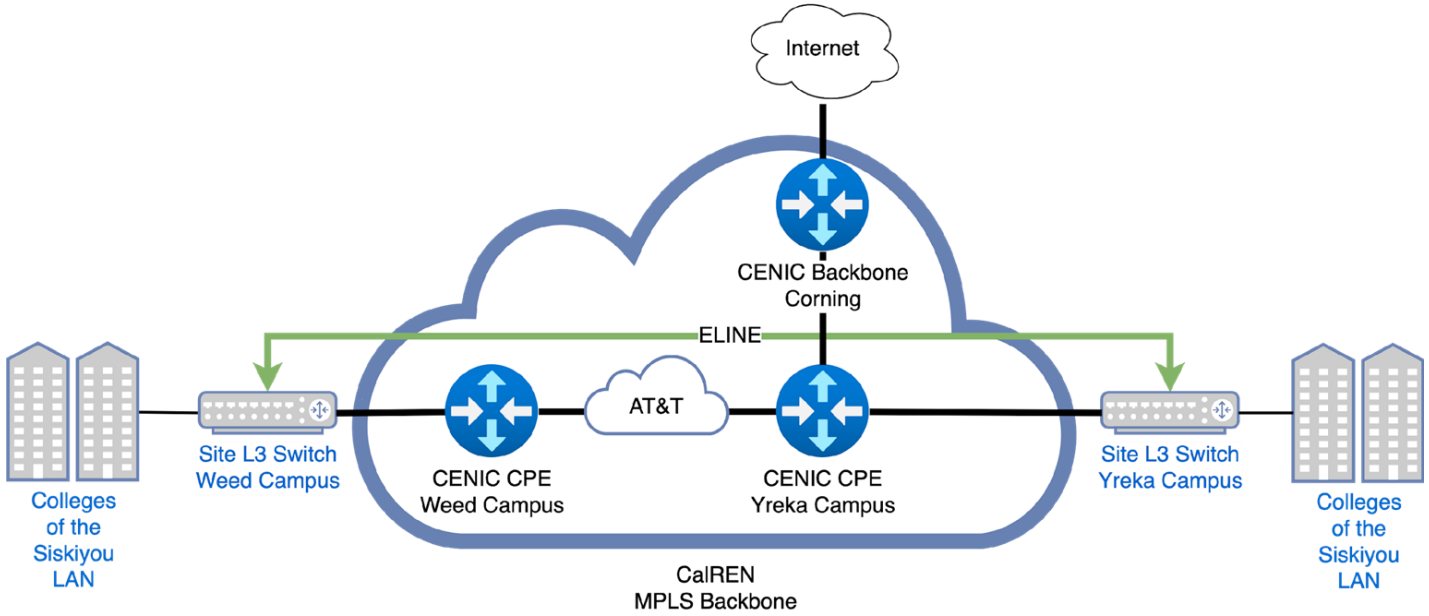
- R&E Only
- Leading edge network for large-application users
- Connectivity to:
  - Internet2 R&E
  - ESnet/LHCONE
  - Pacific Wave Exchange
  - NA-REX
  - And more…
- VRF inside CalREN Backbone



MPLS VPN Services
Layer 2 Virtual Private Networks
E-LINE

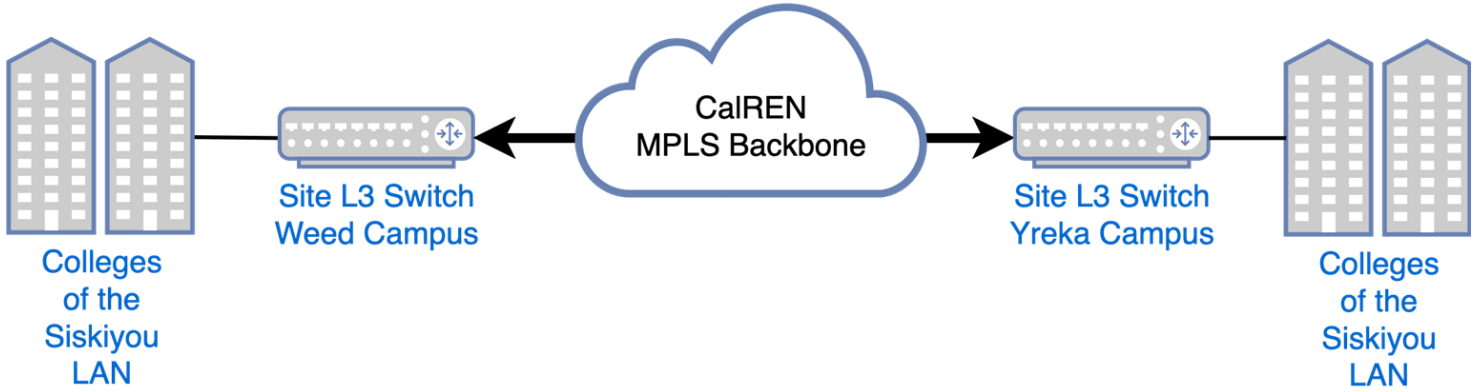
L2VPN – E-LINE

- Use to extend layer 2 networks between 2 remote locations
- Use case: Transparently connect two locations
- Fiber-like connection between locations – with less cost than dark fiber

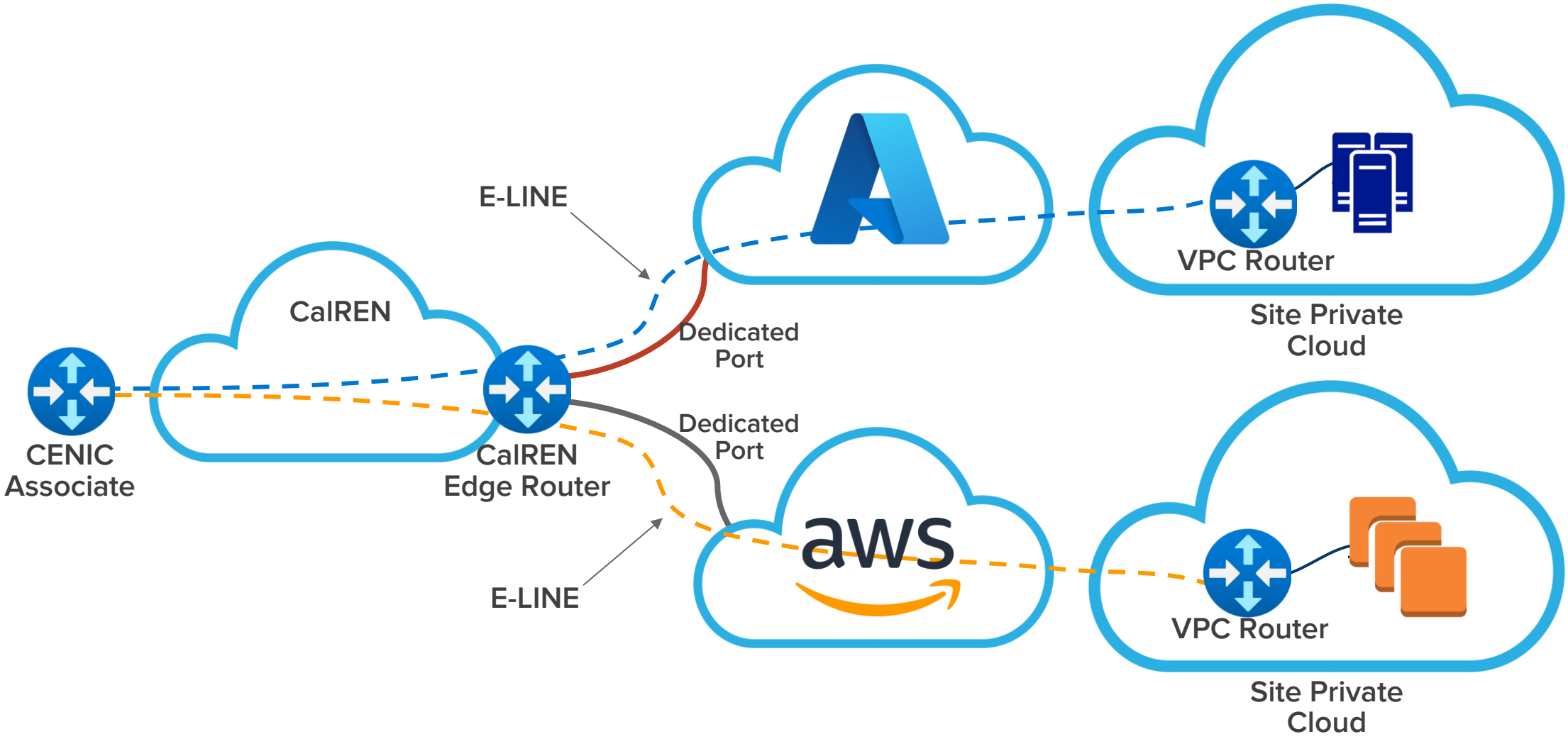


L2VPN – E-LINE Case Study

- Connect remote campuses without routing or extra hardware
- Recently provisioned Weed Campus and Yreka Campus E-LINE for Colleges of the Siskiyou



