

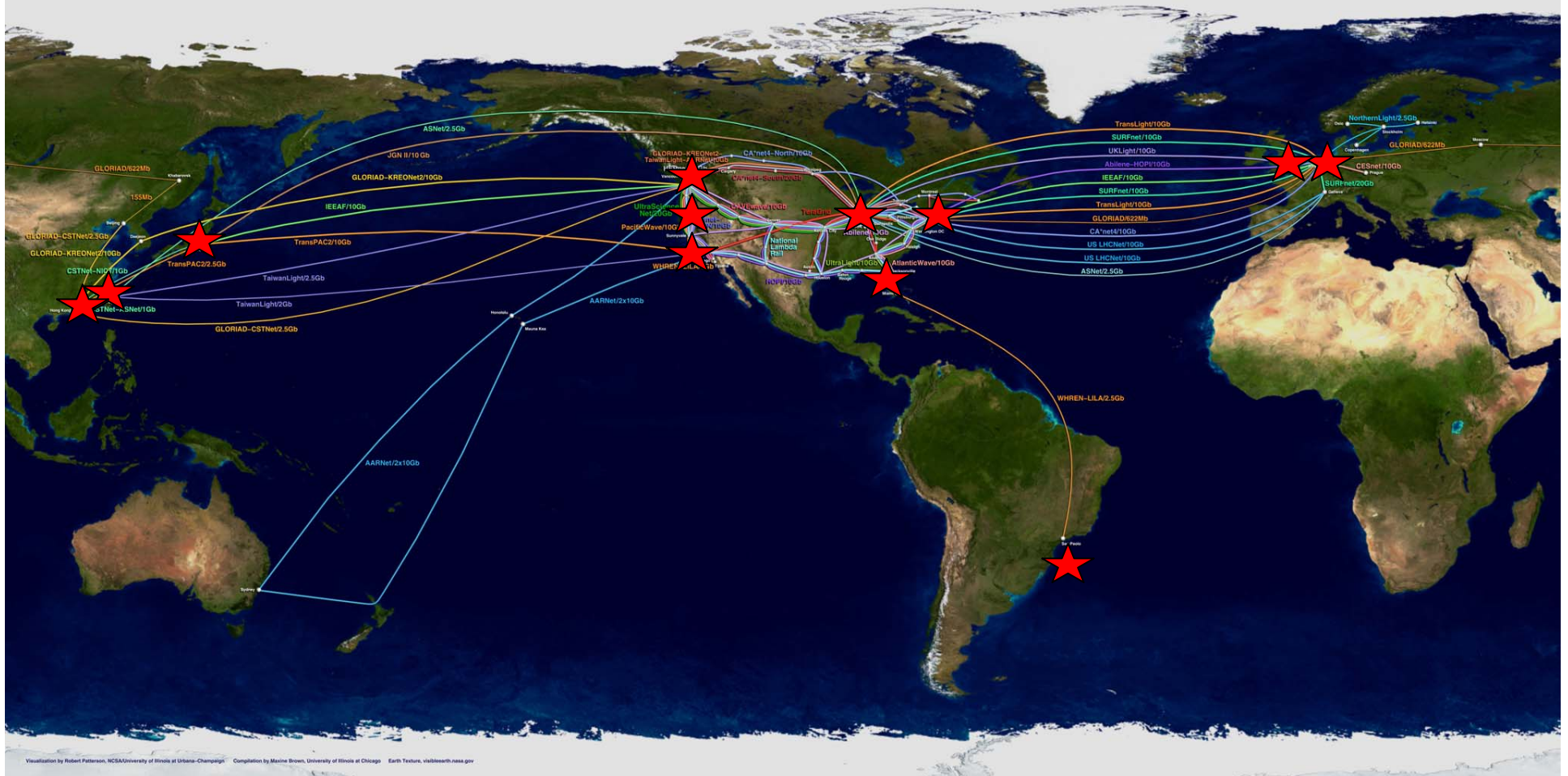
# **PacificWave**

## **Update for APAN-23**

**John Silvester**

*Professor of Electrical Engineering, USC*  
*PI – TransLight/PacificWave Project (NSF)*  
*Board Member, CENIC*

# International Connectivity and Exchanges



Visualization by Robert Patterson, NCSA/University of Illinois-Champaign. Compilation by Machine Brown, University of Illinois at Chicago. Earth Texture, vislabresearch.nasa.gov



Visualization courtesy of Bob Patterson, NCSA.

APAN-23, PacificWave Update, 2007.01.23

[www.glif.is](http://www.glif.is)



# PacificWave

- US West Coast R&E Distributed Exchange with PoP's in Seattle, Sunnyvale, Los Angeles
- **TransLight/PacificWave** project. (NSF-OCI-IRNC [#0441119]).
  - PI: John Silvester (USC), Co-PI: Ron Johnson (UW)
  - Key partners: AARNet, CENIC, PNWG, University of Hawaii.



# Context of Pacific Wave

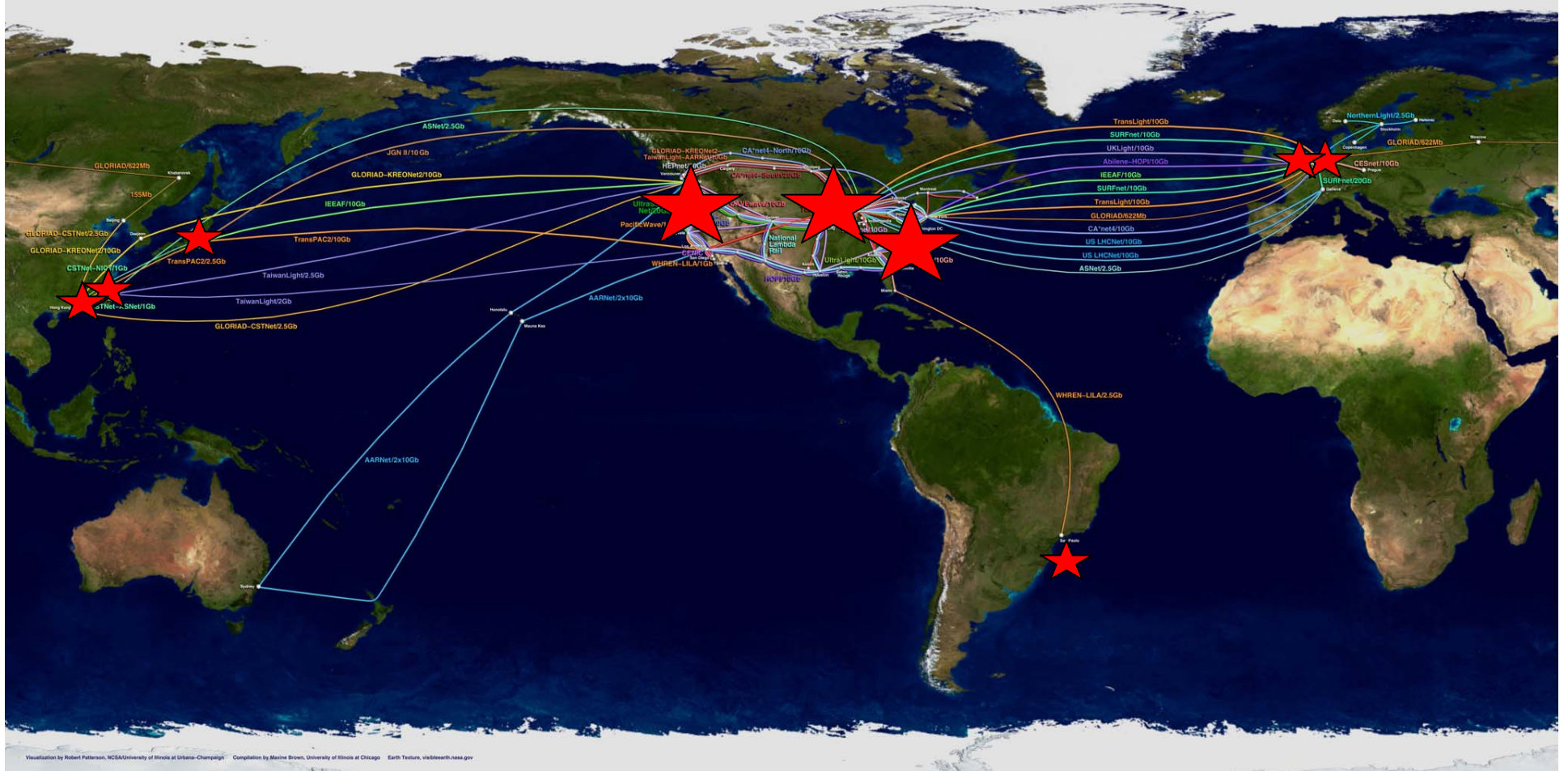
- The US States on the Pacific Coast [Alaska, Washington, Oregon, California, Hawaii] have collaborated in networking for several years. (e.g. US Pacific Consortium is an affiliate of APAN)
- Many international links enter the US through Washington and California (and to a certain extent Hawaii although they tend to remain local there)
- Seattle, Los Angeles, and Sunnyvale are “natural” places for exchange points
- Led to the development of Pacific Wave – a collaboration between CENIC and PNWG to build out exchange capabilities on West Coast.



