GENI

Exploring Networks of the Future

NITRD JET Discussion / May 15, 2012

Chip Elliott
GENI Project Director
www.geni.net

Sponsored by the National Science Foundation

Outline

- GENI – Exploring future internets at scale
- Introducing GENI: an example
- GENI's growing suite of infrastructure
- Experiments going live across the US
- Gearing up for GENI campus expansion
- GENI within a broader context

Global networks are creating extremely important new challenges

Science Issues

We cannot currently understand or predict the behavior of complex, large-scale networks

Innovation Issues

Substantial barriers to at-scale experimentation with new architectures, services, and technologies

Society Issues

We increasingly rely on the Internet but are unsure we can trust its security, privacy or resilience

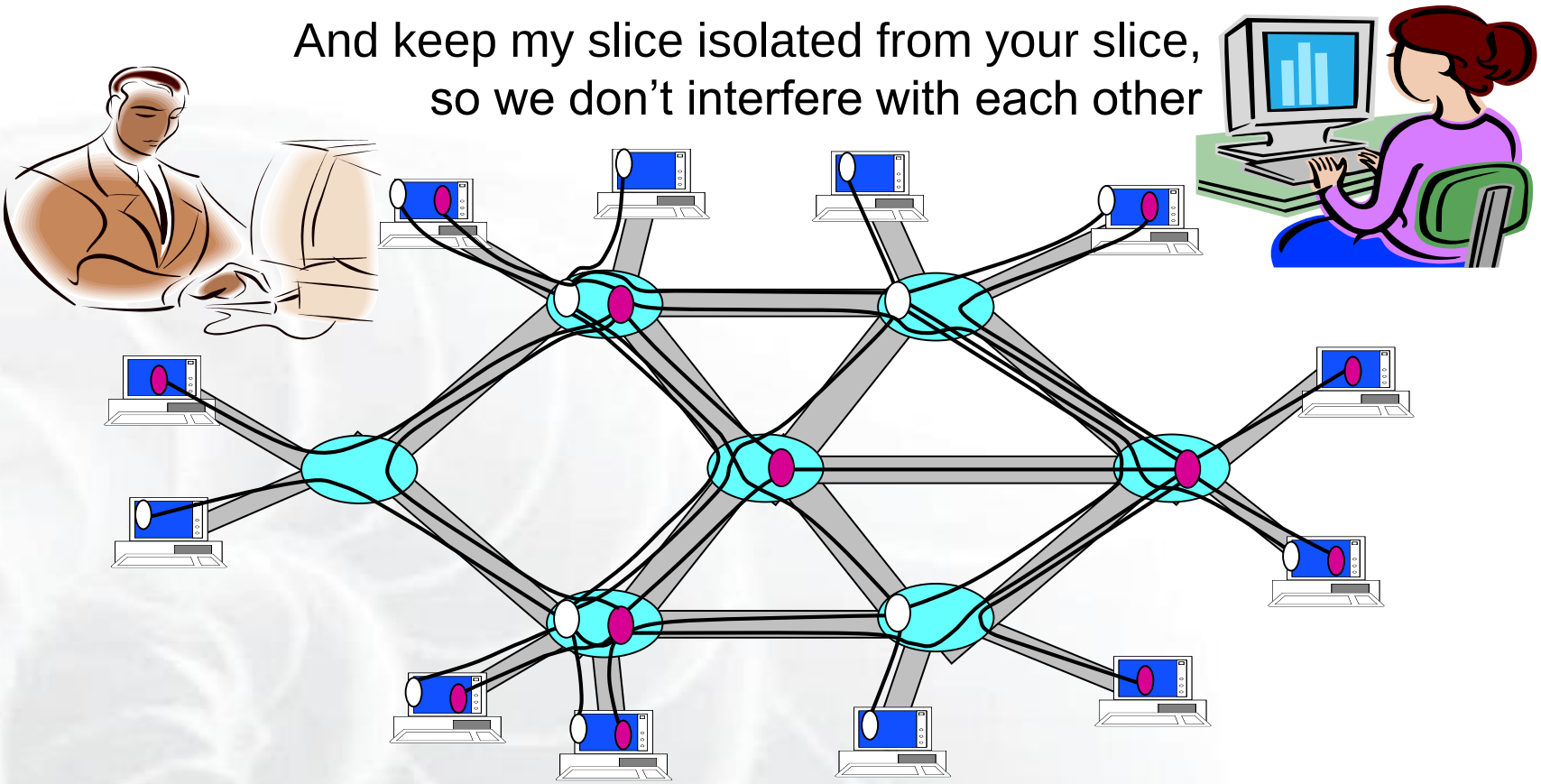
What is GENI?