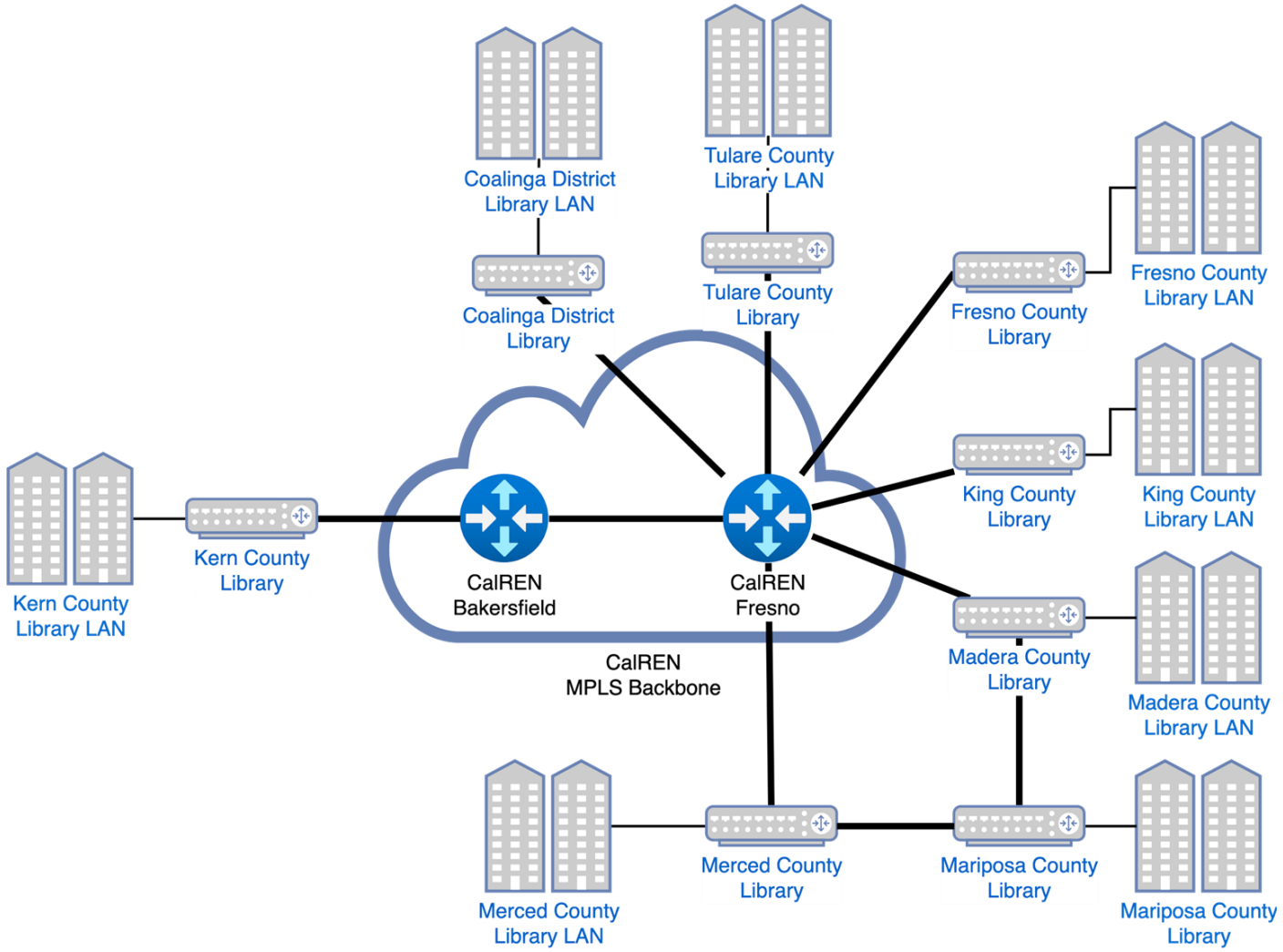
CENIC Rapid Private Interconnect (RPI) over E-LINE



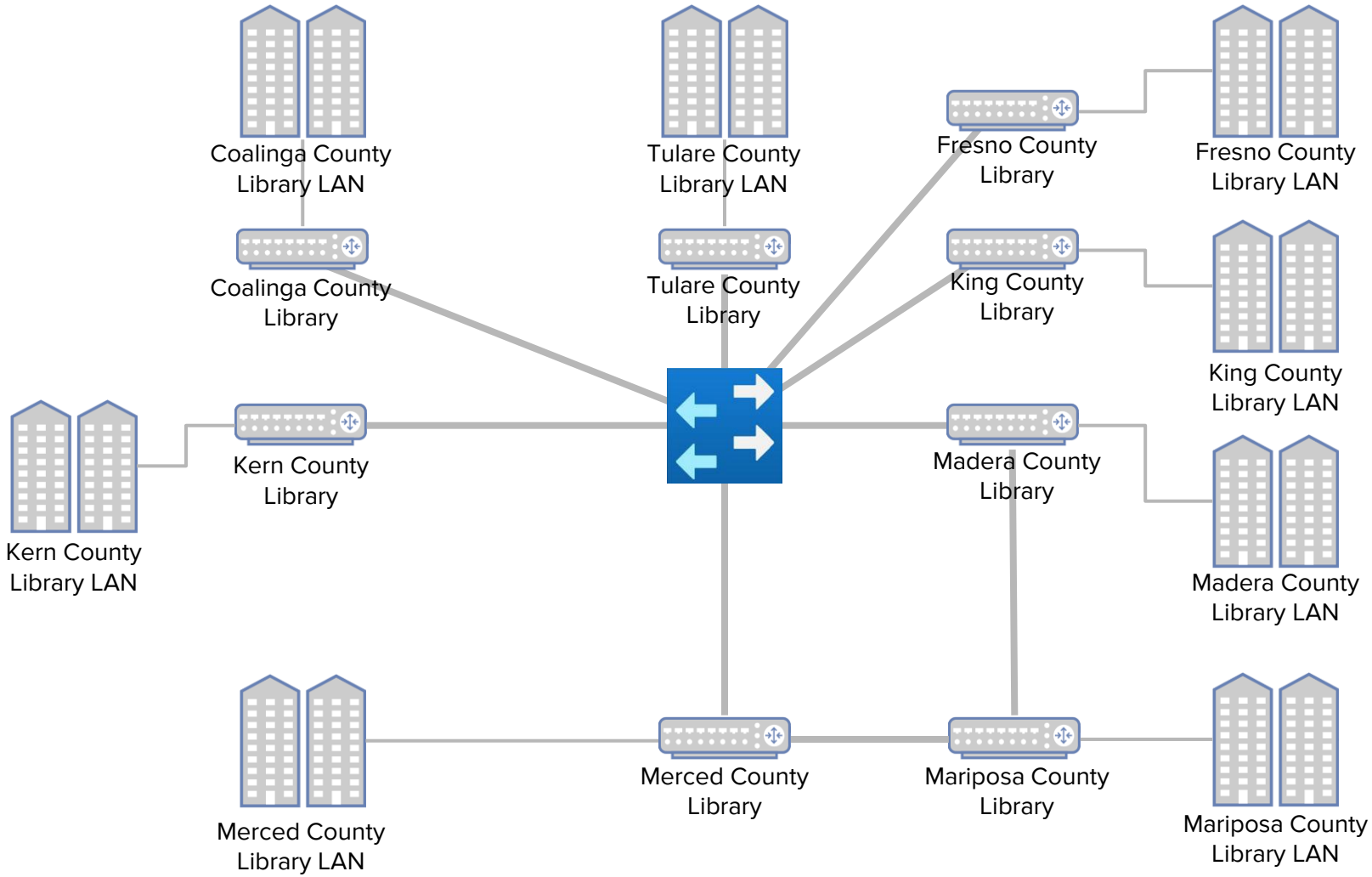
MPLS VPN Services
Layer 2 Virtual Private Networks
E-LAN