# Pacific Wave – an Open Exchange

- Extensible peering exchange and lambda integrated facility
- Nodes (starting in early 2005) in Seattle and Los Angeles, connected by 10GbE wave(s) provisioned over National LambdaRail (2,241 kilometers)
- AUP free
- Supports IPv4 and IPv6; multicast enabled
- Based on Layer 2, Ethernet connections (for layer 3 peering)
- Provides 24x7 NOC support.
- Priced consistently from node to node
- Allows participants to self-select their peering
- Allows participants to connect to one-location and access participants at all Pacific Wave nodes
- Supports advance applications
- Welcomes any research or development network that can meet the minimum network configuration requirements (connect with a router; support BGP; support jumbo-frames)
- Support GLIF connectivity as a participant in Global Optical Lightpath Exchange (GOLE) development

# PacificWave, Starlight, and Atlantic Wave



Visualization by Robert Patterson, NCSA/University of Illinois at Urbana-Champaign. Compilation by Maxine Brown, University of Illinois at Chicago. Earth Texture, visibleearth.nasa.gov



Visualization courtesy of Bob Patterson, NCSA.

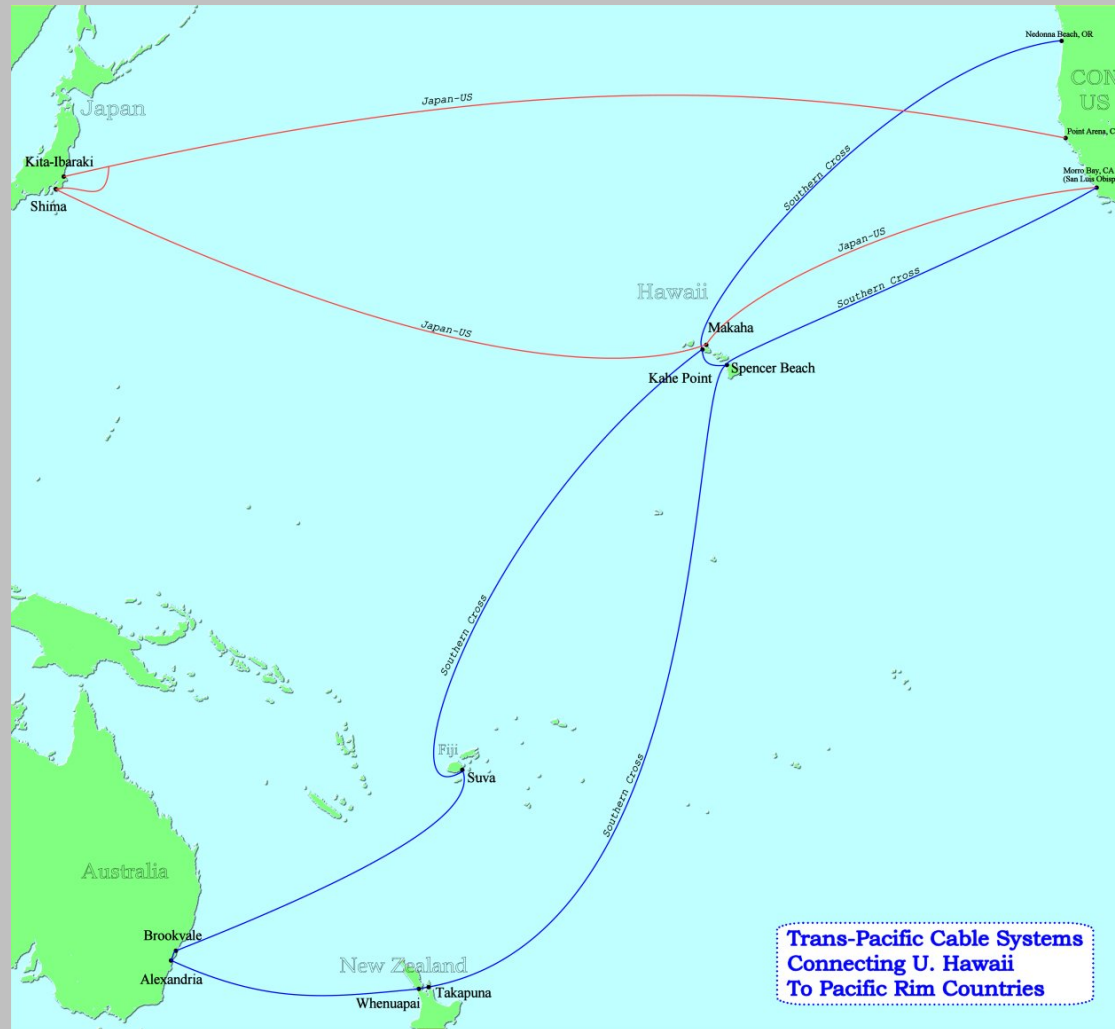
APAN-23, PacificWave Update, 2007.01.23



# TransLight/PacificWave Project

- Facilitate international R&E connections on US Pacific Coast
- Assist in the termination (equipment, backhaul) of AARnet SXTransport links through Hawaii to Seattle and Los Angeles
- Assist in build-out of Hawaii connectivity to observatories
- Further develop PacificWave exchange capabilities
- Assist in operation of IEEAF link Tokyo-Seattle
- Assist in operation and support of other IRNC projects
- Assist in operation and support of other International R&E networks participating in PW
- Develop and operate advanced capabilities to support optical interconnect and exchange needs of R&E networks