- GENI is a virtual laboratory for **exploring future internets at scale**, now rapidly taking shape in prototype form across the United States
- GENI opens up huge new opportunities
  - **Leading-edge research** in next-generation internets
  - **Rapid innovation** in novel, large-scale applications
- Key GENI concept: slices & deep programmability
  - Internet: open innovation in application programs
  - GENI: open innovation deep into the network

Slices and Deep Programmability

Install the software I want *throughout* my network slice (into firewalls, routers, clouds, …)

And keep my slice isolated from your slice, so we don't interfere with each other



We can run many different "future internets" in parallel

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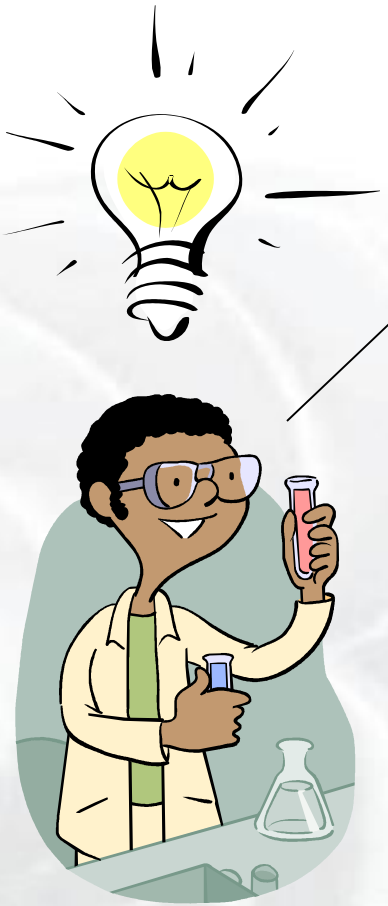
A bright idea



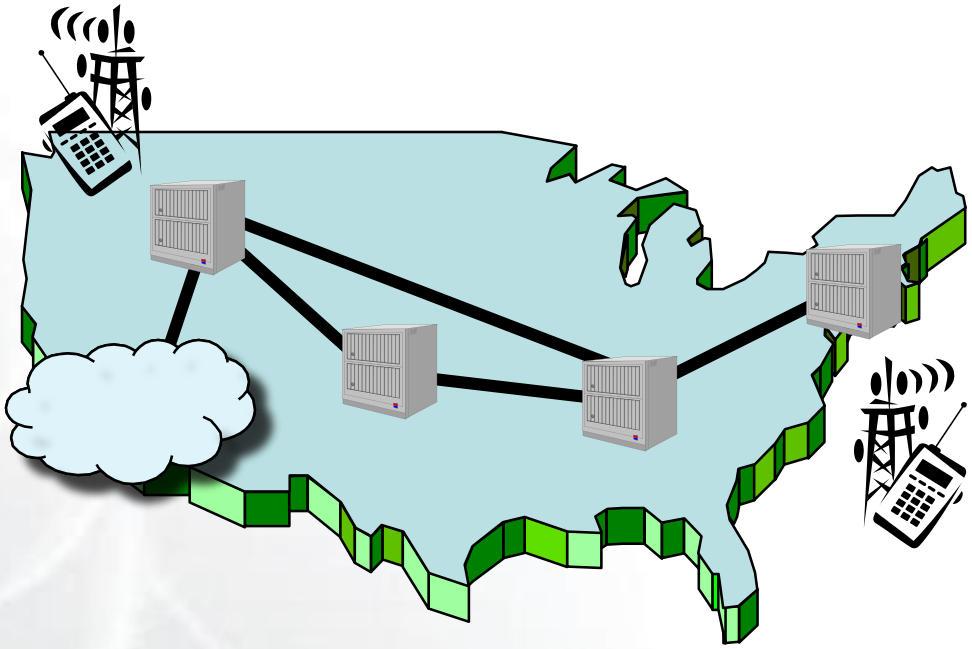
I have a great idea! The original Internet architecture was designed to connect one computer to another – but a better architecture would be fundamentally based on PEOPLE and CONTENT!

That will never work! It won't scale! What about security? It's impossible to implement or operate! Show me!

Trying it out

My new architecture worked great in the lab, so now I'm going to try a larger experiment for a few months.

And so he poured his experimental software into clouds, distributed clusters, bulk data transfer devices ('routers'), and wireless access devices throughout the GENI suite, and started taking measurements . . .



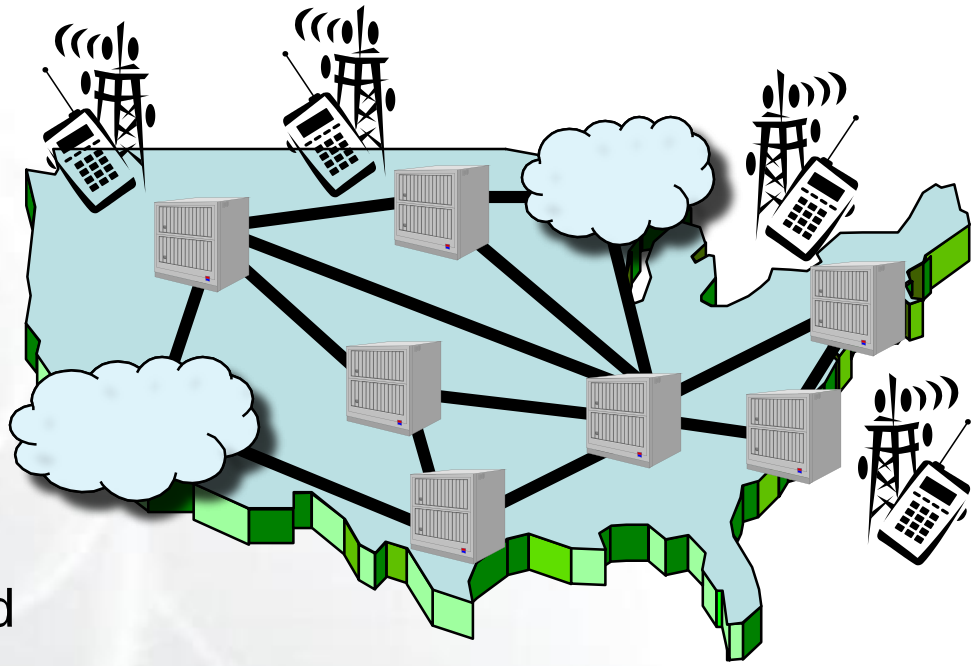
He uses a modest slice of GENI, sharing its infrastructure with many other concurrent experiments.

