



The Evolution of Exchange Points

John Silvester

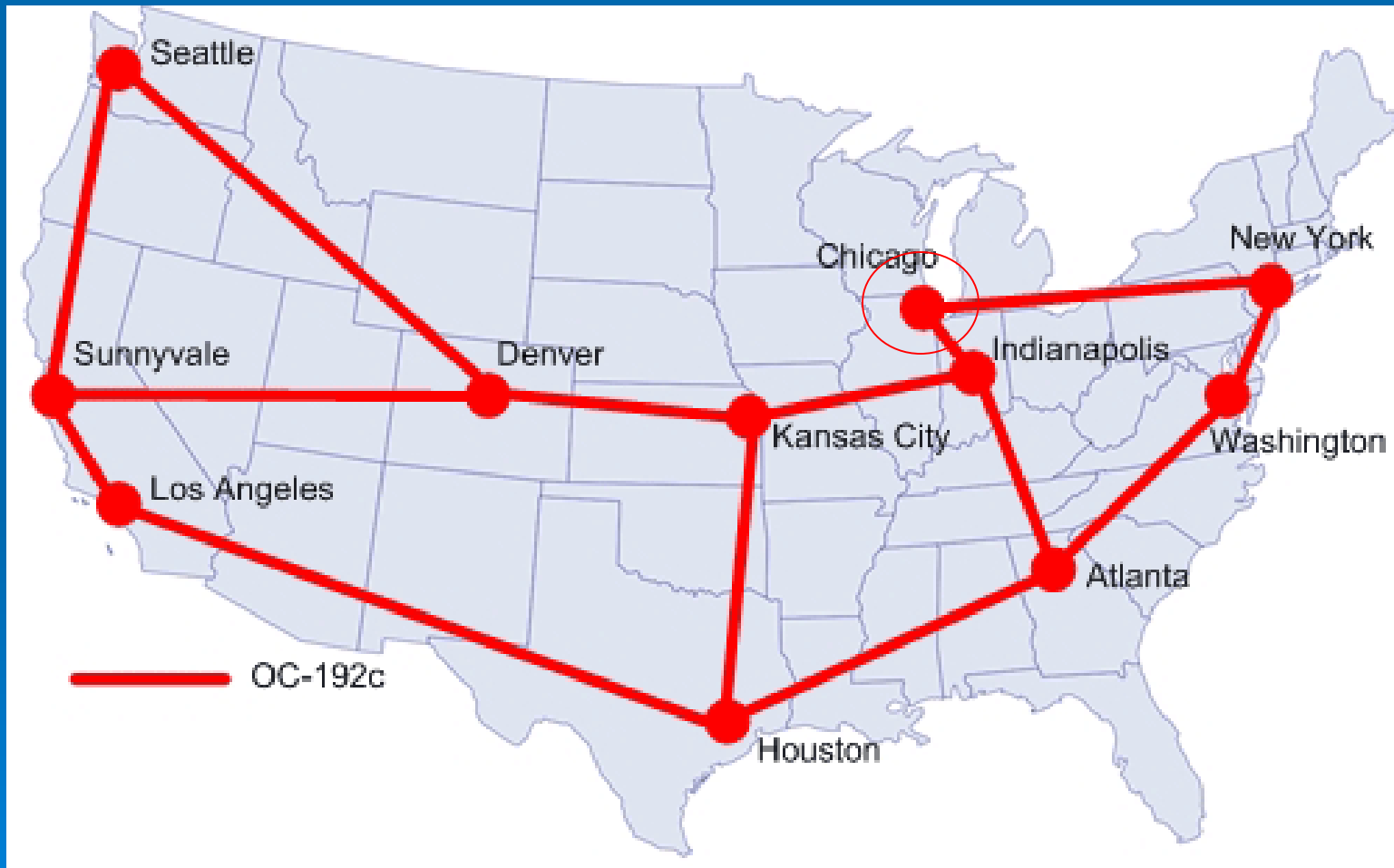
*Professor and Executive Director of the Center for
Scholarly Technology, USC
Chair, CENIC*

