Abilene, HOPI, and Internet2's planning for future networking

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DoE Ultranet Kickoff Meeting

Fermilab

5 November 2003

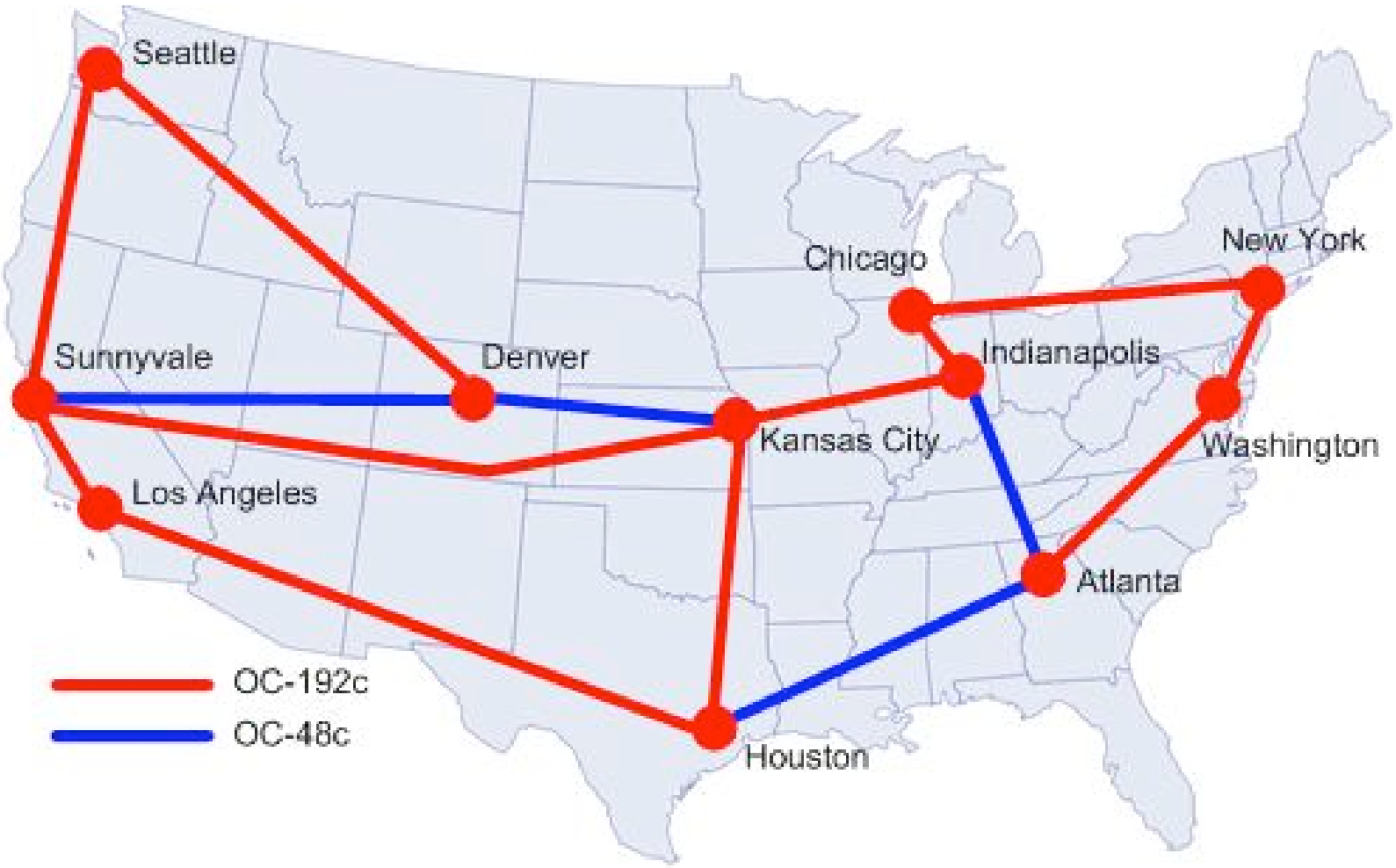
Collaborative effort on evolving ideas

- Guy Almes
- Heather Boyles
- Steve Corbató
- Chris Heermann
- Cheryl Munn-Fremon
- Rick Summerhill
- Doug Van Houweling
- Steven Wallace
- Plus many others

Outline

- Assembling the vital ingredients
  - High-performance national IP network: Abilene
  - Regional Optical Networks (RONs)
    - Supported by FiberCo and SURA initiatives
  - National optical capabilities: NLR
- Exploring hybrid networking
  - Plans for the NLR dedicated to Internet2
  - Steps towards developing a Hybrid Optical Packet Infrastructure (HOPI) …

Abilene Upgrade – Current



Abilene Focus Areas: 2003-2004

- High performance, native advanced services
  - Multicast
  - IPv6
  - Large Flows End-to-End
- Abilene Observatory
  - Supporting Network Research Community
  - Open Measurement & Experimentation Platform
- Dedicated Capability Experimentation
  - QoS-Enabled MPLS tunnels, for example
- Network Security
  - Role of the REN-ISAC
- Advanced Restoration Techniques

This infrastructure continues to surprise us

- Recent plumbing
  - Abilene 10-Gb/s upgrade nearing completion
  - CENIC upgrade includes 10-Gb/s connection
  - DataTAG circuit upgraded to 10 Gb/s via StarLight
- Single-stream TCP tests of October
  - 5.6 Gb/s from Itanium server in CERN to Caltech Itanium Linux in Los Angeles
  - 9000-byte MTU important
  - Very carefully tuned Linux TCP stack by Sylvain Ravot of Caltech
  - Ongoing testing will include FAST TCP etc.

