National LambdaRail (NLR) – Packet, Wave, and Frame Services

John Silvester

Board Member (External Relations),
National LambdaRail
Professor of Electrical/Computer Engineering,
University of Southern California

National LambdaRail Mission

To advance the research, clinical and educational goals of members and other institutions by establishing and maintaining a nationwide advanced network infrastructure.

NLR - Background

- National LambdaRail is a non-profit corporation created (2003) by a consortium of major regional US R&E networks in conjunction with CISCO Systems and Internet2
- Identified the need for experimental and research oriented network(s)
- Research networking AND network research
- Motivated by CENIC CalREN dark fiber build-out in California, took advantage of dark fiber price trough (minimum?) to acquire national footprint 20yr IRU's
- Partnered with CISCO to deploy 40 lambda DWDM network
- Provides a range of services and networks to its members over this infrastructure
- Parallel effort by regional networks (RONS) has developed similar capability for regional connectivity and distribution (e.g. CENIC, LEARN, FLR, …)

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Motivation for Owned and Operated Fiber

- Future-proof against technology advances
- Isolate R&E networks from carrier pressures and restrictions
- Control of the AUP
- Allow maximum flexibility to configure networks and services
- Develop optical networking and engineering skills in R&E community
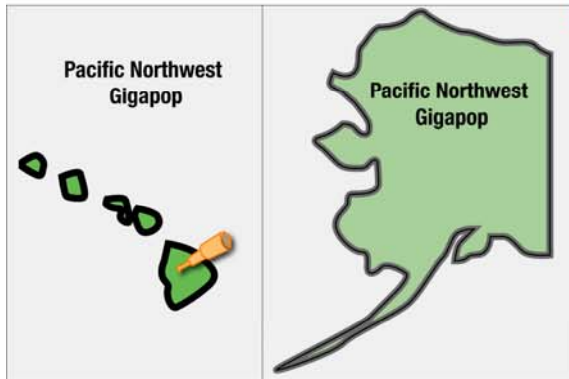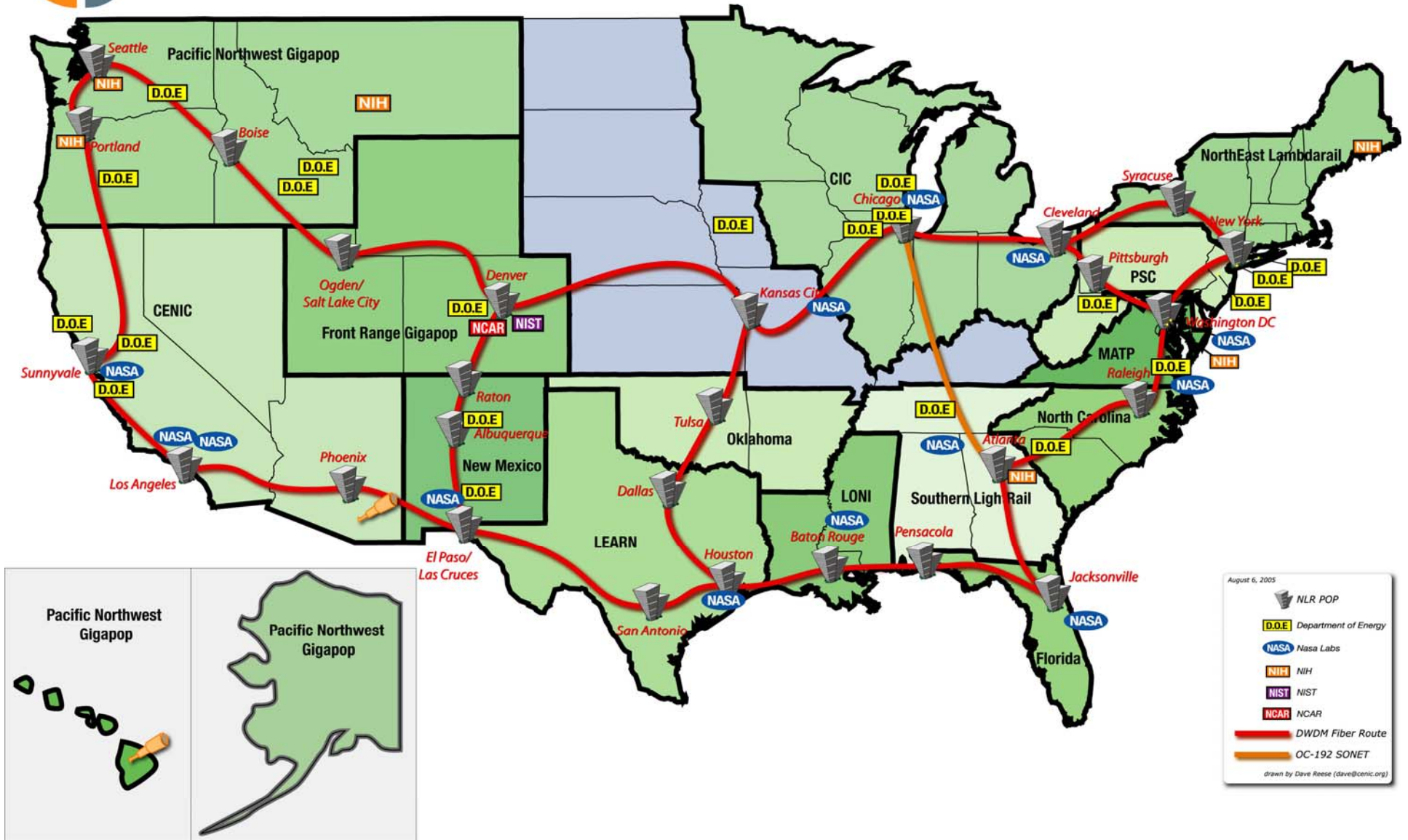- Allow for experimentation at all levels down to the glass

National LambdaRail Members and Associates

- CENIC
- Pacific Northwest Gigapop
- Pittsburgh Supercomputing Center/University of Pittsburgh
- Duke University, representing a coalition of NC universities
- Mid-Atlantic Terascale Partnership
- Cisco Systems
- Internet2
- Florida LambdaRail
- Georgia Institute of Technology

- Committee on Institutional Cooperation (CIC)
- Cornell University
- Louisiana Board of Regents
- Oklahoma State Board of Regents
- Lonestar Education and Research Network (LEARN)
- University of New Mexico (on behalf of the State of New Mexico)
- UCAR/FRGP
- SURA
- Oak Ridge National Lab (ORNL)
- Case Western Reserve University

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National LambdaRail Architecture

NLR — light the future

Pacific Northwest Gigapop

Seattle — NIH — D.O.E
NIH — Portland — D.O.E
Boise — D.O.E — D.O.E
NIH
Ogden/Salt Lake City — Front Range Gigapop
CENIC
D.O.E — Sunnyvale — NASA — D.O.E
D.O.E — Los Angeles — NASA — NASA
Phoenix
Denver — D.O.E — NCAR — NIST
Raton — D.O.E — Albuquerque
New Mexico — NASA — D.O.E
El Paso/Las Cruces
LEARN
San Antonio — NASA
Houston
Dallas — Tulsa
Oklahoma
Kansas City — NASA
CIC — D.O.E — Chicago — NASA — D.O.E
D.O.E — NASA — D.O.E
LONI
Baton Rouge — NASA
Pensacola
Southern Light Rail — NASA — Atlanta — NIH
D.O.E
Jacksonville
Florida — NASA
North Carolina — D.O.E
Raleigh — NASA
MATP
Cleveland — Pittsburgh — PSC — D.O.E
NASA — NIH
Syracuse — New York
NorthEast Lambdarail — NIH
D.O.E — D.O.E
Washington DC — NASA — NIH

