Eric Boyd, Internet2

Senior Director, Strategic Projects

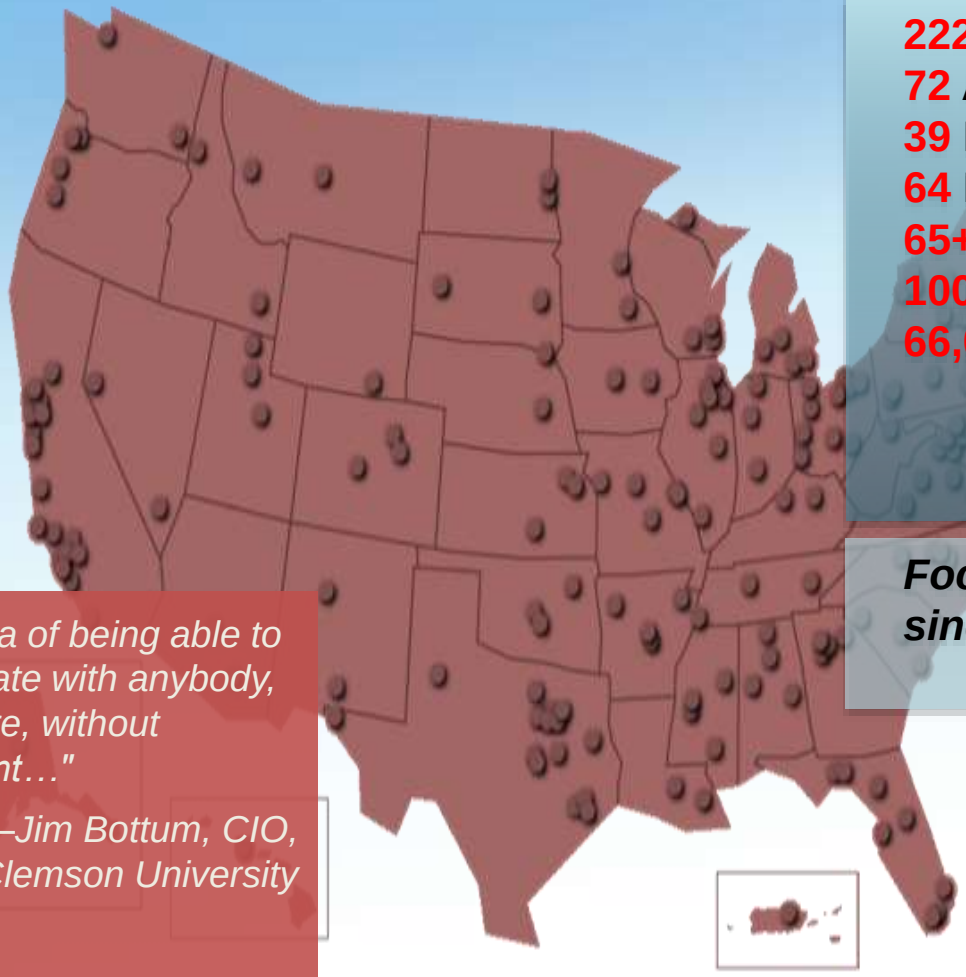
A CHALLENGE TO THE RESEARCH AND EDUCATION COMMUNITY: ENABLING INNOVATION THROUGH ADVANCED NETWORKING


What will global innovators do with the next Innovation Platform?
INTERNET 2®

The Internet2 Community: An unparalleled human network

- Internet2 brings together thought leaders from member organizations and the broader research and education community
- Our community advances frontiers of network-enabled applications
- Our community accelerates innovation and enables transformation

Internet2 Members and Partners



222 Higher Education members
72 Affiliate members
39 R&E Network members
64 Industry members
65+ Int'l partners reaching over
100 Nations
66,000+ Community anchor institutions

Focused on member technology needs since 1996

"The idea of being able to collaborate with anybody, anywhere, without constraint…"

—Jim Bottum, CIO, Clemson University

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Services “Above the Network”

Services at scale—leveraging the advanced network, identity management infrastructure, and market power of the R&E community

Services delivered globally—leveraging Internet2 R&E partnerships around the globe

Service model transformation—tailored for R&E, fundamentally changing the way higher education and industry do business in the cloud

Internet2 NET+

A community partnership that’s grown from **2 services** and **13 campuses** to **38 services** and **333 campuses**!

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Growing Ecosystem of NET+ Service Providers

"Taking the best solutions in the community to all of research and education."

—Shel Waggener, Senior Vice President, Internet2

All the power of the Internet2 community—delivered to community anchor institutions across the country

Creating new innovation opportunities

begins with understanding what enabled innovation in the past

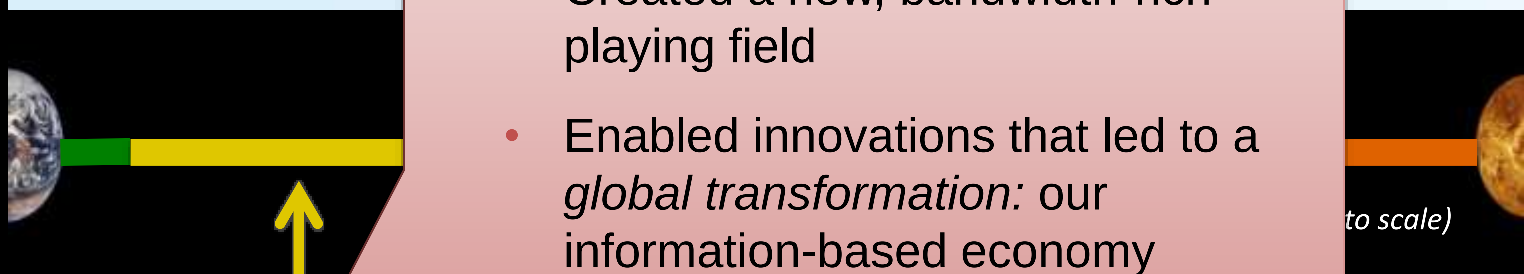
- The research and education community played *a seminal role* in the creation of the modern Internet and the applications that have made it *the most transformative technology* of the last hundred years
- 34 of these leading universities created Internet2 in 1996

R&E networking ROI has been staggering

Total 30-year federal investment to enable the precursors of the Internet is very sma
businesses it spa

Earth 3963 mi

Venus



ARPAnet,
CSNET &
NSFnet
< $250 million
total
investment

Cont
eco
o
NNMoney,

Hamilton Consultants, 2009)

These seminal investments

- Put the R&E community "way out in front" of commercial markets
- Created a new, bandwidth-rich playing field
- Enabled innovations that led to a *global transformation:* our information-based economy

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*

Birth of the commercial Internet

"packet networks won't be as reliable as circuit networks"

"this decentralized model can't scale or be manageable"

Despite all arguments, the Internet, created by the R&E community, became the de facto standard

An observation

1.5 Mb – 100 Mb

innovation accelerates
R&E out in front

Ethernet introduced in R&E

VoIP

Browser & WWW

Search

Chat

Video

Theme in this era is investment and positioning for the future

about our past

100 Mb – 10 Gb

innovation slows
R&E leadership fades

Uncompressed video

Large data exchange

Theme in this era becomes aggregation, cost savings, efficiency, competition

and the future

10 Gb – 1Tb Gb

innovation opportunity where is R&E?

?

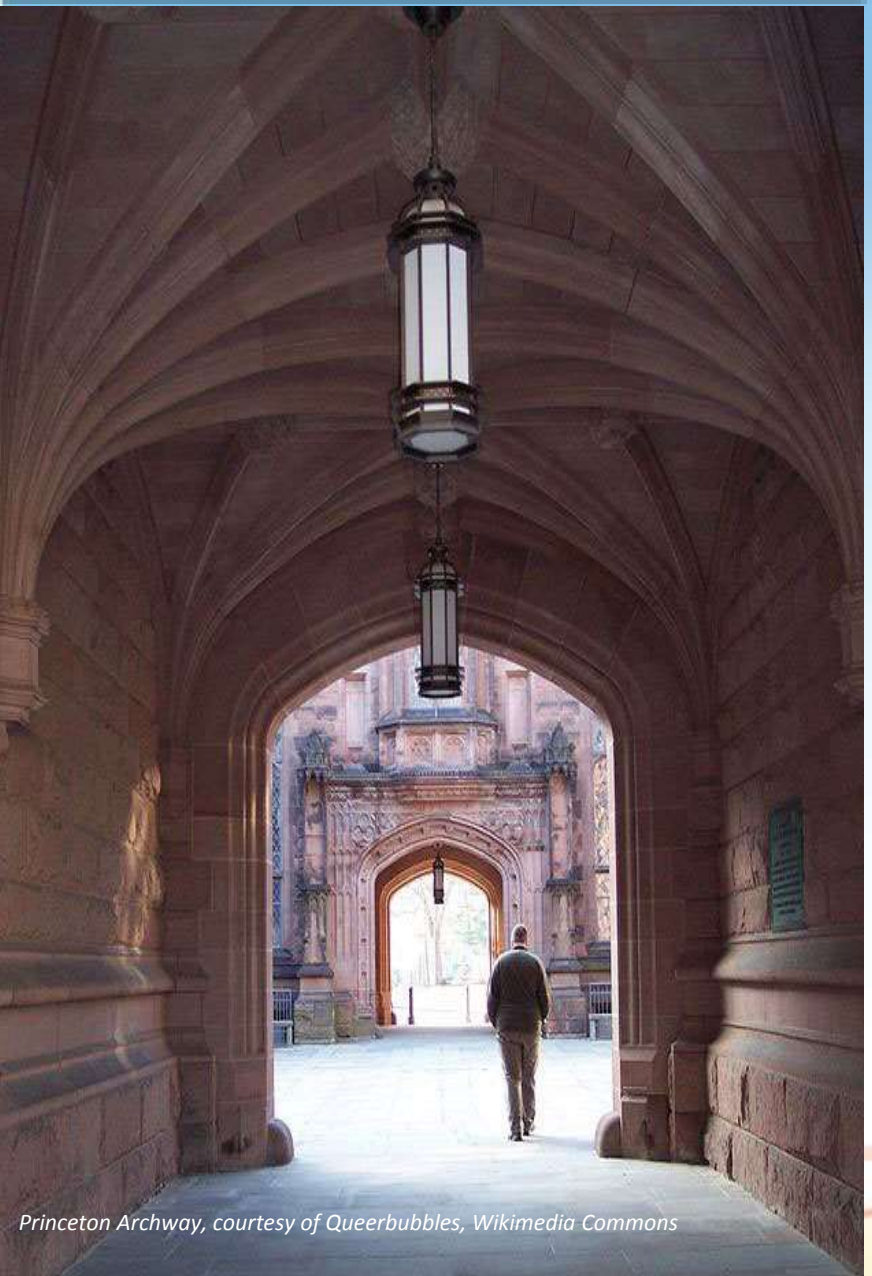
Big data

?

SDN

What will the theme of this era be?

Birth of the commercial Interne



Princeton Archway, courtesy of Queerbubbles, Wikimedia Commons

- Many technologies have roots on university campuses and networks that connect them
- Personal Ethernet services in an era of dial-up and 9.6 lines created massive campus "innovation test beds"
- Push to open "standards," abundant bandwidth, removing constraints sparks innovation