An underlying observation

- Regional networking is fundamentally changing
- The *GigaPoP* model based on *leased, high-capacity circuits* 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, the importance of regional networks in the traditional three-level hierarchy of U.S. advanced networking for R&E is not diminished

Distance scales for U.S. optical networking

	Distance scale (km)	*Examples*	*Equipment*
Metro	< 60	UWash USC/ISI(LA), MAX(DC/MD/VA)	Dark fiber & end terminals
State/ Regional	< 500-1000	I-WIRE (IL), I-LIGHT (IN), CENIC ONI	Add OO Amplifiers (or optical TDM)
Extended Regional/ National	> 1000	TeraGrid 2nd Gen Abilene, NLR	Add OEO regenerators & O&M $'s

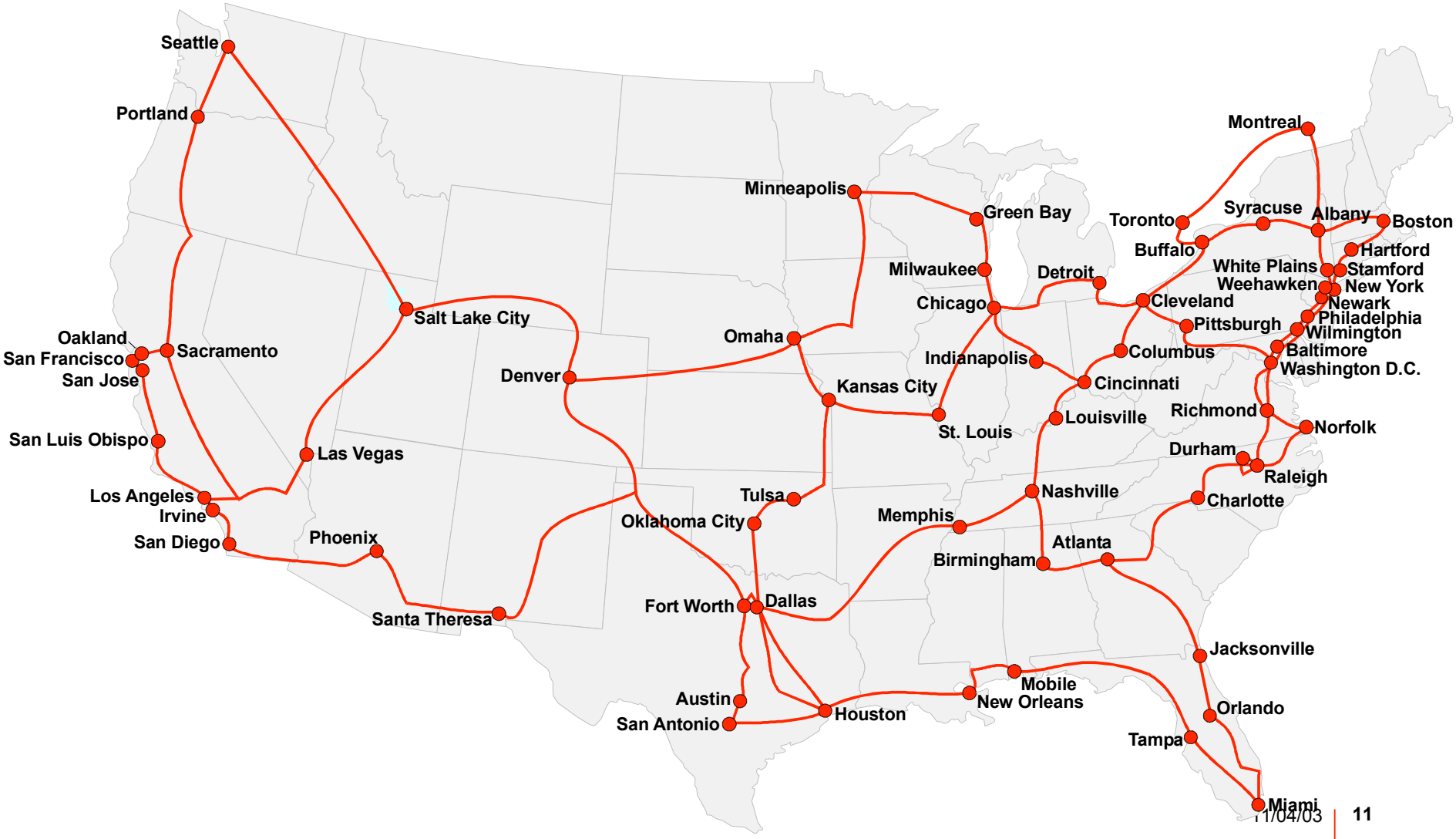
Leading and Emerging *Regional Optical Initiatives*