# Hawaii Connection Opportunities





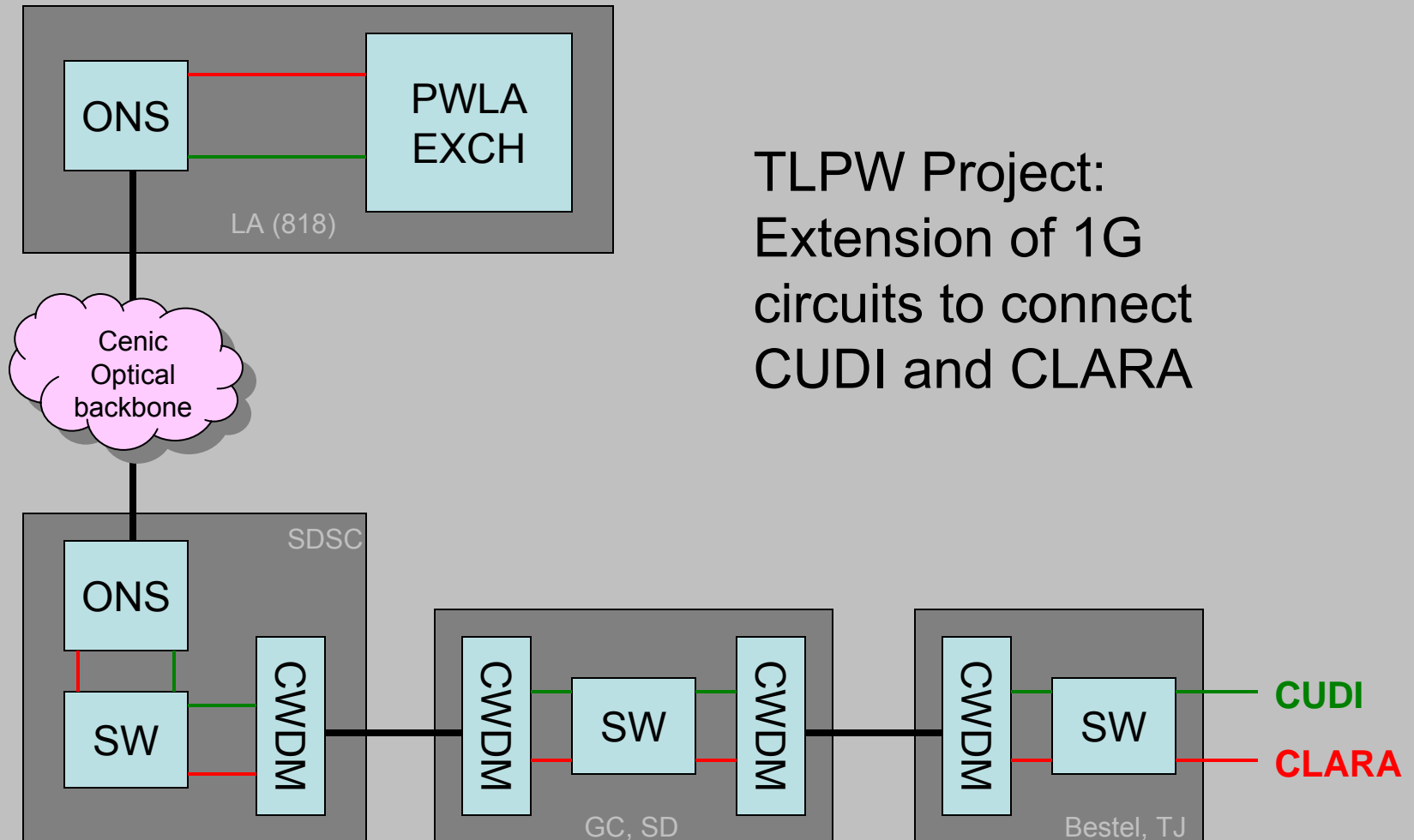
# Application Drivers – A Sampler

- e-VLBI and other astronomy projects (Gemini, Express, CSIRO)
- HPC development & deployment strategies
- Sensor networks, environmental monitoring
- ORION, Neptune & Station Aloha, BioMirror, Ocean Genomics, CREON, ...
- NEESGrid and seismic projects and programs
- Telehealth, telemedicine, disease monitoring and control (Centie, Stanford, ...)
- High definition video for HDTV, immersive videoconferencing, megaconferences, collaboratories & VO development

# PW-Activities (2005.03 – 2006.10)

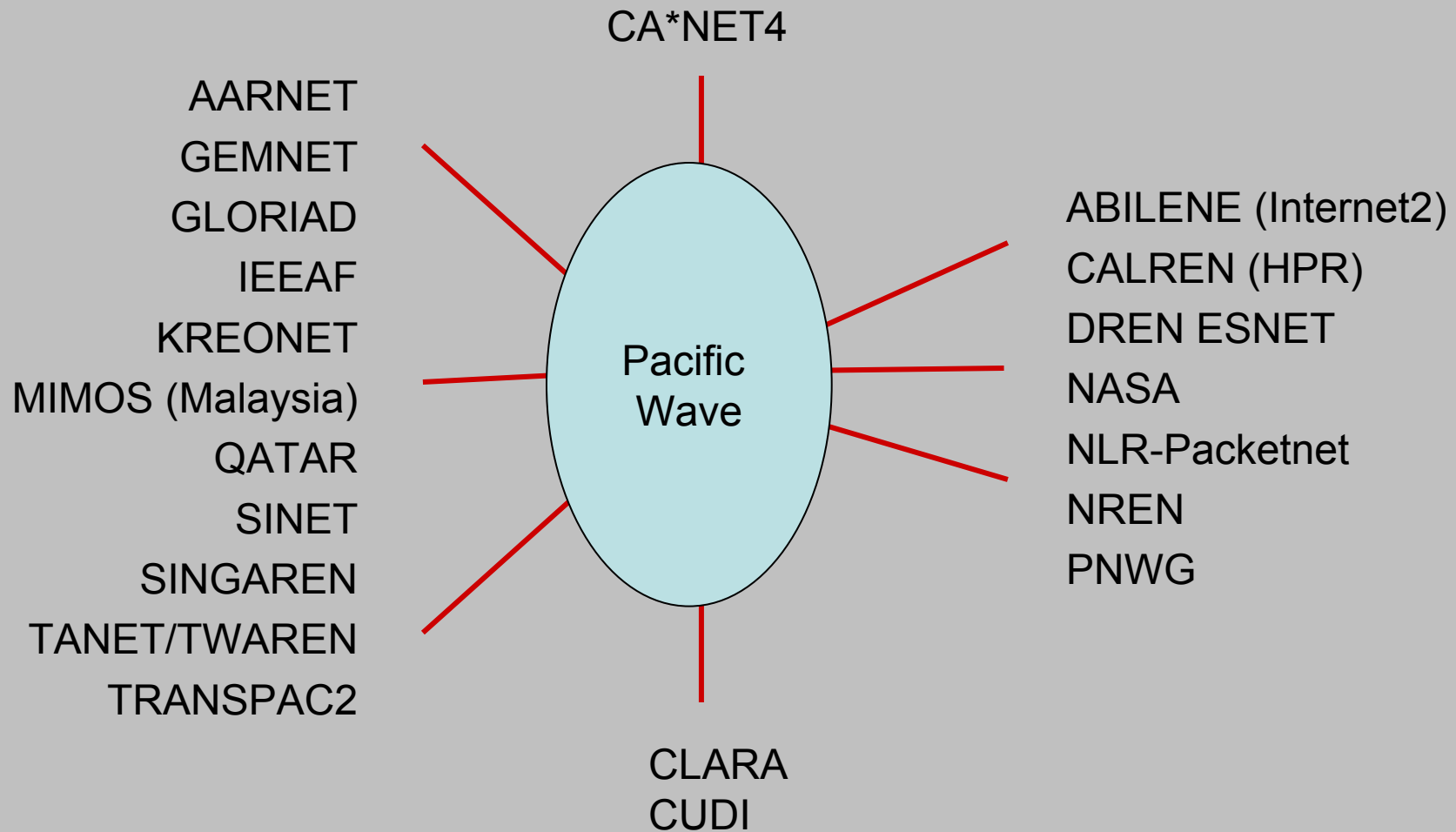
- 2005.04 - Transpac2 connected to PW-Los Angeles with 10GbE
- 2005.04 - Ultralight joins PW-Los Angeles at 10GbE
- 2005.05 - AARnet SX-North connected to PW-Seattle
- 2005.06 - Sunnyvale Exchange point site Operational
- 2005.09 - Cinegrid joins PW-Los Angeles at one GigE
- 2005.09 - Mimos Berhad joins PW-Los Angeles at one GigE.
- 2005.09 - ESNNet joins PW-Sunnyvale at 10GbE
- 2005.10 - Singaren adds a one GigE at PW-Los Angeles
- 2005.10 - NII/Sinet joins PW-Los Angeles with three GigE ports
- 2006.01 - TWAREN/TANET2 upgrades to 10GbE in PW-Los Angeles
- 2006.04 - Palo Alto Exchange point site Operational
- 2006.05 - KreoNet2/KOREN upgrades port to 10 gigabit at PW-Seattle
- 2006.06 - Translight/Pacific Wave and Translight/Starlight connect via 10GbE connection donated by Cisco
- 2006.08 - KAREN/REANNZ joins PW-Seattle at 1 GbE
- 2006.08 - NREN joins PW-Sunnyvale at 10GbE
- 2006.10 - CUDI joins PW-Los Angeles at 1 GbE
- 2006.10 - CLARA joins PW-Los Angeles at 1 GbE