It turns into a really good idea

Boy did I learn a lot! I've published papers, the architecture has evolved in major ways, and I'm even attracting real users!

Location-based social networks are really cool!

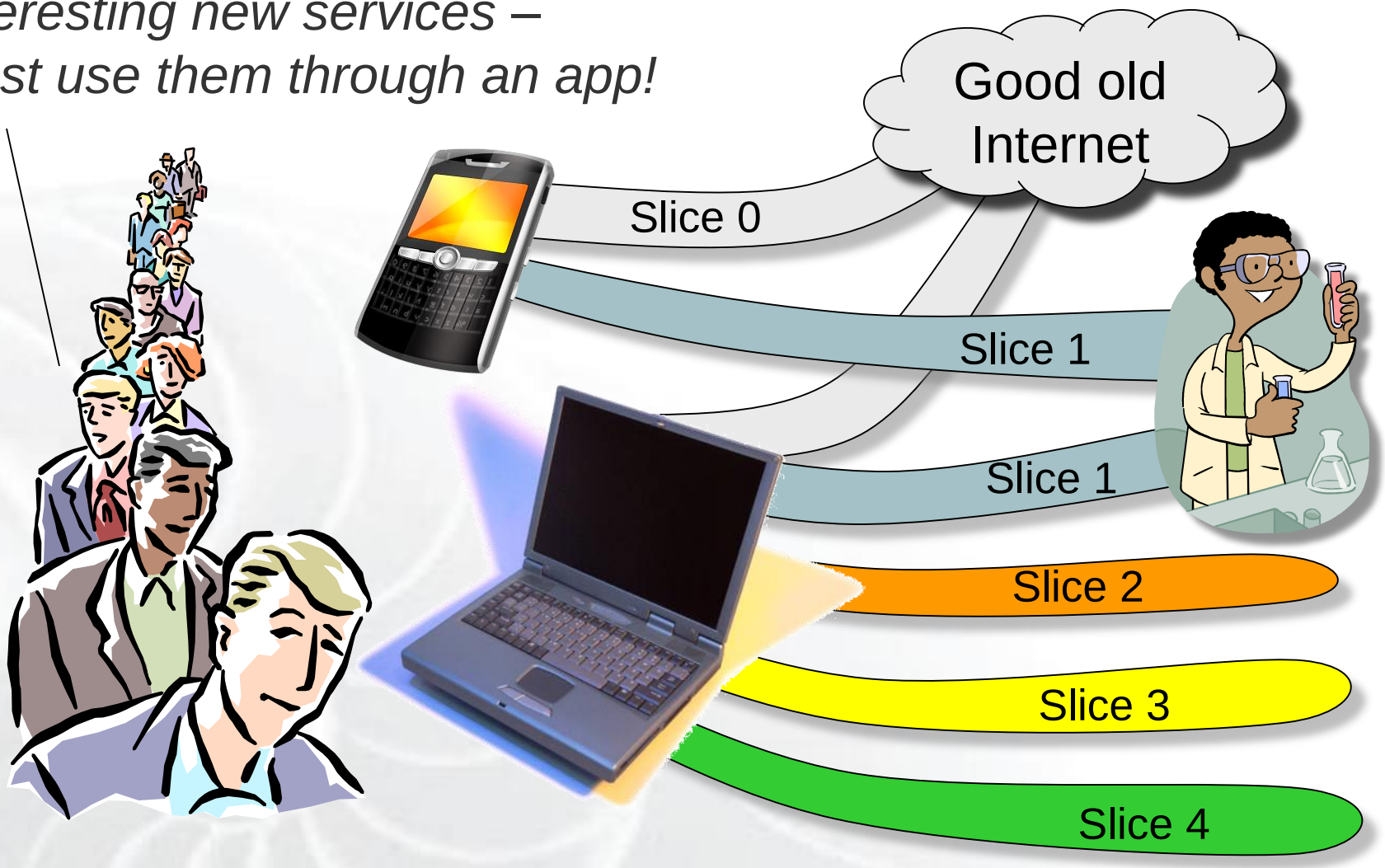
His experiment grew larger and continued to evolve as more and more real users opted in . . .



His slice of GENI keeps growing, but GENI is still running many other concurrent experiments.