Pacific Northwest Gigapop

Pacific Northwest Gigapop

August 6, 2005

NLR POP
D.O.E — Department of Energy
NASA — Nasa Labs
NIH — NIH
NIST — NIST
NCAR — NCAR
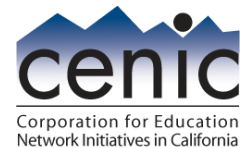DWDM Fiber Route
OC-192 SONET

drawn by Dave Reese (dave@cenic.org)

Regional Optical Networks - RONs

- California (CALREN)
- PNWGP
- Colorado/Utah (FRGP)
- Illinois (I-WIRE)
- Michigan (MLR)
- Indiana (I-LIGHT)
- New York (NYSERnet)
- Maryland, D.C. & Virginia (MAX/MATP)

- N. Carolina (NCREN)
- Georgia (Southern Light Rail)
- Florida (Florida LambdaRail)
- Louisiana (LONI)
- Texas (LEARN)
- Oklahoma (OneNet)
- Ohio (TFN)

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Courtesy of Steve Corbato

CalREN Optical Backbone
Serving California's Research and Education Community

CALIFORNIA

Corning
702 South 2nd Ave
Corning, CA 96021

Sacramento
1107 9th St
Sacramento, CA 95814

Oakland
5000 Hollis St
Emeryville, CA 94608

San Francisco
200 Paul Ave
San Francisco, CA 94124

Fergus
2236 N Franklin Rd
Merced, CA 95348

Sunnyvale
1380 Kifer Rd
Sunnyvale, CA 94086

Fresno
305 W Napa Ave
Fresno, CA 93706

Soledad
500 A Front St
Soledad, CA 93960

Bakersfield
7731 Dimiller Dr
Bakersfield, CA 93307

San Luis Obispo
Cal Poly University
San Luis Obispo, CA 93407

Riverside
900 University Ave
Riverside, CA 92521

Los Angeles
818 W 7th St
Los Angeles, CA 90017

Tustin
14452 Franklin Ave
Tustin, CA 92614

San Diego
9500 Gilman Dr
La Jolla, CA 92093
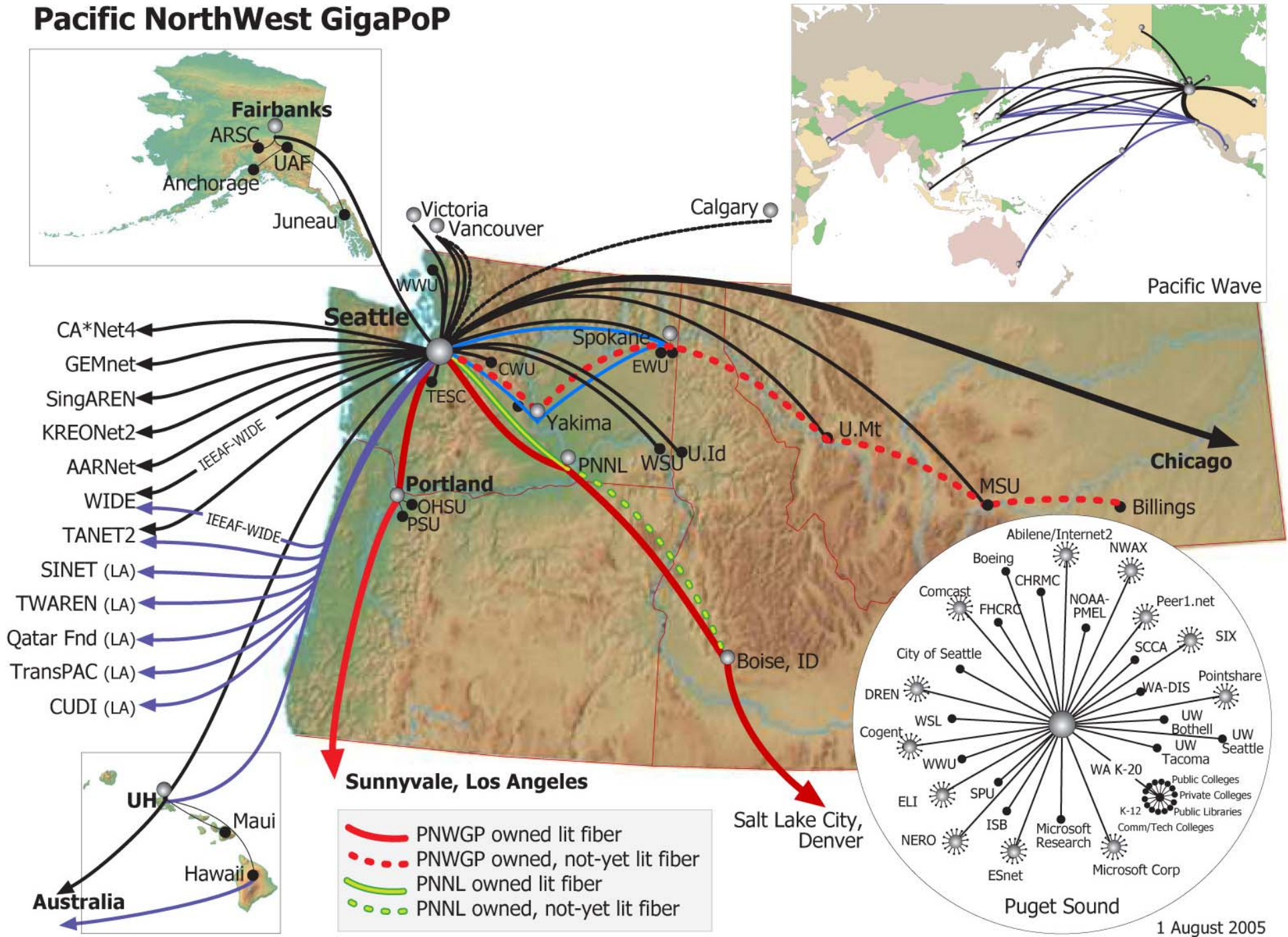
CalREN Backbone Facility

Optical Amplifier Facility

to Arizona

Leading the Way to Tomorrow's Internet

Dave Reese (dave@cenic.org) July 27, 2005

Pacific NorthWest GigaPoP

Fairbanks
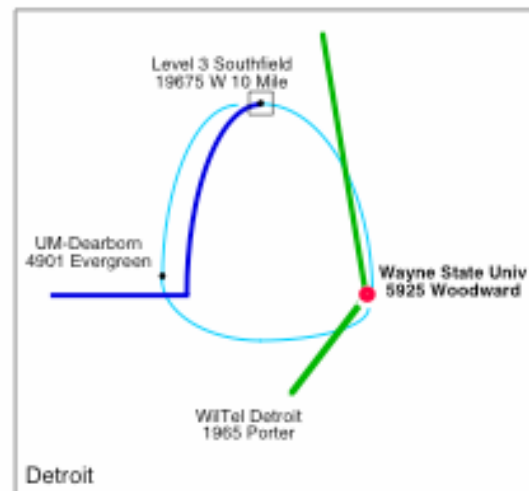ARSC
UAF
Anchorage
Juneau

Victoria
Vancouver
Calgary

Pacific Wave

WWU

CA*Net4
GEMnet
SingAREN
KREONet2
AARNet
WIDE
TANET2
SINET (LA)
TWAREN (LA)
Qatar Fnd (LA)
TransPAC (LA)
CUDI (LA)