- California (CALREN)
- Colorado (FRGP/BRAN)
- Connecticut (Connecticut Education Network)
- Florida (Florida LambdaRail)
- Indiana (I-LIGHT)
- Illinois (I-WIRE)
- 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 (NIH-BRIN funded Lariat)
- Rhode Island (OSHEAN)
- SURA Crossroads (southeastern U.S.)
- Texas
- Utah
- Wisconsin

FiberCo

- Designed to *support* optical initiatives
  - Regional
  - National
- Not an operational entity – supporting project
  - Will not light any fiber
- Fiber options
  - Holding company for any future initiatives
  - Assignment vehicle
    - Regional initiatives
    - National initiatives (e.g., NLR)
- Internet2 took responsibility for LLC formation
  - Idea was spin-off from NLR formation discussions
  - National R&E Fiber Co. incorporated in Delaware
  - First acquisition of dark fiber for FiberCo through Level 3 Communication on 21-Mar-2003

Available fiber topology



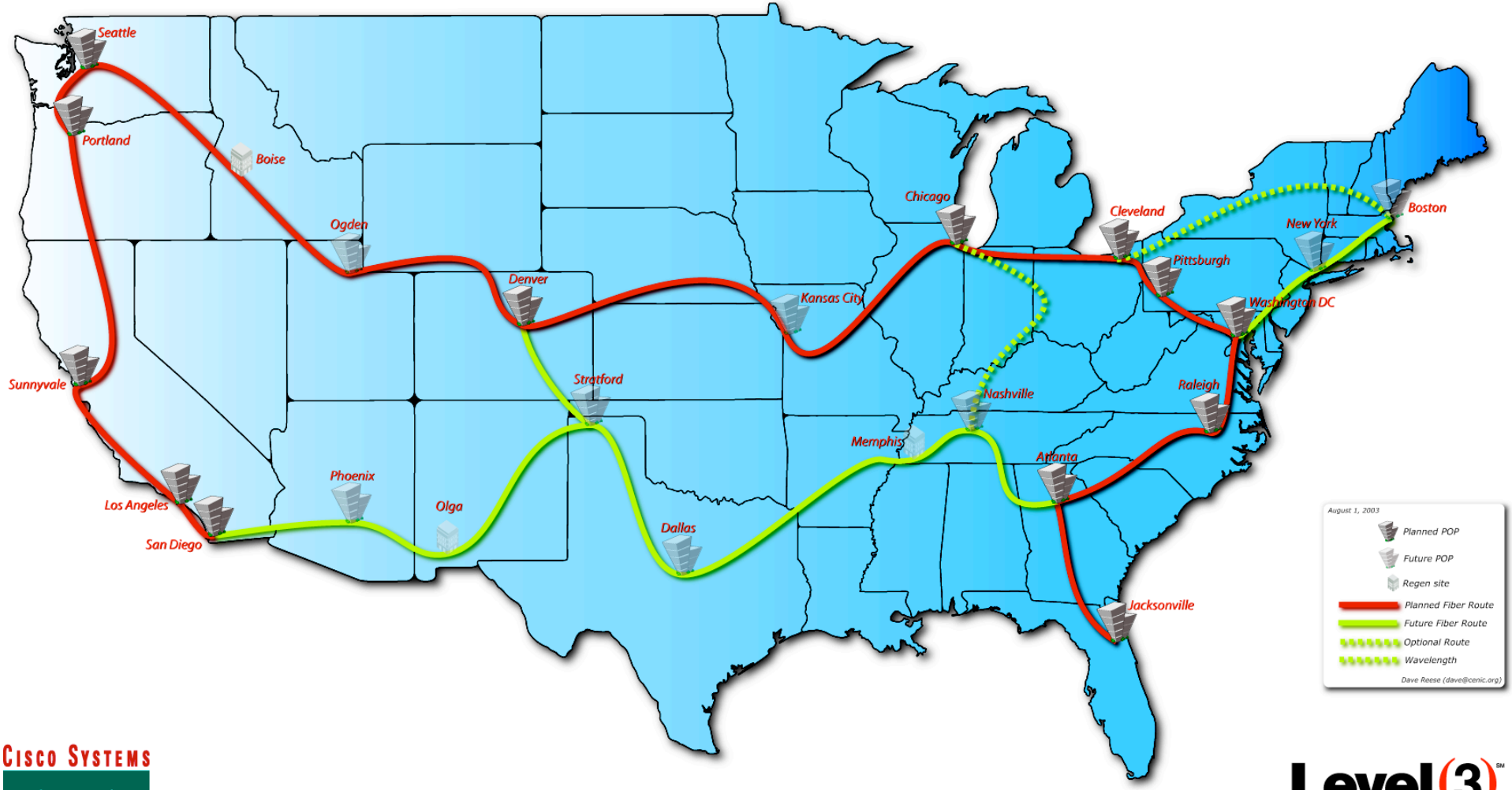
How is the fiber distributed?

