Designing a New Networking Environment for U.S. Research & Education

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Outline

- Internet2 international efforts
- National packet (IP) networking
  - Abilene Network
- New optical networking facilities
  - Regional projects
    - FiberCo example
  - National initiative (to be addressed by John Silvester)
    - National LambdaRail (NLR)
- Developing a hybrid architecture
  - Hybrid Optical and Packet Infrastructure (HOPI)

Internet2

- Internet2's mission is to develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow's Internet

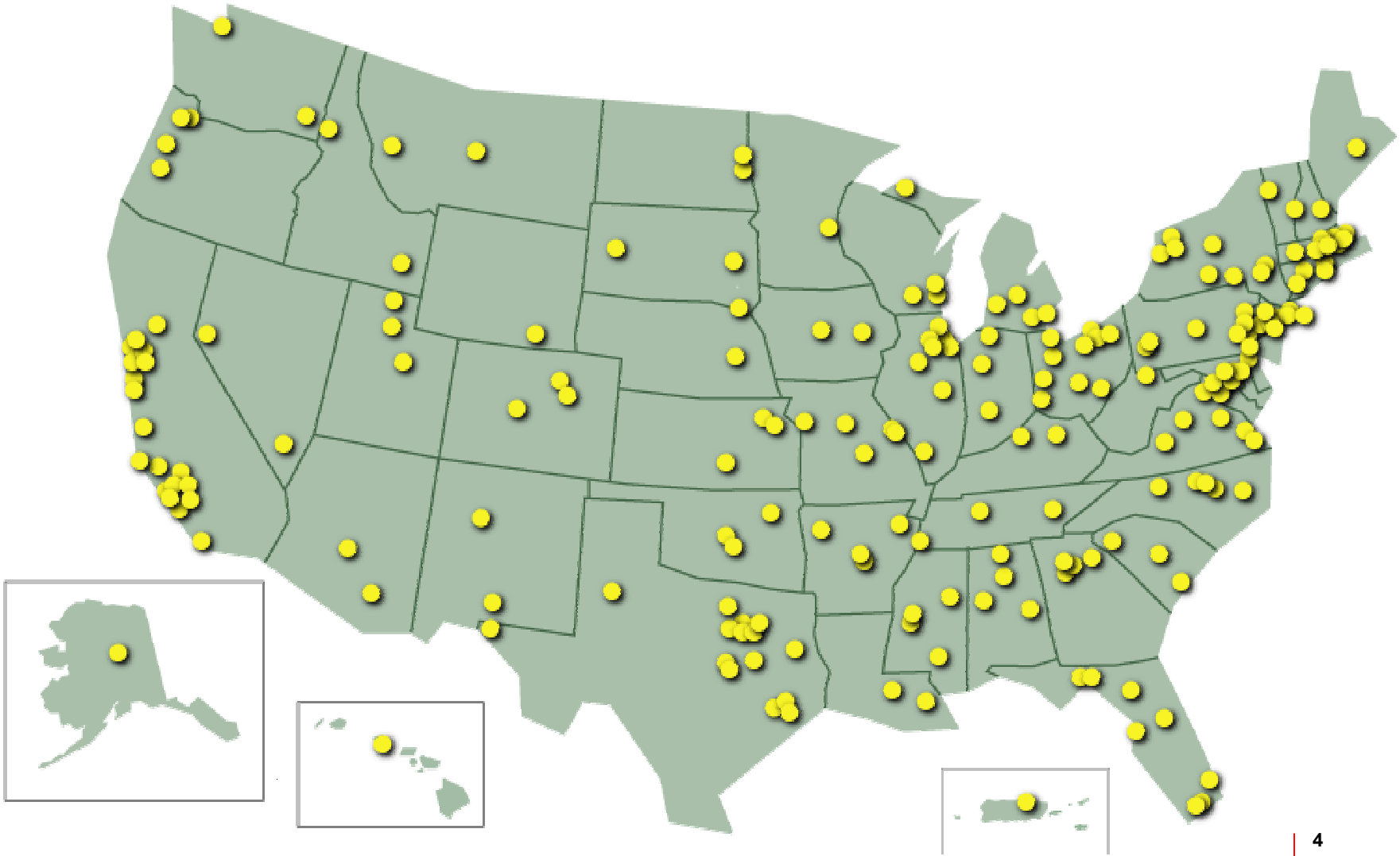
Goals

  - Enable new generation of applications
  - Re-create leading edge R&E network capability
  - Transfer capability to global production Internet

- Membership organization of more than 200 US research universities
  - Non-profit organization has board of directors composed primarily of university and foundation presidents
- Its initiatives are supported by numerous partnerships with government, industry, and international