IEEAF-WIDE

IEEAF-WIDE

Seattle

Spokane
CWU
EWU
TESC
Yakima
WSU U.Id
PNNL
U.Mt

Chicago

MSU
Billings

Portland
OHSU
PSU

Boise, ID

Sunnyvale, Los Angeles

UH
Maui
Hawaii

Australia

Salt Lake City, Denver

	PNWGP owned lit fiber
	PNWGP owned, not-yet lit fiber
	PNNL owned lit fiber
	PNNL owned, not-yet lit fiber

Puget Sound

Abilene/Internet2
Boeing
CHRMC
NWAX
Comcast
FHCRC
NOAA-PMEL
Peer1.net
City of Seattle
SCCA
SIX
DREN
WA-DIS
Pointshare
WSL
UW Bothell
Cogent
UW Seattle
UW Tacoma
WWU
WA K-20
ELI
SPU
Public Colleges
Private Colleges
K-12
Public Libraries
Comm/Tech Colleges
NERO
ISB
Microsoft Research
Microsoft Corp
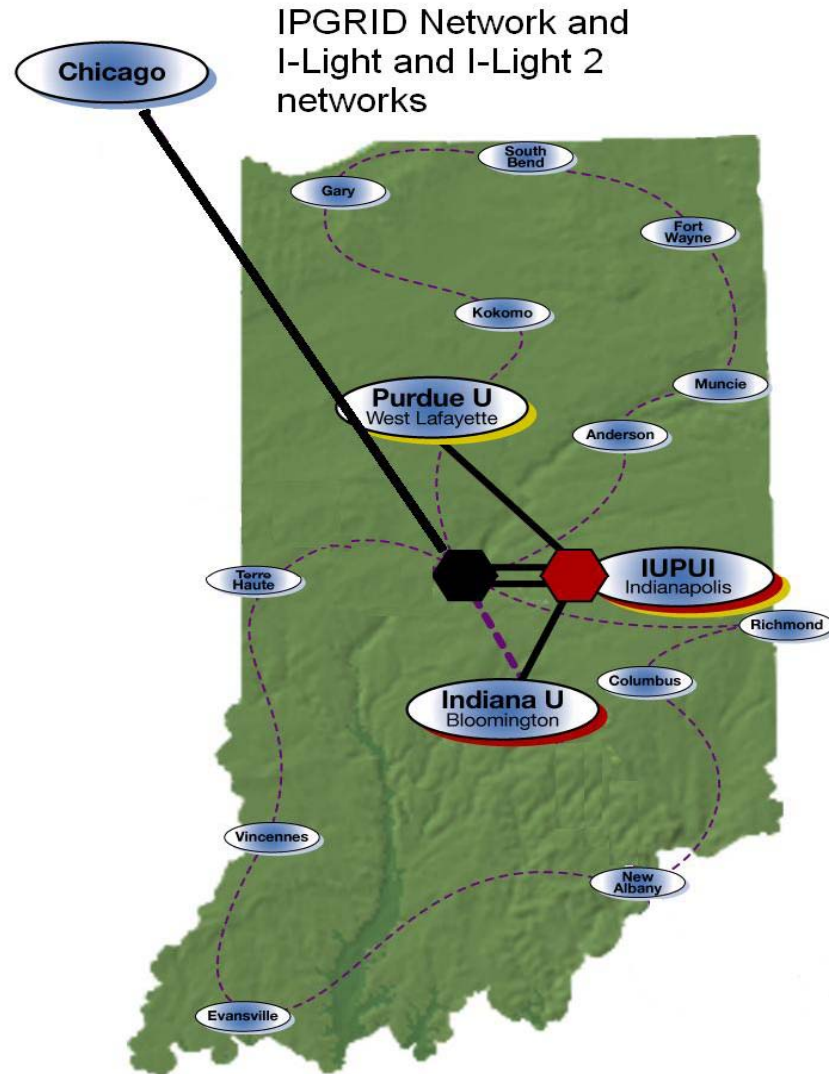ESnet

1 August 2005

Michigan LambdaRail (MiLR)

Legend:
- Level 3 Intercity fiber
- WilTel Intercity fiber
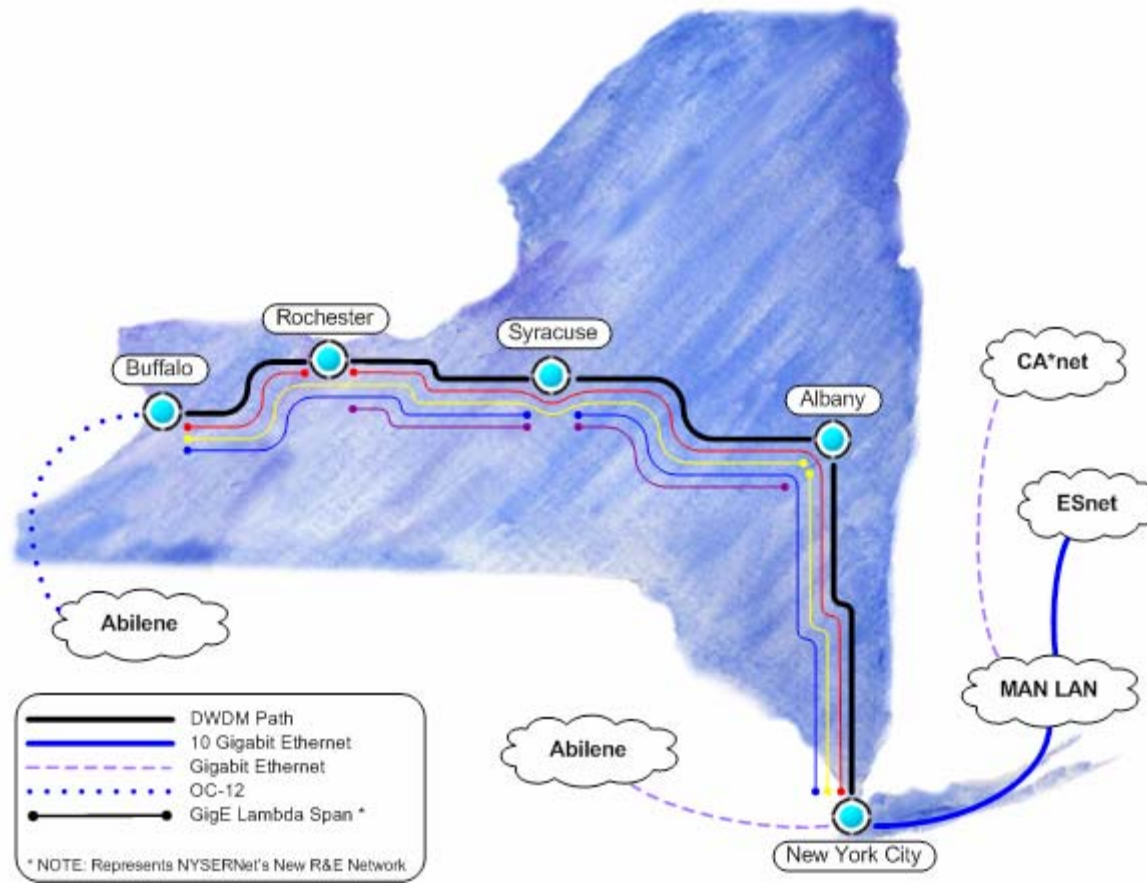- Level 3 Detroit fiber
- CIC Chicago fiber