# Extension to CUDI and CLARA

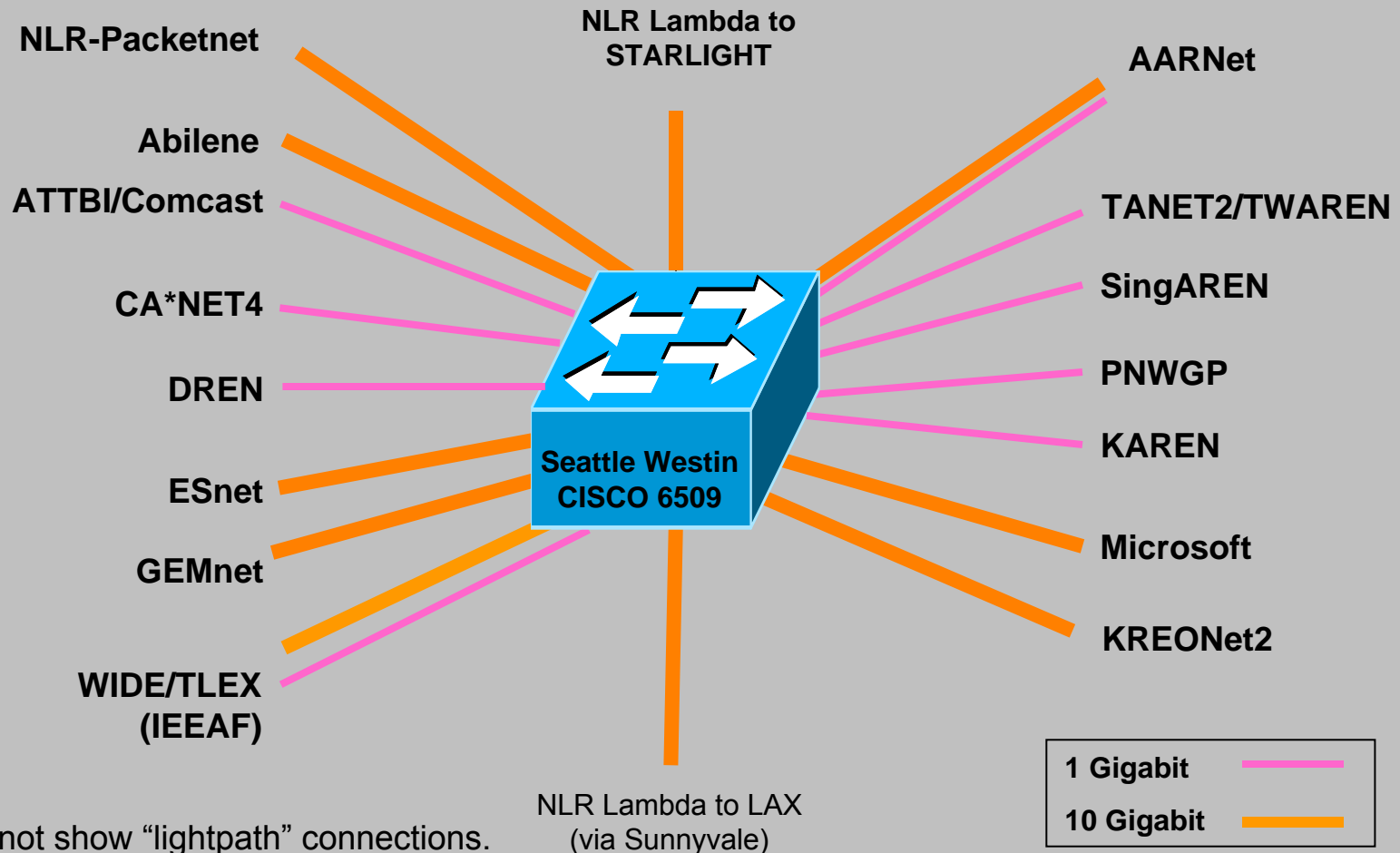


TLPW Project:  
Extension of 1G  
circuits to connect  
CUDI and CLARA

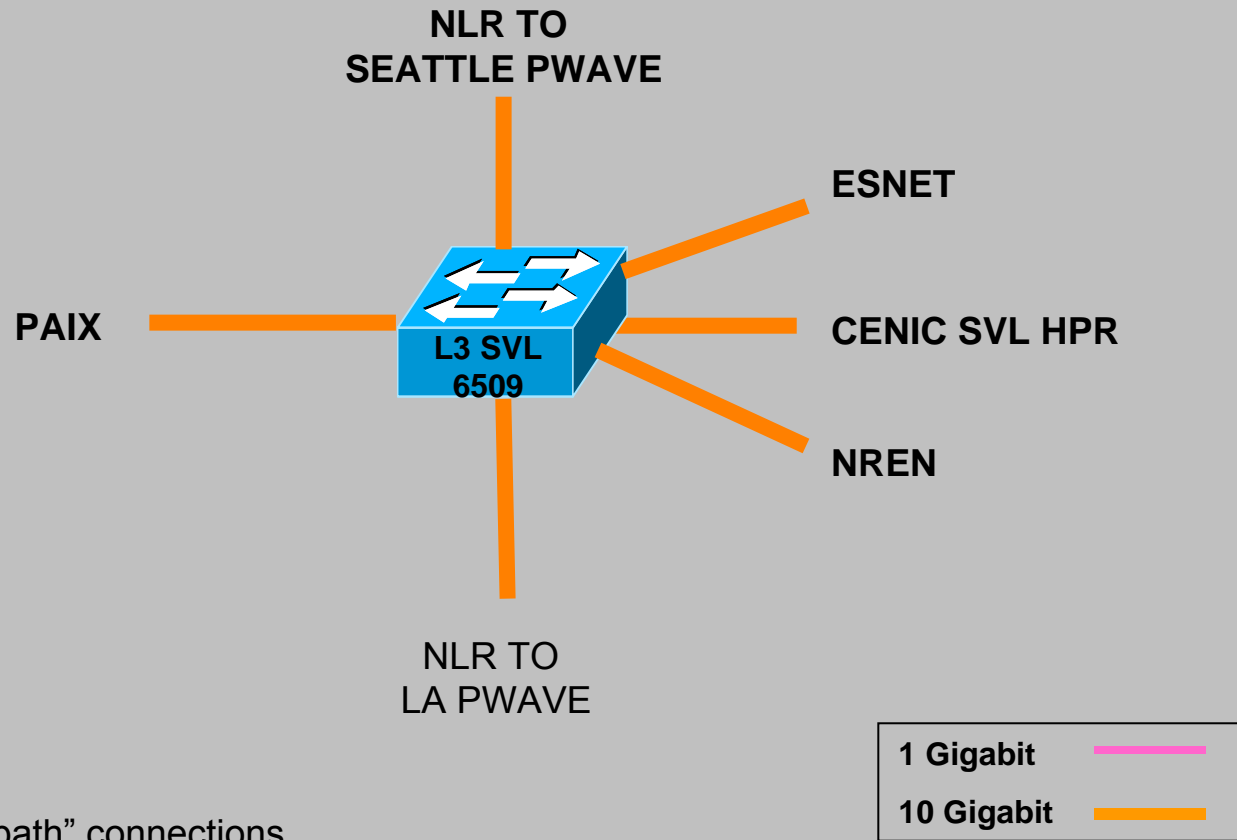
# “Layer 3” R&E Networks and Pacific Wave