APAN21, January 24, 2006, Tokyo, Japan

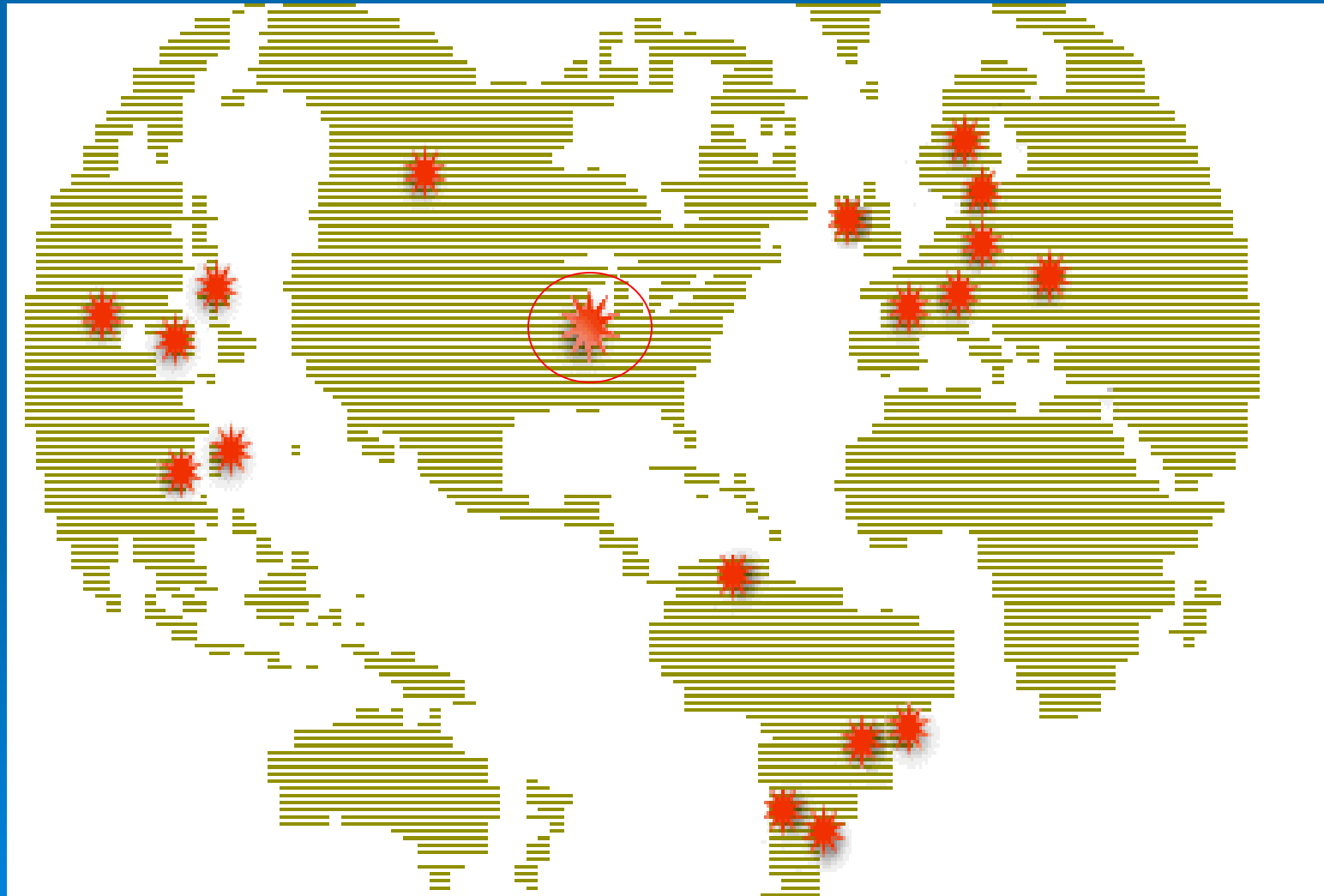
In the beginning ...

- Things were simple.
- There was vBNS and then Abilene (Internet2) and various International networks that wanted to connect to the US community and to each other
- This led to the develop of Startap – a single Exchange Point to allow exchange of layer three traffic in Chicago.