- ● Optical Add/Drop Mux (OADM)
- ■ Optical Amplifier (OpAmp)
- • Fiber splice or jumper point
- ☐ Carrier major network facility
- ○ Carrier transmission line facility

Main map labels: Grand Rapids, Durand, MSU, Lansing, Troy, Southfield, Albion, UM, WSU, Dexter, Detroit, Schoolcraft, Kalamazoo, Chicago, StarLight, Niles, 111 N Canal, 600 S Federal, South Bend, Riverdale, Gary, Valparaiso

Chicago inset:
- WilTel 662 N Hudson
- StarLight 710 N Lakeshore
- Level 3 - NLR 111 N Canal
- WilTel 600 S Federal
- Chicago

Detroit inset:
- Level 3 Southfield 19675 W 10 Mile
- UM-Dearborn 4901 Evergreen
- Wayne State Univ 5925 Woodward
- WilTel Detroit 1965 Porter
- Detroit

I-Light in Indiana

IPGRID Network and
I-Light and I-Light 2
networks

New York – Nysernet et al

DC/Virginia: *MAX – MATP Combined Regional Infrastructure*

KEY:

MAX Members & Projects

MATP Members & Resources

V **MATP VORTEX DWDM Node**

— **OC-48 POS**

— **10 GE**

NASA
DREN
NREN
NISN

Baltimore — JHU

NGIX

Abilene

ESnet

DRAGON

GWU
GU

MAX
DC metro
WDM

CLPK

UMD

BoSSnet

ATDnet

NLR

McLean LVL3

MATP OSR

MAX T640

Network
Virginia

UVA

Ashburn

Arlington

GMU

Charlottesville

VCU

VT

Richmond

Lynchburg

Ring completes
via Pittsburgh

E-Light

ODU

W&M

Norfolk

JeffLab

Roanoke

Ring completes
via Durham
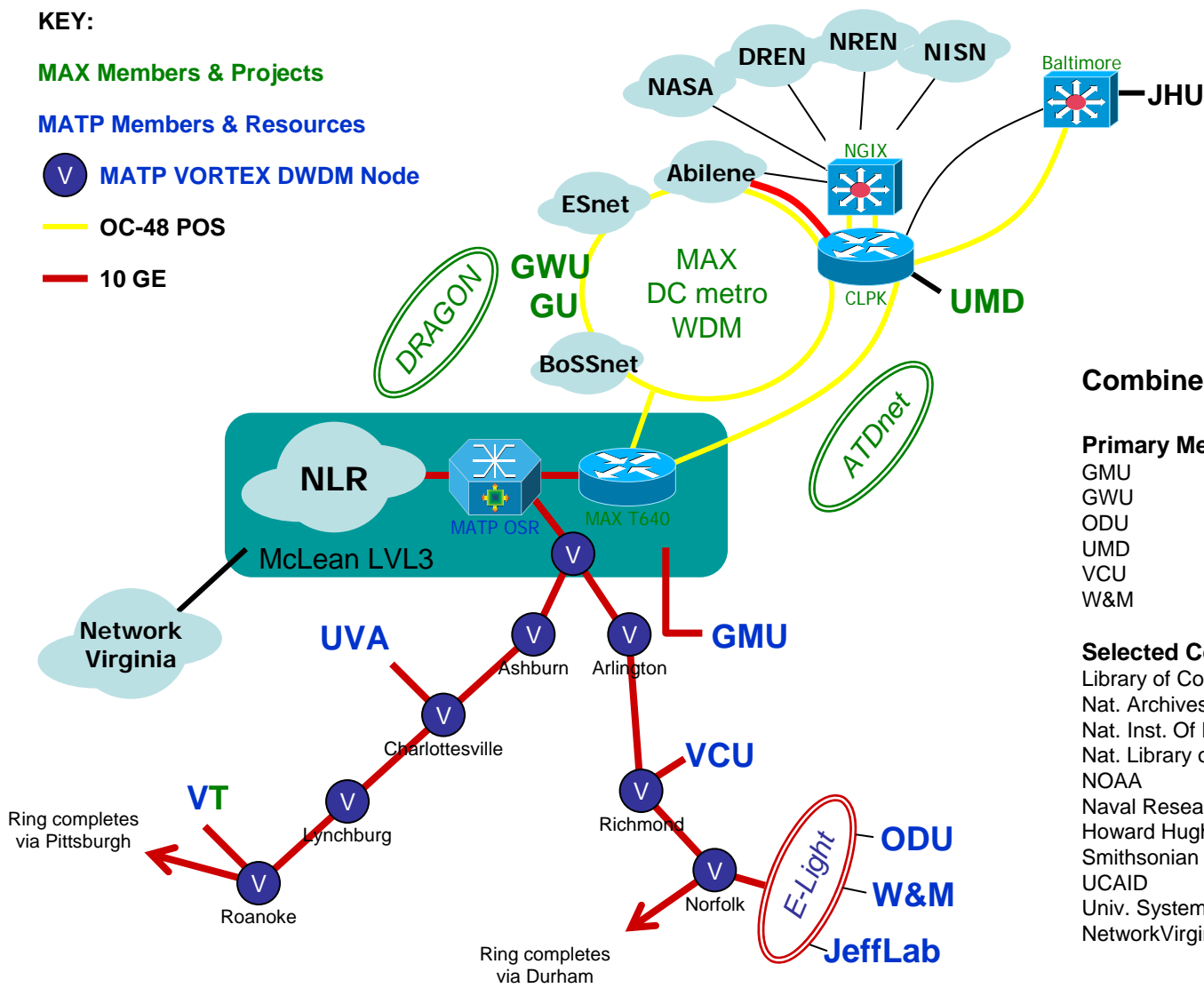
Combined Participants (partial)

Primary Members (MAX and MATP)

GMU	GU
GWU	JeffLabs/SURA
ODU	NASA
UMD	UVA
VCU	VT
W&M	

Selected Connectors

Library of Congress	NASA GSFC
Nat. Archives & Records Ad.	NSF
Nat. Inst. Of Health	ATDnet
Nat. Library of Medicine	USGS
NOAA	USDA
Naval Research Lab	US Census
Howard Hughes Med. Inst.	JHU
Smithsonian Institution	ISI East
UCAID	World Bank
Univ. System of Maryland (11 campuses)	
NetworkVirginia (651 campuses)	