Internet2 Universities

206 University Members, May 2004



Additional Participation

- 60+ corporate members
- 40+ affiliate (non-profit) members
- 45+ international partners

International Partnerships

- **Ensure global interoperability**
  - of the next generation of Internet technologies and applications
- **Enable global collaboration**
  - in research and education providing/promoting the development of an advanced networking environment internationally
- Build effective partnerships in other countries with organizations of similar goals/objectives and similar constituencies
- Mechanism: bilateral Memoranda of Understanding

Last updated: 7 October 2003

Internet2 International Partners

Europe-Middle East

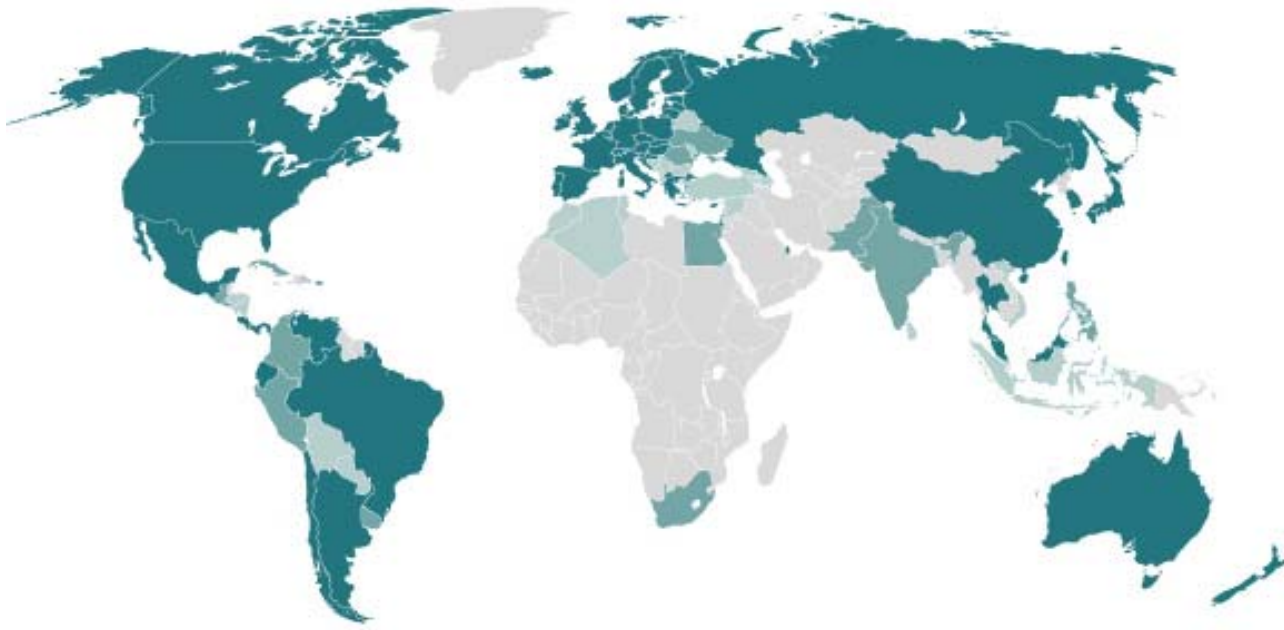
- ARNES (Slovenia)
- BELNET (Belgium)
- CARNET (Croatia)
- CESnet (Czech Republic)
- DANTE (Europe)
- DFN-Verein (Germany)
- GIP RENATER (France)
- GRNET (Greece)
- HEAnet (Ireland)
- HUNGARNET (Hungary)
- INFN-GARR (Italy)
- Israel-IUCC (Israel)
- NORDUnet (Nordic Countries)
- POL-34 (Poland)
- FCCN (Portugal)
- RedIRIS (Spain)
- RESTENA (Luxembourg)
- RIPN (Russia)
- SANET (Slovakia)
- Stichting SURF (Netherlands)
- SWITCH (Switzerland)
- TERENA (Europe)
- JISC, UKERNA (United Kingdom)
- Qatar Foundation Network (Qatar)

Asia-Pacific

- AAIREP (Australia)
- APAN (Asia-Pacific)
- APAN-KR (Korea)
- APRU (Asia-Pacific)
- CERNET, CSTNET, NSFCNET (China)
- JAIRC (Japan)
- JUCC (Hong Kong)
- NECTEC / UNINET (Thailand)
- NG-NZ (New Zealand)
- SingAREN (Singapore)
- TAnet2 (Taiwan)