Internet2 (Abilene)



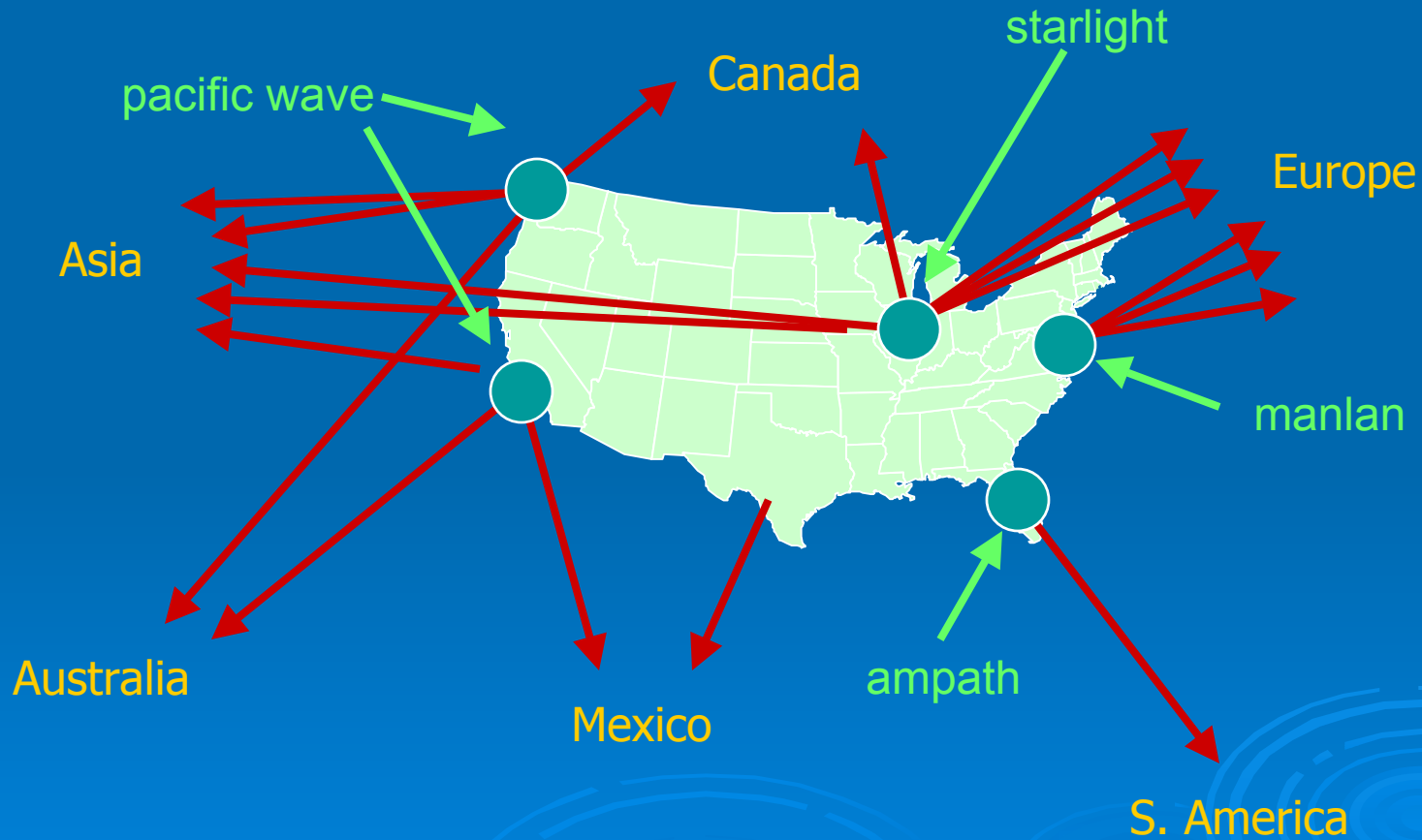
Startup



Proliferation of Exchanges

- There were lots of reasons to have other places to connect to in the US and so other exchange points were developed.