NCREN

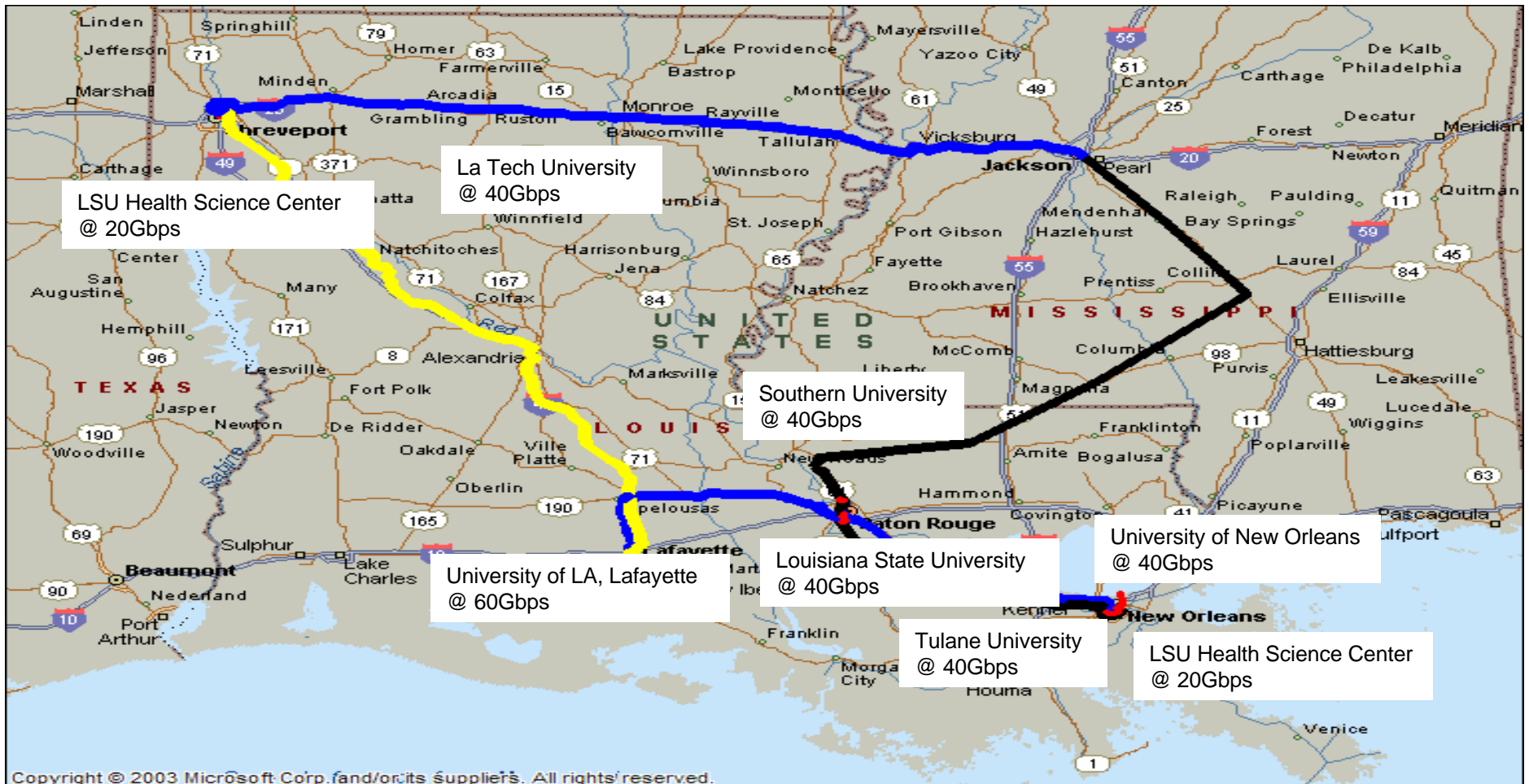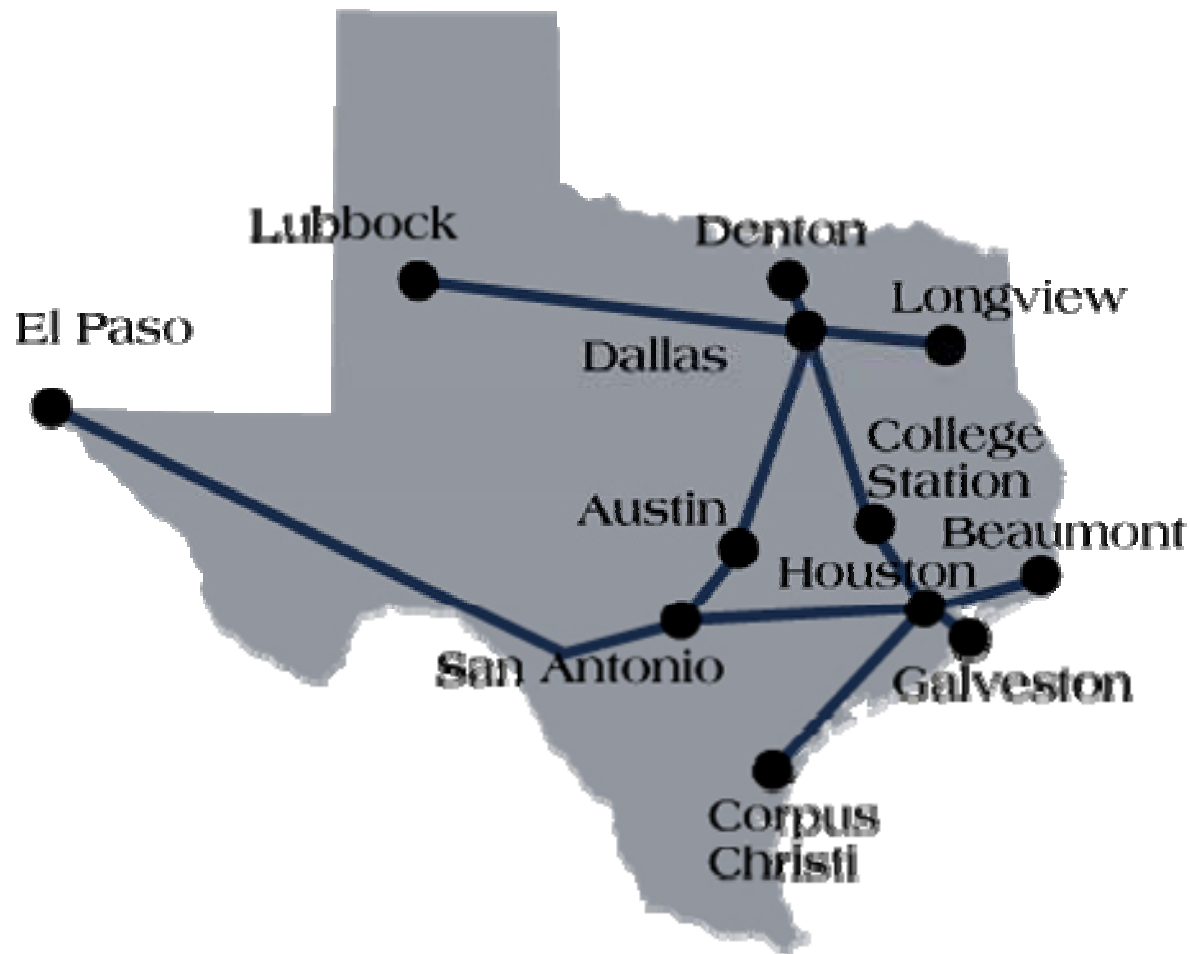## North Carolina Research & Education Network

WinstonNet

WinstonNet Access Router

WFU
WFU-SM
NCSA
WSSU

NLR
Abilene
Internet

NCA&T   UNC-G
Greensboro

ASU

UNC-A
Winston-Salem   RTP/Raleigh

ECSU

Asheville

UNC-C

Greenville

WCU

Charlotte

FSU

Morehead City

Internet

UNC-P

Wilmington

Research Triangle

Duke
NCCU
MCNC
NCSU
UNC-CH   UNC TV
UNC GA   Internet
NCSU
Centennial
Internet
Abilene