L2VPN – E-LAN

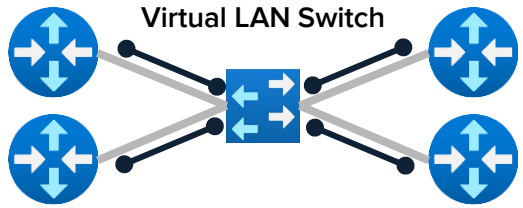
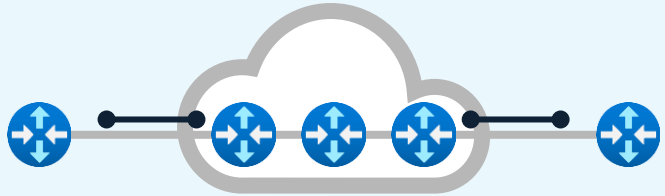
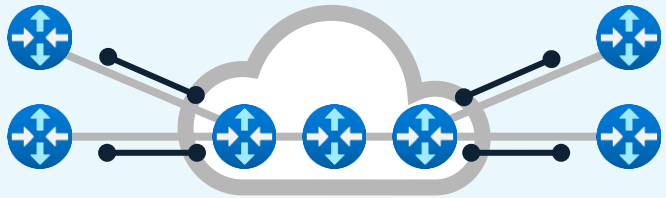
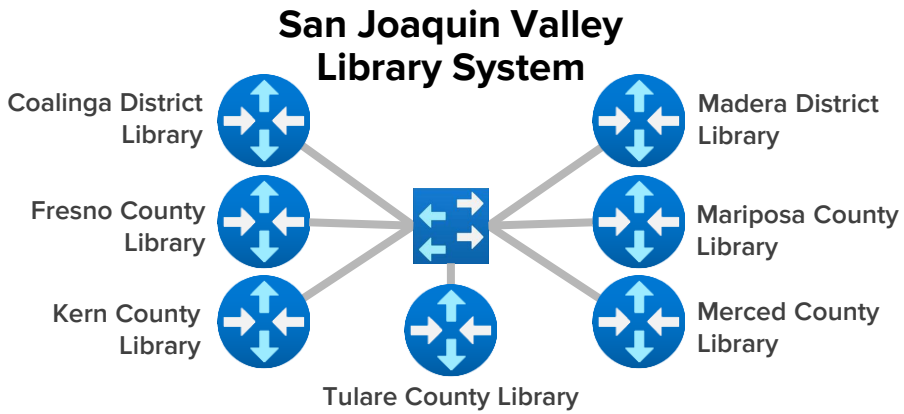
- Use to extend layer 2 networks between 2 or more remote locations
- Use case: Transparently connect three or more campuses
- Let us do the switching for you



L2VPN Private Network Service – E-LAN User View



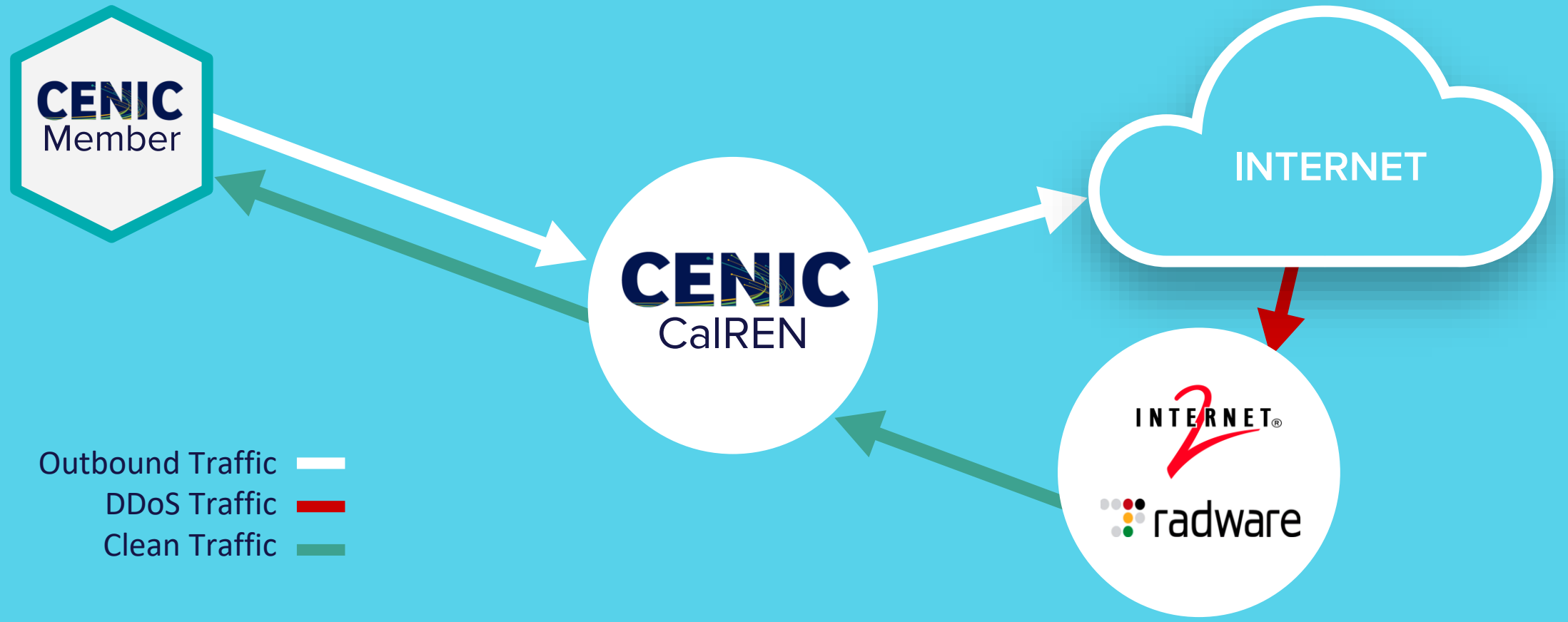
E-LAN and E-LINE Comparison

SERVICE TYPE	E-LINE	E-LAN
CONNECTION	Point-to-Point	Multipoint-to-Multipoint
ASSOCIATE VIEW		
CENIC VIEW		
EXAMPLES		

CENIC DDoS Mitigation Service (DMS)

DDoS Mitigation Service (DMS)

DDoS Mitigation Service: A managed solution that works to clean CENIC's traffic by Internet2's Radware DDoS scrubbing infrastructure. Scrubbing centers are located in the US.



DDoS Mitigation Service (DMS) – Options

- **Operationally & Technically Identical**
- **Differing Responsibilities for Monitoring & Response Activity**

CENIC Managed Solution

- Subscriber of CENIC's DDoS Mitigation Service
- CENIC will perform the following:
  - All Technical Setup to Support Mitigation Routing
  - DDoS Detection of Volumetric Attacks
  - Activation of Mitigation Scrubbing Services - Upon Customer Approval
  - Provide Quarterly Reports of Mitigation Activity

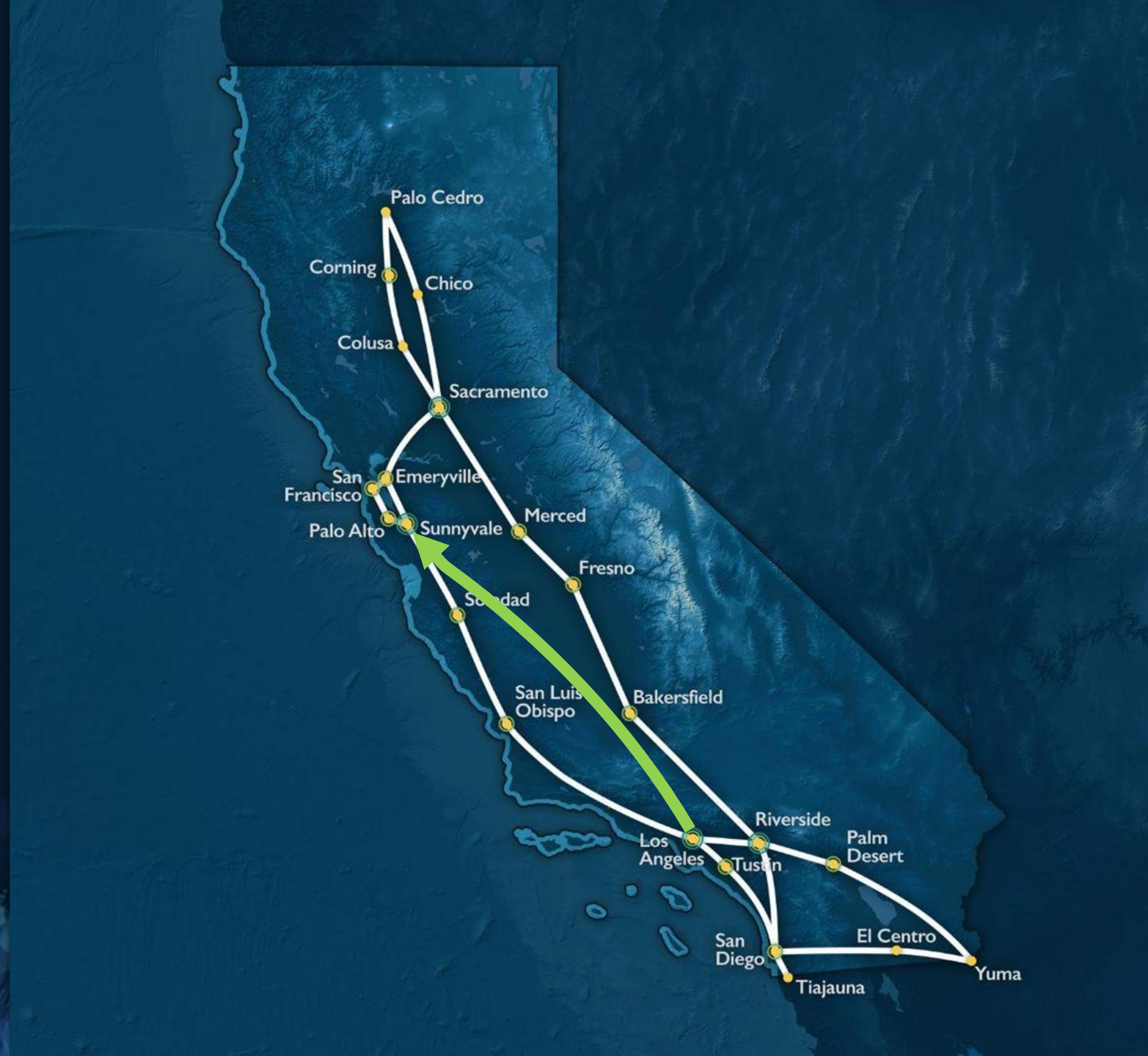
Self-Service Solution

- Downstream Tenant of Internet2/Radware
  - Direct Access to the Service Provider Security Operations Center (SOC):
    - *Initiate Scrubbing*
    - *Portal Access to Review Mitigation Efforts and Reporting*
    - *Direct VRF*
- Responsible for Own DDoS Detection and Activation of Mitigation Scrubbing Services