- FiberCo assigns both the fiber IRU asset and recurring O&M agreements through an assignment agreement
  - Assignee has option to waive preferred provider relationship
  - Transaction fee charged to recover costs
    - 2003: $10k; expect higher in 2004
- Ongoing bilateral relationship directly between Level 3 and assignee
- LLC investment by a non-profit organization is also an option in lieu of assignment
    - 'fiber bank' model
- Assignees advised to keep recurring IRU tax liabilities and possible exemptions in mind

FiberCo and NLR

- NLR and FiberCo have developed a strong collaborative relationship
- FiberCo will provide fiber for NLR Phase 1 as CENIC's initial allocation is exhausted
  - ~1700 miles (68% of FiberCo's initial allocation)
- FiberCo will meet NLR's future requirements
  - FiberCo's IRU and recurring price points are in place through early 2006
- NLR has the independent ability to exercise the best available fiber options

NLR National Fiber Network



Cisco Systems

Level(3) Communications

Initial Coordinating Participants

cenic Corporation for Education Network Initiatives in California

FLR

Georgia Institute of Technology

Internet2

IWIRE

NCAR

Pacific Northwest GigaPOP

Pittsburgh Supercomputing Center

Texas Consortium

Virginia Tech

NLR Current Members and Associates

- CENIC
- Pacific Northwest Gigapop
- Pittsburgh SC
- Duke Univ./NCLR
- MATP/Va. Tech
- Cisco Systems
- Internet2
- Florida LambdaRail
- Georgia Tech
- CIC
- Pending:
  - Texas University Consortium

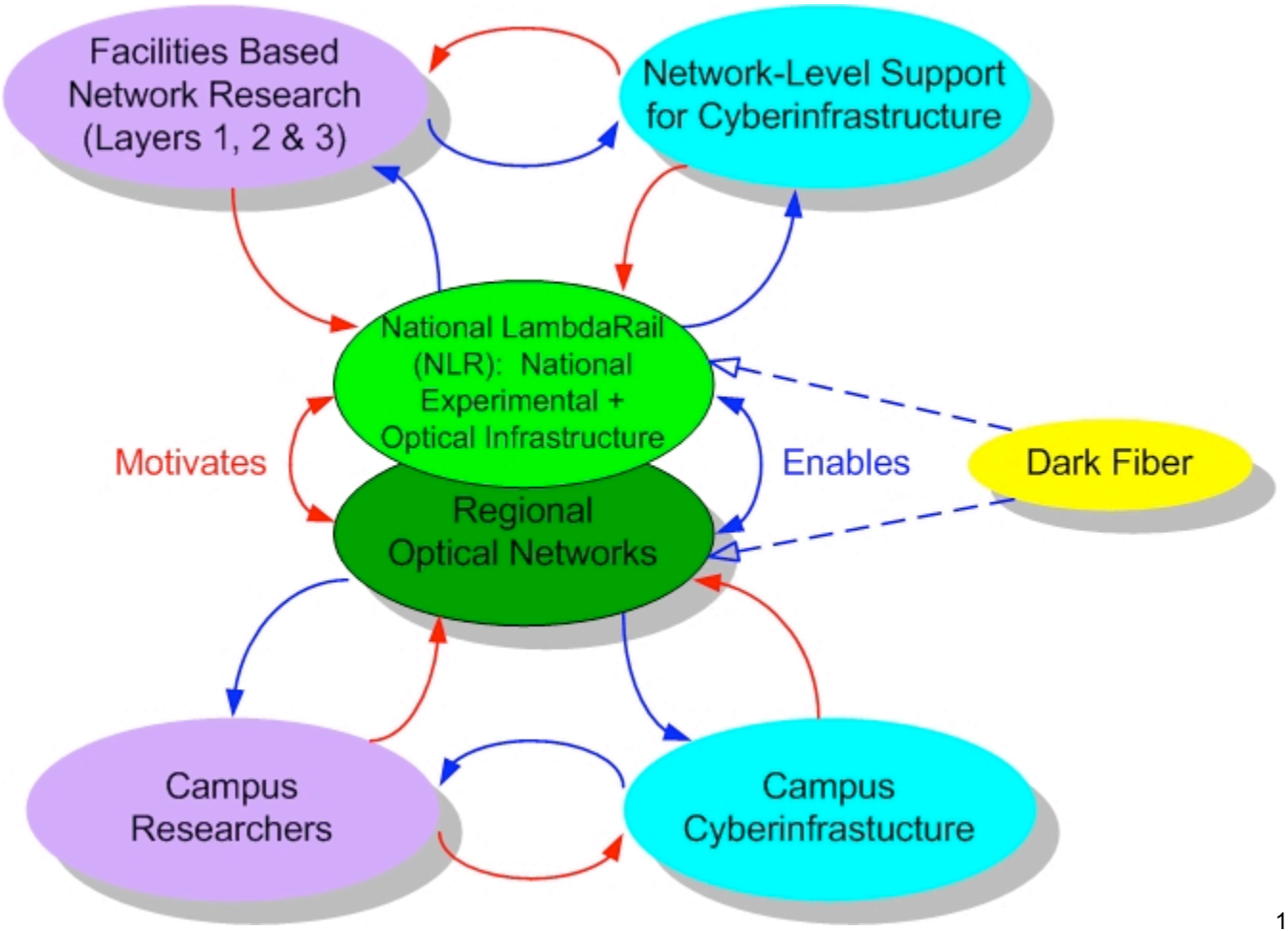
NLR distinguishing features: I

- Largest higher-ed owned/managed optical networking and research facility in the world
  - About 10,000 route-miles of dark fiber
  - Four 10-Gb/s λ's provisioned at outset
    - One allocated to Internet2
- First and foremost, an experimental platform for research
  - Optical, switching & IP capabilities (layers 1, 2, and 3)
  - Research committee integral in NLR governance
  - Advance reservation of λ capacity for research
  - Experimental support center