Main US R&E Exchange Points

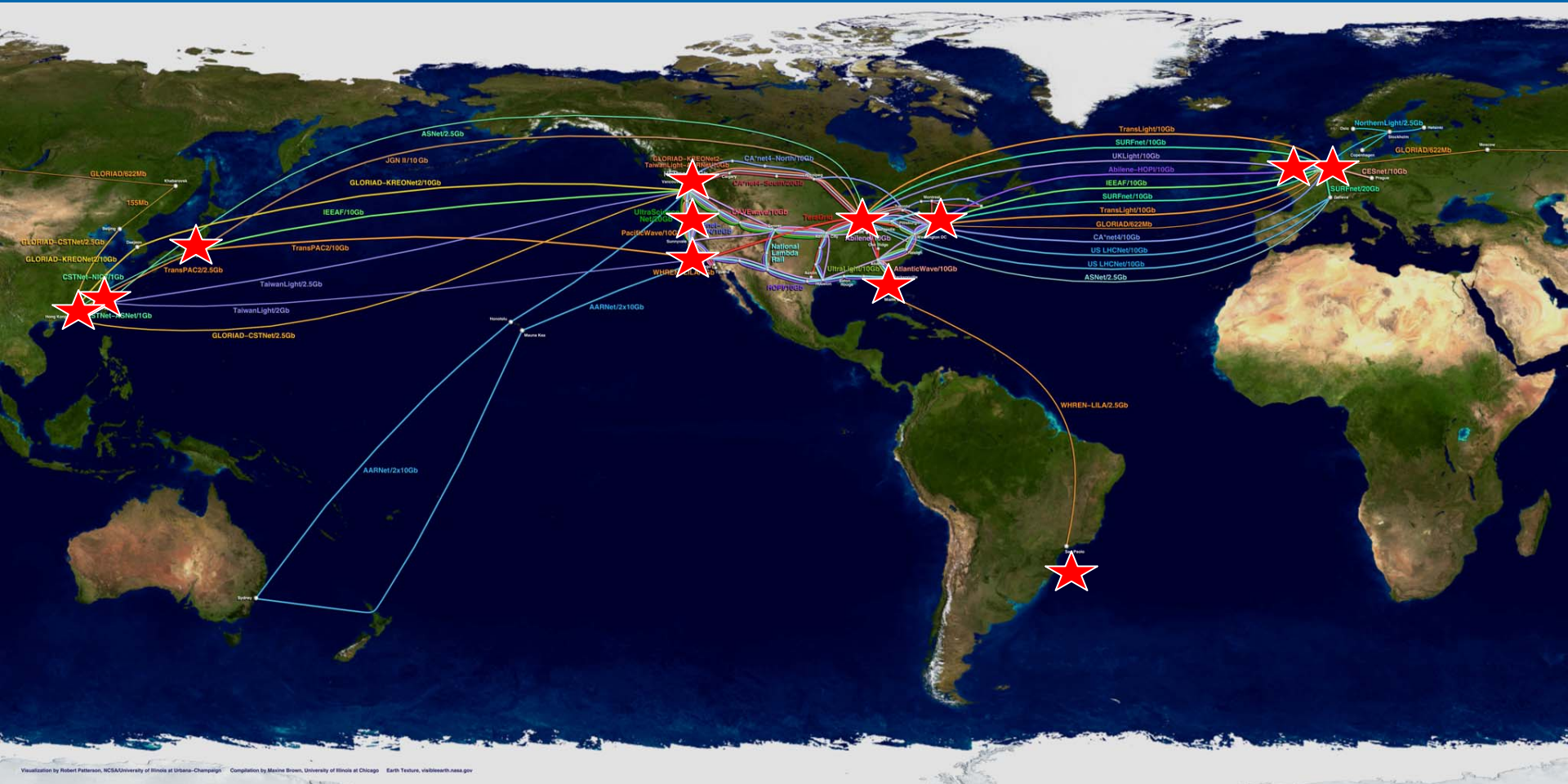


On the International Front

- Connectivity increased dramatically and regional collaborations strengthened leading to the development of exchange points around the world.