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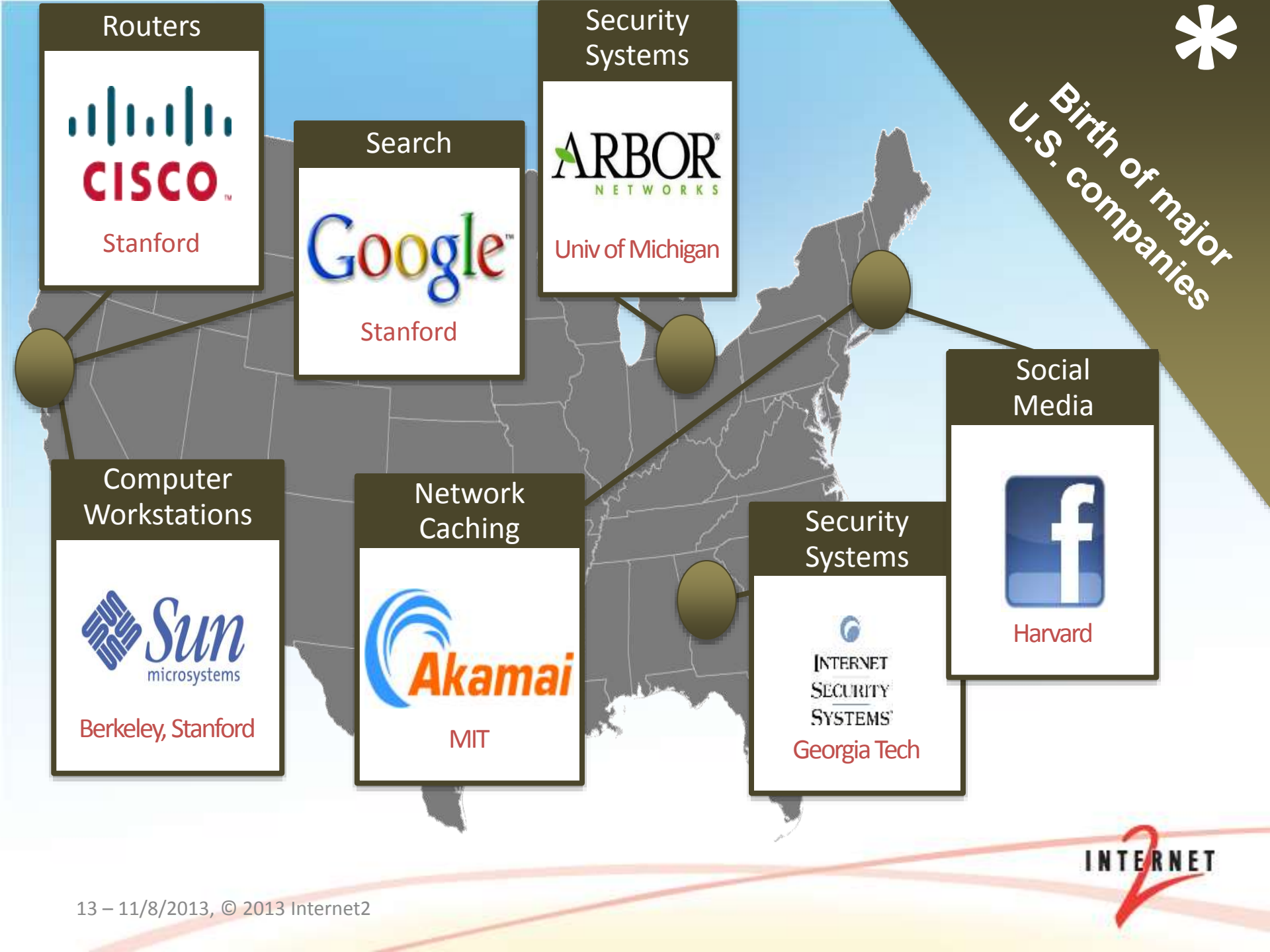
Routers
CISCO
Stanford
Search
Google
Stanford
Security Systems
ARBOR NETWORKS
Univ of Michigan
Birth of major U.S. companies
Social Media
Harvard
Computer Workstations
Sun microsystems
Berkeley, Stanford
Network Caching
Akamai
MIT
Security Systems
Internet Security Systems
Georgia Tech
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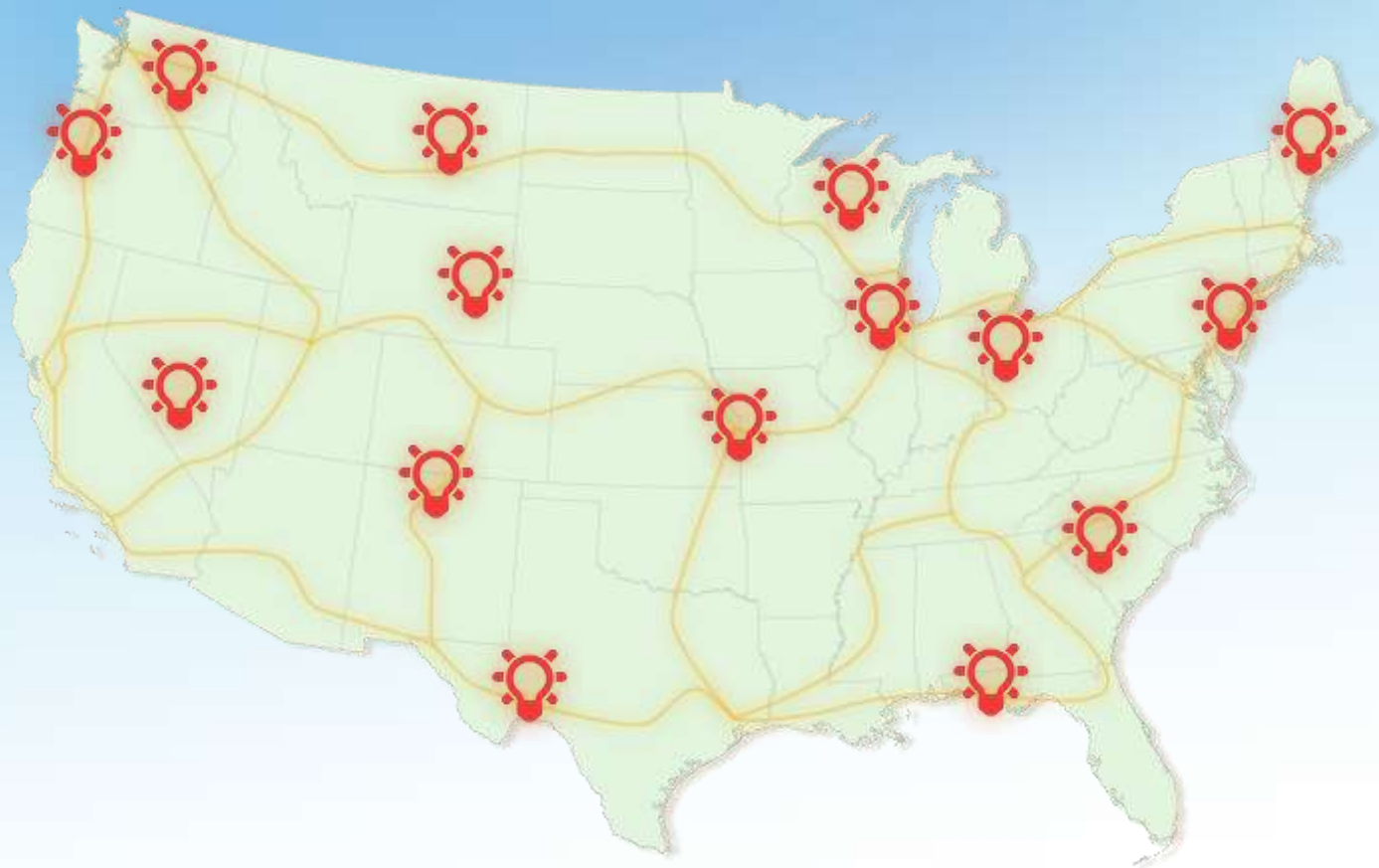
2013 Internet2 Innovative Application Awards



GOLD

Juniper Networks

SILVER

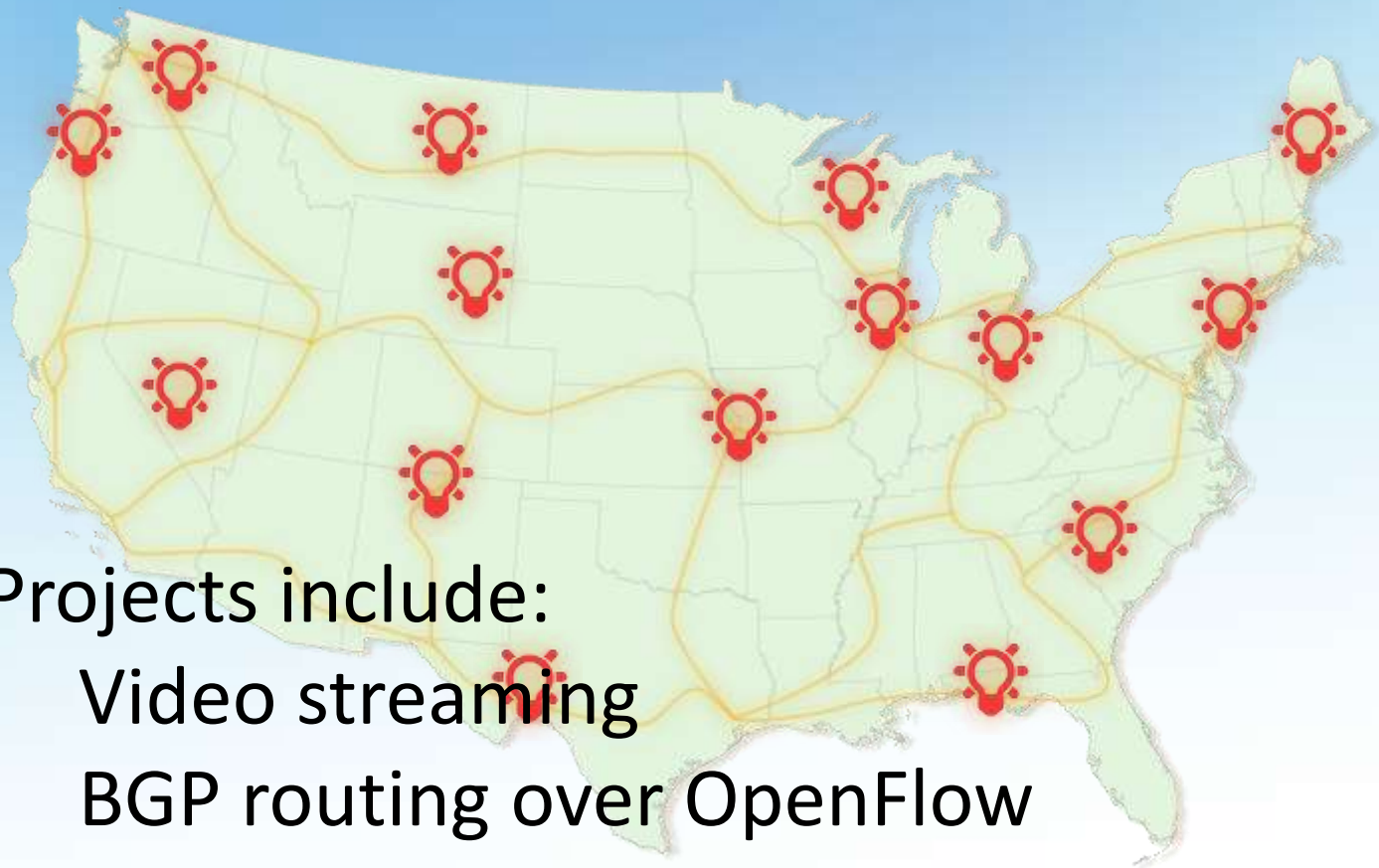
ciena

BRONZE

Brocade

Internet2

2013 Internet2 Innovative Application Awards



GOLD

Juniper Networks

SILVER

ciena

BRONZE

BROCADE

Projects include:

- Video streaming
- BGP routing over OpenFlow
- SDN for Exchange Points
- GENI integration