Layer 1 Services
Optical Service

Optical Service

- Gets you from here to there and back on top of dark fiber, with no layer 2 or layer 3 equipment in between
- Any network can be run over the top of an optical service
- Example: 400 Gigabits per second of capacity between Los Angeles and Sunnyvale



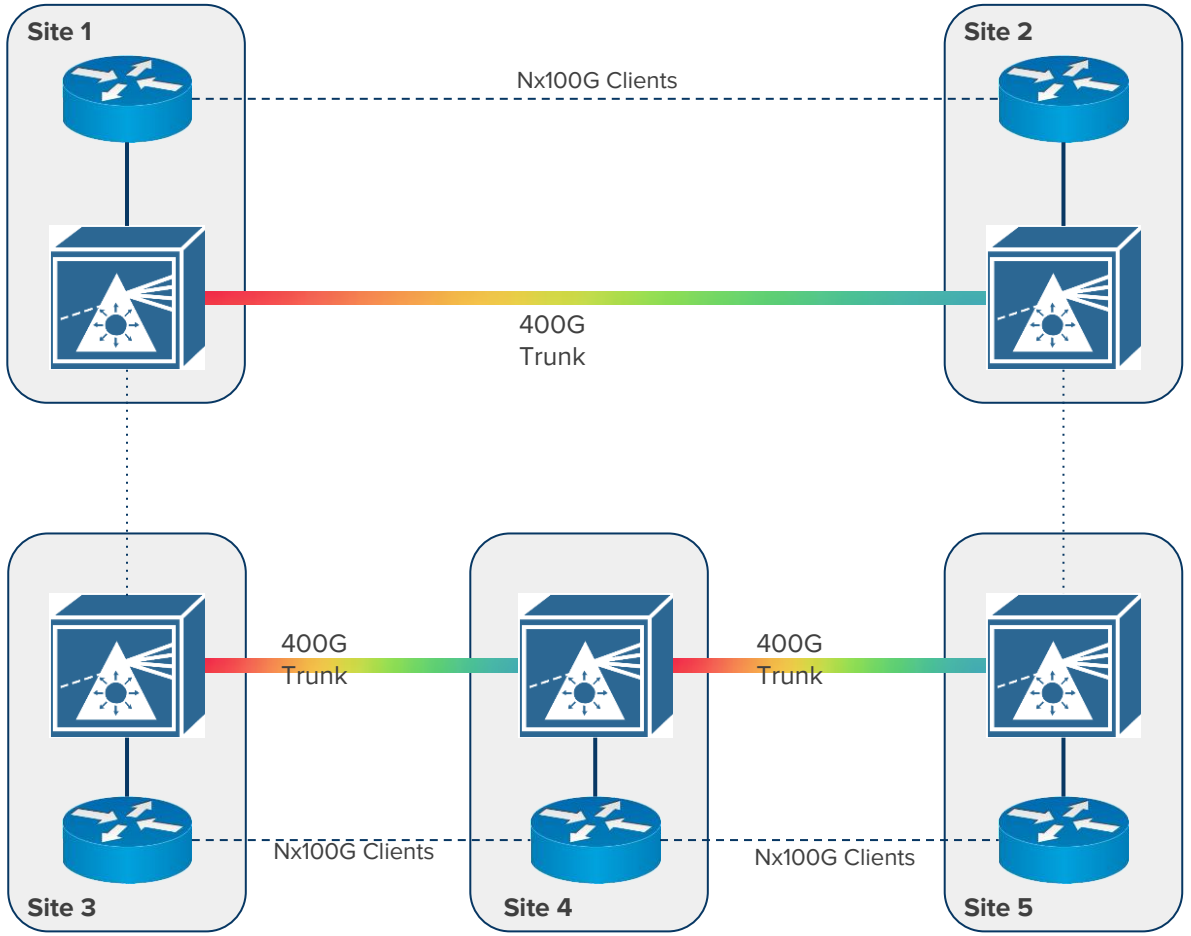
Metro Optical Services

Metro Optical Solutions

- CENIC currently manages 33 WAN optical circuits connecting associates to CalREN over dark fiber
- While optical networking is a critical component of CalREN, it is typically a lower priority for CENIC Associates
- Many associates do not have engineers with optical experience on-staff
- CENIC is now able to offer a metro optical solution, in which CENIC manages an associate's non-CalREN connecting optical network
- This design is an optional addition to WAN optical solutions
- At this time, CENIC is only able to offer metro optical services using CENIC approved hardware and software

Metro Optical Example

- Three 400G trunk circuits over dark fiber (ranging from 15-85km)
- CENIC manages the optical hardware, while the Associate manages the directly connected switches
- 2x100G client handoffs provisioned initially
- Ability to grow up to 3x400G per span (12x100G clients per optical device)



CENIC AIR

CENIC AIR is the CENIC-connected part of the National Research Platform (nrp.ai) providing California's R&E communities a means for faculty and students to

develop and refine topical AI curricula,

contribute to the transformations promised by these new technologies and,

collaborate extensively with colleagues nationwide over the NRP infrastructure.

It adds CENIC's network planning, engineering, and operations activities toward expanding AI resources to instructional as well as research-focused campuses.

It also adds CENIC Communications: Telling the CENIC AIR story across media channels to reach, educate, and inform multiple audiences.

CENIC AIR

CENIC ARTIFICIAL INTELLIGENCE RESOURCE

"The most powerful and heavily used section of the National Research Platform (NRP)"

References:

CENIC AIR

https://cenic.org/news/learn-what-cenic-and-our-members-accomplished-together-in-the-cenic-2022-24-community-report

CENIC AIR consists of high-performance compute and storage infrastructure voluntarily contributed to by members of the CENIC community.

Hosted Compute Resources by Site

The following institutions host listed compute resources for the use of all CENIC AIR participants.

	CPU	GPU		CPU	GPU
Cal Poly Humboldt	88	8	Sacramento State	28	8
Sunnyvale (CENIC)	191	0	UC Merced	84	14
Sunnyvale (Internet 2)	72	1	UC Riverside	216	20
UC Santa Cruz	433	27	CSU San Bernardino	196	16
Stanford U	28	0	LAX (CENIC)	48	0
CSU Monterey Bay	28	0	CSU Fullerton	572	70
UC Santa Barbara	60	17	U Southern California	12	0
UC Los Angeles	72	0	San Diego CCD	24	8
Caltech	72	0	San Diego State U	1944	172
UC Irvine	96	14	UC San Diego	7656	547
CSU Chico	28	15			