International Connectivity and Exchanges



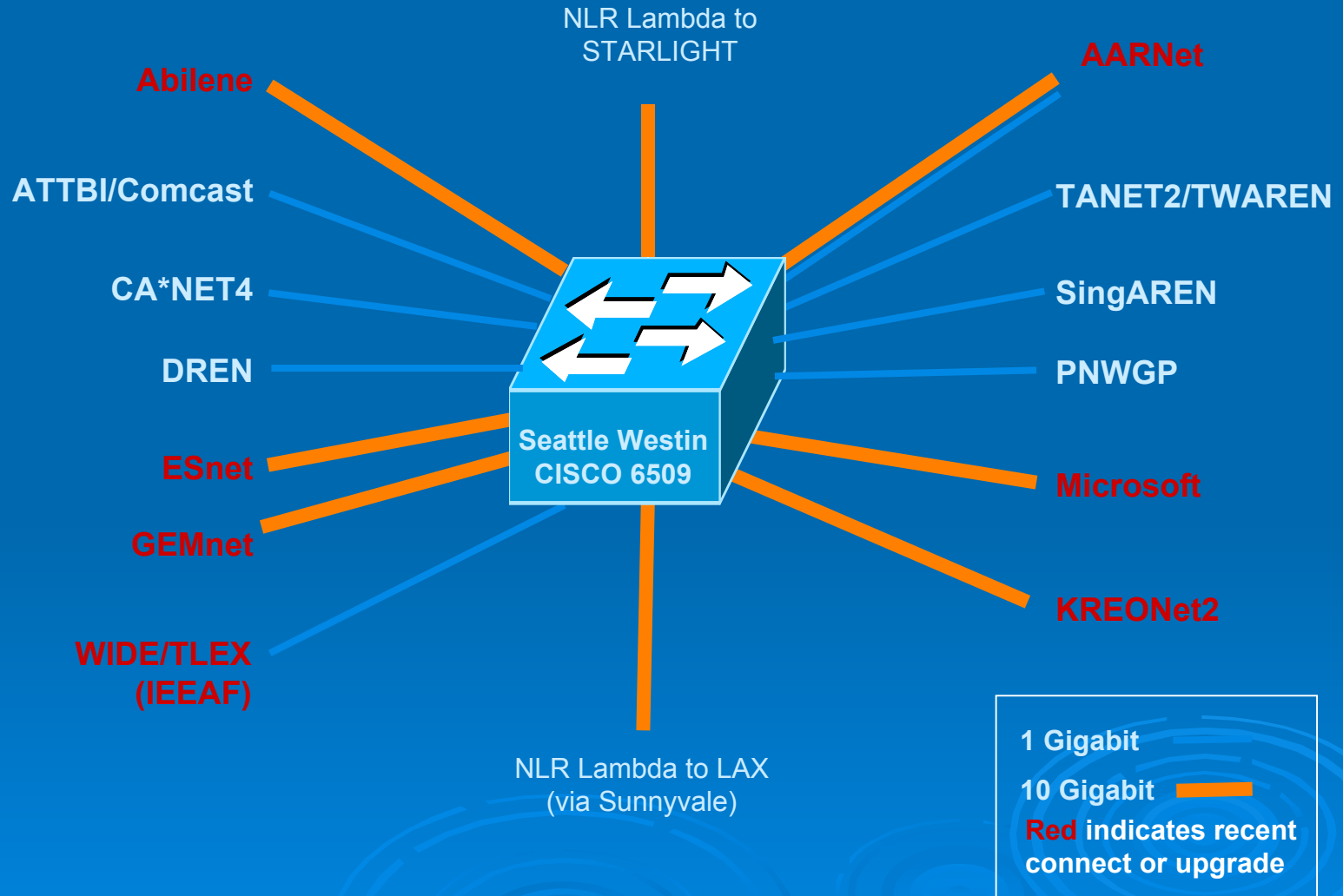
Visualization courtesy of Bob Patterson, NCSA.