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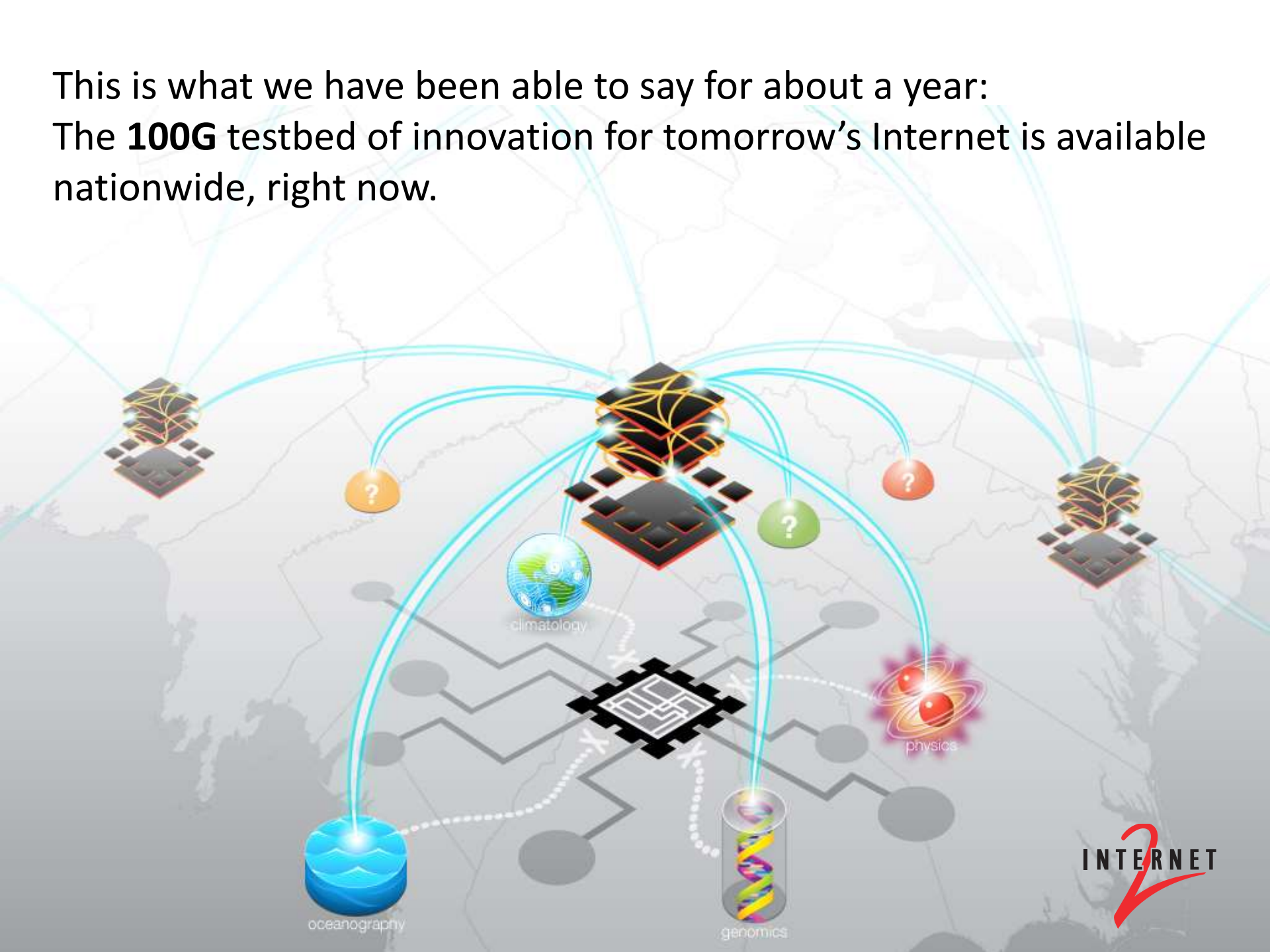
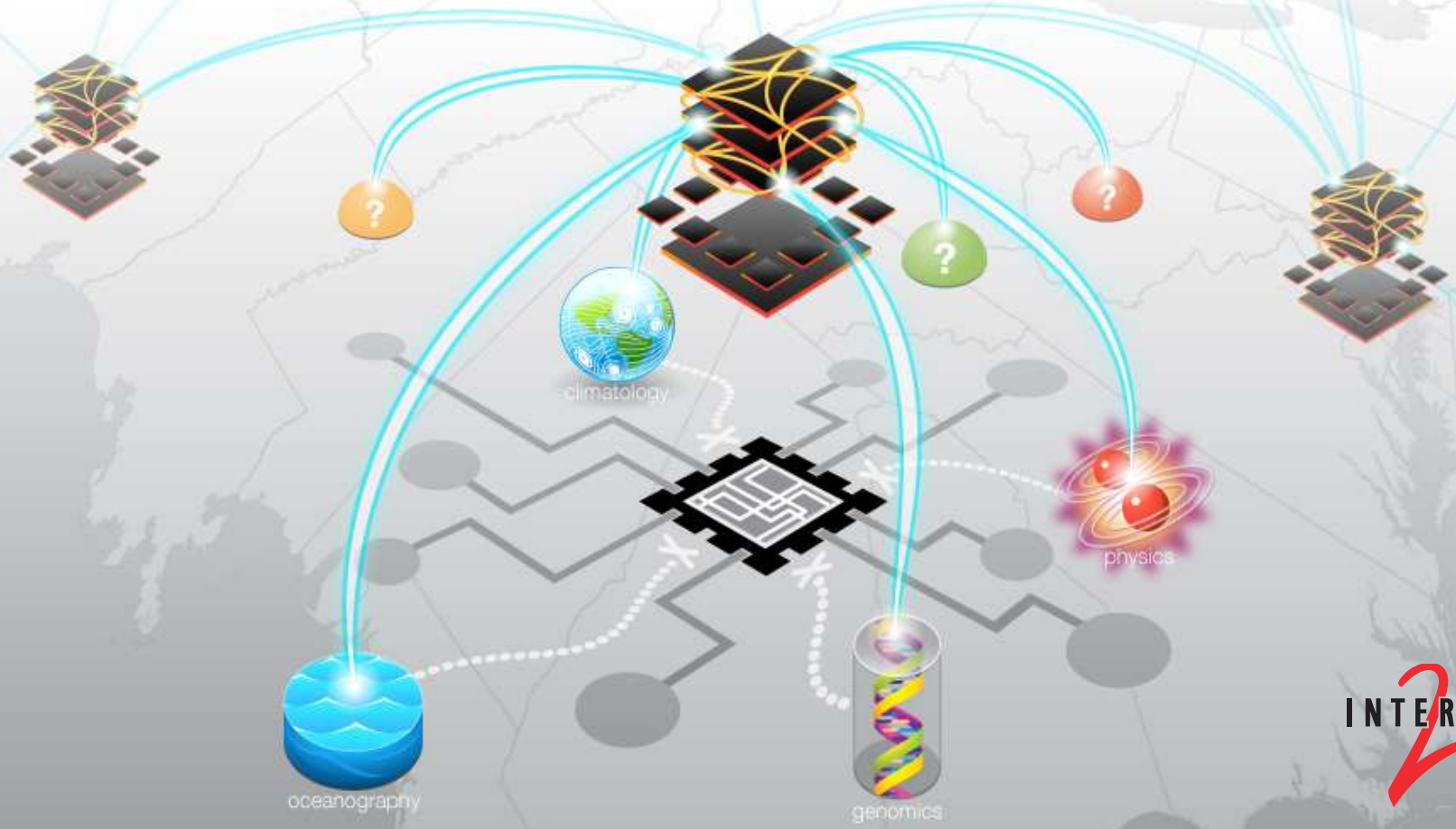
This is what we have been able to say for about a year:
The **100G** testbed of innovation for tomorrow's Internet is available nationwide, right now.

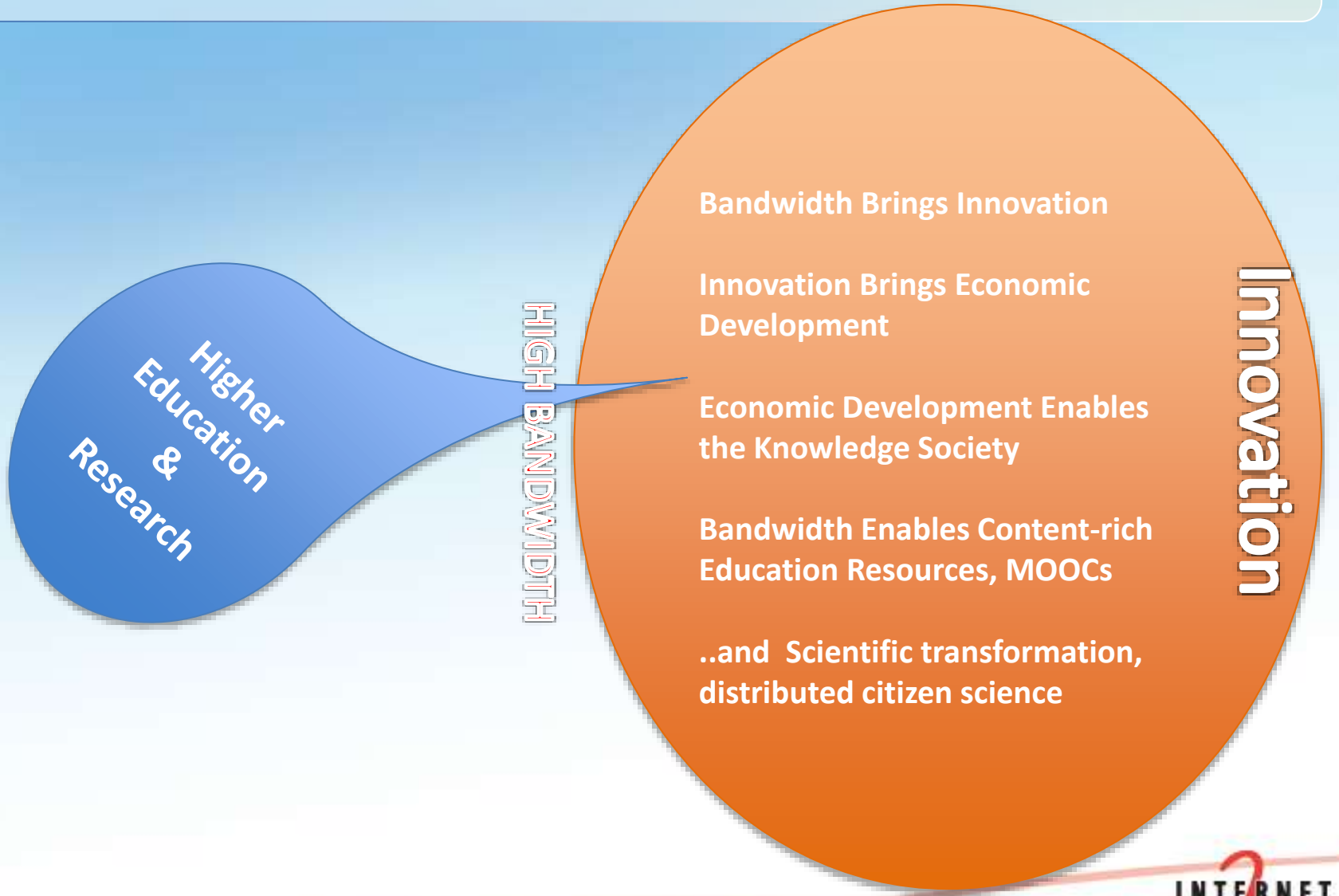


Does this create a platform for innovation?

- Abundant bandwidth to enable innovation?
- Programmability to encourage application innovation?
- Support data intensive science?



Broadband's Importance to R&E



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The *4th Gen* Internet2 Network

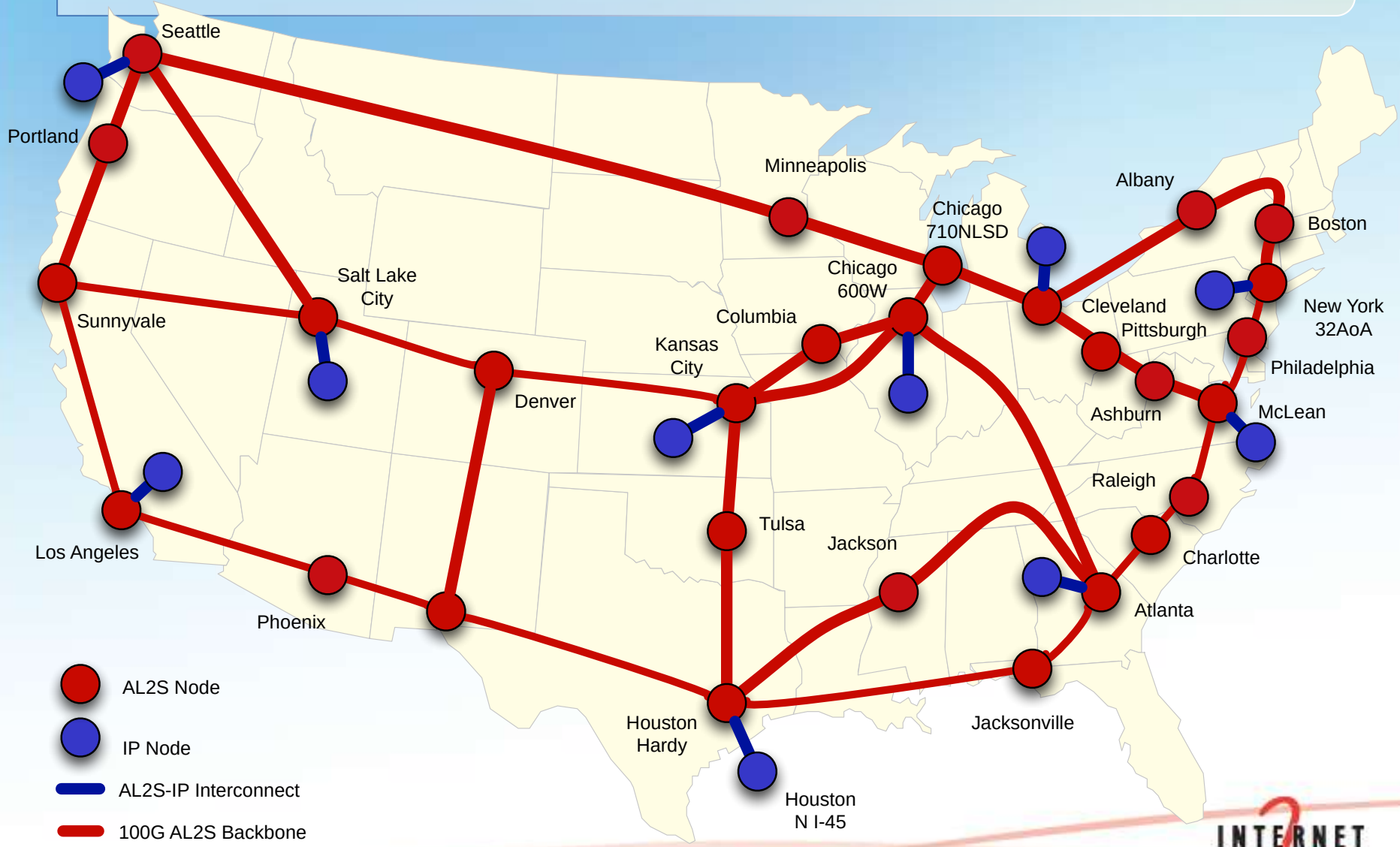
Internet2 Network
by the numbers

- 17 Juniper MX960 nodes
- 21 Brocade and Juniper switches
- 250+ amplification racks
- 15,717 miles of newly acquired dark fiber
- 2,400 miles of partnered capacity with Zayo Communications
- 8.8 Tbps of optical capacity
- 100 Gbps of hybrid Layer 2 and Layer 3 capacity
- 300+ Ciena ActiveFlex 6500 network elements

"It's the network that makes all of this possible."

—Michael McRobbie, President, Indiana University

Advanced Layer2 Service Deployment



How do we create an at-scale Innovation Platform for the next era?