— OC48 (2.5 Gigabits/second)

— Gigabit Ethernet

— OC12 (622 Megabits/second)

smj Apr'05

Board of Regents of the University System of Georgia
Fiber Optic Network Map

Confidential and Proprietary Information
January 2005

GeorgiaPublicWeb

GPW System
— User Routes
— Proposed User Routes
● GPW Equipment Bldg.
Board of Regents
🏛 Research University
🏛 Regional University
🏛 State University
🏛 State College
🏛 Two-Year College

GEORGIA

Florida—Florida LambdaRail (FLR)

Florida LambdaRail
Optical Topology Map
Final Version 1/7/2004

⬠ Optical/Transient POP Site

▲ Optical POP Site

● ILA Site

Louisiana Optical Network Initiative (LONI)

LSU Health Science Center @ 20Gbps

La Tech University @ 40Gbps

Southern University @ 40Gbps

University of LA, Lafayette @ 60Gbps

Louisiana State University @ 40Gbps

University of New Orleans @ 40Gbps

Tulane University @ 40Gbps

LSU Health Science Center @ 20Gbps

Texas—Lonestar Education and Research Network (LEARN)

Oklahoma Research Network
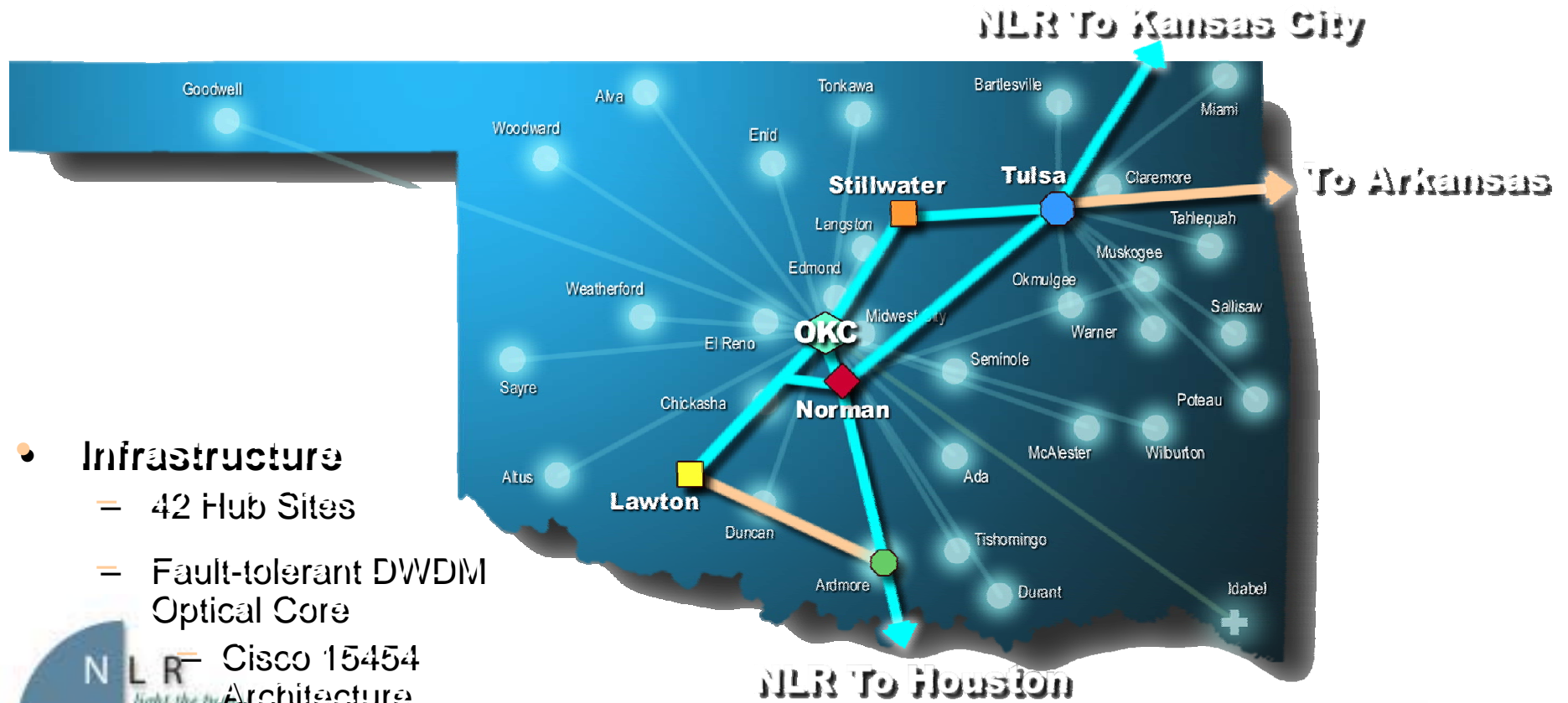
- **Infrastructure**
  - 42 Hub Sites
  - Fault-tolerant DWDM Optical Core
  - Cisco 15454 Architecture