www.glif.is

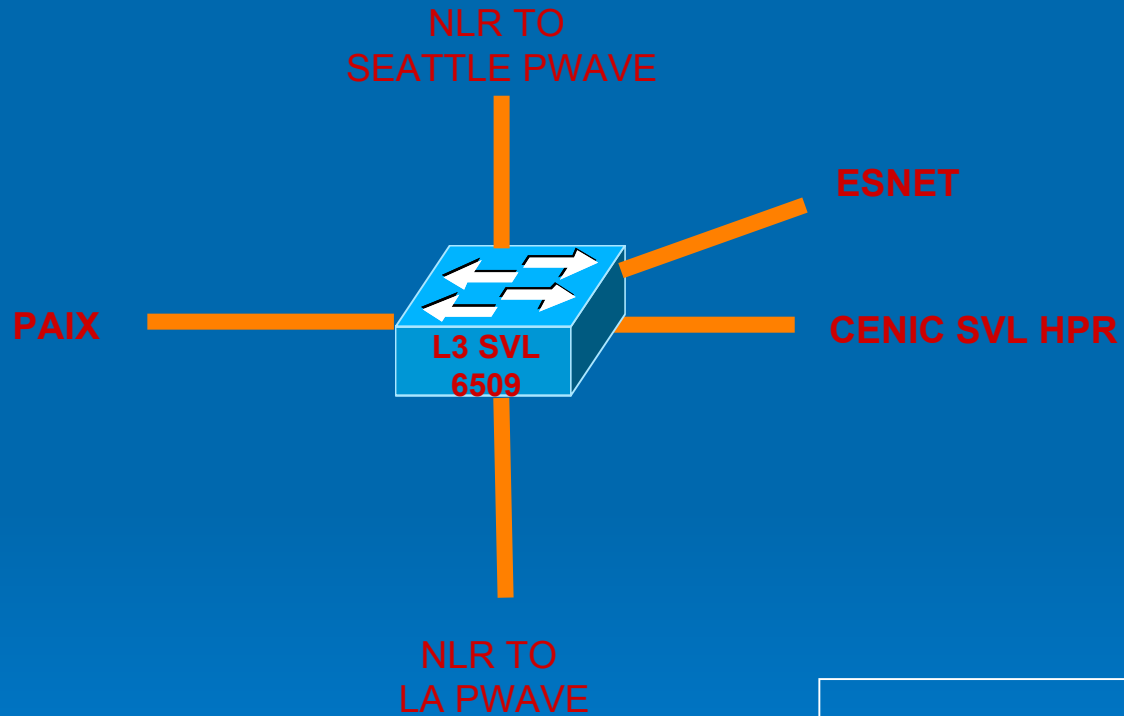
Pacific Wave

- With the US West Coast Exchange “merged” to form Pacific Wave – a “distributed exchange” allowing participants to peer with other networks at any of the exchange points (over an transparent layer 2 network)
- (similar plans for Atlantic Wave)