Innovation Platform vision:

Abundant bandwidth

Innovation roadbloc

- Limited capacity a major barrier—*need more than incremental boosts*
- Too expensive and risky to try totally new approaches
- Closed approaches limit applications or use cases

Innovation route

- Raw capacity now available on Internet2 Network a key imagination enabler
- Incent disruptive use of new, advanced capabilities
- Promote “open” and creative freedom of use

Innovation Platform vision:

Software-defined networking (SDN)

Innovation roadbloc

- Proprietary software in routers and switches
- Communications with hardware limited by actual, physical, proprietary components
- Application developers have to use the network as prescribed

Innovation route

- Open up network layer to innovation
- Let innovators communicate with and program *the network itself*
- Allow developers to optimize the network for specific apps

Innovation Platform vision:

Support for data-intensive science

Innovation roadbloc

- One-size-fits-all approach to network data flows
- Lack of transparent performance monitoring solution
- No way to customize and optimize the network via SDN

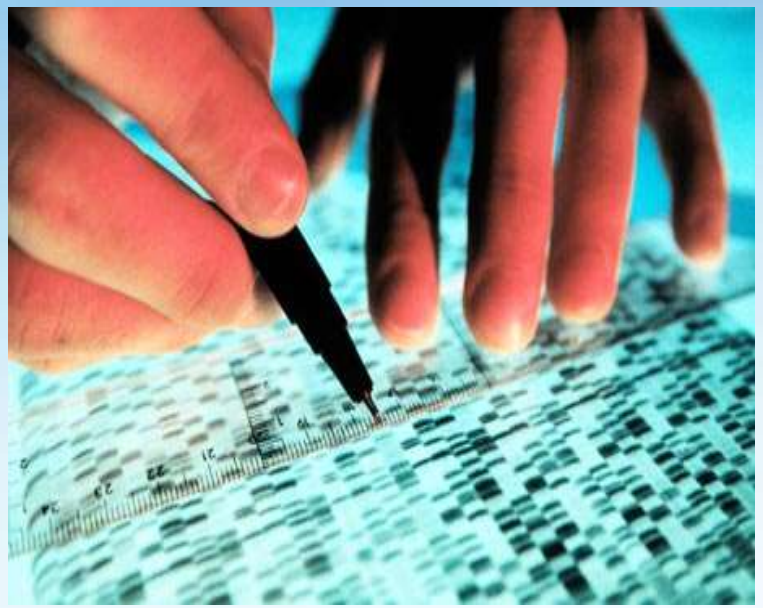
Innovation route

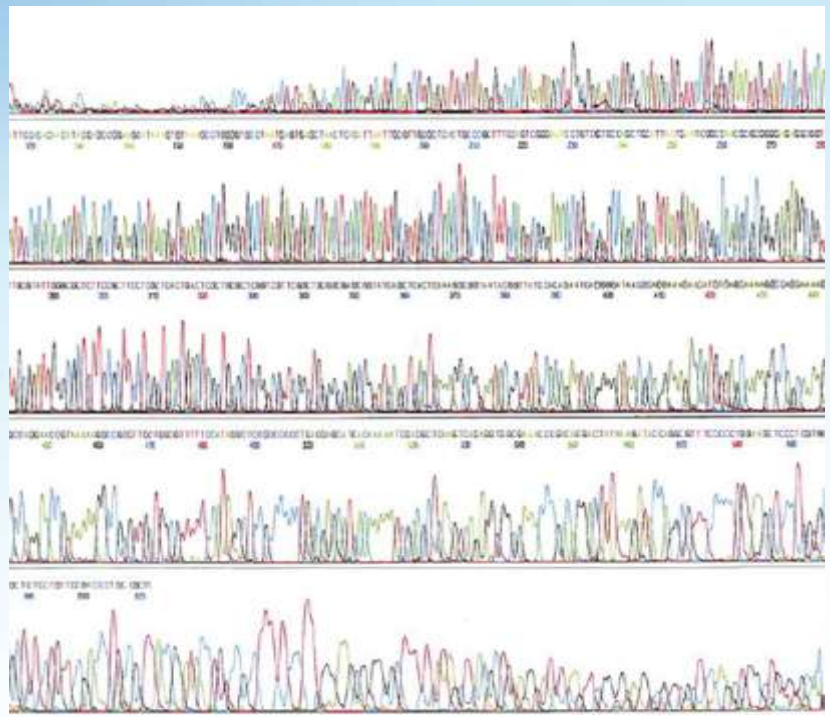
- Architect a special solution to allow higher-performance data flows
- Include end-to-end performance monitoring
- Include SDN server to support programmability

Innovation Platform Program Pilot Sites

Innovation Use Case: Genomics Analysis

How do we bring petabytes of distributed data to and from compute resources and correlate gene sequences to accelerate cures for disease?





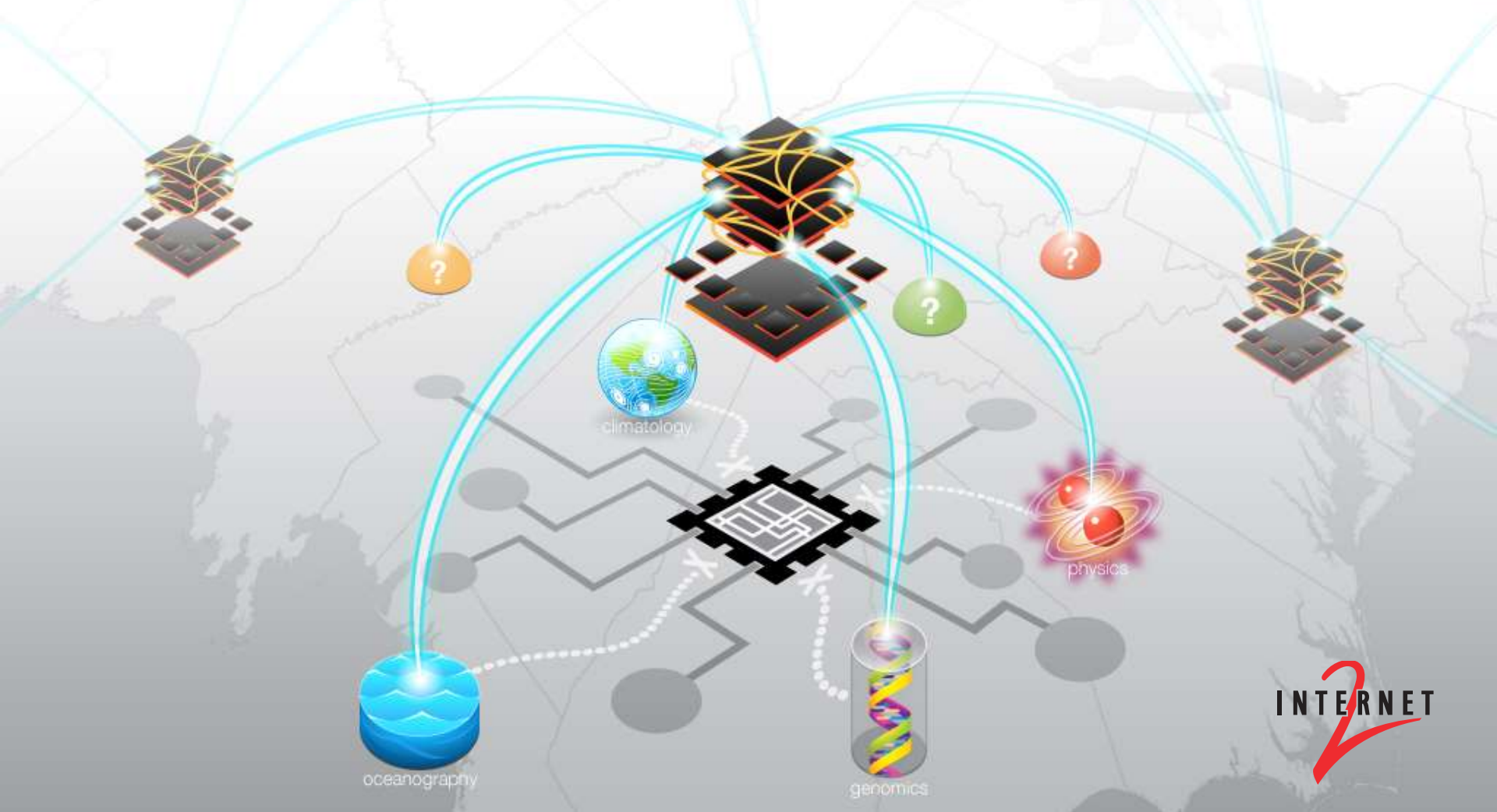
- Accelerated Bulk File Transfer of Massive File sets
- Content Distribution Caching / Distribution
- Clear Authorities & Health Security compliance
- High Performance Compute, Storage, Visualization

Does this create a platform for innovation?

Abundant bandwidth to enable innovation? ☑

Programmability to encourage application innovation? ☑

Support data intensive science? ☑



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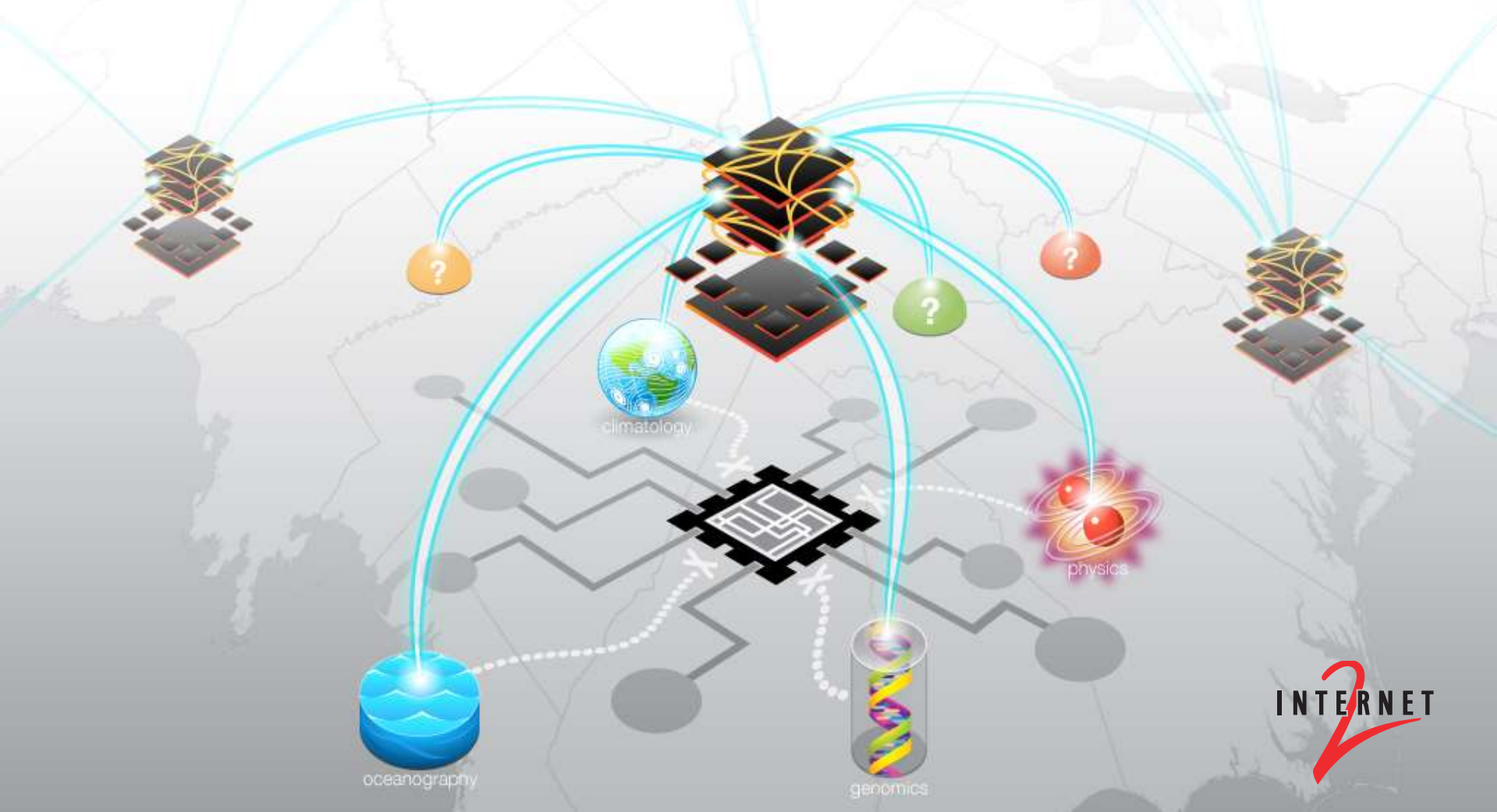