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CENIC AIR

CENIC ARTIFICIAL INTELLIGENCE RESOURCE

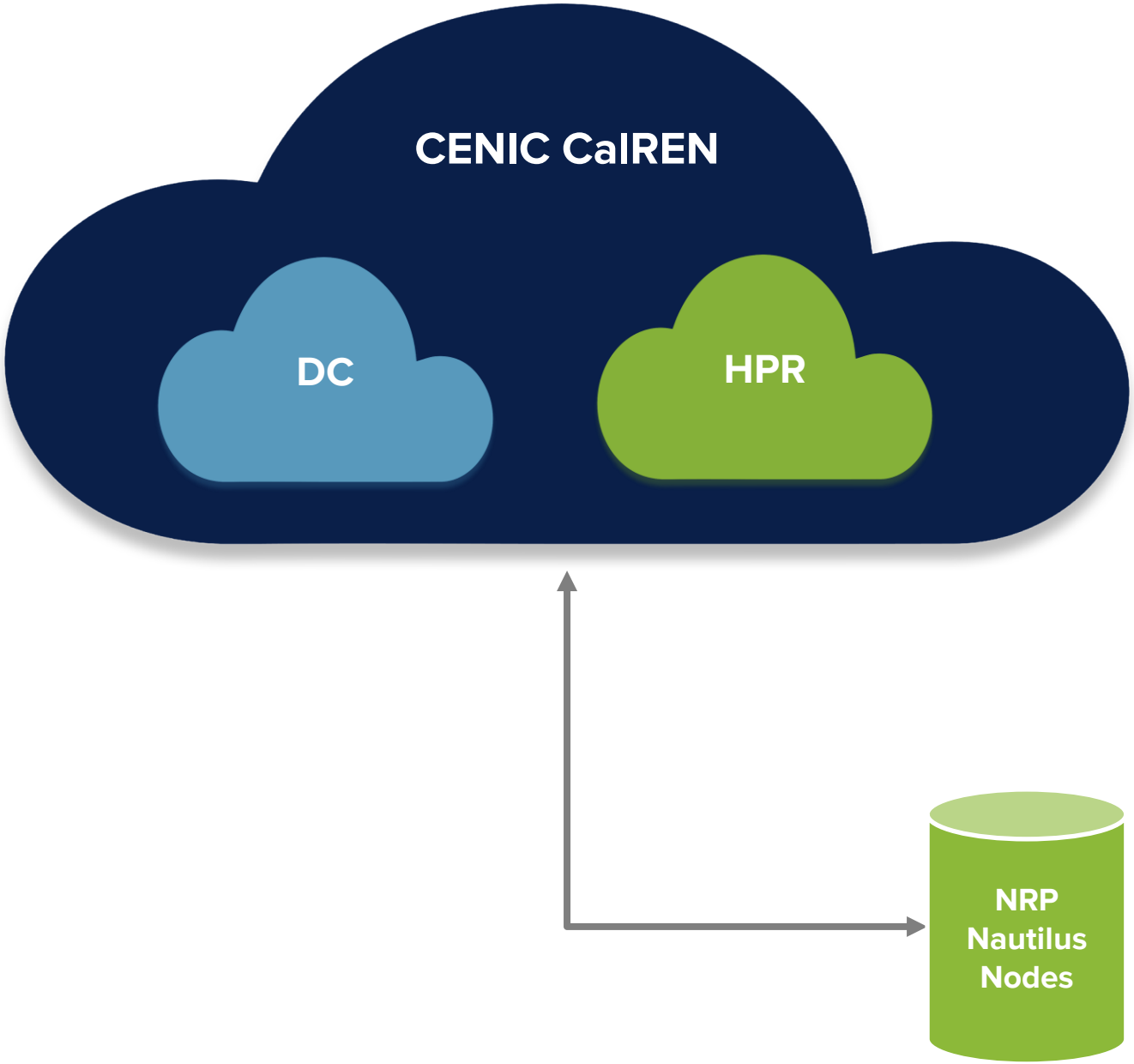
California State Universities	23
The University of California	10
California Community Colleges	116
Independent Universities	4
CENIC AIR Network Path	
Hosted Capacity and Capabilities	
• CPU Cores	11,948
• GPUs	937
• TB Storage & growing!	4561

The Majority of ***Nautilus*** GPUs Reside in the CENIC AI Resource (CENIC AIR): Hosted by and Available to CENIC Associates

NRP Nautilus

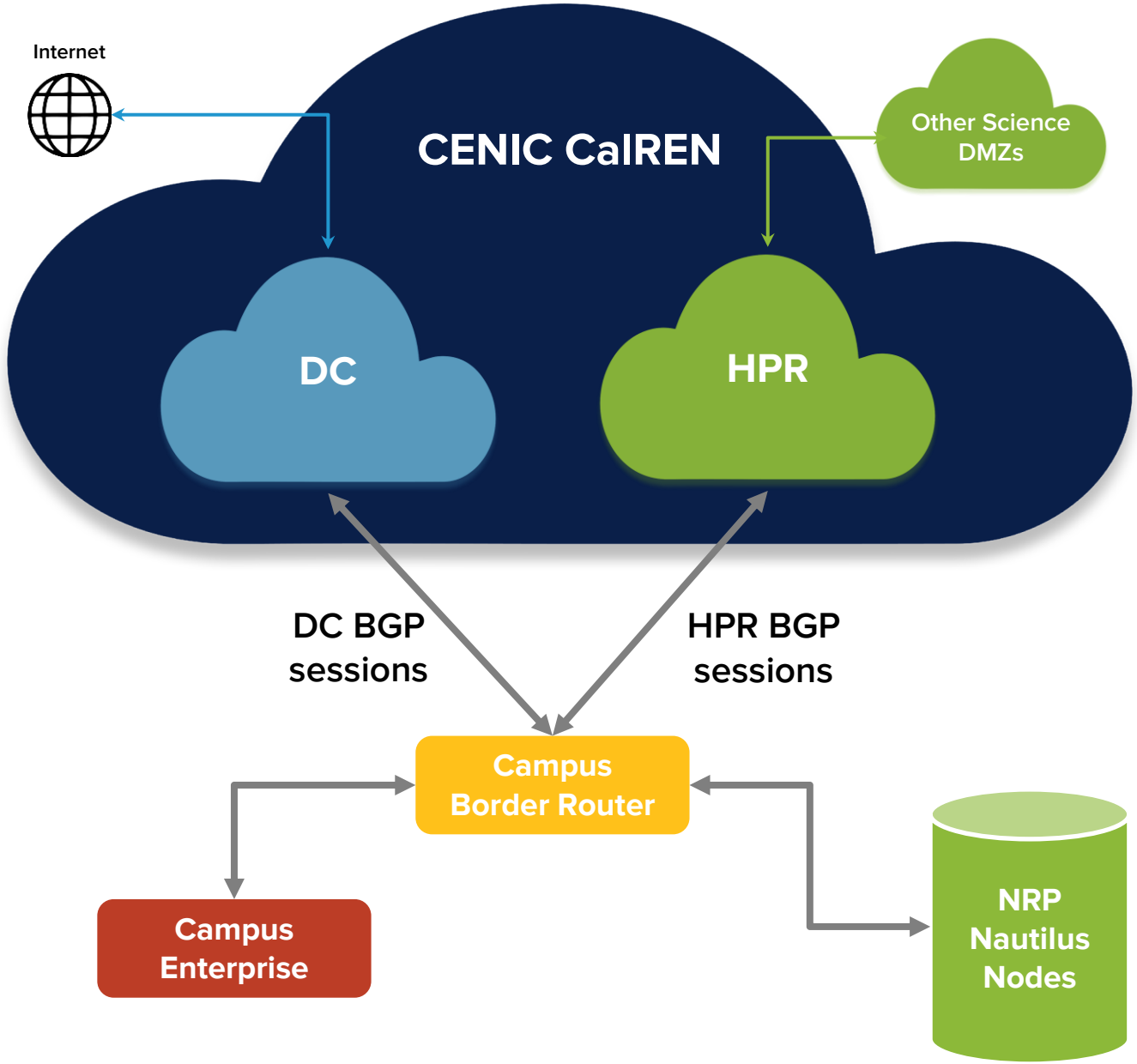
What resources do Nautilus nodes need?

- CalREN DC (Digital California)
  - Internet access
    - OS and software updates
    - DNS/NTP/etc.
  - Standard MTU (1500 bytes)
- CalREN HPR (High Performance Research)
  - Nautilus infrastructure and other nodes
  - Jumbo MTU (9000 bytes)
- ***DC and HPR are separate networks with separate routing tables.***



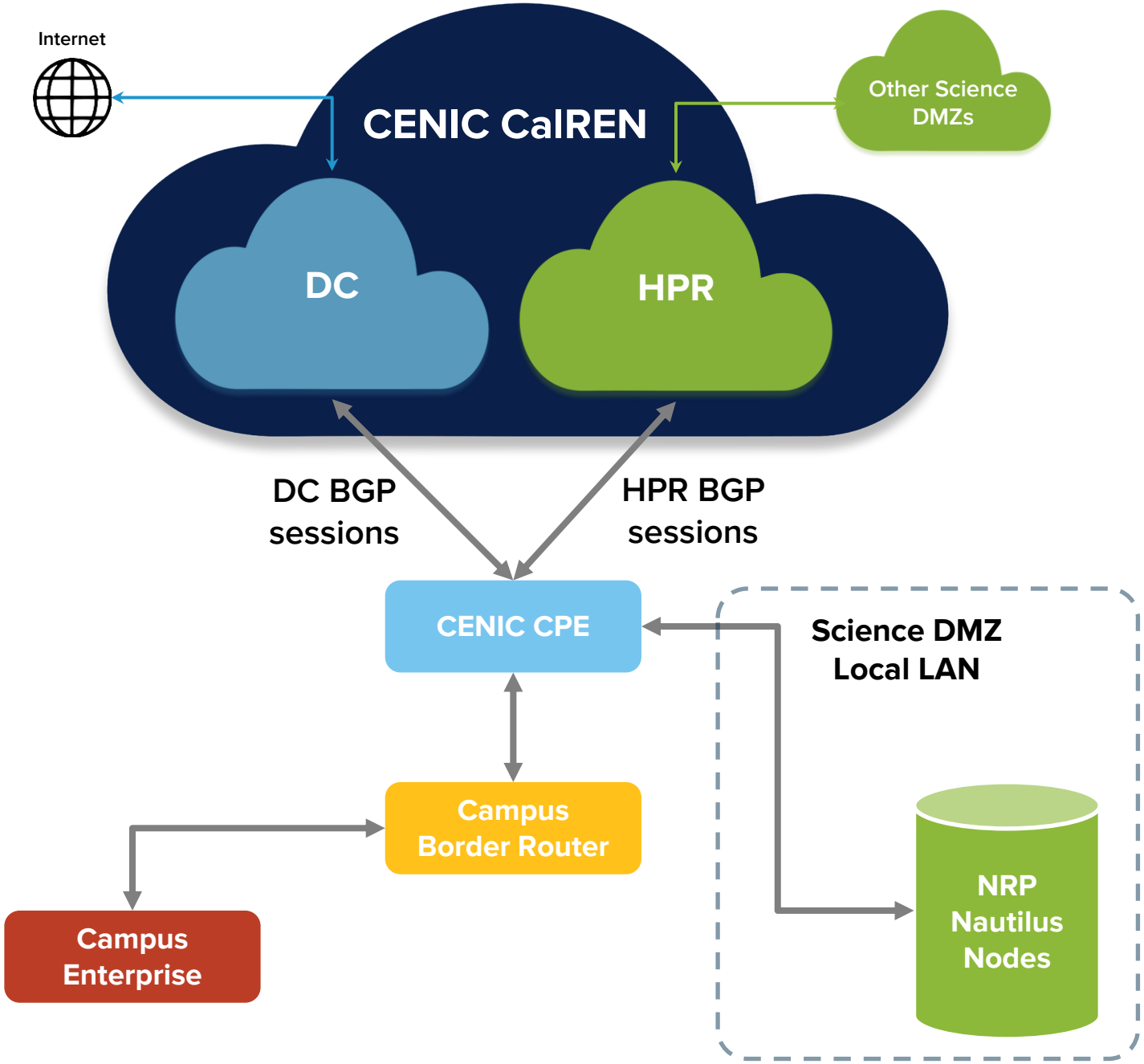
Science DMZ Design Options - Traditional Model