Americas

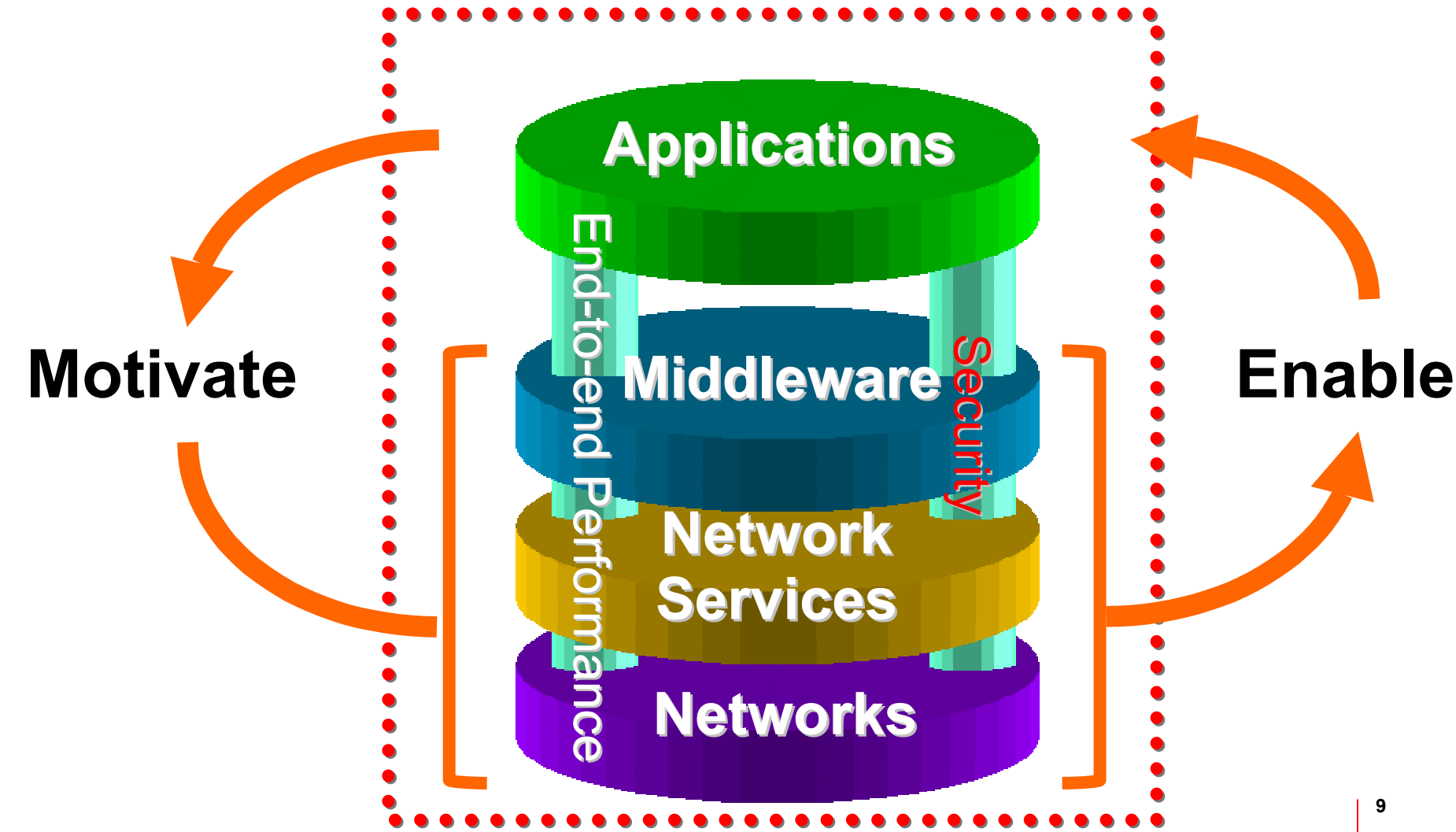
- CANARIE (Canada)
- CEDIA (Ecuador)
- CLARA (Latin America and Caribbean)
- CNTI (Venezuela)
- CR2NET (Costa Rica)
- CUDI (Mexico)
- REUNA (Chile)
- RETINA (Argentina)
- RNP [FAPESP] (Brazil)
- SENACYT (Panama)