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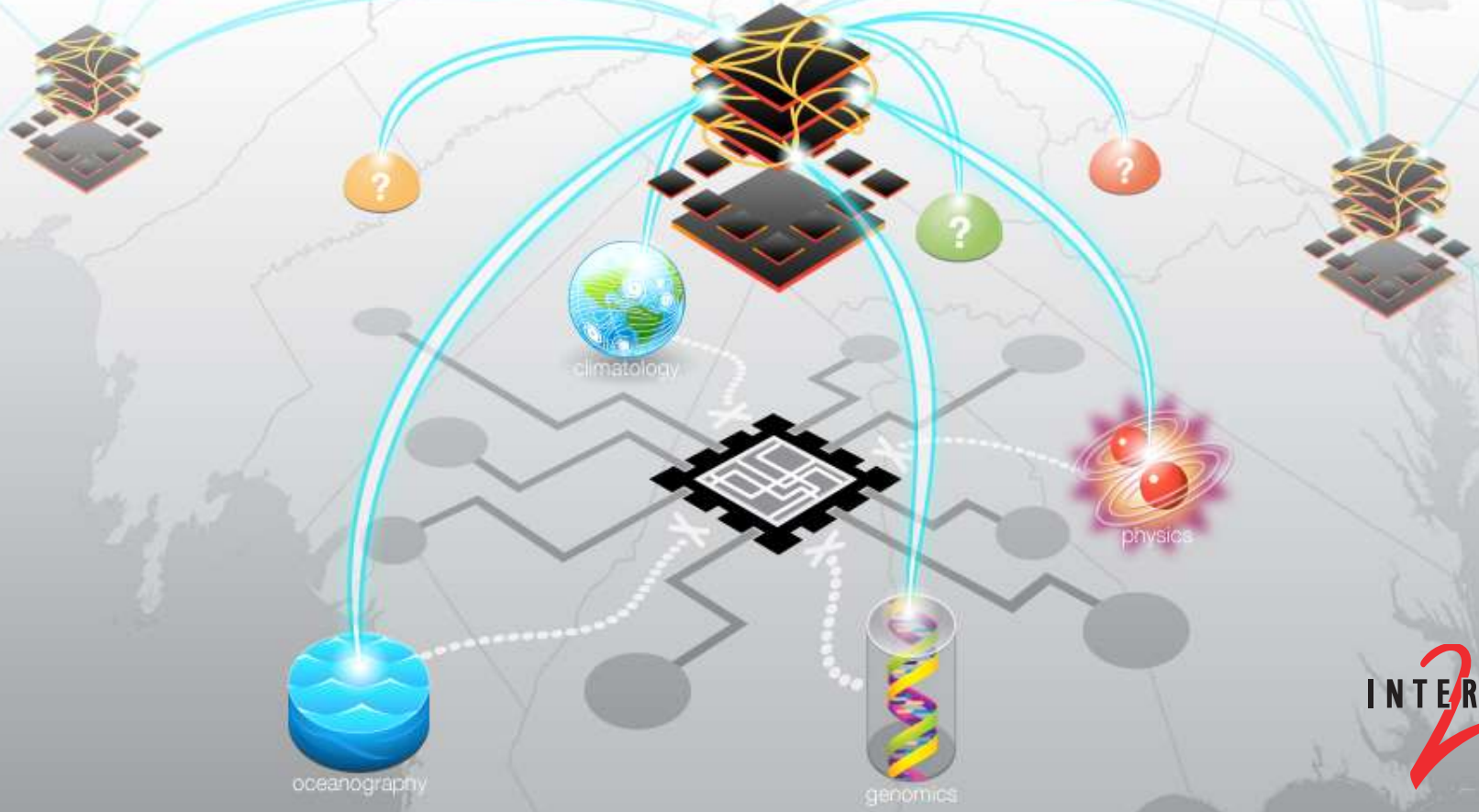
Does this create a platform for innovation?

- Abundant bandwidth to enable innovation? ☑
- Software-defined networking substrate? ☑
- Support data intensive science? ☑
- Virtualization? ☐
- Integrate network with compute and storage? ☐



INTERNET 2

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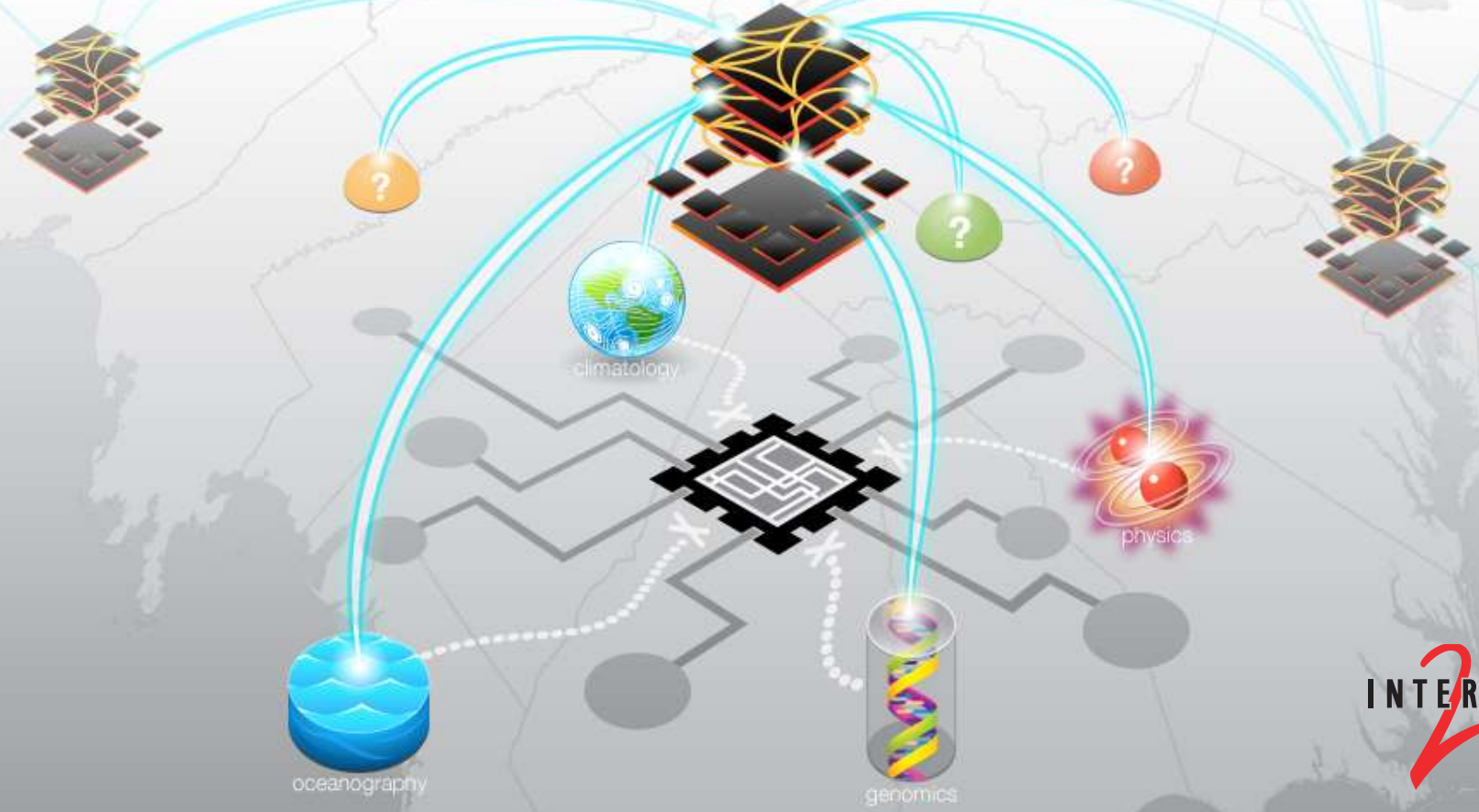
- Support data intensive science? ☑
- *Virtualization*? ☐
- Integrate network with compute and storage? ☐



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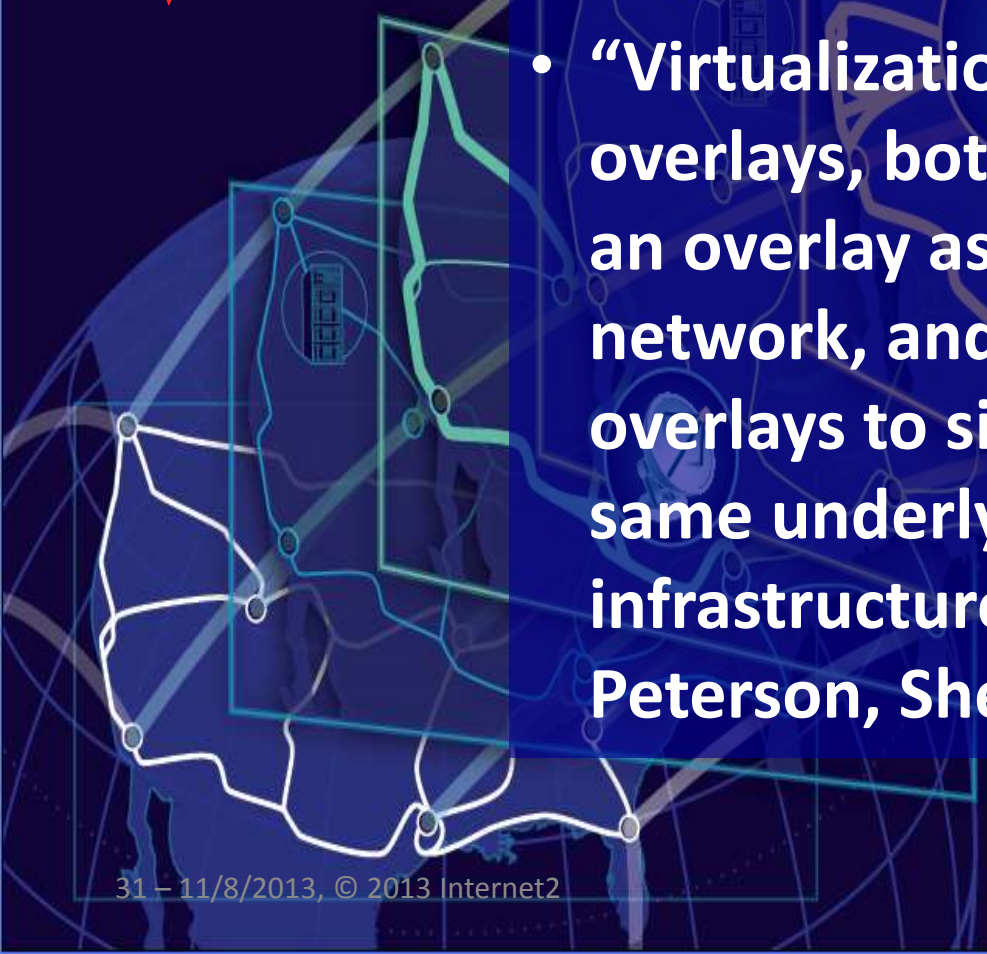
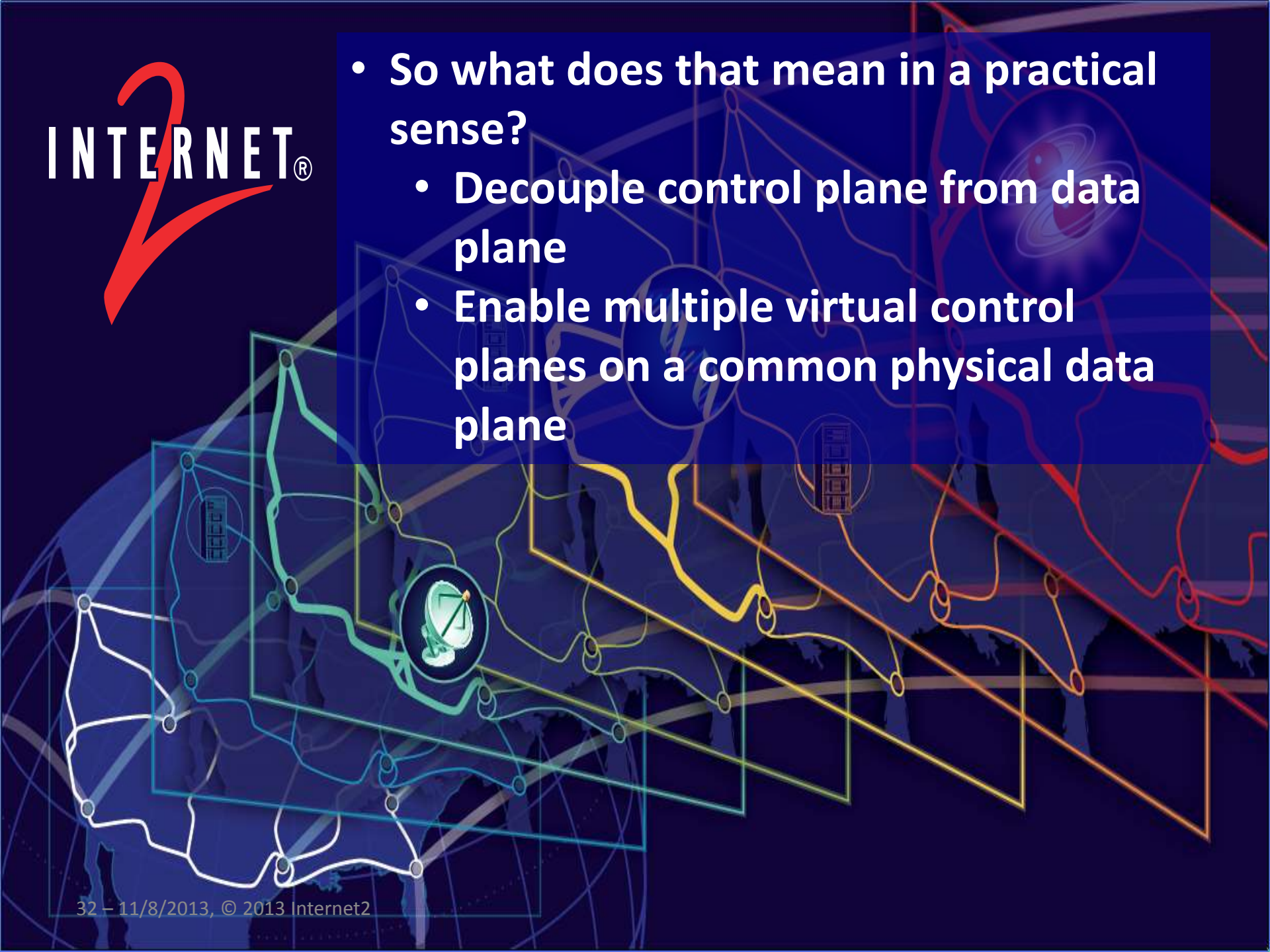
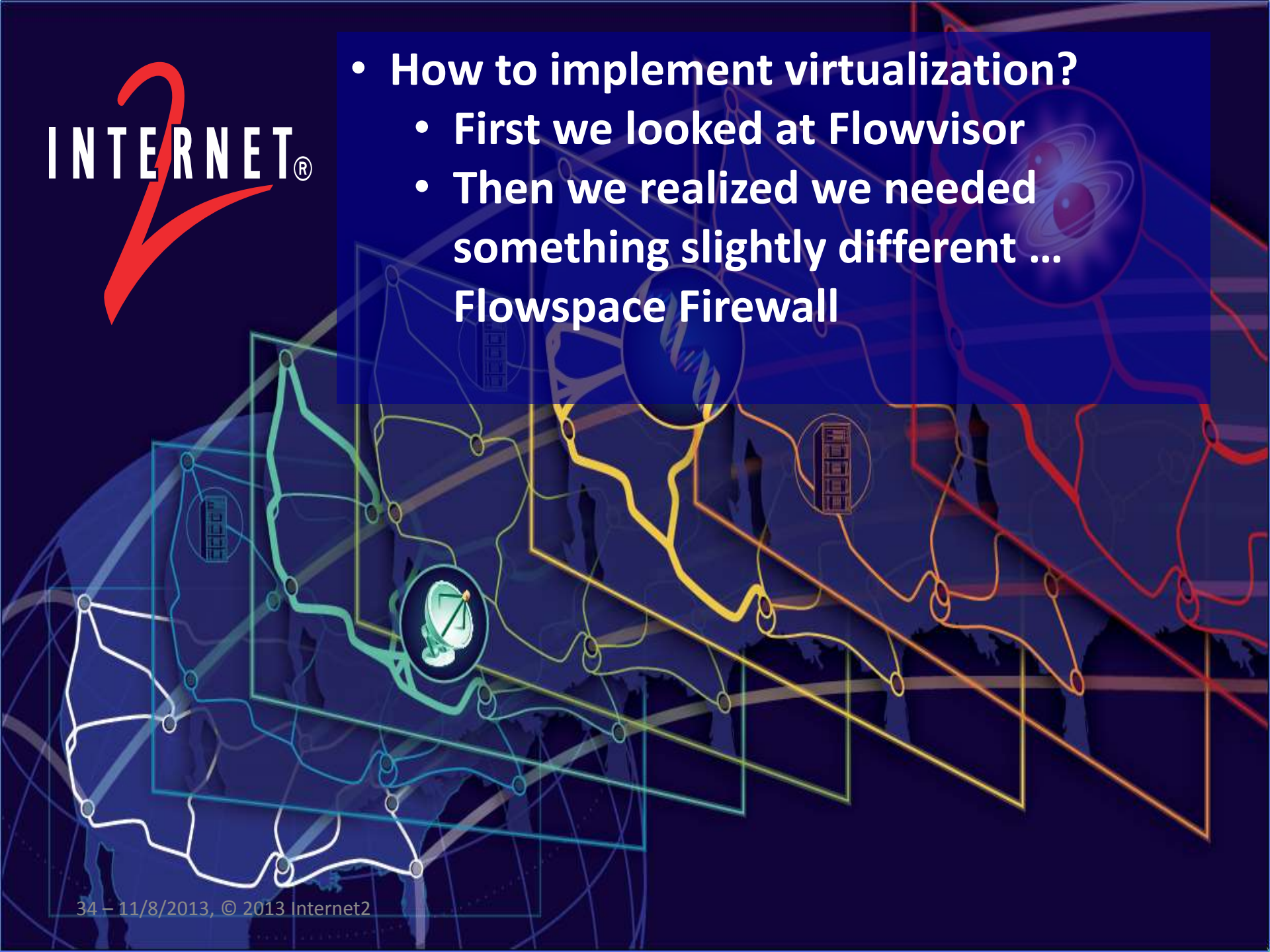
- We've had virtualization of storage and servers for quite some time
- How to define Network Virtualization?
- "Virtualization is the core principle in overlays, both allowing nodes to treat an overlay as if it were the native network, and allowing multiple overlays to simultaneously use the same underlying overlay infrastructure." (2004 – Anderson, Peterson, Shenker, Turner)