- Campus maintains separate BGP sessions for DC and HPR
- Science DMZ routing for Nautilus is the campus's responsibility.
- Many campuses still use and prefer this model:
  - Fine-tuned control over routing policy, bandwidth/QoS, and firewall rules.
  - No CENIC involvement needed in Science DMZ config.
- May be complicated to set up from scratch and requires campus network staff to be confident in BGP knowledge.



Science DMZ Design Options
CENIC-managed routing

- CENIC now offers a dedicated Science DMZ handoff option.
- CENIC handles the routing internally.
- Handoff from the CPE is simply a local LAN for the Science DMZ with a static default gateway.
- No BGP configuration needed.



2x800G Backbone
Final NGI Phase

NGI Optical - Overview

Legacy Optical Platform

NCS2006 Shelf

+

4x 100G Transponder

NCS1010 Next-Gen Line System

CISCO NCS1010 ROADM Node

+

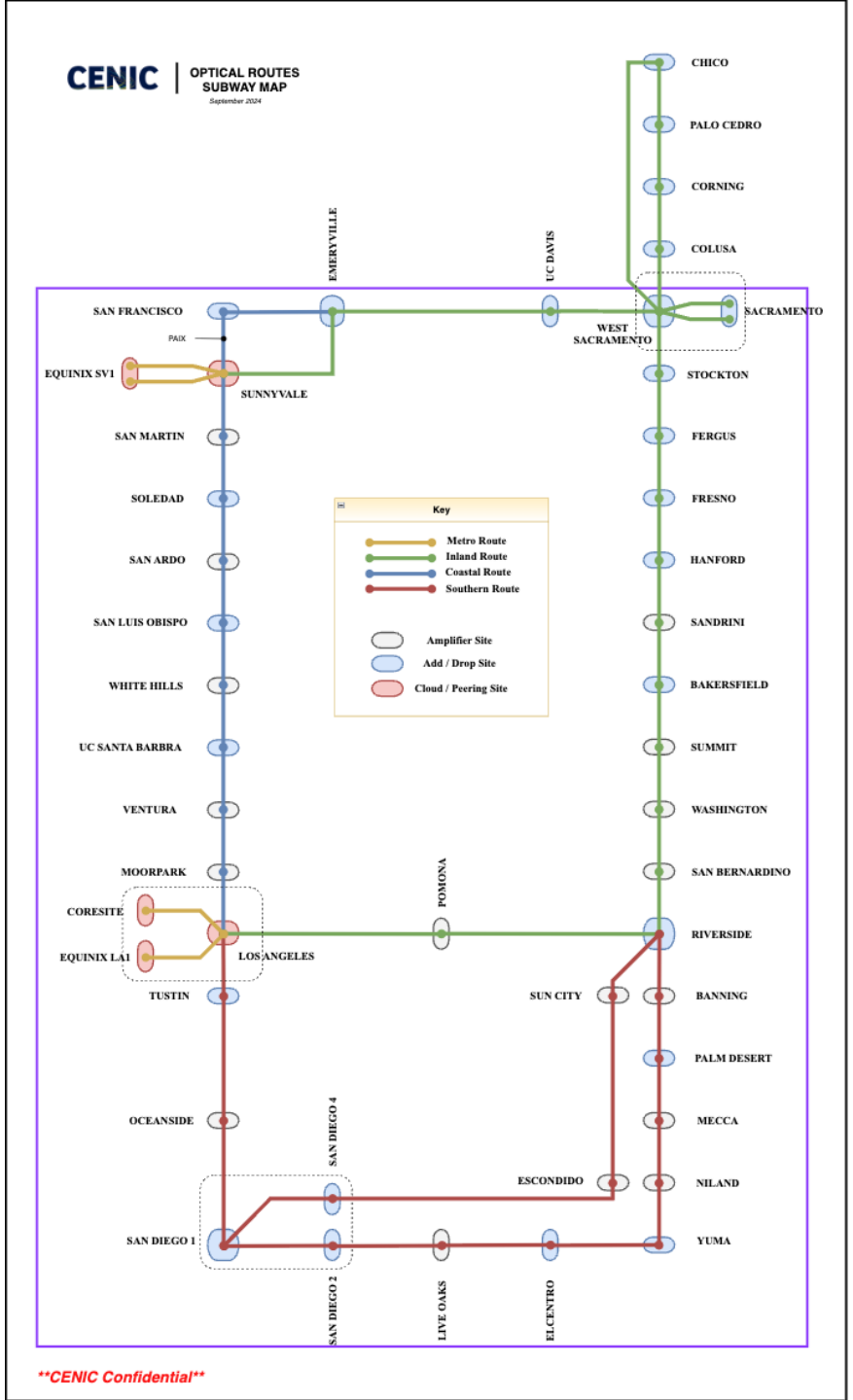
400ZRP Coherent Optics

Refresh all legacy optical platforms with the NCS1010 next-gen line system

- Improvement of 400G and 800G member optical service deployments
- Estimated reductions of **54%** and **77%** for colocation space and power
- Estimated Cisco maintenance spend reduction of **60%**
- Increase operational visibility and capability, reducing mean time-to-repair (MTTR)
- Total fiber capacity of **51.2** Tbps, or **64** 800G optical services

NGI Optical Project Plan

- Foundation of all CENIC services
  - Methodical planning required to mitigate risks
- Initially projected to require **four** years to complete
  - **26** Add/Drop sites
    - **63** fiber paths total
  - **17** Amplifier sites
  - **236** backbone & member optical services
- First year nearing completion



NGI Optical Initial 4-Year Roadmap

Inland Route

- **16** Add/Drop & **4** Amplifier sites
- **80+** Optical Services
- Projected Start: July 2025
- **Actual Start: January 2025**
- Projected End: June 2027