The (opt-in) user's view

Interesting new services –
I just use them through an app!



Experiment turns into reality

My experiment was a real success, and my architecture turned out to be mostly compatible with today's Internet after all – so I'm taking it off GENI and spinning it out as a real company.

I always said it was a good idea, but way too conservative.

Meanwhile . . .

I have a great idea! If the Internet were augmented with a scalable control plane and realtime measurement tools, it could be 100x as robust as it is today . . . !

And I have a great concept for incorporating live sensor feeds into our daily lives !

If **you** have a great idea, check out the
NSF CISE research programs for current opportunities.

Moral of this story

- GENI is meant to enable . . .
  - **At-scale experiments**, which may or may not be compatible with today's Internet
  - **Both repeatable and "in the wild" experiments**
  - '**Opt in' for real users** into long-running experiments
  - Excellent **instrumentation and measurement** tools
  - **Large-scale growth for successful experiments**, so good ideas can be shaken down at scale

GENI creates a huge opportunity for ambitious research!

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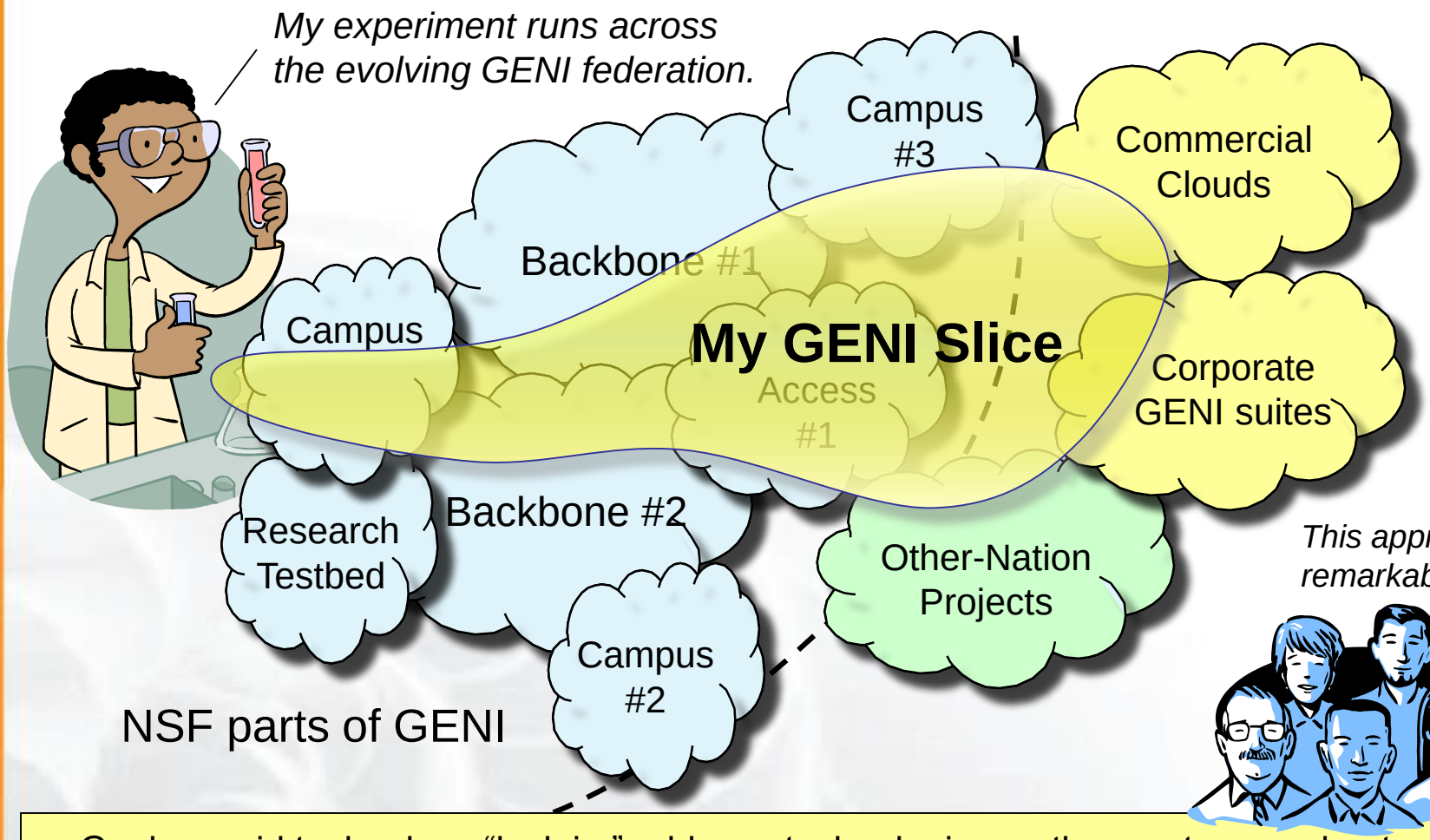
Federation

GENI grows by "GENI-enabling" heterogeneous infrastructure

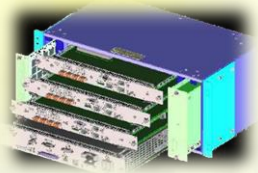


Goals: avoid technology "lock in," add new technologies as they mature, and potentially grow quickly by incorporating existing infrastructure into the overall "GENI ecosystem"