# PacificWave Seattle

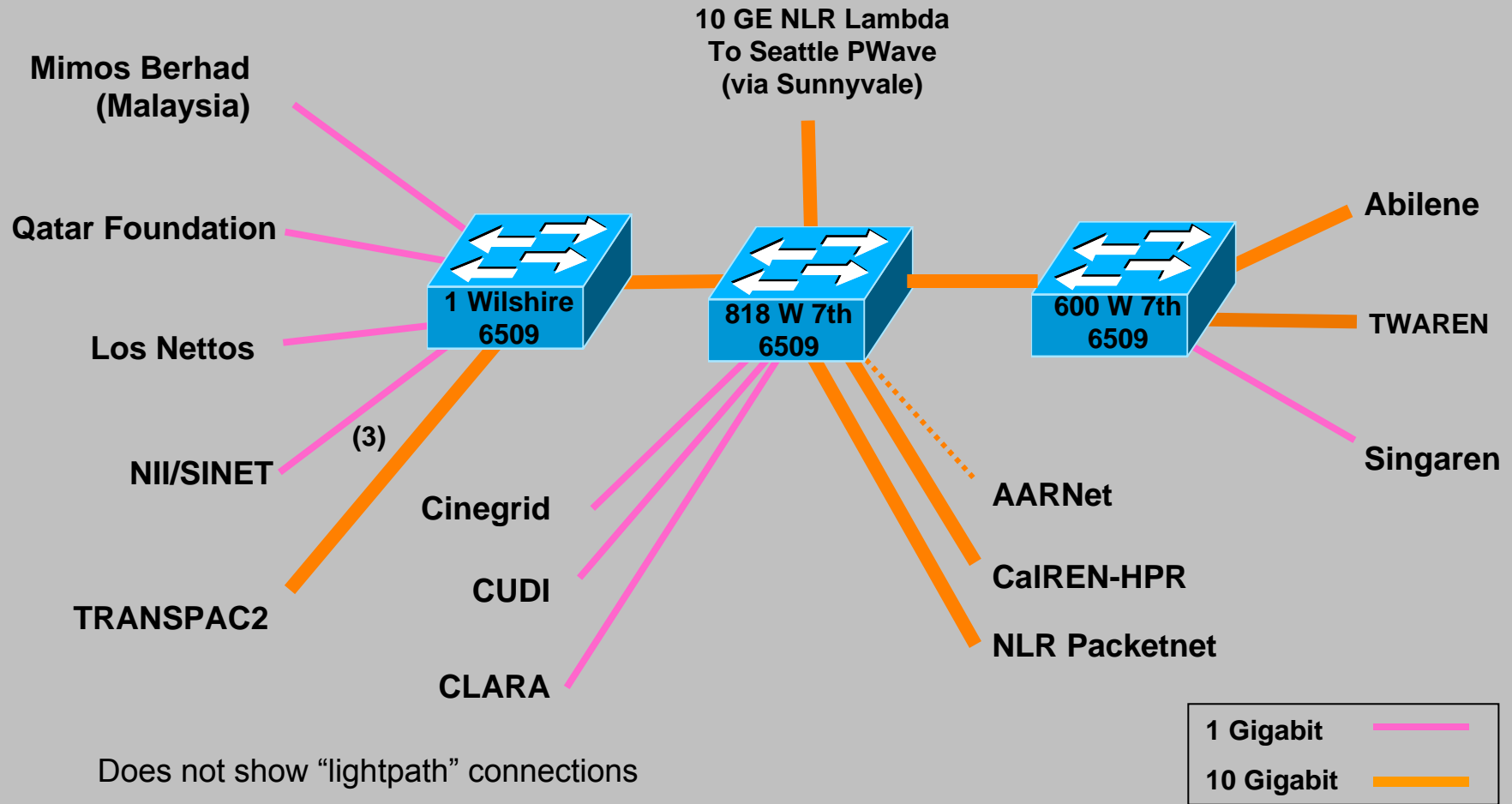


# Pacific Wave - Sunnyvale

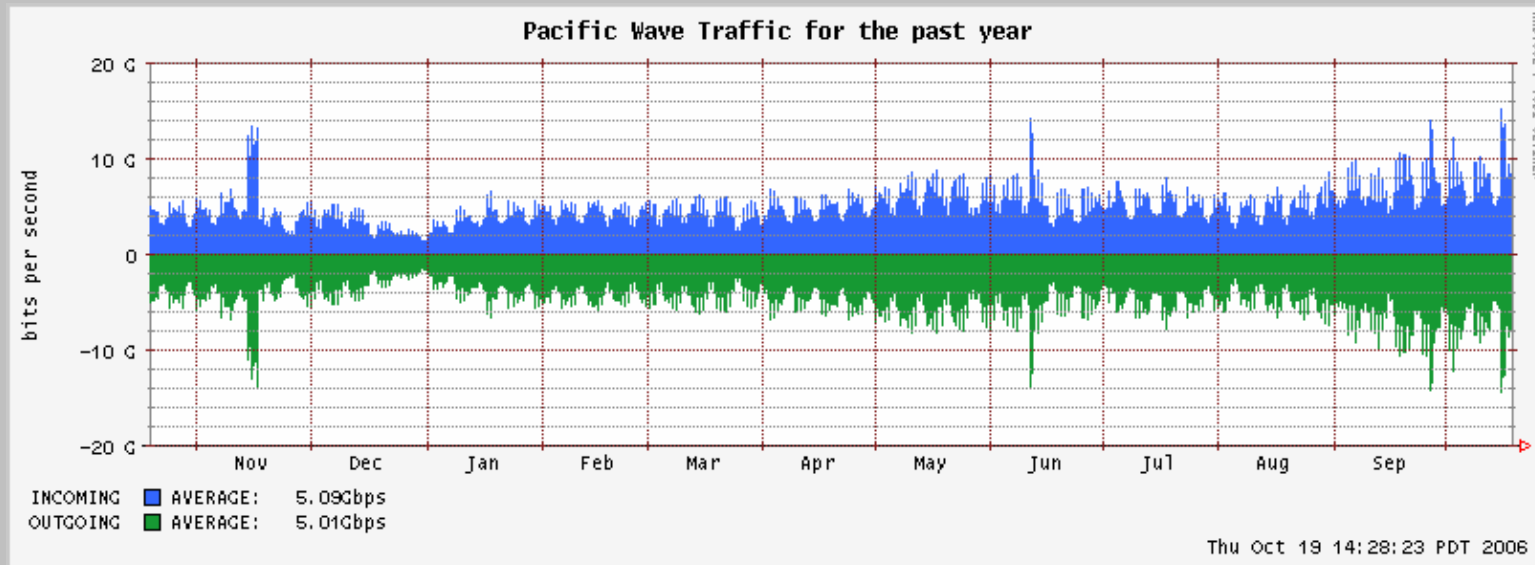


Does not show "lightpath" connections

# Pacific Wave - Los Angeles



# Overall PW Exchange Traffic



[Live link to current stat](#)

[Live link to pw stat page](#)