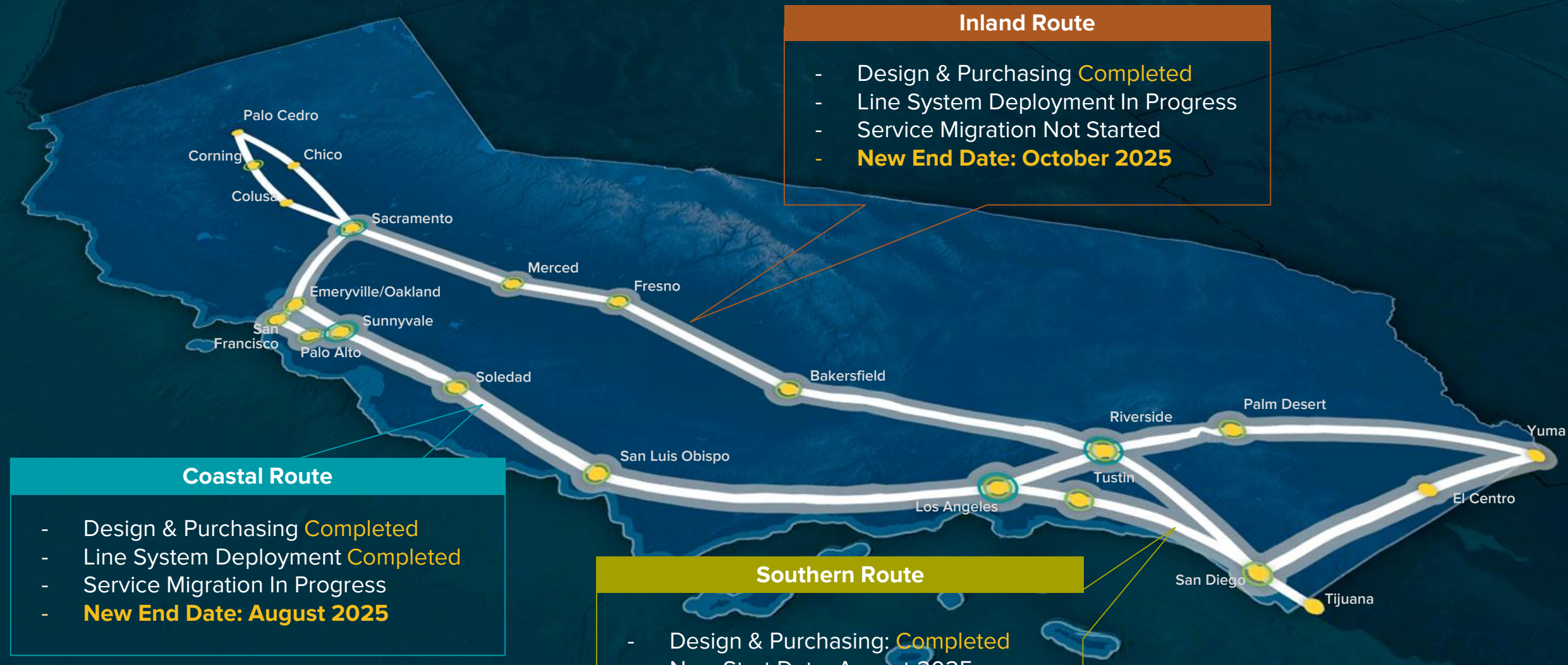
Coastal Route

- **7** Add/Drop & **5** Amplifier sites
- **50+** Optical Services
- Projected Start: July 2024
- **Actual Start: July 2024**
- Projected End: June 2026

Southern Route

- **9** Add/Drop & **8** Amplifier sites
- **90+** Optical Services
- Projected Start: July 2026
- Projected End: June 2028

NGI Optical Roadmap Improvements



Inland Route

- Design & Purchasing Completed
- Line System Deployment In Progress
- Service Migration Not Started
- **New End Date: October 2025**

Coastal Route

- Design & Purchasing Completed
- Line System Deployment Completed
- Service Migration In Progress
- **New End Date: August 2025**

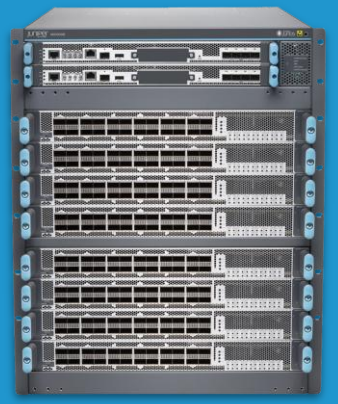
Southern Route

- Design & Purchasing: Completed
- New Start Date: August 2025
- **New End Date: June 2026**

NGI Routers - Overview & Status

- Current 400G-Based Backbone Router: Juniper MX10008
  - Does not support 800G services today
- Next-Gen 800G-Based Backbone Router: **Juniper PTX10002**
  - Native 800G support
  - Distributed design offers greater flexibility and cost-effective upgrade cycles
  - Automation leveraged to offset the more complex topology

400G-Based Platform



Juniper MX10008

- Native 100G / 400G Support
- Modular Linecards and Routing Engines
- Monolithic Design