Enabling “at scale” experiments

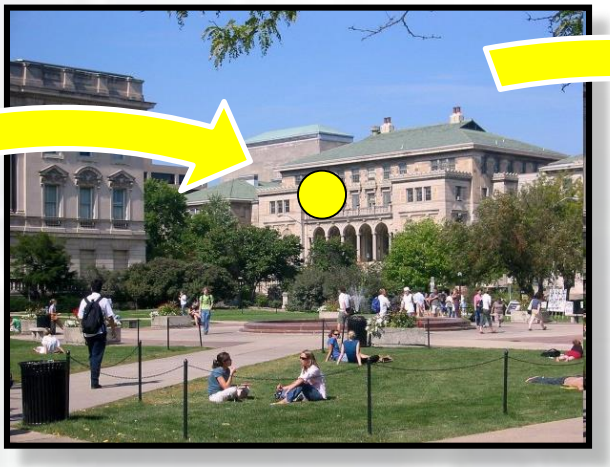
- **How can we afford / build GENI at sufficient scale?**
  - Clearly infeasible to build research testbed “as big as the Internet”
  - Therefore we are “GENI-enabling” testbeds, commercial equipment, campuses, regional and backbone networks
  - **Students are early adopters / participants in at-scale experiments**
  - Key strategy for building an at-scale suite of infrastructure

HP ProCurve 5400 Switch

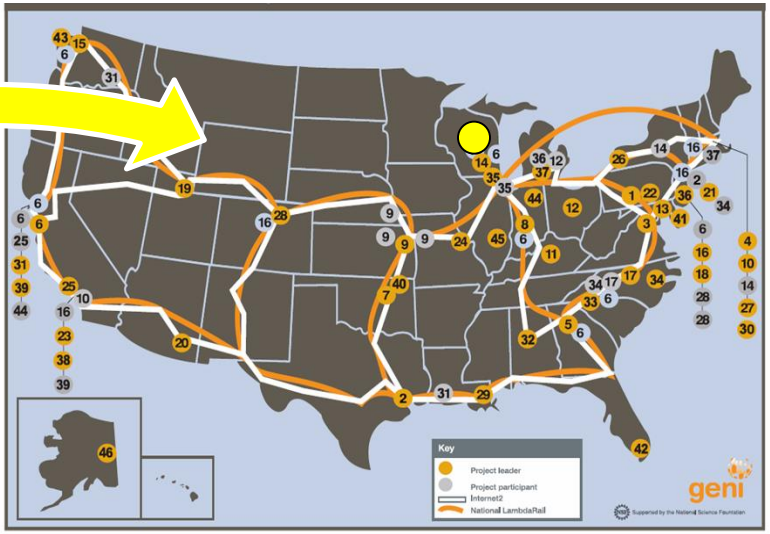


NEC WiMAX Base Station

GENI-enabled equipment



GENI-enabled campuses, students as early adopters



“At scale” GENI prototype

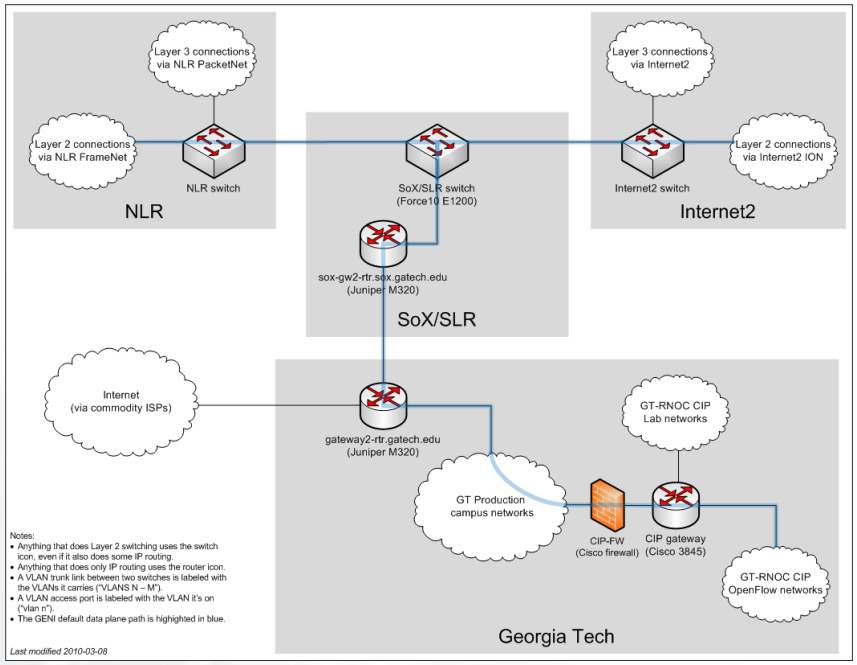
Georgia Tech: a great example
One of the first 14 GENI-enabled campuses