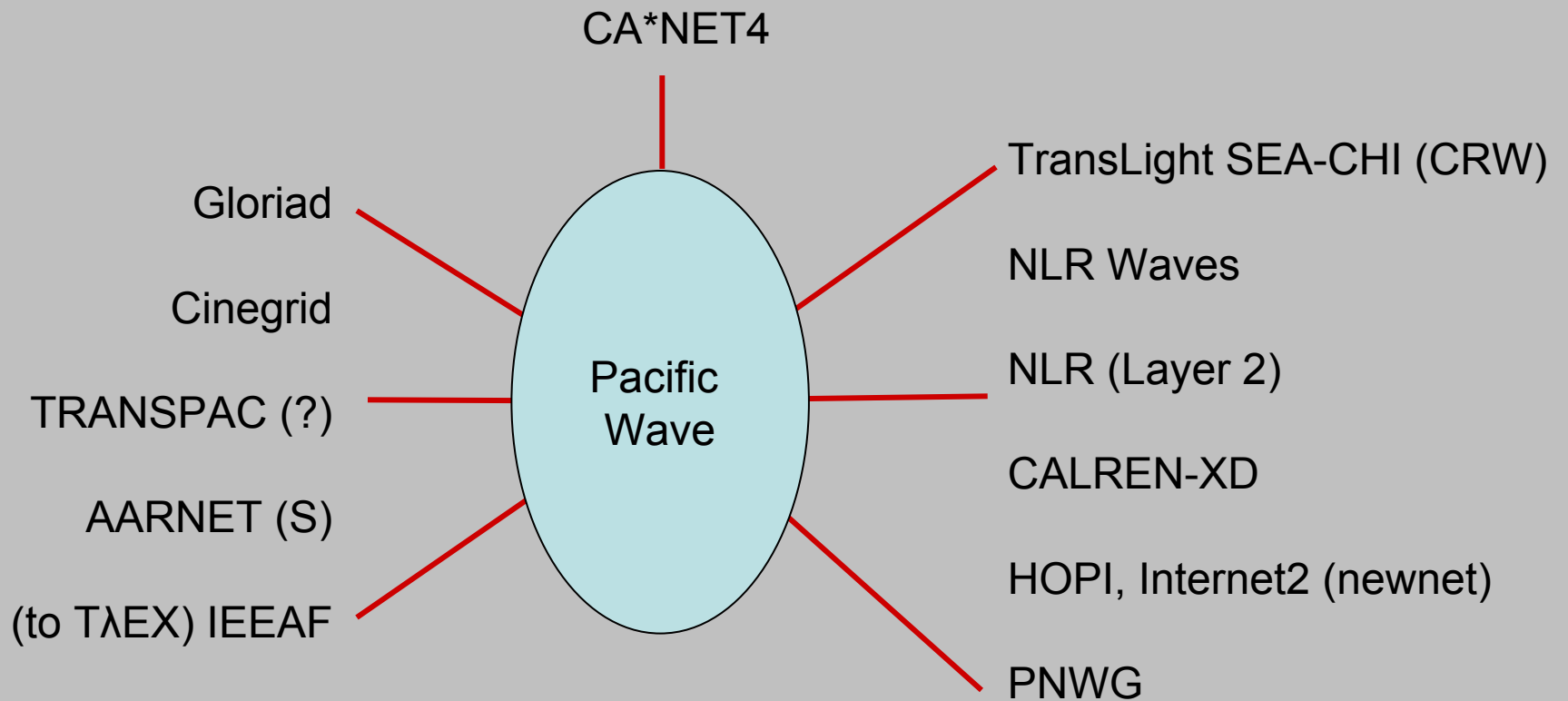
The data provided here is an aggregate of inbound and outbound IP packets on Participant ports.



# Pacific Wave Lightpath Interconnect

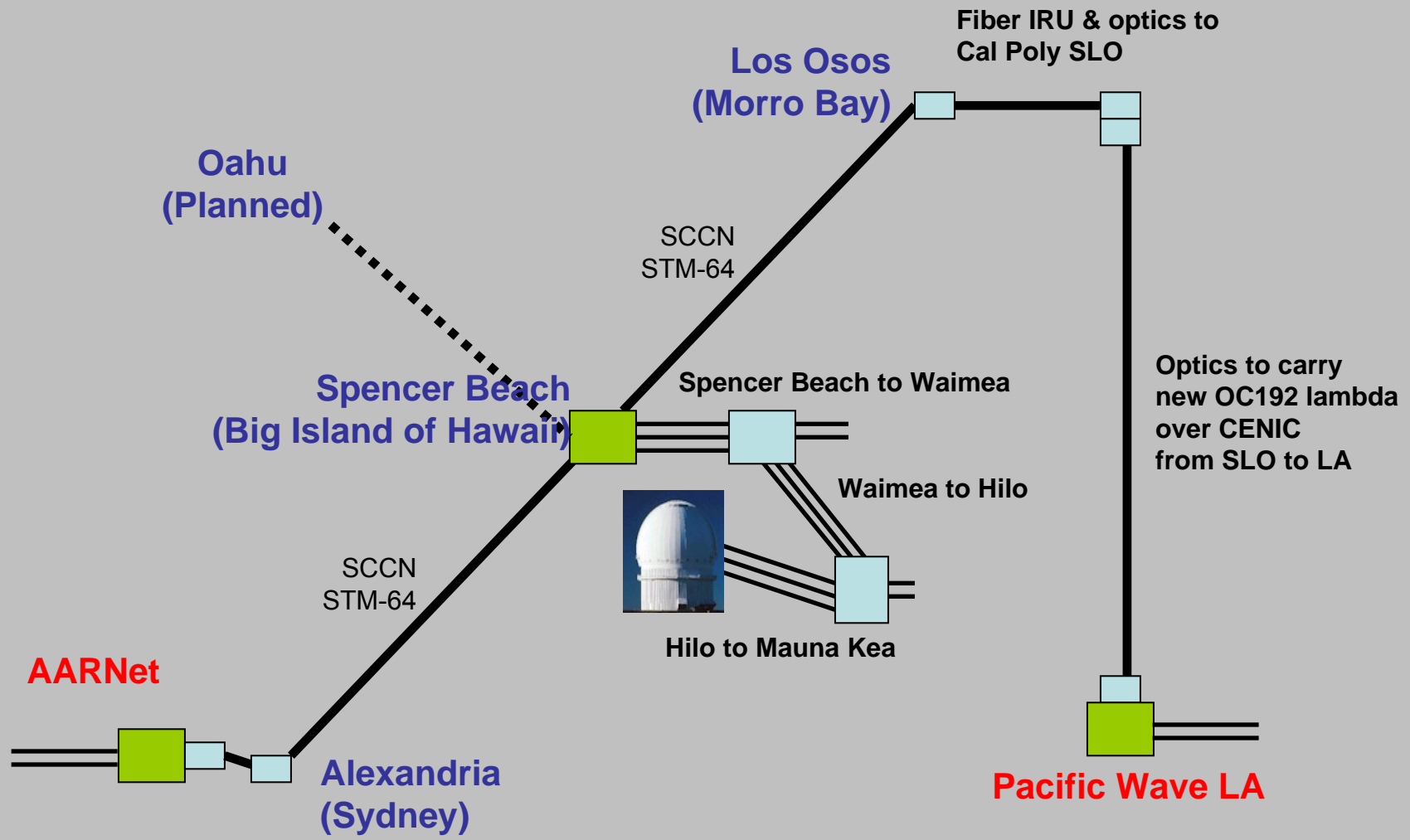
- Primary focus has been on Layer 3 interconnect
- There is a lot of interest in Layer 2 (“lightpaths”) and Layer 1 (“waves” and “lambdas”) interconnect. [GLIF, etc]
- SXTransport(S) is configured as 8x1GE
- PW has deployed additional OC192 from LA to SEA configured as 8x1GE to allow interconnect for AARNet and other nets as demand grows.
- Linking the Translight projects: 10G link from PW-Seattle to Starlight (Chicago) available (CRW) further enhancing layer 3 and lightpath interconnect capability