TFN (Ohio)
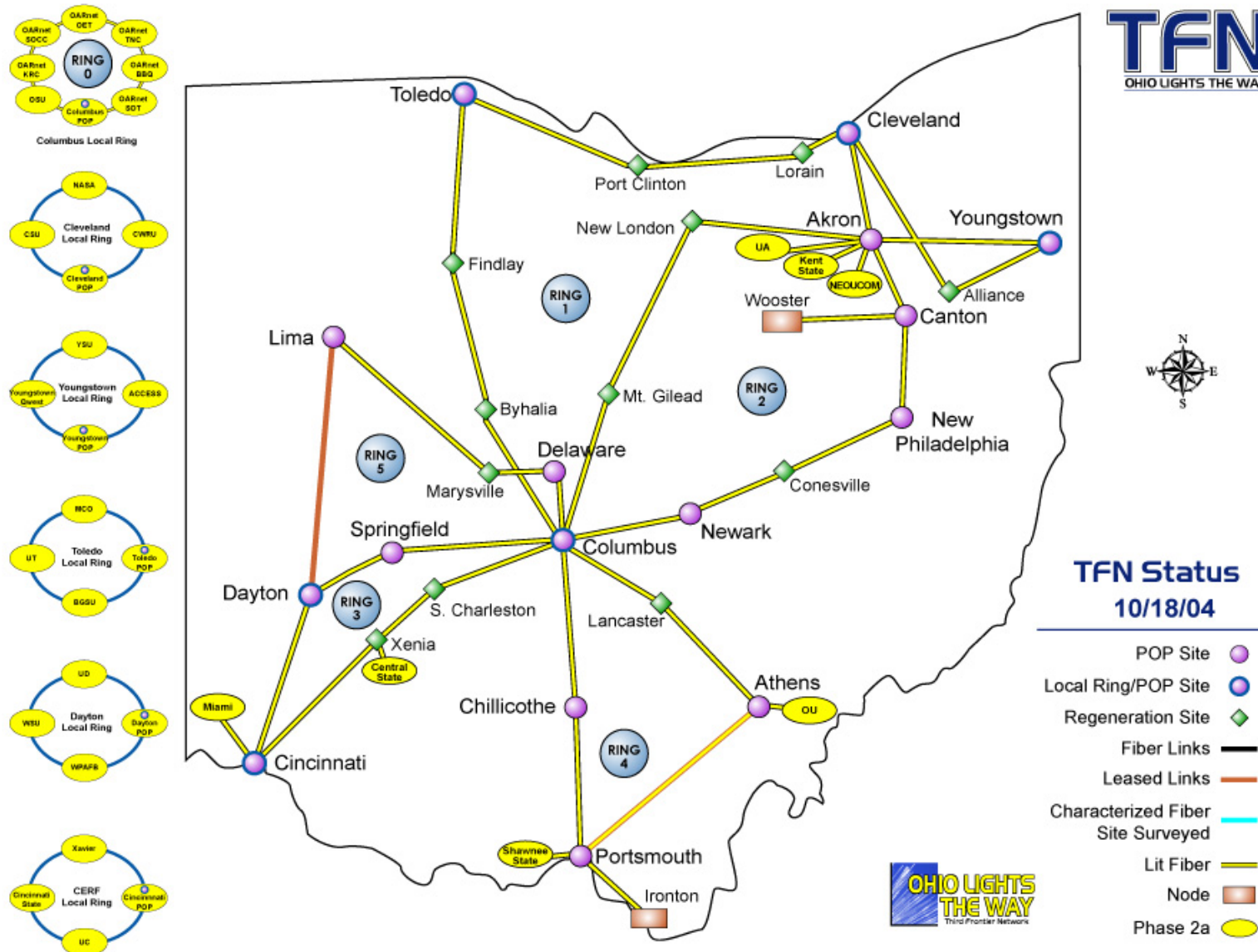
NLR Infrastructure

- Over 11,000 route miles (17,000 km) of fiber in backbone plus much more in RON's

- Owned Fiber: 20-yr IRUs-Level 3, Wiltel, AT&T

- Layer 1 Optics: Cisco 15808s and 15454s supporting up to 40 10 Gbps lambdas LANPHY

- Layer 2: Cisco 6509 switches for Gigabit Ethernet

- Layer 3: Cisco CRS-1 routers for IP

- Wavelengths available for experimental or production networks

- Dark Fiber possible for experimental Layer 1 research

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NLR Services

- ## Network of Networks
  - Multiple types of networks and services available
- ## Main Services
  - WaveNet - point-to-point "lambdas" – actually these are currently point-to-point circuits consisting of concatenated (OEO) dedicated wave segments
  - FrameNet(s) – Dedicated and shared Ethernet based services
  - PacketNet(s) - IP based networks
- ## Other Services
  - Co-location
  - Remote Hands
  - Fiber IRUs

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NLR Infrastructure Status - June 2006

NLR owned fiber*

● NLR WaveNet, FrameNet & PacketNet PoP
● NLR WaveNet & FrameNet PoP
● NLR WaveNet PoP

□ PoP for primary connection point by a member ("MetaPoP")
◇ PoP needed because of signal regeneration requirements but can also be used for secondary connection by a member
△ PoP established by NLR for members regional needs
☆ PoP established at exchange points

* Fiber on the SAND-LOSA-SUNN path belongs to CENIC
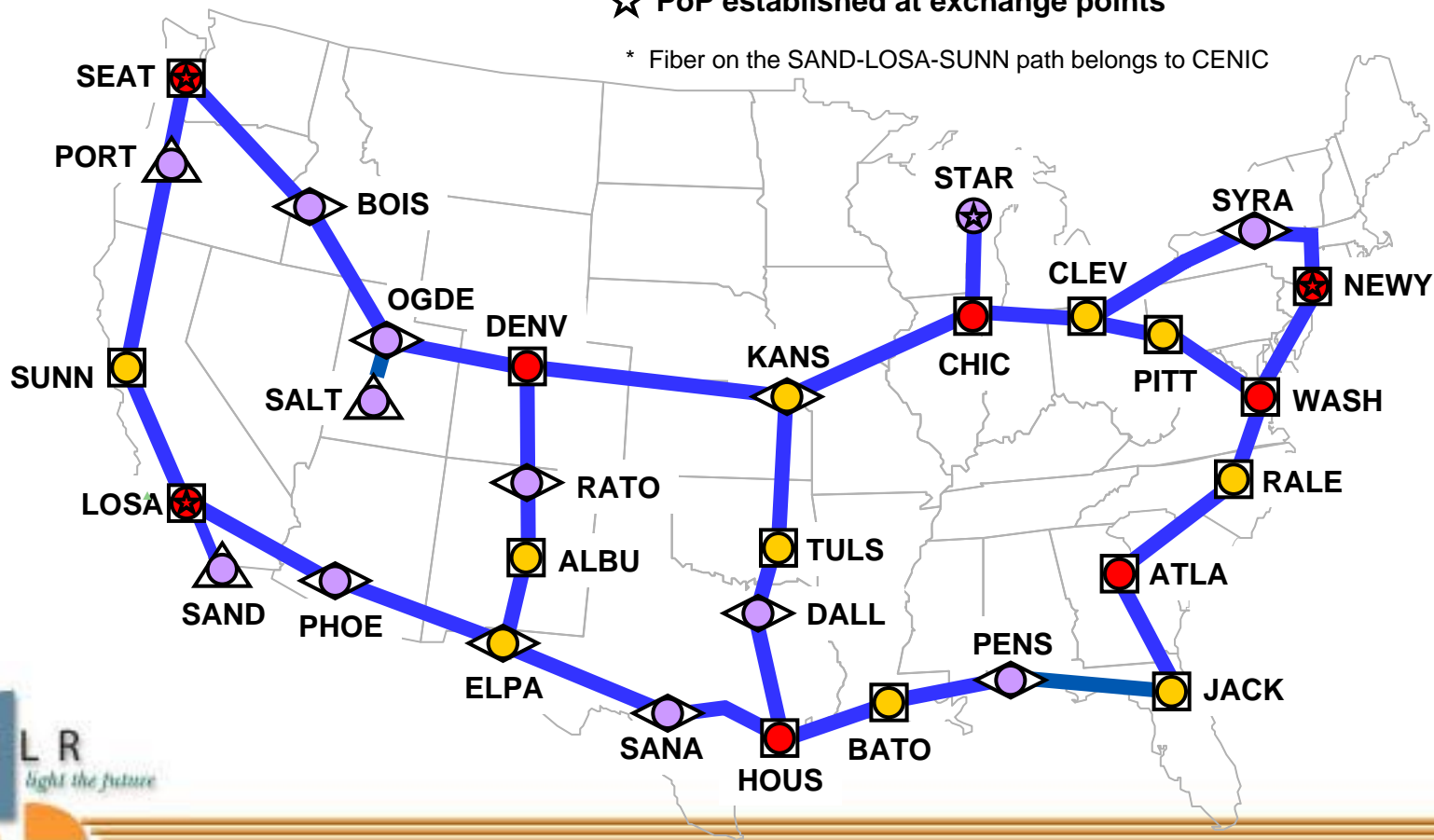
Current Nets and Waves on NLR

- Stable layer 3 network
- Experimental layer 3 IP network
- National Peering Fabric (Transitrail)
- Switched layer 2 Ethernet network providing Point-Point and Multi-Point with assigned capacity
- National layer 2 shared Ethernet network
- National wave for sparing and quickstart
- 2 national footprint research waves for research projects supported by Cisco
- Various project specific ETE circuits (concatenated wave segments)

(in development)

WaveNet Overview

- ETE circuits consisting of wave segments

- Includes research waves, supported by CISCO, made available in support of approved research projects

- Quickstart waves (if available and preemptible for fail-over)