Nick Feamster
PI

Ellen Zegura

Russ Clark,
GT-RNOC

Ron
Hutchins,
OIT

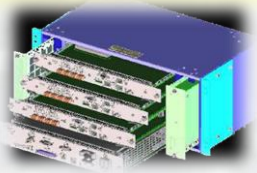


- OpenFlow in 4 GT lab buildings ***now***
- OpenFlow/BGPMux coursework ***now***
- Dormitory trial
- Students will "live in the future" – Internet in one slice, multiple future internets in additional slices

Trials of "GENI-enabled" commercial equipment

HP ProCurve 5400 Switch

Juniper MX240 Ethernet Services Router



NEC WiMAX Base Station

HTC Android smart phone

Toroki LightSwitch 4810

GENI racks

NEC IP8800 Ethernet Switch

Arista 7124S Switch

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Major research demos

9 major experiments demo'd

- **Some of the nation's best young researchers . . .**
  - Academic and industrial
  - Networking and distributed systems
  - Some helped build GENI, most have not
- **Demonstrating their earliest research experiments**
  - Many different ideas for "future internets"
  - Now being **tried out experimentally** for the first time
- On the nationwide, "meso-scale" GENI prototype

GENI supported 9 different future internet experiments, simultaneously, each in its own slice

Pathlet Architecture

GEC 9 experiment demonstration

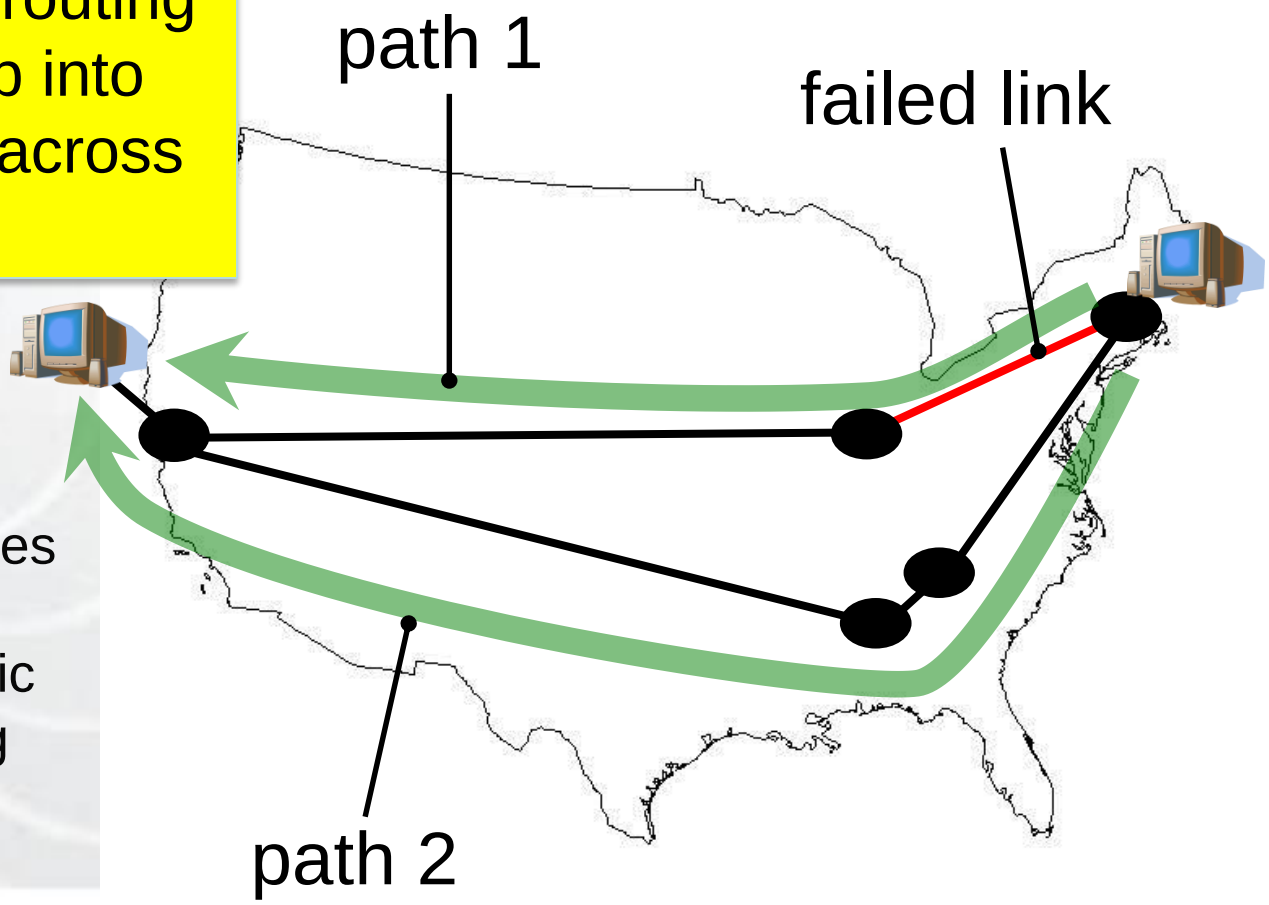
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Resilient Routing in the Pathlet Architecture