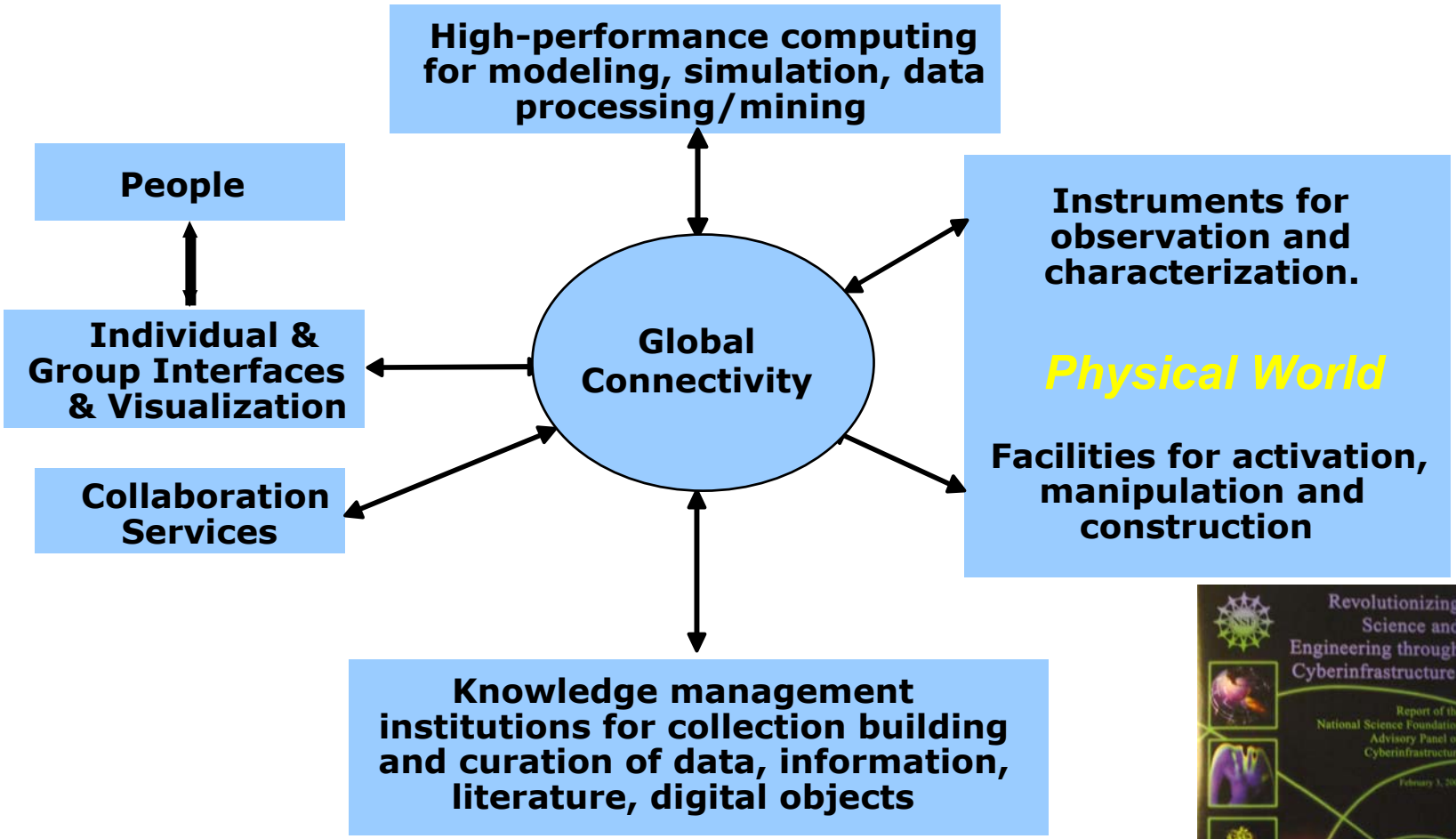
Partnerships in the Americas

- Canada, Mexico, US cross-border connectivity
- Chile, Venezuela, Brazil, Argentina connected to Miami via 45Mpbs (AMPATH)
- Cable infrastructure around the region
- CLARA backbone network

Internet2's multi-threaded 'Virtuous Circle'



Cyberinfrastructure-enabled science & engineering (NSF)



Source: Paul Messina – Fall 2003 Internet2 member meeting,
"Cyberinfrastrucutre: Promises and Challenges"
presentation at http://www.internet2.edu/presentations/fall-03/20031014-Plenary-Messina.htm

Infrastructure context

- Drivers of change
  - Grid computing: the network as a schedulable element
  - NSF Cyberinfrastructure vision
  - Contrarian opportunities posed by the telecom economy crash
- Key questions
  - Buy vs. build (or both?)
  - Packets vs. circuits (or both?)
- Persistence of network hierarchy
  - Campus
  - Regional
  - National
  - International