NLR distinguishing features: II

- Use of high-speed Ethernet for WAN transport
  - 1O Gigabit Ethernet LAN PHY is primary interface
  - Traditional OC-192 SONET available, too
- ‘Sparse backbone’ topology
  - Each participant/node typically commits $5M
  - Concurrent responsibility for developing optical networking capabilities and sustaining performance in nodal region

NLR's 'Virtuous Circles' and the Vital Role of Dark Fiber



Next steps for Internet2 and U.S. R&E optical networking development

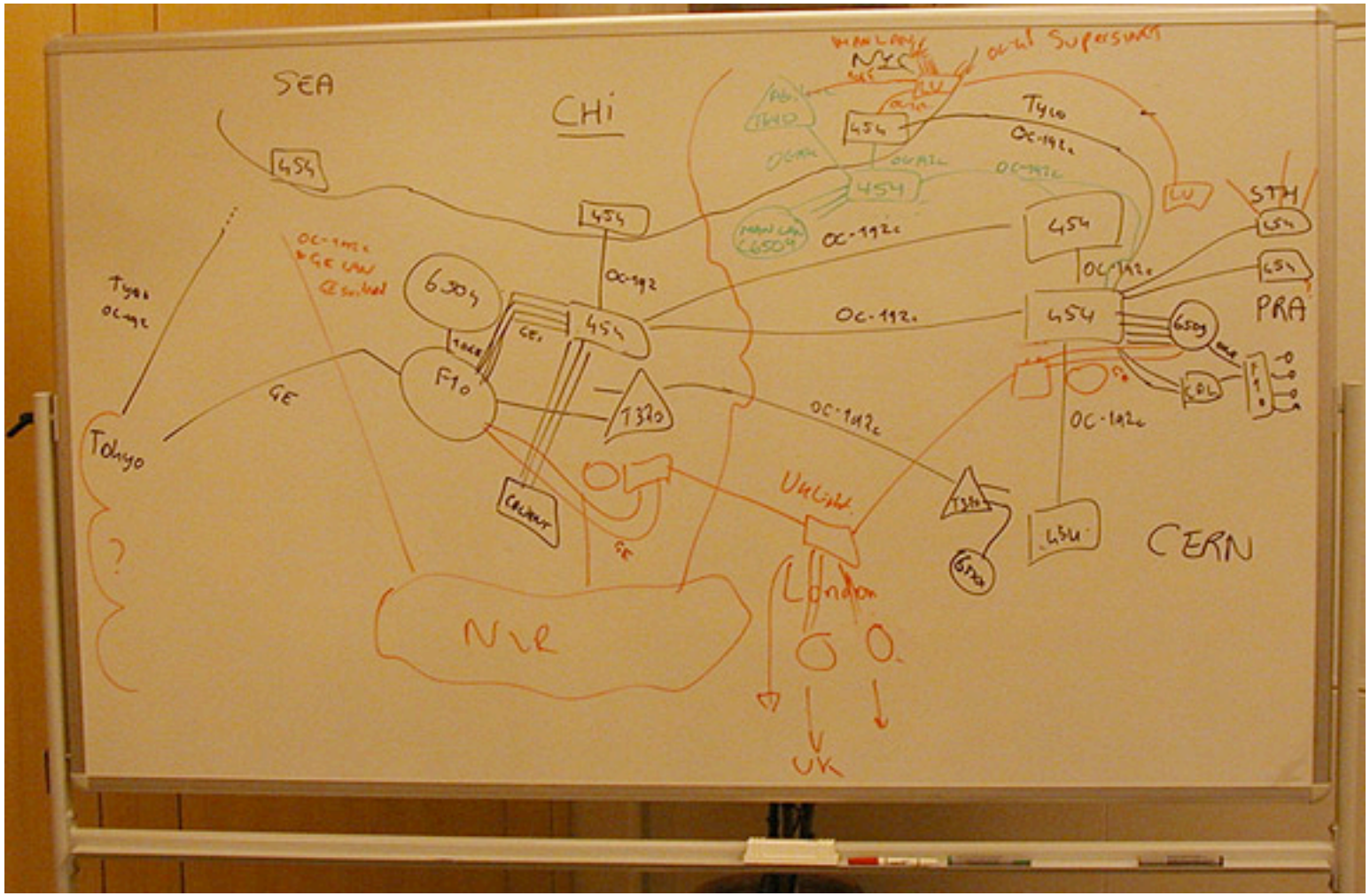
Overview of U.S. advanced networking environment

- Despite last two years of debate, an incredible amount has been achieved:
  - A novel, national, *facilities-based optical network* - **NLR** – has gained critical mass and is being deployed.
  - A major corporate partner - **Cisco** - has made a substantial *reinvestment* and has encouraged us to *reengage the researchers.*
  - **USA Waves** is on the verge of a *major fiber donation* and has given us a *conceptual model* for carrier-based, incremental pricing for □'s
  - *Over 10,000 miles of dark fiber* have been acquired by the community for *national and regional optical networks* by **CENIC**, **FiberCo**, and others.
  - The **Abilene Network** has been *upgraded* to a 10-Gb/s backbone and supports the research university community through initiatives such as *IPv6 deployment* and the *Observatory*.