# Lightpath Networks and PW

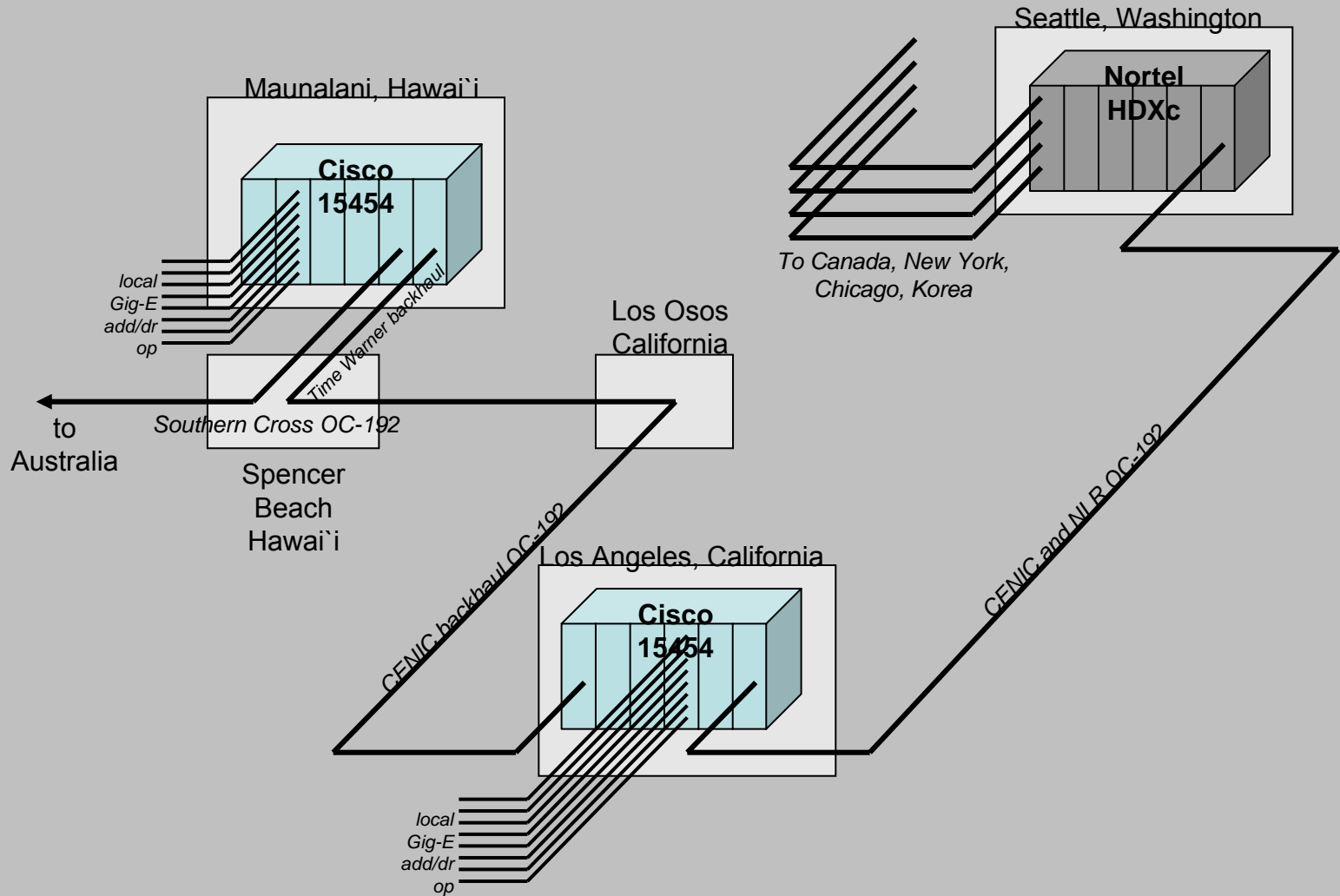


Others in the planning stages

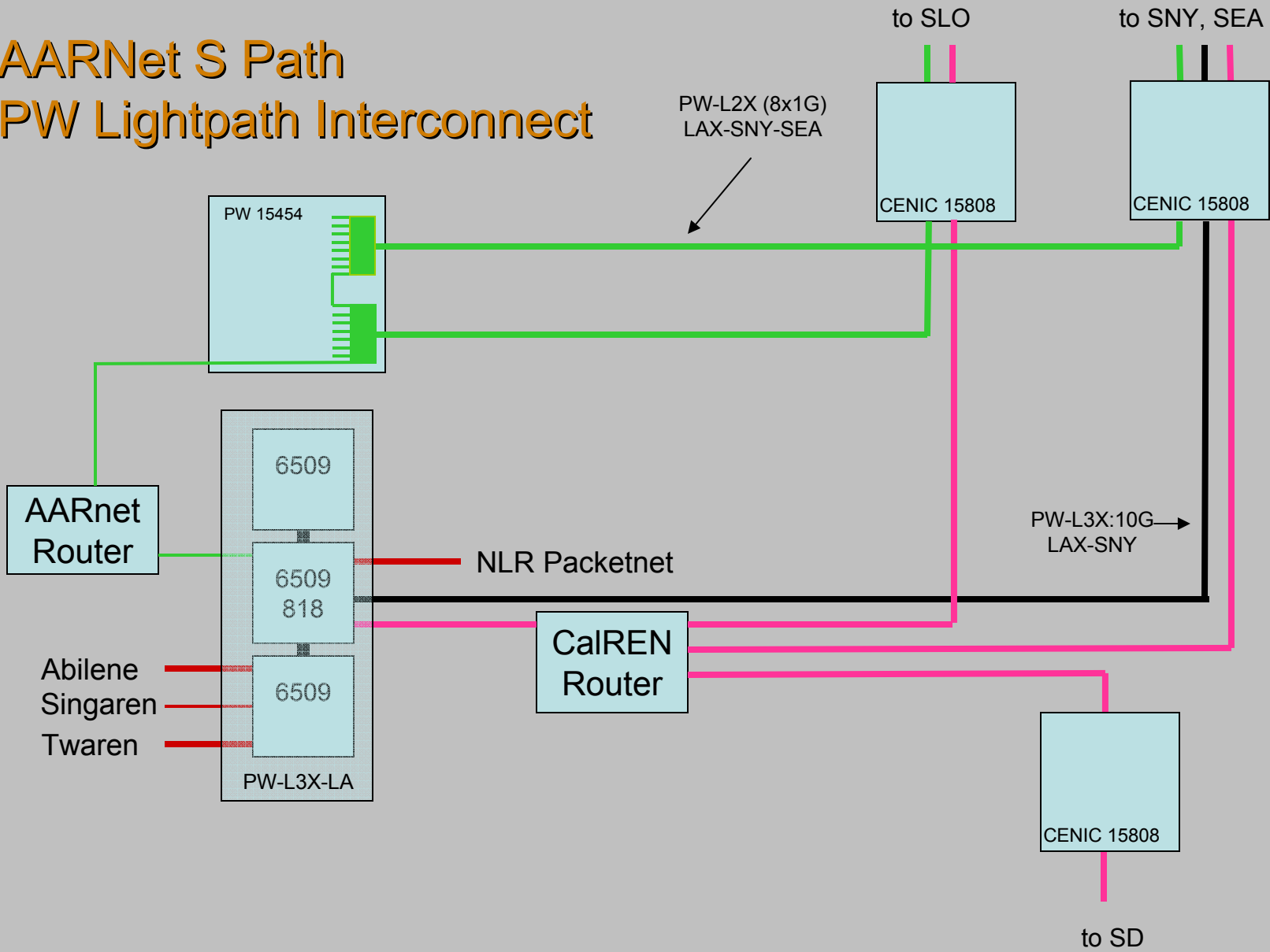
# AARNet SX-Transport (S)