Abilene Network

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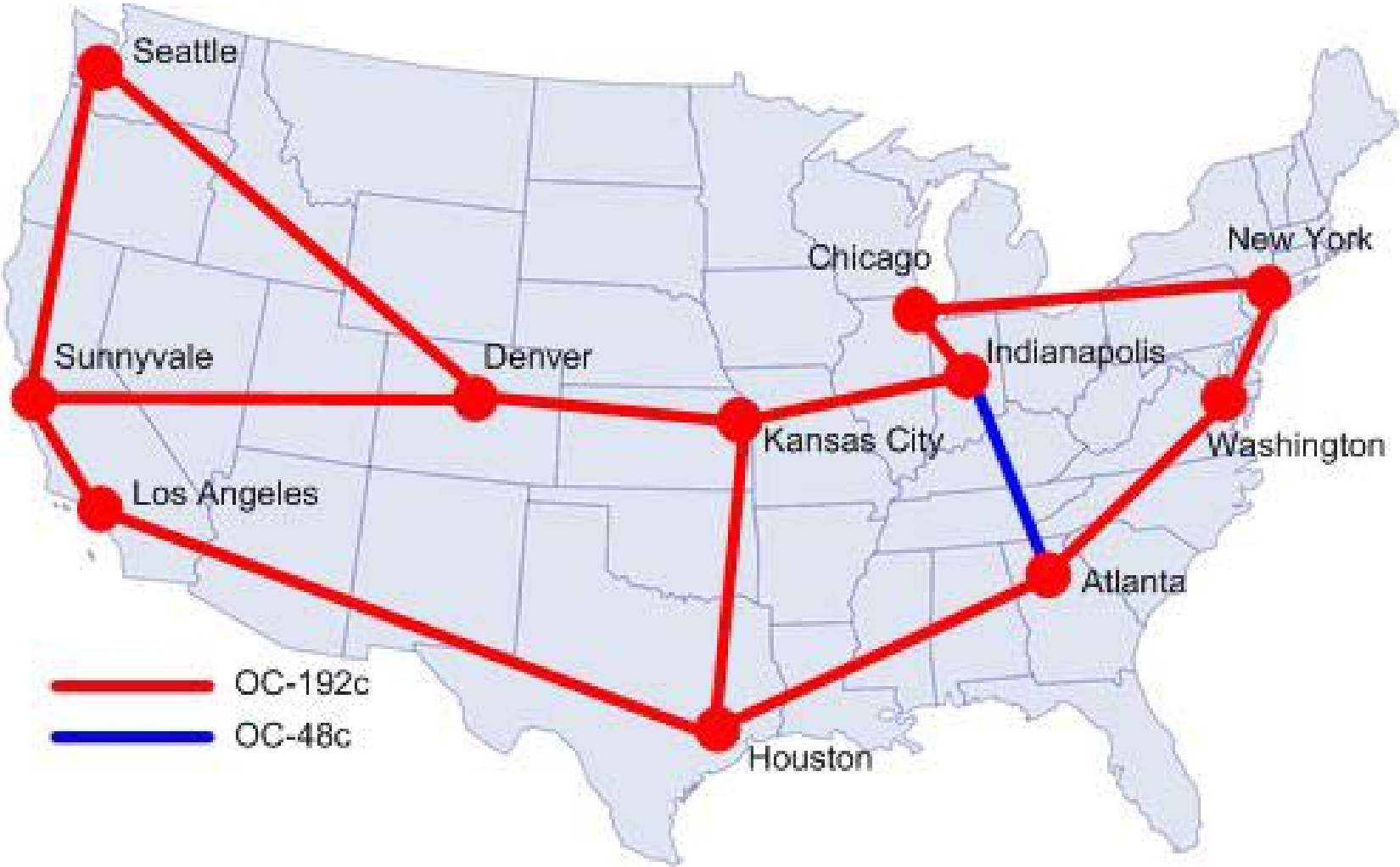
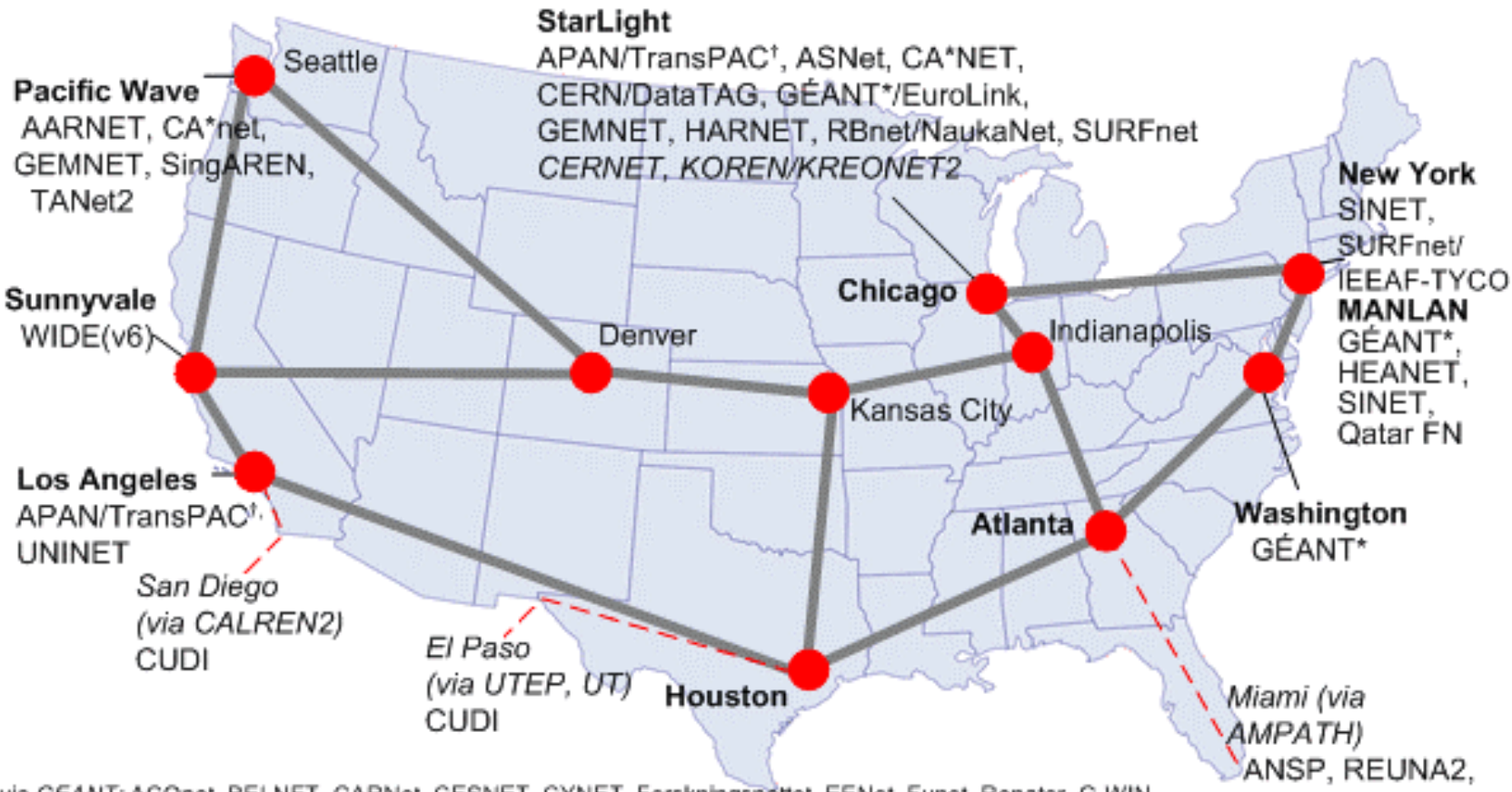
Abilene Network – second generation