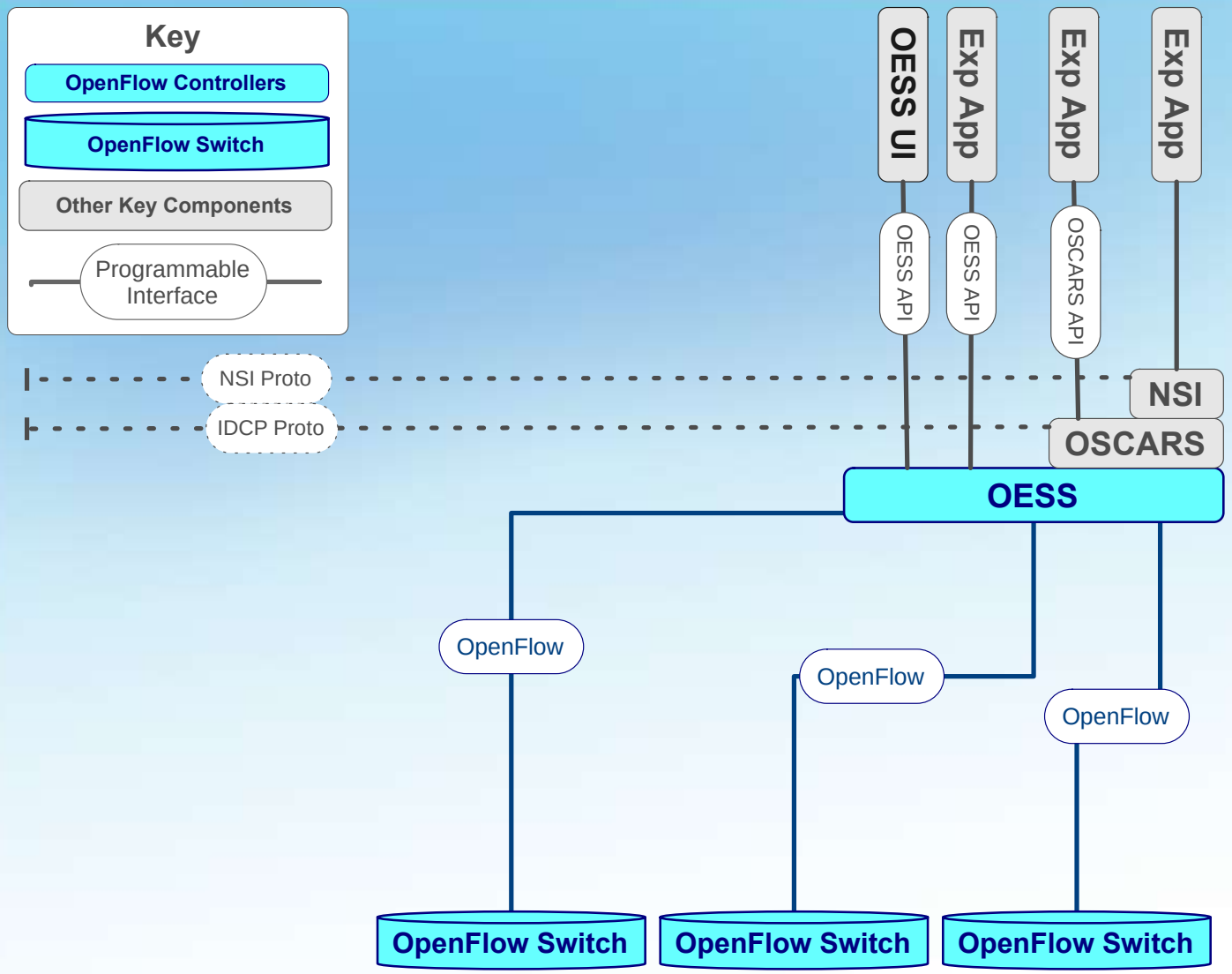


- So what does that mean in a practical sense?
  - Decouple control plane from data plane
  - Enable multiple virtual control planes on a common physical data plane

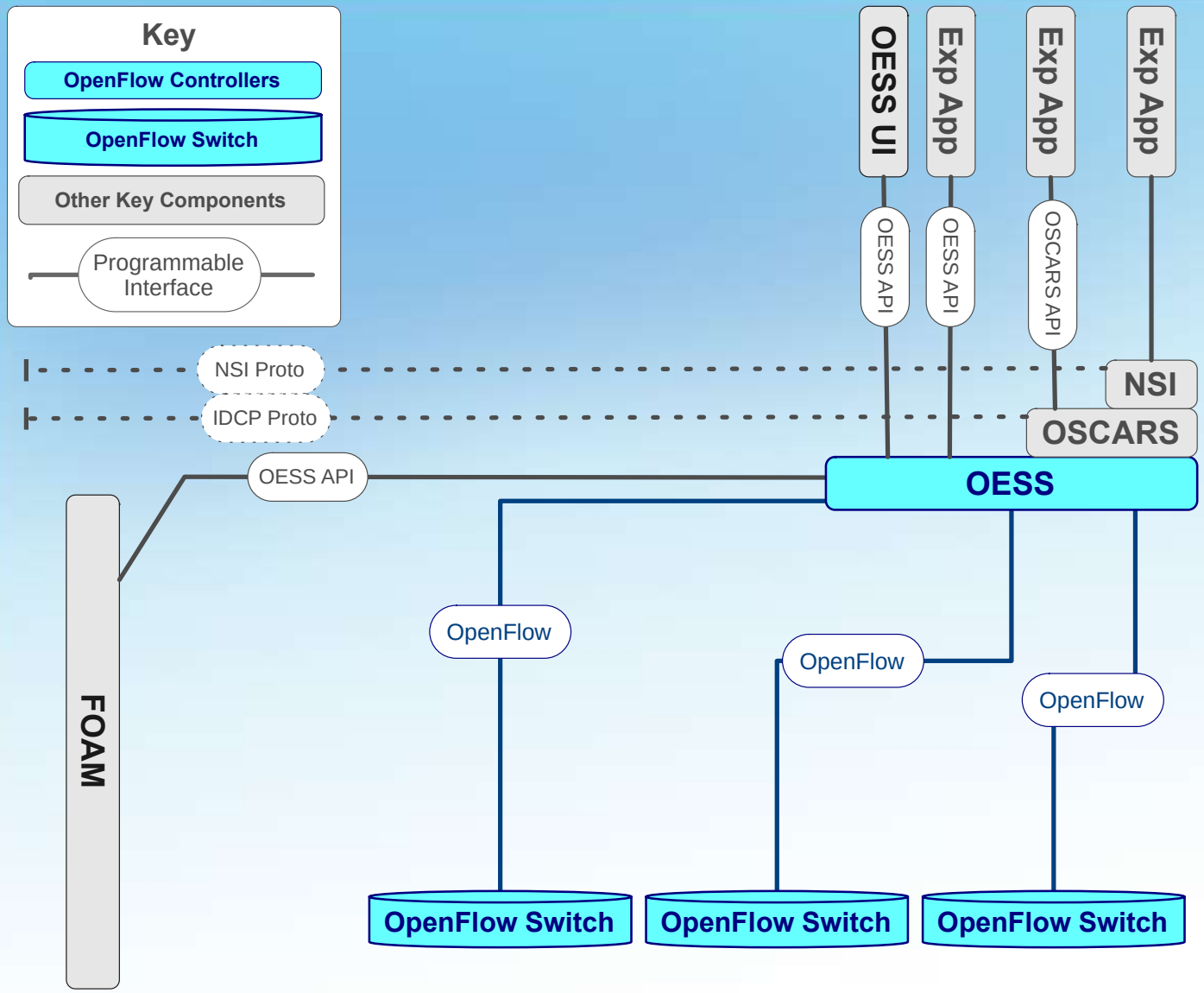
- Internet2 in partnership with Indiana University has been building / deploying an architecture to support network virtualization
  - Provide network multi-tenancy at Layer 2 and Layer 3
  - Enforce non-overlapping Layer 2 tag-based flowspace
    - Experiment Foo can use VLAN tag range 1-200 (a sliver)
    - Experiment Bar can use VLAN tag range 201-400 (a sliver)