WaveNet Summary

- Several projects and members using dedicated waves (Teragrid, Optiputer, ESNET, Ultrascience, NASA, PacificWave, Atlantic Wave, Cheetah,various backhauls)

- Several projests using CICSO research waves (LONI, EnLIGHTened, TransLight, UltraLight, and CineGrid)

- Segment utilization
  - 24% April 2006
  - 32% expected by August 2006

- Adding 21 new circuits by August 1st
  - 77 new layer 1 segments

NLR Layer 1 (Wavenet) Map

FrameNet Overview

- **National Exchange Fabric**
  - NEF is a single VLAN and broadcast domain that extends to every member
  - Allows members to arrange bi-lateral peerings
  - Every member gets a single 1GigE interface on their local NLR FrameNet node for use of the NEF service
- **Point-to-point, Dedicated Bandwidth Service**
  - Members may order private VLANs to connect 2 different locations together, with dedicated bandwidth, for a circuit-like service
  - Bandwidth available from 100Mbps to 10Gbps
- **Point-to-multipoint, Best Effort Service**
  - Members may order private VLANs to multiple locations for a circuit-like service
  - Traffic on these VLANs carried through the network on a best effort basis

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FrameNet Summary

- Use of non-dedicated service is growing
- Currently primary use of dedicated service is for Layer 3 backup connections
- Interest by research groups
  - Collaborative multi-point projects
  - Experiment on non-dedicated service, understand utilization, then migrate to dedicated service.
- New Services being Developed
  - Investigation of **on-demand** dedicated services
  - Develop process to implement - both backbone and RONS (and campuses)

FrameNet Research Projects

- ## VINI (GENI precursor?)
  - PI Larry Petersen/Jennifer Rexford
  - Virtual network infrastructure that allows network researchers to evaluate their protocols and services in a realistic environment that provides a high degree of control over network conditions.
  - Infrastructure - an overlay testbed using NLR co-location, FrameNet and PacketNet services.

- ## UltraLight
  - PI - Harvey Newman, Caltech
  - Collaboration of experimental physicists and network engineers whose purpose is to provide the network advances required to enable petabyte-scale analysis of globally distributed data.
  - Infrastructure - migrating to 10 GE PacketNet and 10 GE FrameNet

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Layer 2 (Framenet) Weather Map

NLR NOC Layer 2 Weathermap

PacketNet Overview

- Potential for several packet networks on different lambdas (or VLANS) can use virtual routing capability of CRS-1 or multiple router instances

- "Production" 10G Layer 3 IP network, fully operational

- "Experimental" for research use to be made available when needed

PacketNet

- Member connection status
  - 12 out of 14 Members are connected
  - 9 of the 12 have 10 GE connections, 6 also have 1 GE secondary connections
  - 3 with GE or multiple GE
  - Total routes ~3500
- Peering with other national (federal) REN's ESnet
  - DREN, ESNET, USGS
  - NREN - pending
- Present at all major R&E peering facilities (Starlight, PacificWave, MANLAN) Establishment of peering with international REN's in progress
  - CA*Net
  - Transpac2
  - TWAREN
  - Starlight AS
  - Others in process
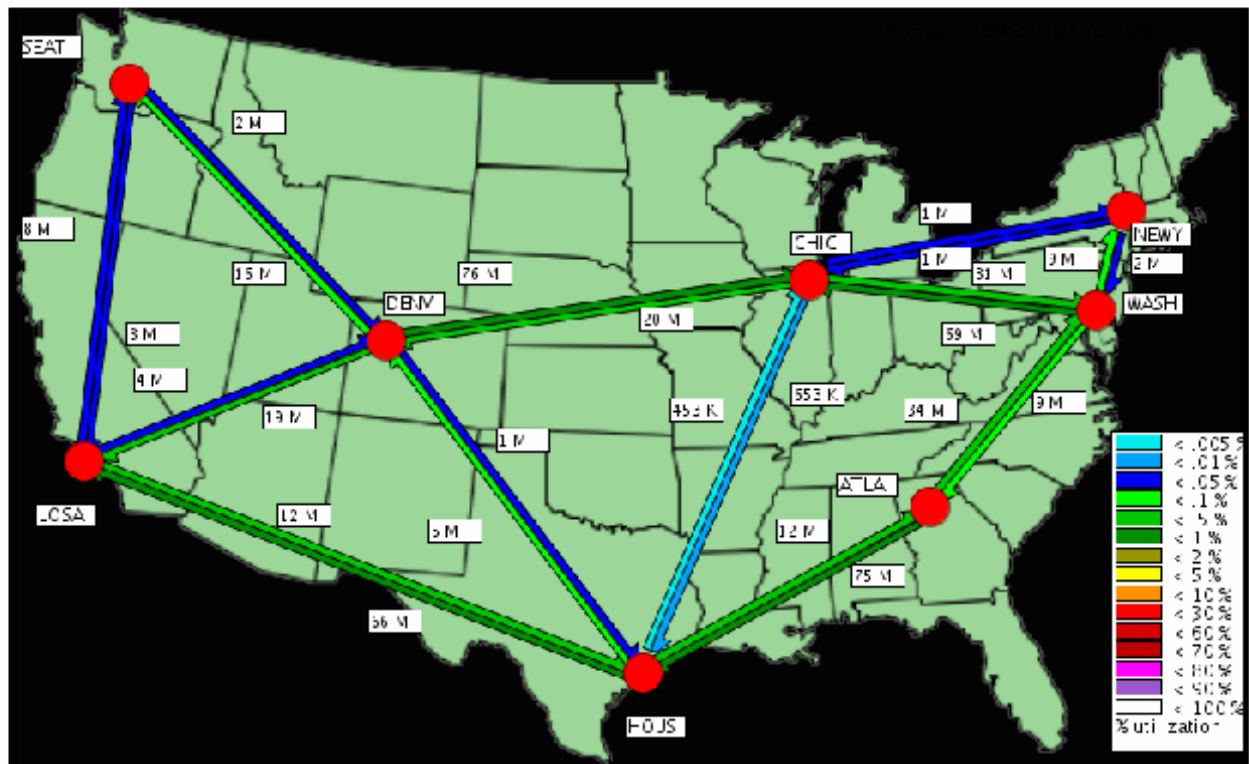- Multi-national project networks
  - Ultralight

PacketNet Weather Map

Participation in Major Conferences

- iGRID'05 (San Diego)

- Supercomputing'05 (Seattle) - 0.5 TBps!

- Supercomputing'06 (Tampa)

Cisco's Support of R&E Networking Research through NLR

- Cisco has been a major and consistent contributor of support to the National Lambda Rail

- Recent extension of relationship

- Cisco support of R&E Networking Research Projects include providing access to Cisco Waves (lambdas over NLR), vLANs over Cisco networks overlayed on NLR, and access to NLR's L2 and L3 network services

- Projects supported include: LONI, EnLIGHTened, TransLight, UltraLight, and CineGrid

- We can expect several new projects to be announced soon

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Relationship to GLIF

- NLR infrastructure interconnects all US GOLES with Packet Frame and Wave services

- Is the only operational infrastructure reaching a large number of US research institutions at Wave, Frame and Packet level, allowing for a variety of lambda connection possibilities.

- Is a key component of many projects that run over GLIF resources

- Can make use of Packetnet and Framenet and some Wavenet links

- With additional research waves being made available, more NLR based GLIF resources will come into play.

Contact Information

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jsilvester@nlr.net
(or silvester@usc.edu)

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