Abilene International Peering



* *via GÉANT:* ACOnet, BELNET, CARNet, CESNET, CYNET, Forskningsnettet, EENet, Funet, Renater, G-WIN, GRNET, HUNGARNET, Rhnet, HEAnet, IUCC, GARR, LANET, LITNET, RESTENA, Univ. Malta, SURFnet, UNINETT, POL34, RCTS2, RoEduNet, RBnet, SANET, ARNES, RedIRIS, SUNET, SWITCH, JANET, ULAKBYM, CERN

† *via APAN/TransPAC:* WIDE/JGN, IMnet, CERNet/CSTnet/NSFCNET, KOREN/KREONET2, PREGINET, SingAREN, TANET2, ThaiSARN

Abilene Focus Areas - 2004

- Support of high-throughput flows (multi-Gbps)
  - Collaboration with Internet2 End-to-End Performance Initiative
  - Ensuring that large flows are the standard across the Internet2 Infrastructure
- IPv6
  - Furthering its deployment throughout the Internet2 networking environment
- Abilene Observatory
- Security
- Network resiliency

Abilene Observatory

- A project designed to support the computer science network research and advanced engineering communities
- Two components
  - *In situ* experimentation
  - Access to comprehensive set of network performance data
- Hosted Projects
  - PlanetLab (Berkeley/Princeton/Intel Research/NSF)
  - AMP Project (SDSC/NSF)
- Access to Network Performance data
  - Objective is to maintain time-correlated data archive
  - Multiple time-corrected data views – traffic flows, passive measurements, routing data, SNMP and syslog data
- http://abilene.internet2.edu/observatory/

Optical Networking Development

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Underlying hypothesis

- The fundamental nature of regional networking is changing
  - The *GigaPoP* model based on *provisioned, high-capacity services* steadily is being replaced – on the *metro and regional scales*
- A model of *facility-based networking built with owned assets* – Regional Optical Networks *(RONs)* – has emerged
  - Notably, this change *increases* the importance of regional networks in the traditional *three-level hierarchy* of U.S. R&E advanced networking