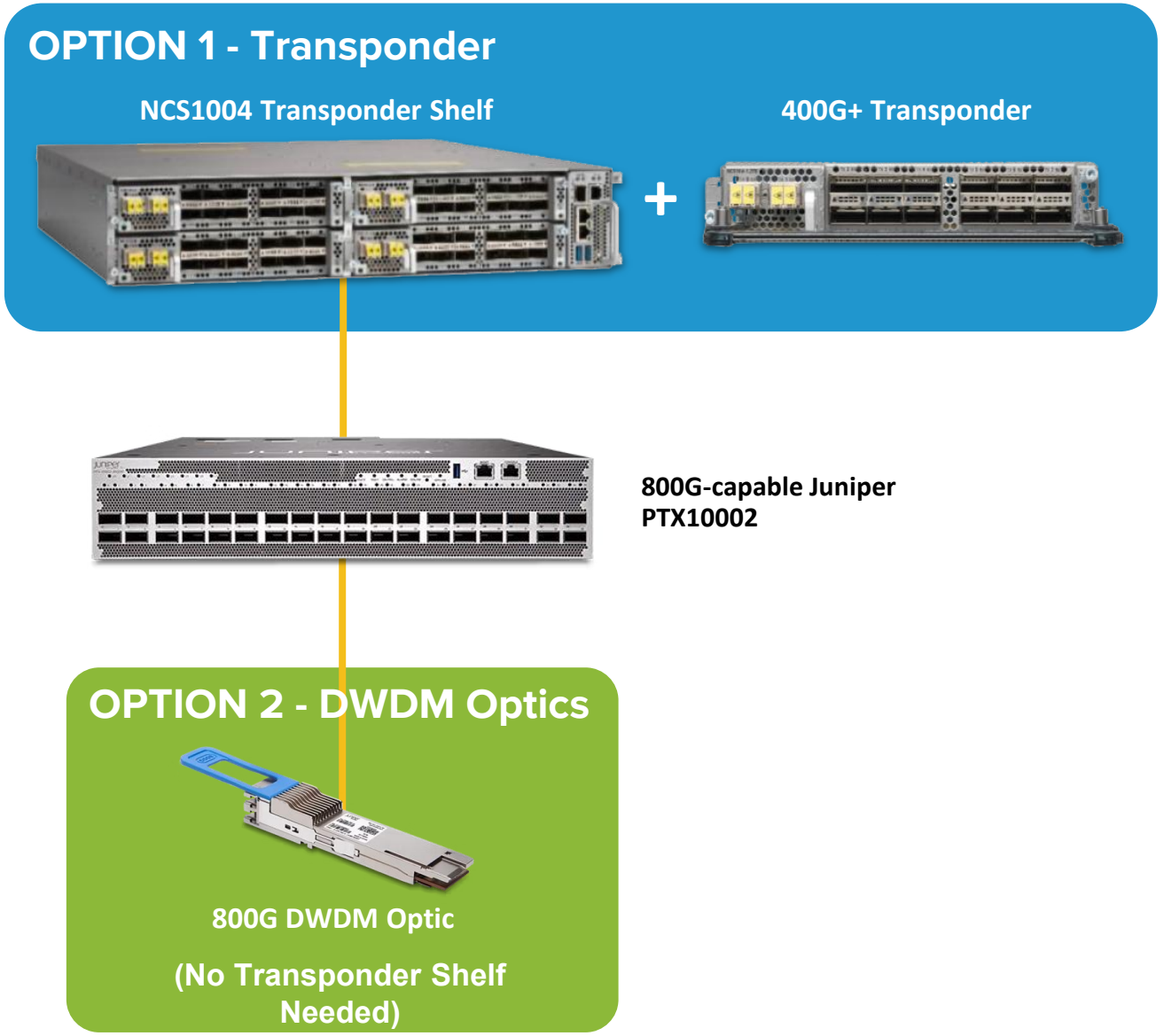
800G-Based Platform

Juniper PTX10002

- Native 100G / 400G / 800G Support
- Chassis-based System
- Distributed Design

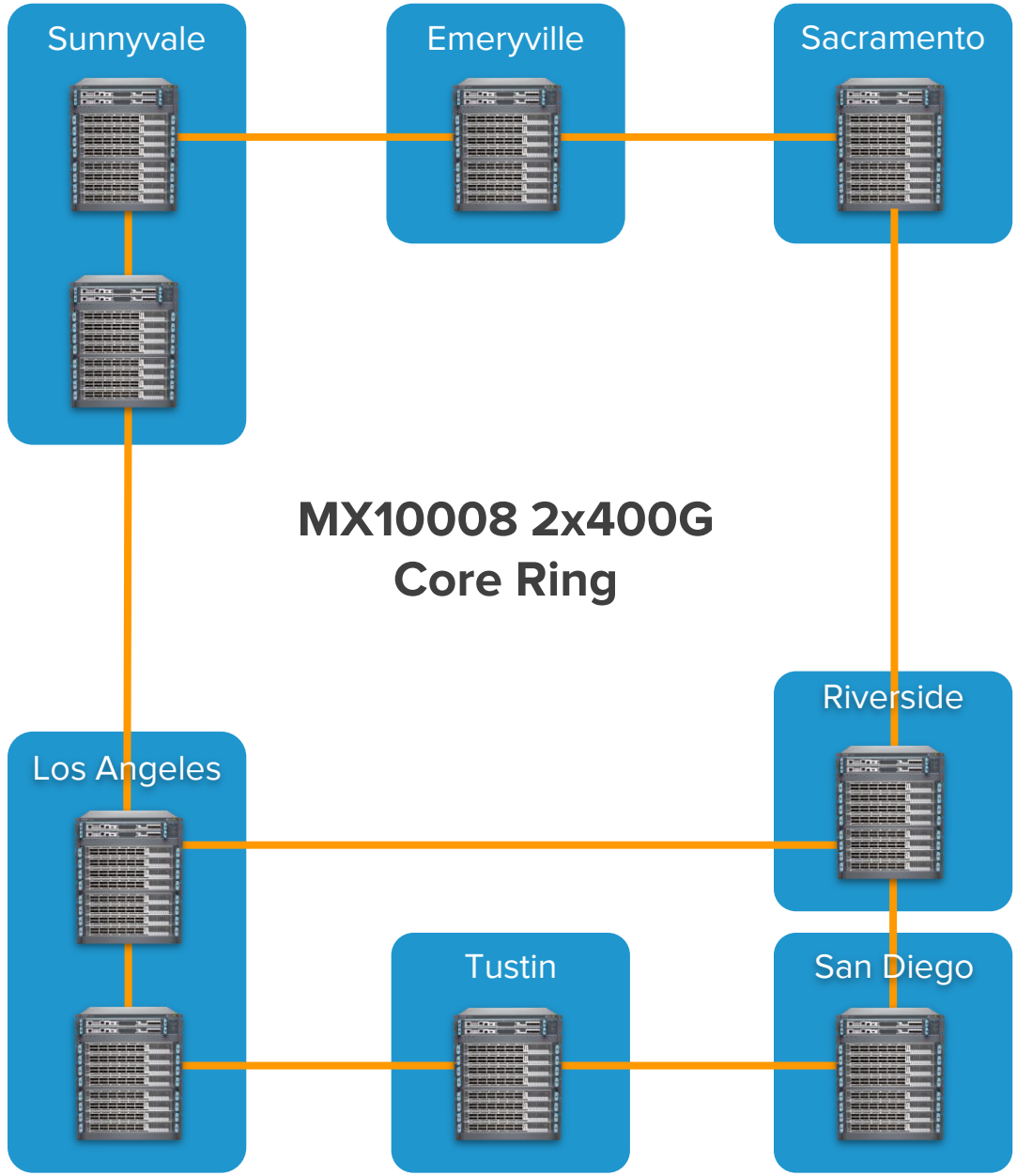
NGI DWDM Solutions

- Two options
  - Transponder
  - DWDM optic
- Transponders
  - Higher cost, more capable
  - Best for longer fiber spans
- DWDM Optics
  - Cost-effective
  - Perfect for most of the CalREN fiber spans



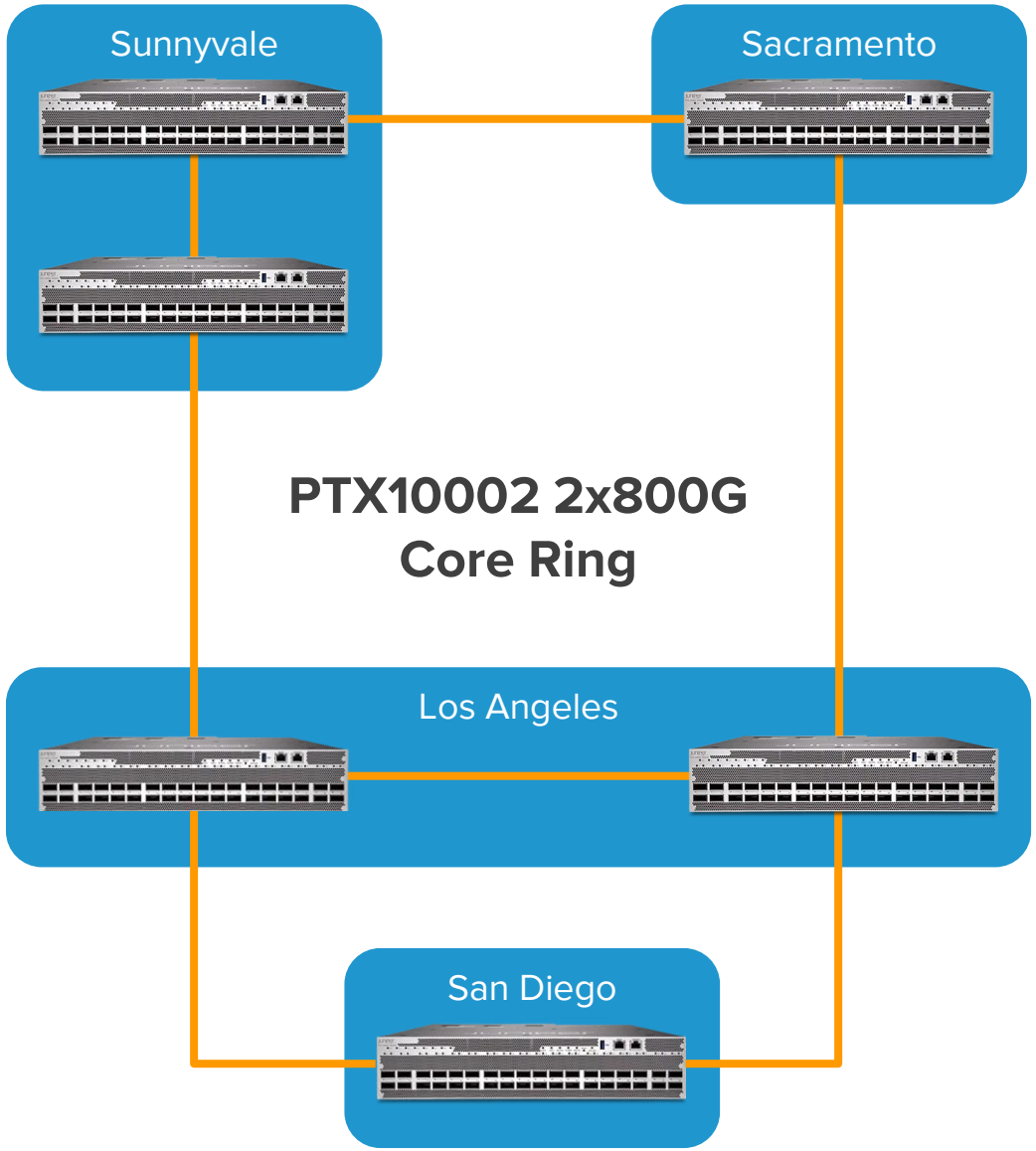
Current Backbone: 400G-Based

- All spans except two are at 2x400G today
- The remaining spans will be completed June 2025
- Current design uses MX10008 routers with 400G-based line cards



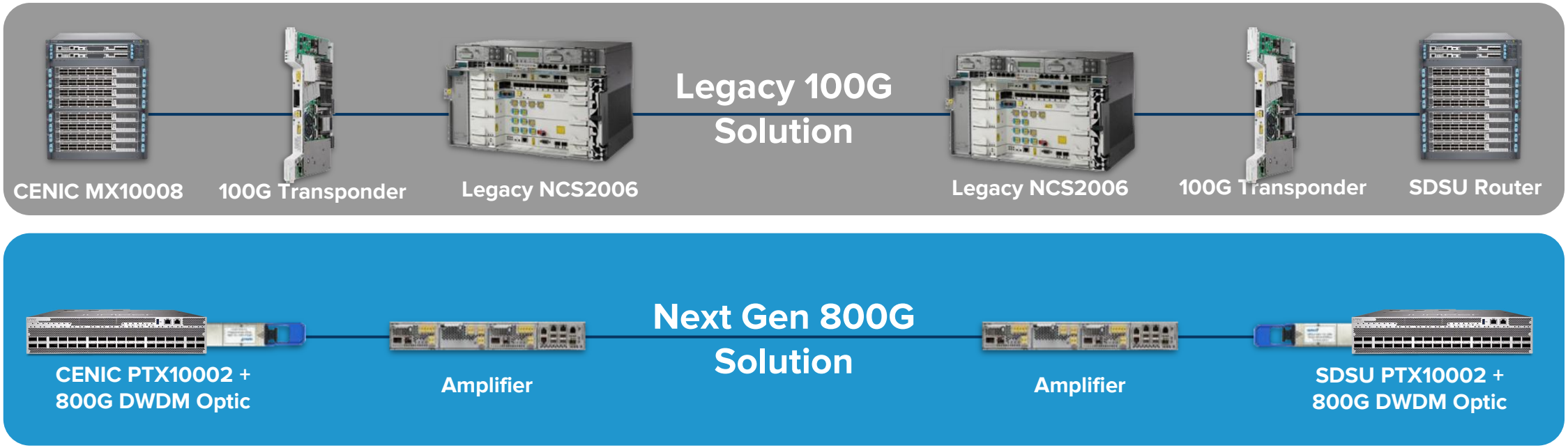
Future Backbone: 800G-Based

- Cost-optimized design
  - PTX10002 800G Routers
  - DWDM Optics
- Improved upgrade cycles
  - Faster adoption of newer speeds and technologies
- Initial 800G locations:
  - LA, Sunnyvale, Sacramento, and San Diego
  - Additional locations will be upgraded as demand requires
  - All other locations can still use 800G optical services



NGI 800G - Member Benefits

- Upgraded from 100G to 800G, **skipping 400G**, reducing lifecycle costs and **doubling** the capacity for similar costs as 400G
- The strategies, designs, and lessons learned through the NGI project made for a smooth transition to 800G for SDSU



Thank you!