Global Lambda Integration Facility (GLIF)

- Ongoing effort to build dedicated *lightpaths* (circuit switched sub- λ's) between HPC resources internationally
  - StarLight (Chicago), CA*Net (Canada), SURFnet (The Netherlands) are established leaders
  - NORDUnet (Scandinavia), Czech Republic, Japan active
- Internet2 now proposes to enter this effort
  - Now placing an optical Ethernet/SONET multiplexer (Cisco 15454) in the MAN LAN facility in New York
  - Planning to move the 10-Gb/s IEEAF/Tyco λ (NYC-Amsterdam/SURFnet) from Abilene NYC router to MAN LAN optical TDM
  - Will interconnect with CA*Net GLIF effort in NYC
  - Also will interconnect with Abilene and MAN LAN Ethernet-based international R&E exchange

The current state of the GLIF Reykjavik, August 2003



Emerging dedicated capability options in the U.S.

- Abilene: MPLS tunnels over 10-Gb/s IPv4/v6 backbone
- NLR: Gigabit Ethernet VLAN service over one 10-Gb/s □
- I2□ NLR: multiplexed circuits over one 10-Gb/s □
- NLR: individual 10-Gb/s □'s
- FiberCo: dark fiber route-miles

Towards a hybrid optical/packet infrastructure

- Need to converge the two worlds
  - Sustaining dependable flows in the 10-Gb/s range over shared IP networks may be difficult due to transport and security problems
  - Scaling the current GLIF optical/TDM networking model beyond a limited number of sites will definitely be difficult
  - Dedicated capabilities do provide a vehicle for testing (e.g., advanced transport technologies) and very high-end requirements
  - Potential end-states:
    - Shared IP networks with lambda resources dynamically balanced and optimized to meet changing needs
    - Dedicated lambda (or subrate lightpath) resources visible to high-end applications in response to application demands
    - Hybrids (but of what nature?)