Leading & Emerging *Regional Optical Networks*

- California (CALREN)
- Colorado (FRGP/BRAN)
- Connecticut (Conn. Education Network)
- Florida (Florida LambdaRail)
- Georgia (Southern Light Rail)
- Indiana (I-LIGHT)
- Illinois (I-WIRE)
- Louisiana (LONI)
- Maryland, D.C. & northern Virginia (MAX)
- Michigan
- Minnesota
- New York + New England region (NEREN)
- North Carolina (NC LambdaRail)
- Ohio (Third Frontier Network)
- Oregon
- Pacific Northwest (Lariat – supported by NIH)
- Rhode Island (OSHEAN)
- SURA Crossroads (southeastern U.S.)
- Texas
- Utah
- Virginia (MATP)
- Wisconsin

FiberCo

- Dark fiber holding company
  - Operates on behalf of U.S. higher education and affiliates – the Internet2 membership
  - Fiber acquisition and assignment vehicle for regionals and NLR
  - Fundamentally, a dark fiber *market maker* for U.S. R&E
- Project designed to *support* optical initiatives
  - Regional (RONs)
  - National (NLR)
- Not an operational entity
  - Will not light any of its fiber
- First acquisition of dark fiber through Level 3
  - 2,600 route miles – March, 2003

Gauging U.S. R&E community-wide progress with dark fiber

- Aggregate dark fiber held for or assigned to U.S. R&E optical initiatives (segment-miles):
  - CENIC 6,100
  - FiberCo 4,900
  - SURA 6,000
    - (plus 2,000 route-miles for research)
  - Oak Ridge National Lab 900
  - Ohio 1,500
  - Other state projects (IN,IL,MI,OR, etc.) 1,900+

- **Total (conservative estimate) 21,000+**

A new model for carrier support of advanced networking?

- Fundamental premise:
  - Total system ownership, control, and responsibility are neither the most cost-effective nor the optimum solution for higher education's optical networks
- Emerging optical networks offer new opportunities for carriers to provide services with potentially higher ROI
  - Higher education is willing to assume much of the initial and ongoing capital costs in this model

What higher ed really seeks at the minimum?

- Dark fiber ownership
  - Co-location capabilities
  - Open fiber interconnectivity
- Significant equity stake in the optronics
  - Ability to provision new waves at incremental cost
  - Full management visibility
  - Ability to switch waves
- Many opportunities for carrier services here
  - Fiber O&M
  - Colocation & power
  - Anchor tenant for next generation optronics
  - Hands & eyes support
  - Higher level support services
  - Significant ancillary business (off-net waves, IP)

National optical networking and network research

National LambdaRail (NLR)

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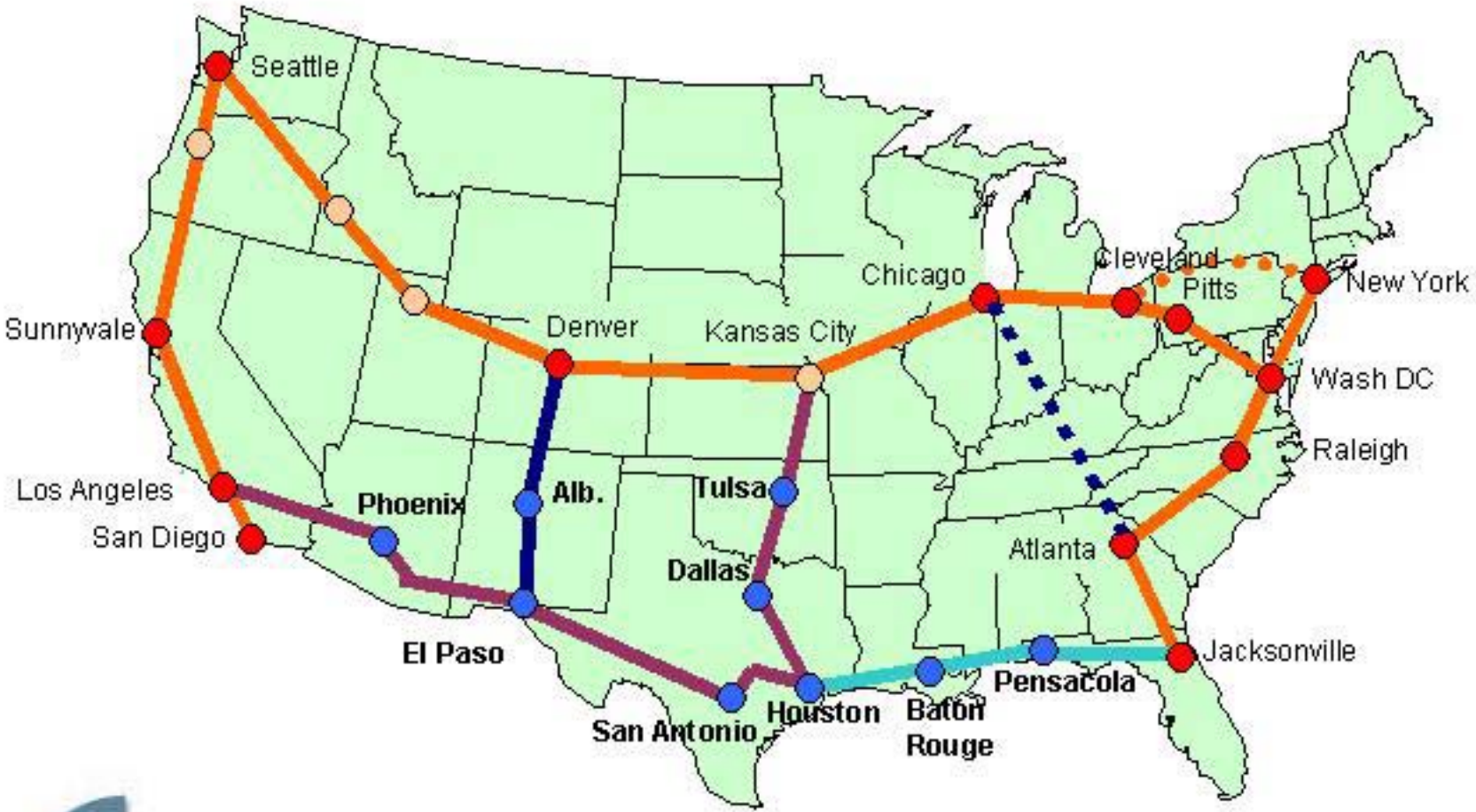
National LambdaRail – Proposed Final Topology