Ashish Vulimiri and Brighten Godfrey
University of Illinois at Urbana-Champaign

Deploy innovative routing architecture deep into network switches across the US

- Lets *users* monitor and select their own network paths to optimize their services
- Protects critical traffic even without waiting for adaptation time



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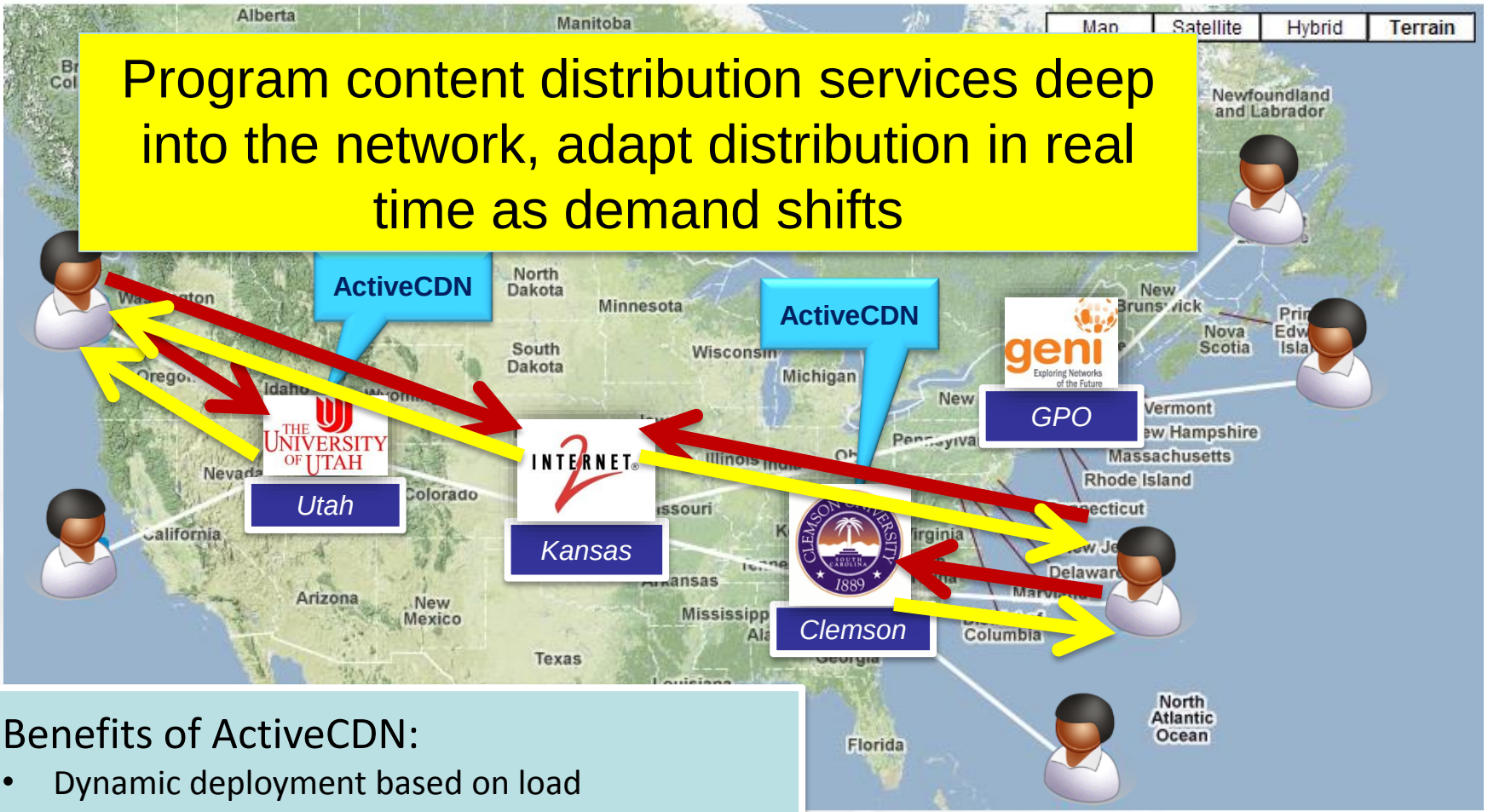
ActiveCDN

GEC 9 experiment demonstration



Benefits of ActiveCDN:

- Dynamic deployment based on load
- Localized services such as weather, ads and news

Jae Woo Lee, Jan Janak, Roberto Francescangeli, SumanSrinivasan, Eric Liu, Michael Kester, SalmanBaset, Wonsang Song, and Henning Schulzrinne
Internet Real-Time Lab, Columbia University

Weather NowCasting

GEC 9 experiment demonstration

ViSE views steerable radars as shared, virtualized resources
http://geni.cs.umass.edu/vise

David Irwin et al

Generate "raw" live data ViSE/CASA radar nodes

http://stb.ece.uprm.edu/current.jsp

Create and run realtime "weather service on demand" as storms turn life-threatening