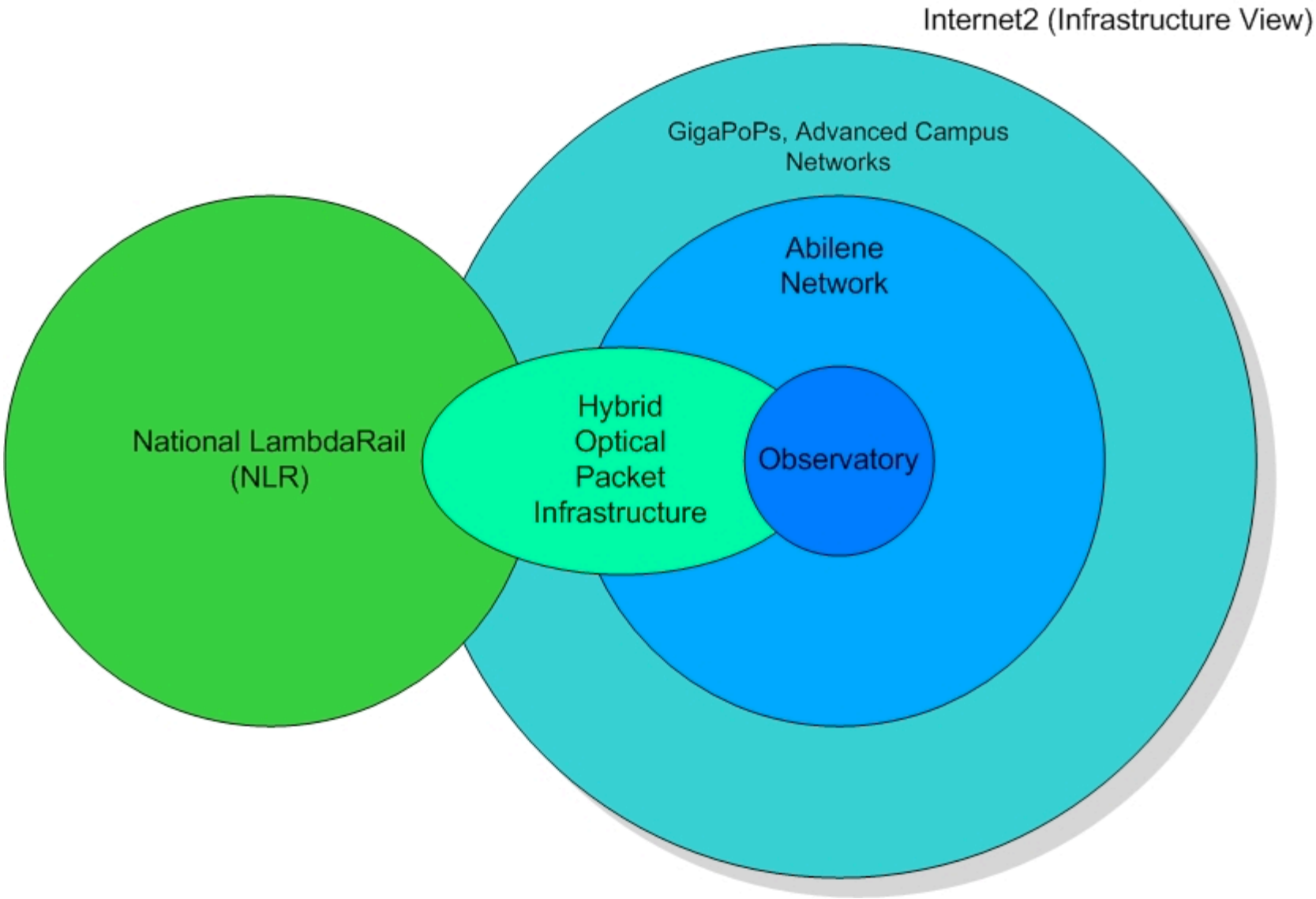
HOPI: raw materials new service models

- Abilene high-performance IP network
  - Capabilities for MPLS tunnels
- 10-Gb/s over full NLR footprint
  - Details
    - 5-year commitment
    - Likely 10 GigE framing (in lieu of OC192c SONET)
  - Expect some type of ‘TDM’ infrastructure to be provisioned by Internet2 in collaboration with NLR
    - Additional capital investment required
- Tie points for international collaboration
  - MAN LAN (NYC) and IEEAF (NYC-Amsterdam)
  - StarLight collaboration (Chicago)
  - Expect similar capabilities to emerge in Seattle (Pacific Wave)

HOPI next steps

- Convene a HOPI design team
  - Focused on both architecture and design
  - Leverage the set of available 'raw materials'
  - Objective: Short-term trials lead to scalable long-term hybrid architecture
  - Assembling a team of advanced practitioners and experienced standards body (IETF, OIF) participants
  - Academic and industrial representations
  - Target for deliverables: early 2004
- Can be viewed as a prelude to the process for the 3rd generation Internet2 network architecture
  - 2005-2006 time frame for implementation
  - In the interim, we will observe the SURFnet process carefully