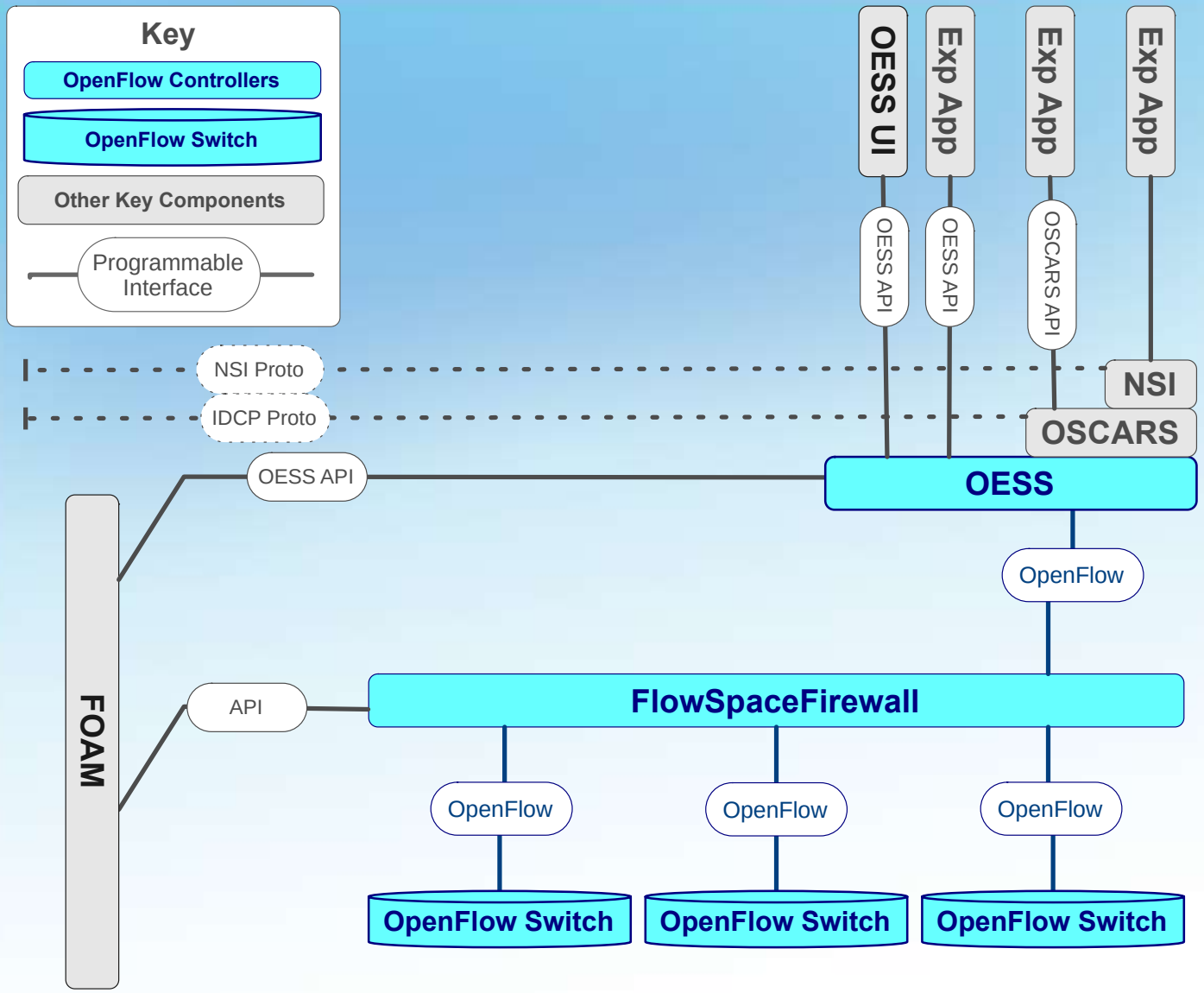
- How to implement virtualization?
  - First we looked at Flowvisor
  - Then we realized we needed something slightly different … Flowspace Firewall



AL2S Software Stack GEC17 Configuration

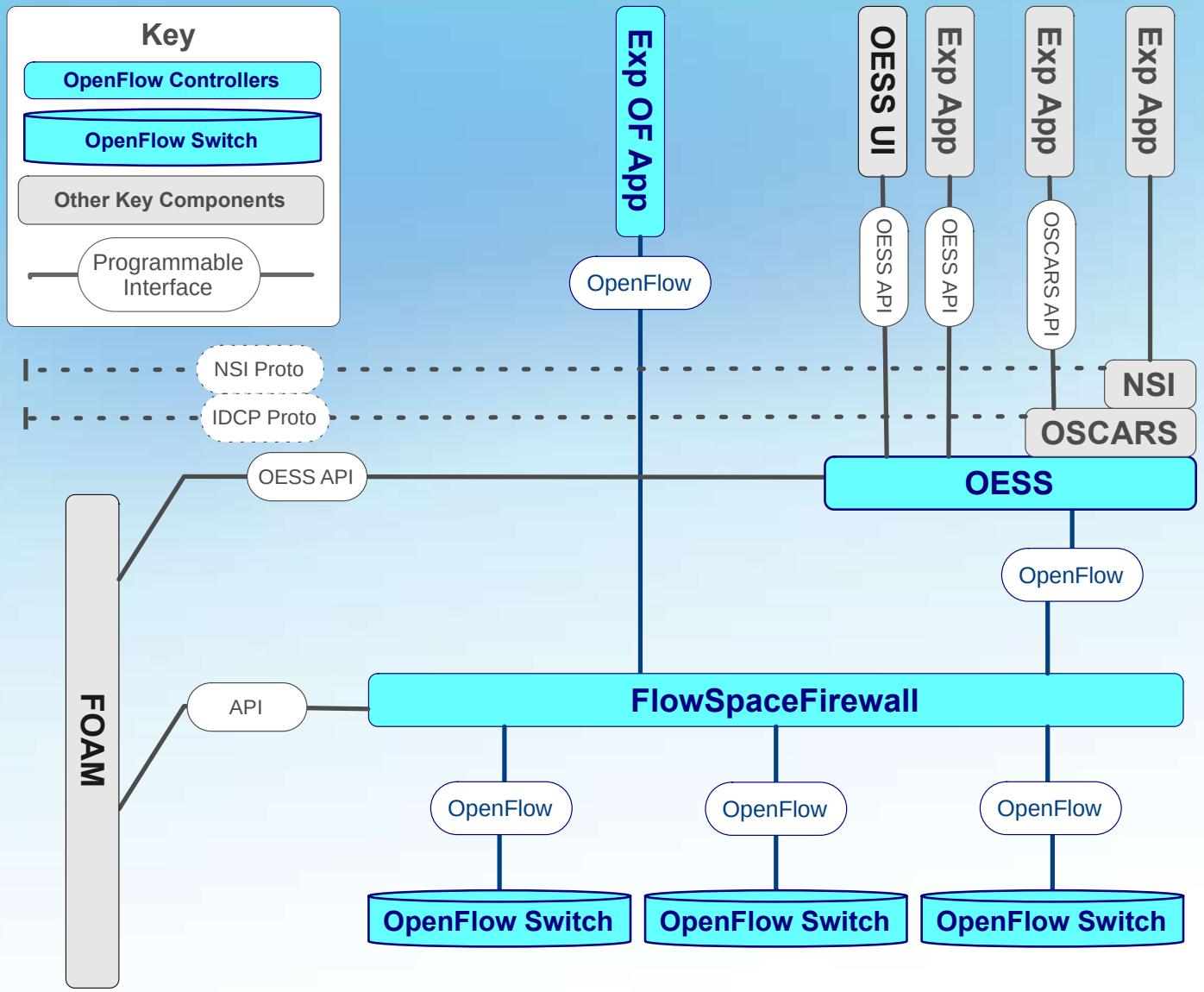


AL2S Software Stack GEC18 Configuration

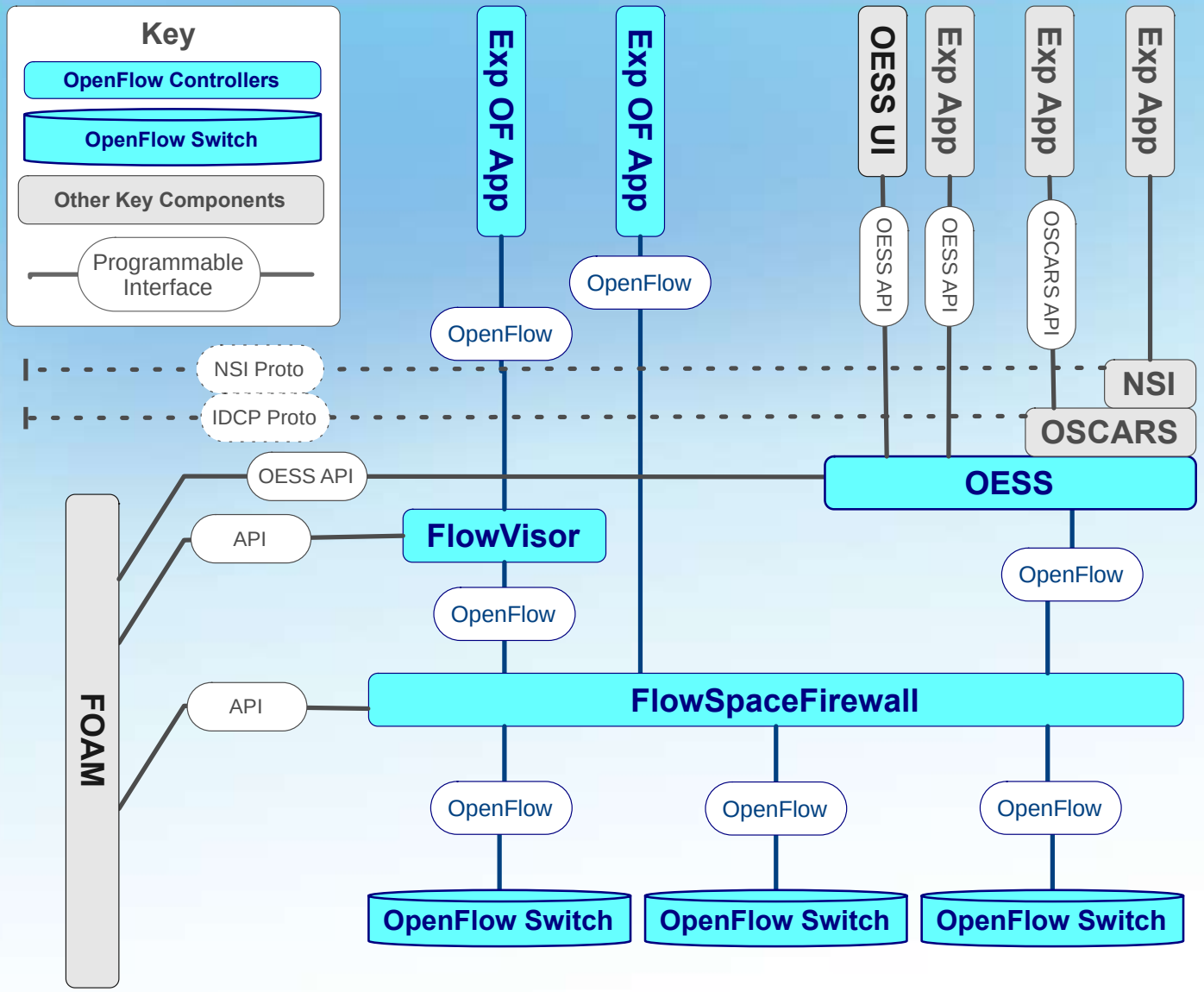


AL2S Software Stack Late Q4 2013?

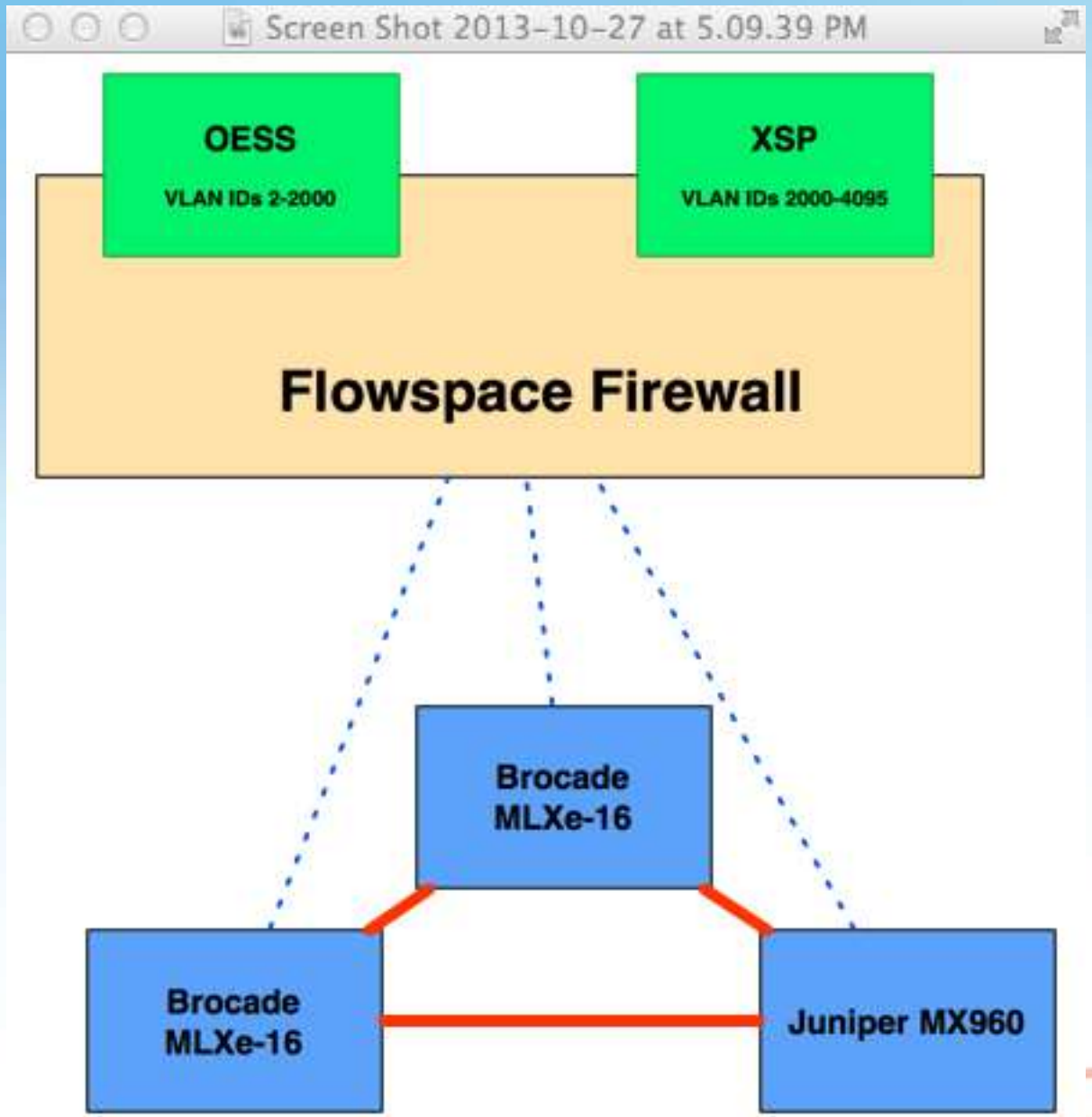
INTERNET 2



AL2S Software Stack Q1 Early 2014?