NLR
light the future

NLR distinguishing features

- Largest higher-education owned & managed optical networking & research facility
  - Over 10,000 route-miles of underlying dark fiber
  - Four 10-Gbps λ's provisioned at outset
    - One allocated to Internet2
- First & foremost, an experimental facility for research
  - Optical, switching & IP capabilities (layers 1, 2 & 3)
- Use of high speed Ethernet (10 Gbps) for wide area transport
- Sparse backbone topology
  - Each participant commits $5M over 5 years and assumes responsibility for a regional node

Next steps for optical networking development

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HOPI Project Goals

- Examine new hybrid architectures for the future
  - Model a set of packet and optical capabilities
- Immediate goals
  - **White paper describing architecture options and testbed plan developed**
    - Request comments on the testbed plan
  - Engage high-level, corporate technical participation
  - Implement HOPI testbed over the next year
  - Coordinate and experiment with other similar projects
  - Collaborate with other projects (e.g., GLIF, NLR, DRAGON)
- Have formed a design team to coordinate and recommend activities over the next year

HOPI Design Team

- **Linda Winkler, Argonne/TeraGrid/I-WIRE (co-chair)**
- **Rick Summerhill, Internet2 (co-chair)**
- Cees de Laat, U of Amsterdam
- Rene Hatem, CANARIE
- Mark Johnson, MCNC
- Tom Lehman, USC/ISI
- Peter O'Neil, NCAR
- Bill Owens, NYSERNet
- Philip Papadopoulos, UCSD
- Sylvain Ravot, Caltech/CERN
- David Richardson, U Washington/PNWGP
- Chris Robb, Indiana U
- Jerry Sobieski, U Maryland/MAX
- Steven Wallace, Indiana U
- Bill Wing, Oak Ridge/UltraNet
- Supporting staff from Internet2: Guy Almes, Heather Boyles, Steve Corbató, Chris Heermann, Christian Todorov, Matt Zekauskas

HOPI's raw materials

- The Abilene Network
  - 10-Gbps IPv4/IPv6 + MPLS tunnels
- Internet2's 10-Gbps λ over NLR
- MAN LAN exchange point – New York City
  - Ethernet Switch – layer 2 switching
  - TDM Switch – layer 1 switching
  - Venue for international collaboration
    - SURFnet, CANARIE, ESnet, SINET, Abilene
- IEEAF/Tyco 10-Gbps λ - NYC-Amsterdam
- Collaborations with Regional Optical Networks (RONs) and other related efforts (e.g., GLIF, DRAGON)

HOPI testbed objective

- Given resource availability, we cannot use individual wavelengths yet to model candidate architectures
- Instead, we will model them using lower-bandwidth, deterministic paths that resemble circuits – *"light paths"*
- Basic HOPI service: a 1/10 GigE point-to-point path with reasonable throughput, jitter, latency, and loss characteristics
- Design team report: http://hopi.internet2.edu

More information

- http://abilene.internet2.edu
- http://abilene.internet2.edu/observatory
- http://ipv6.internet2.edu
- http://www.fiberco.org
- http://hopi.internet2.edu
- http://www.nationalambdarail.org


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