# AARnet SX-Transport S. Link

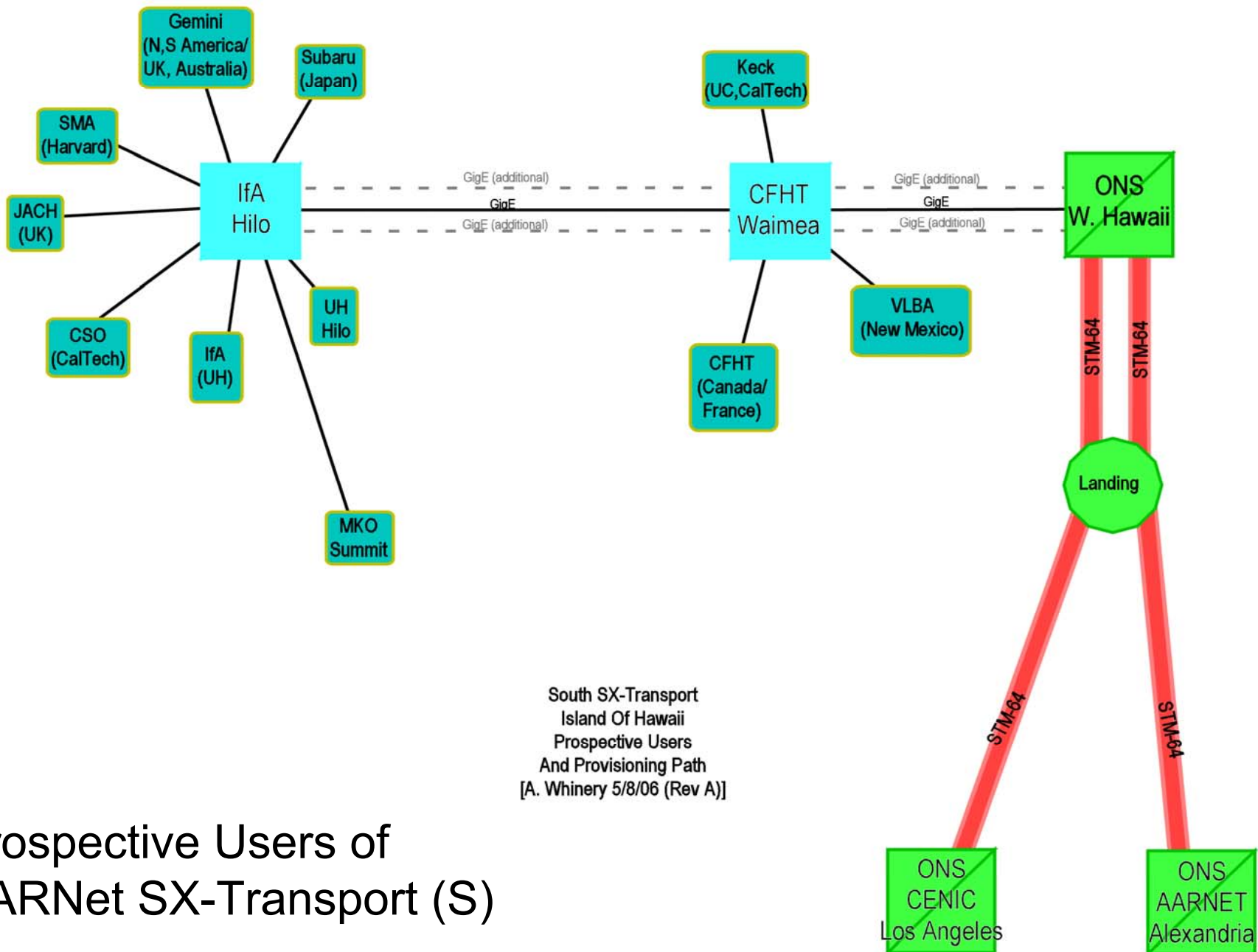


# AARNet S Path PW Lightpath Interconnect



# Operational Status

- Backhaul from Los Osos landing through SLO to LA has been implemented and tested
- End to end testing (light) from CA to AU
- Wave between LA and SEA tested including interoperability between CISCO 15454 and Nortel HDXc
- Pending for
  - Installation of equipment in Sydney (AARnet)
  - Final cross-connects in Hawaii



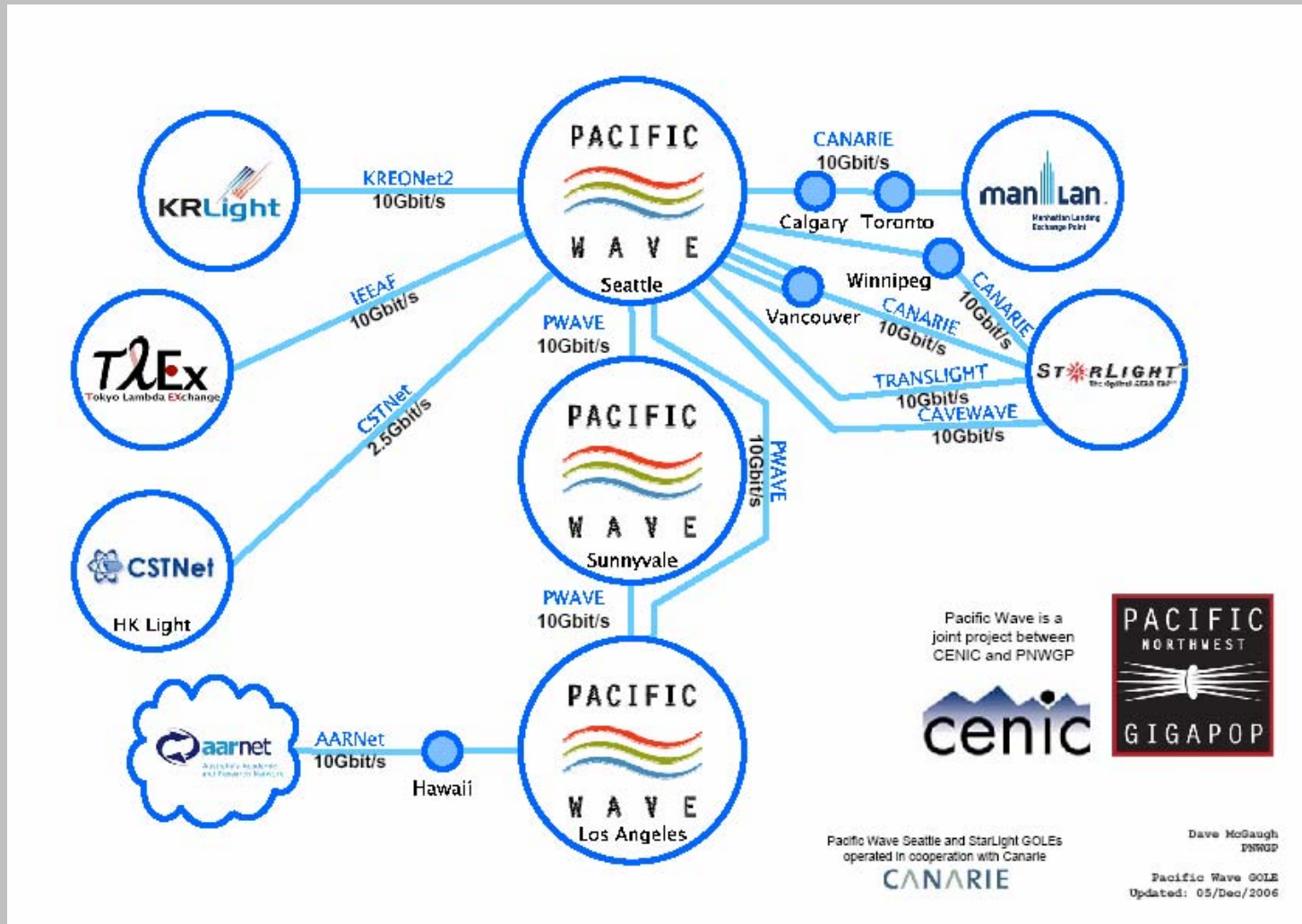
# Prospective Users of AARNet SX-Transport (S)

# Trends in High Speed R&E Networking

- Faster transport - 10Gbps is standard now with multiple links deployed on single and diverse fiber paths
- Not just layer 3 routed networks any more
- Assignable waves, mostly GbE for now
- Moving to 40Gbps transport & denser WDM on expensive links (soon)
- Global end-to-end performance: ~7 Gbps (IPV6 & V4)
- Greater international collaboration, but the importance of geography (and politics) hasn't disappeared yet
- Importance of (open) exchanges (GOLES)



# PacificWave GOLE Diagram



# PacificWave Plans

- As we see increasing demand for lightpath services, PW plans to automate its handling of these dedicated connections.
- Also, as the new Internet2 network is deployed, PacificWave needs to have automated hand-off to dynamic scheduling mechanisms are used.
- Continued participation in GLIF will require that certain technical standards are met.
- Additional capacity between PW PoP's will soon be necessary to handle the lightpath demands.
- Demand for 40G (and later 100G) services may also require upgrades in equipment. We can anticipate this in 2008.
- Explore partnerships with other International networks to help rationalize trans-pacific R&E networking.

Thank you

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