AL2S Software Stack Q1 Late 2014?


Screen Shot 2013-10-27 at 5.09.39 PM
OESS
VLAN IDs 2-2000
XSP
VLAN IDs 2000-4095
Flowspace Firewall
Brocade
MLXe-16
Brocade
MLXe-16
Juniper MX960

Circuit Details

https nddi-dev.bldc.net.internet2.edu/oess/index.cgi?action=view_details

Reader

OS3E The Open Science, Scholarship & Services Exchange

Documentation | Feedback | Admin

Workgroups > Home > Circuit Details

Workgroup: GEC

Summary

Description
test

Type	Bandwidth	Restore To Primary	Status	Owned By
Local	0 Mbps	Off	active	GEC

Edit Circuit

Remove Circuit

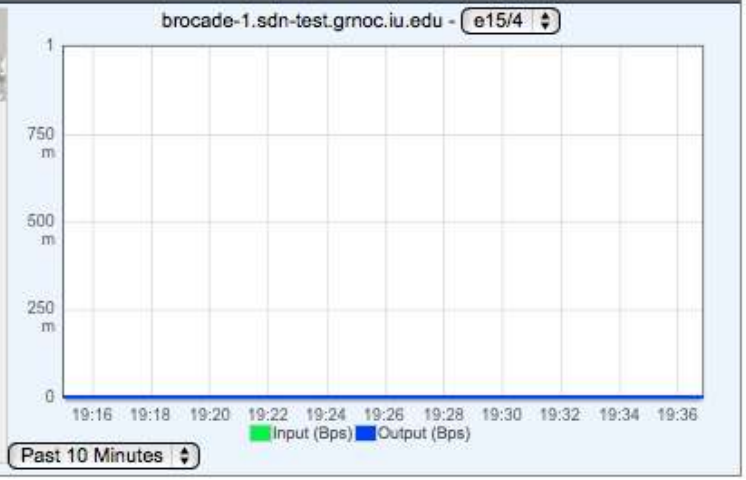
Change Path

Force Reprovision

Endpoints

Interface	Interface Description	VLAN
mx960-2.sdn-test.grnoc.iu.edu - xe-7/0/0.0	xe-7/0/0.0	200
brocade-1.sdn-test.grnoc.iu.edu - e15/2	e15/2	200

Utilization | History | Scheduled Events | Circuit Layout | Circuit Layout Raw



monitor.incntre.iu.edu/fsfscope/topology/generic/1/

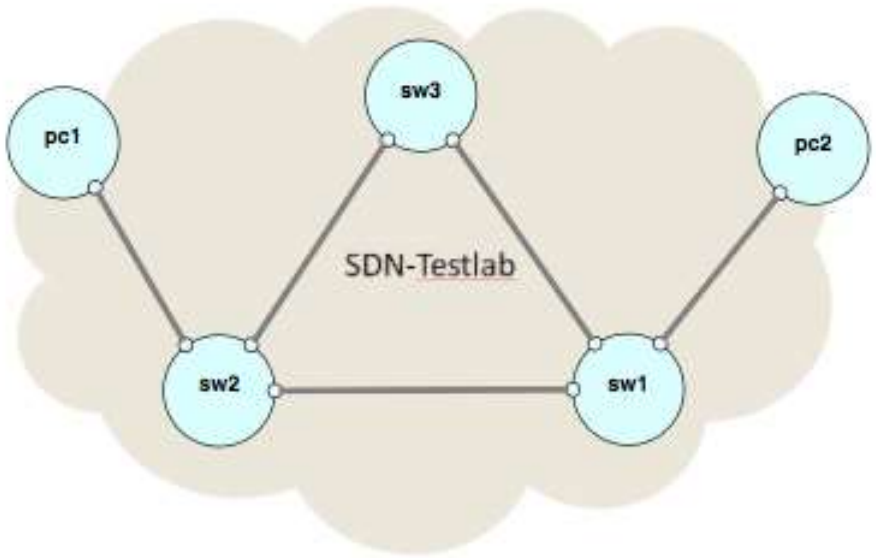
Periscope Testbed Monitoring

Topologies

- fsf

Misc

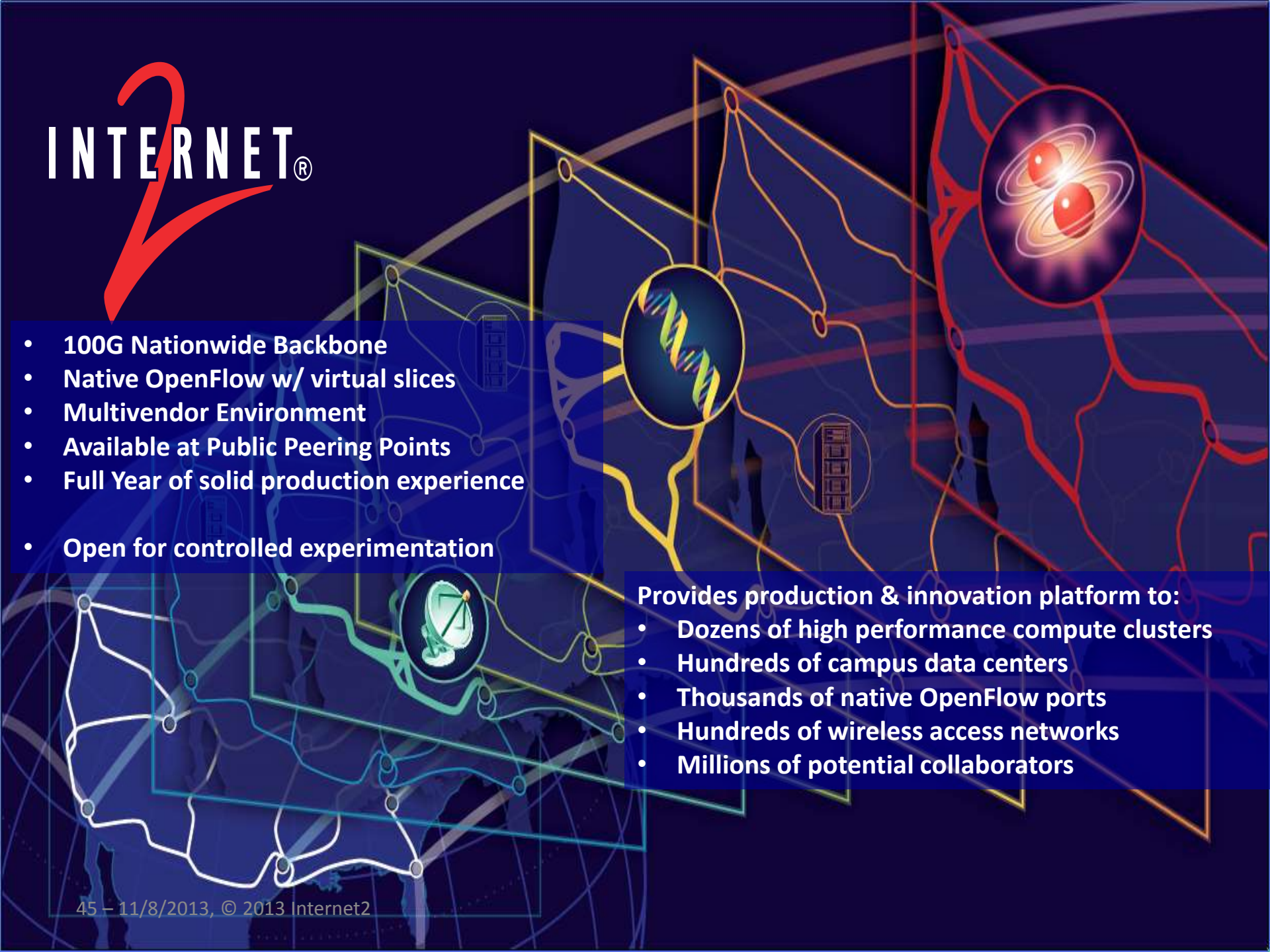
Transfer Rate



Delete selected paths | Save topology locations

GRI	Status	Source	Destination	Start Time	Duration (s)	Misc
XSP-netPath-1542	DOWN	pc1	pc2	2013-10-27 19:35:21	...	alt
XSP-netPath-1543	DOWN	pc1	pc2	2013-10-27 19:35:46	...	
XSP-netPath-1544	DOWN	pc1	pc2	2013-10-27 19:36:10	...	alt
XSP-netPath-1545	DOWN	pc1	pc2	2013-10-27 19:36:35	...	
XSP-netPath-1546	UP	pc1	pc2	2013-10-27 19:37:00	...	alt

reen Shot 2013-10-27 at 5.09.39 PM



- 100G Nationwide Backbone
- Native OpenFlow w/ virtual slices
- Multivendor Environment
- Available at Public Peering Points
- Full Year of solid production experience

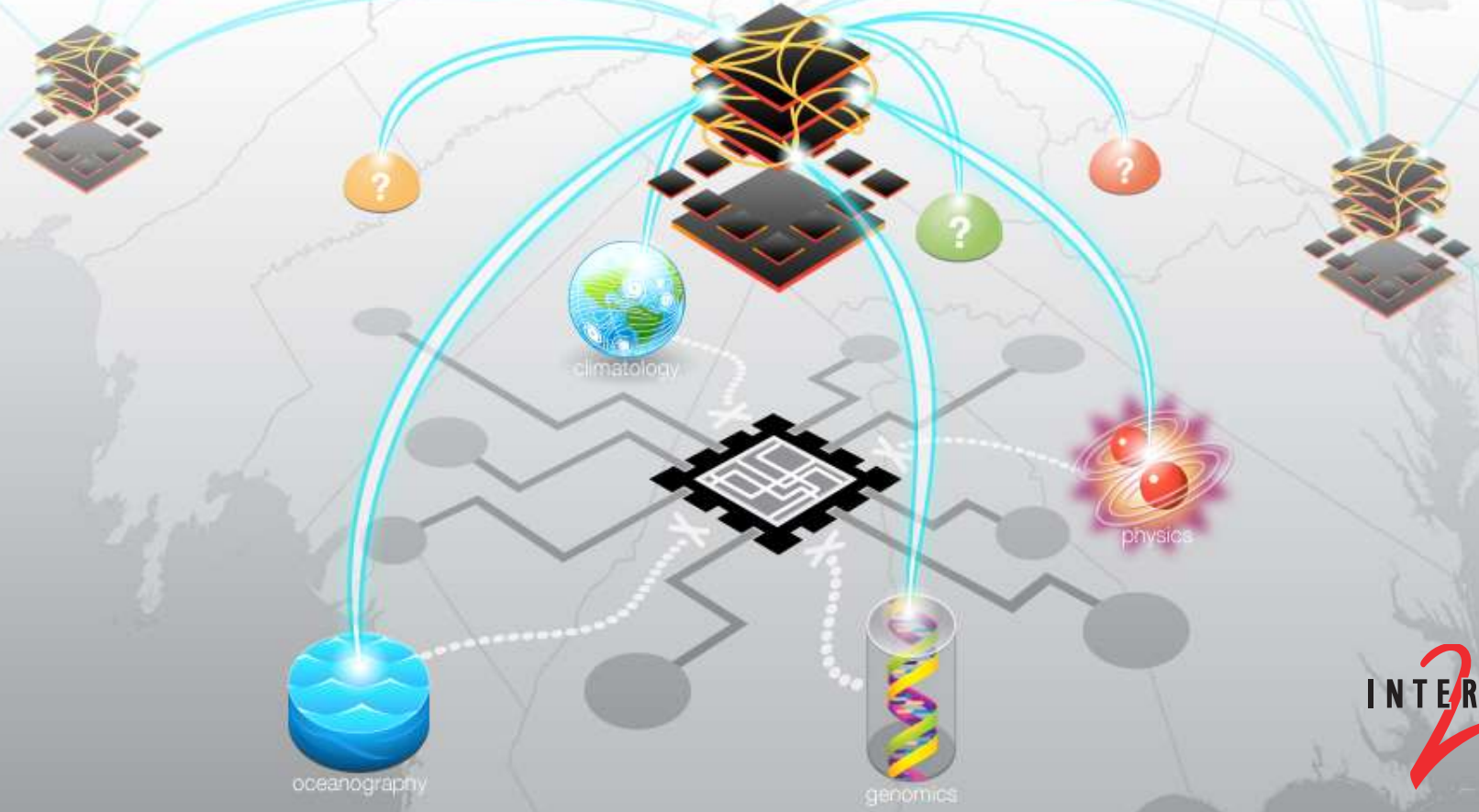
- Open for controlled experimentation

Provides production & innovation platform to:

- Dozens of high performance compute clusters
- Hundreds of campus data centers
- Thousands of native OpenFlow ports
- Hundreds of wireless access networks
- Millions of potential collaborators

Does this create a platform for innovation?

- Abundant bandwidth to enable innovation? ☑
- Software-defined networking substrate? ☑
- Support data intensive science? ☑
- Virtualization? ☑ In progress
- Integrate network with compute and storage? ☐ Next step

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Senior Director, Strategic Projects

eboyd@internet2.edu

Thank you. For more information,
visit http://www.internet2.edu
or e-mail innovation@internet2.edu