PacificWave Seattle



Pacific Wave - Sunnyvale

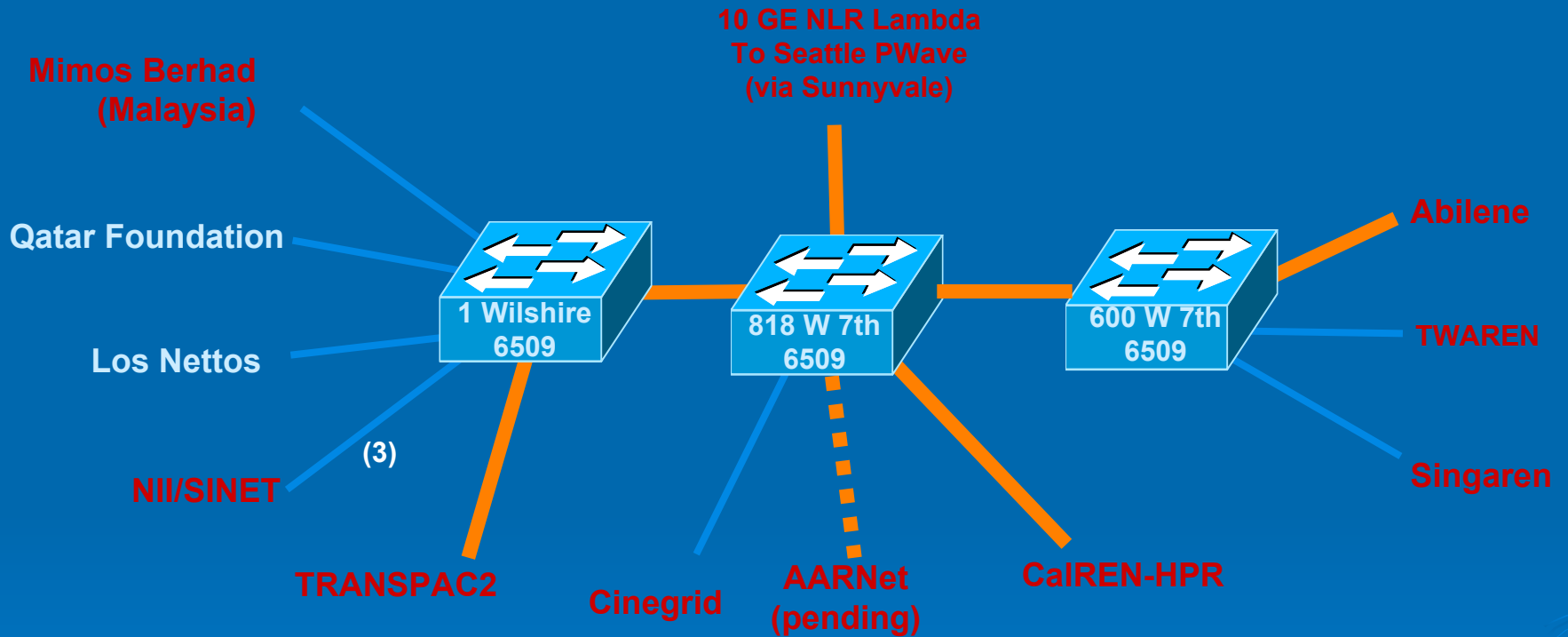


1 Gigabit

10 Gigabit

Red indicates recent connect or upgrade

Pacific Wave - Los Angeles



1 Gigabit
10 Gigabit
Red indicates recent connect or upgrade

Proliferation of Networks

- In addition to Internet2's Abilene there were other US networks of interest, mostly "agency networks": Energy, NASA, etc.
- And the development of regional networks such as CENIC's Calren and other state based networks

CENIC's Development

- Started in 1997 – Calren was the California Research and Education Network
- In 2001 acquired dark fiber to build out a multi-wavelength network in California with several network
 - CalrenDC – Digital California
 - CalrenHPR – High Performance Research
 - CalrenXD – Experimental Development

National LambdaRail (NLR)

- Extended the California Optical Network to a National US footprint
- Made it possible to build multiple networks on this owned infrastructure

National Connections - NLR



Regional Optical Networks (RON's)

- The NLR and Fiberco efforts led to the development of many Regional Networks (Florida LambdaRail, LEARN, ...)



Discipline and Project Specific Networks

- Goal of NLR was to allow groups to build their own networks and they did, Optiputer being a good example.
- Other networks took advantage of the NLR waves to build out their own networks.

Layer 3 Networks in the US

- So there is now a large number of Layer 3 networks in the US including two national footprint Higher Education Networks
 - Abilene (Internet2)
 - NLR (Experimental) Layer 3 Network
 - Many Agency specific networks like ESNet
 - Many project oriented networks like Teragrid
 - And multiple regional networks like CalREN
- => Increased Important of the Exchanges

Layer 1 and 2 Networks

- NLR also allowed development of networks at the link or Ethernet layer and Lambda or Lightpath layer.
- NLR National Layer 2 Network
- Most others (today) are project specific like Optiputer
- HOPI, GLIF are large-scale examples of future developments in this area
- And we can expect others to emerge

Changing Requirements for Exchanges

- The Exchange points need to provide a wider array of services:
 - Layer 3 Interconnect (routed)
 - Layer 3 Interconnect (over layer 2 switch)
 - Layer 2 Interconnect (Ethernet switching)
 - Layer 1 Interconnect (wave switching)
 - Layer 0 Interconnect (fiber interconnect)