One view of the NLR – Internet2 relationship



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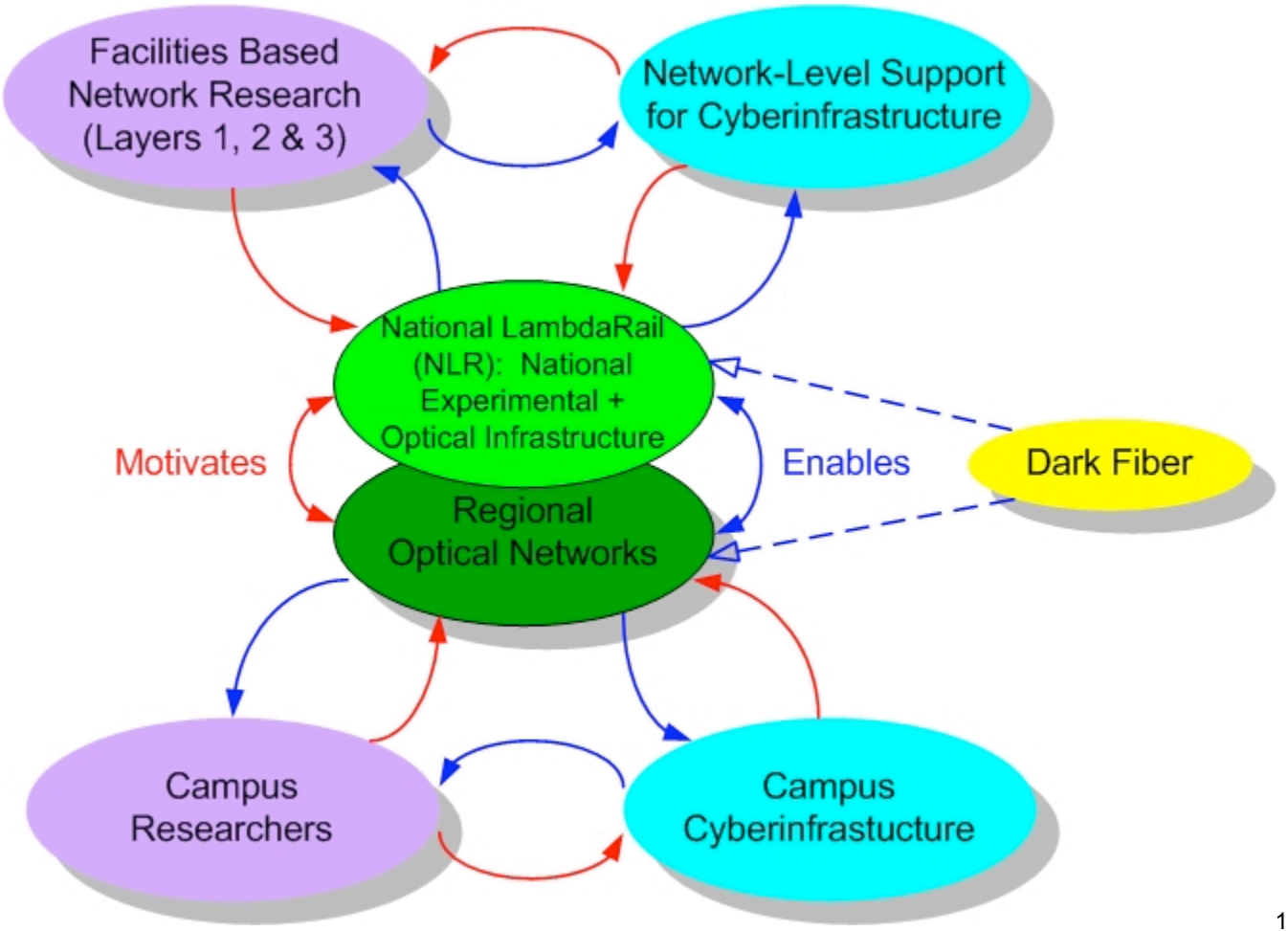
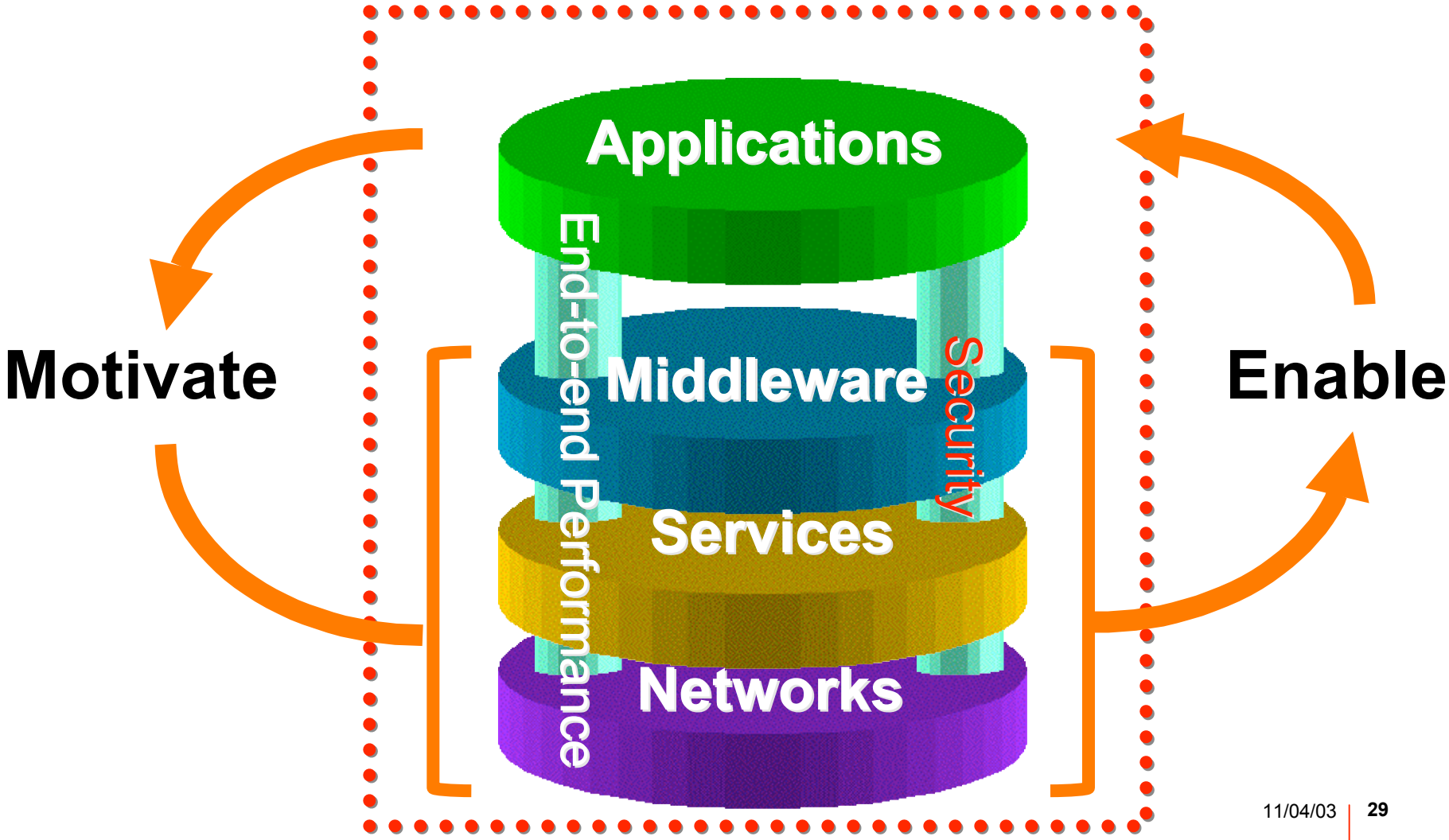


Internet2 Today



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