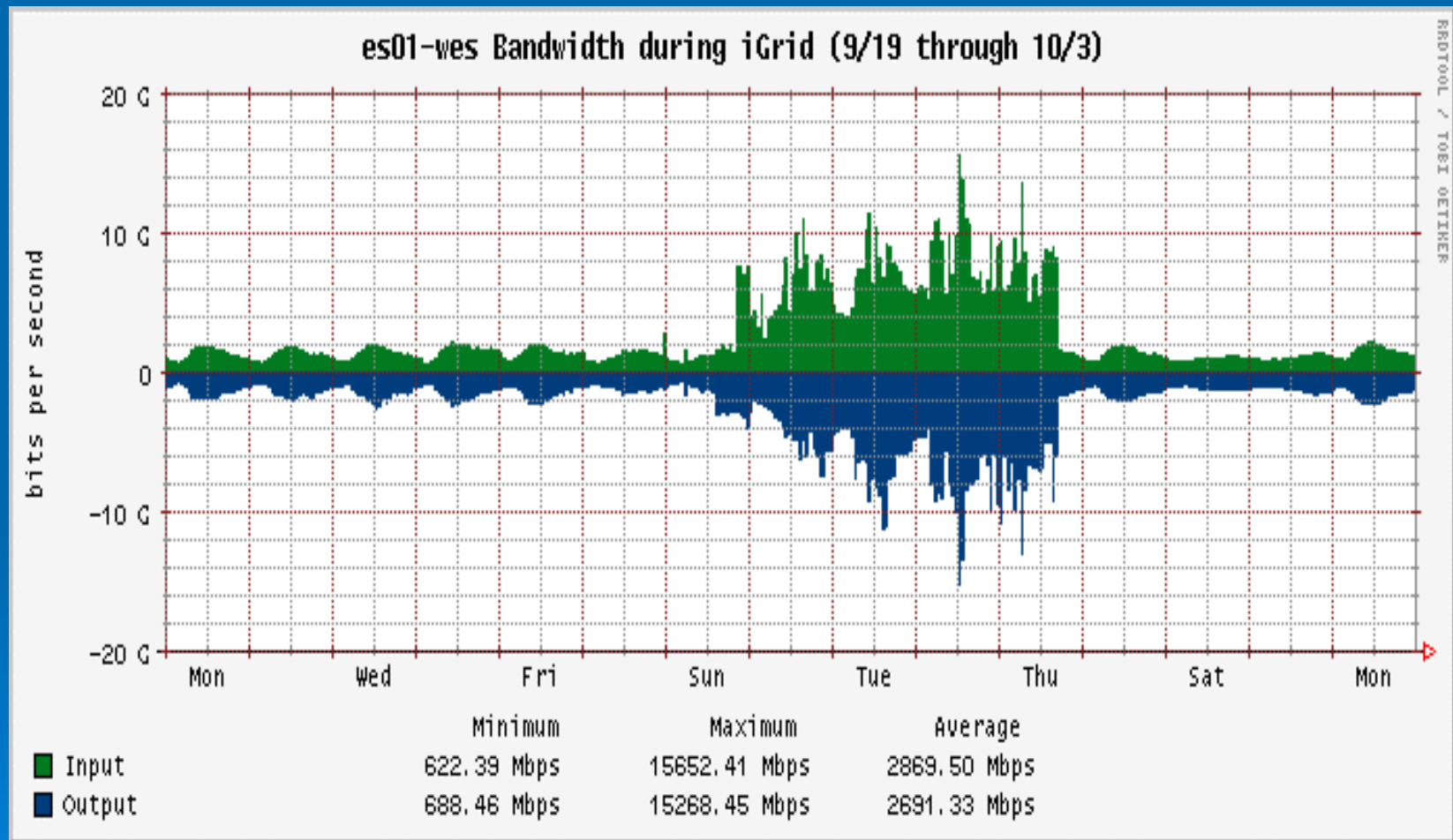
In process ...

- There is a lot of development of capability in the various exchanges worldwide.
- Efforts to standardize the approach through GLIF – GOLE
- There is an opportunity for more structured interactions between the existing exchanges to develop common approaches

Applications

- All of this is to enable more demanding applications to make effective use of the enhanced Global Connectivity we are all developing.
- We have seen remarkable demonstrations at iGRID'05 and SC'05 that would not have been possible without NLR, the massive increases in International Connectivity and the Exchanges - especially Pacific Wave 😊

Sample Traffic Measurement from iGRID



Thank
you!



Contact: silvester@usc.edu