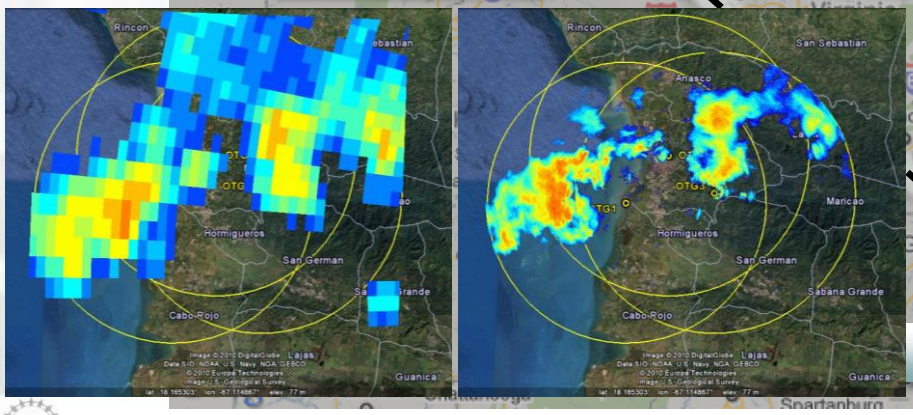
"raw" live data

Nowcast images for display

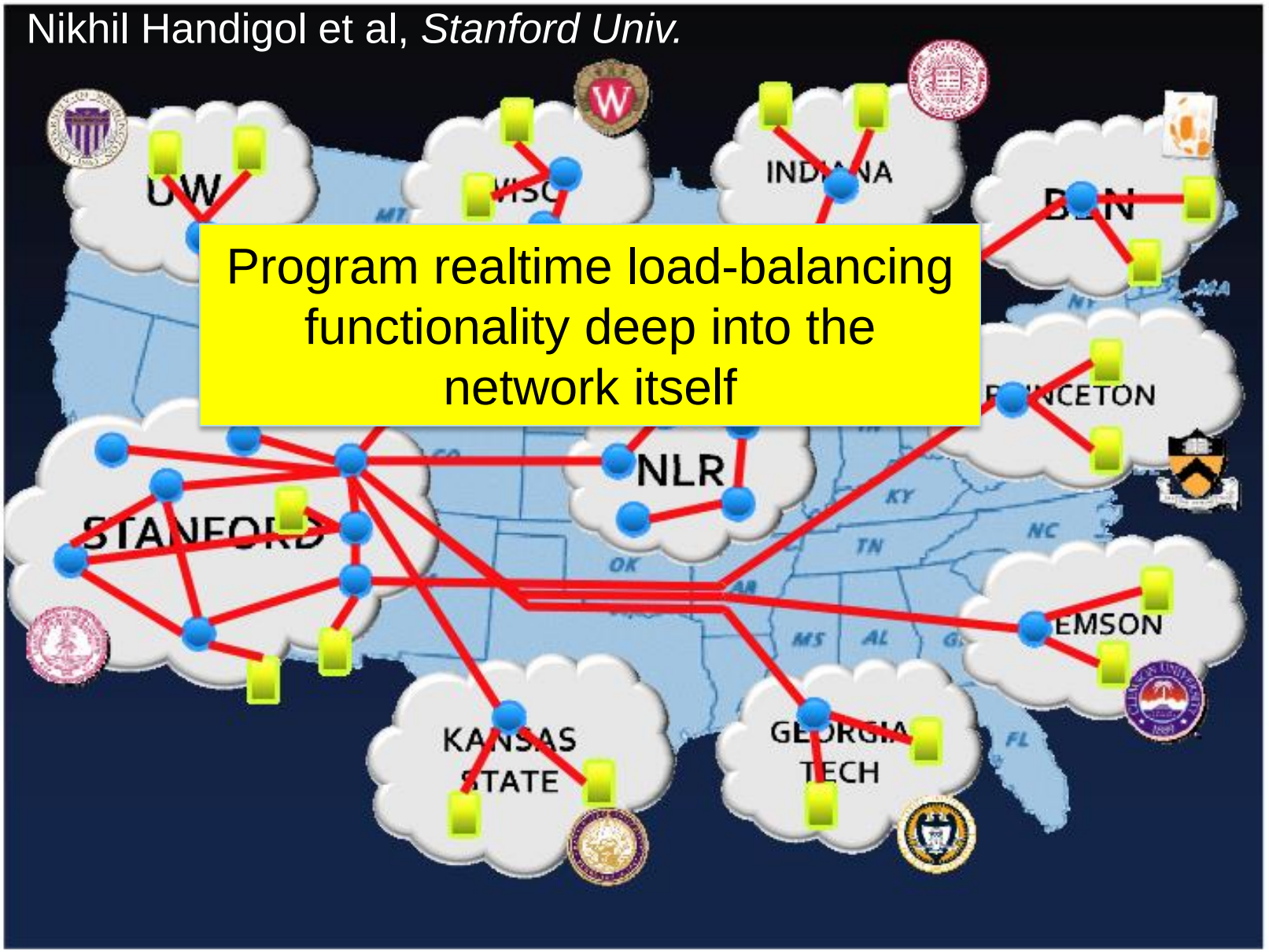
1. Spin up system in Amazon commercial EC2 and S3 services on demand

Multi-radar NetCDF Data

Nowcast Processing



Aster*x Load Balancing (via OpenFlow)



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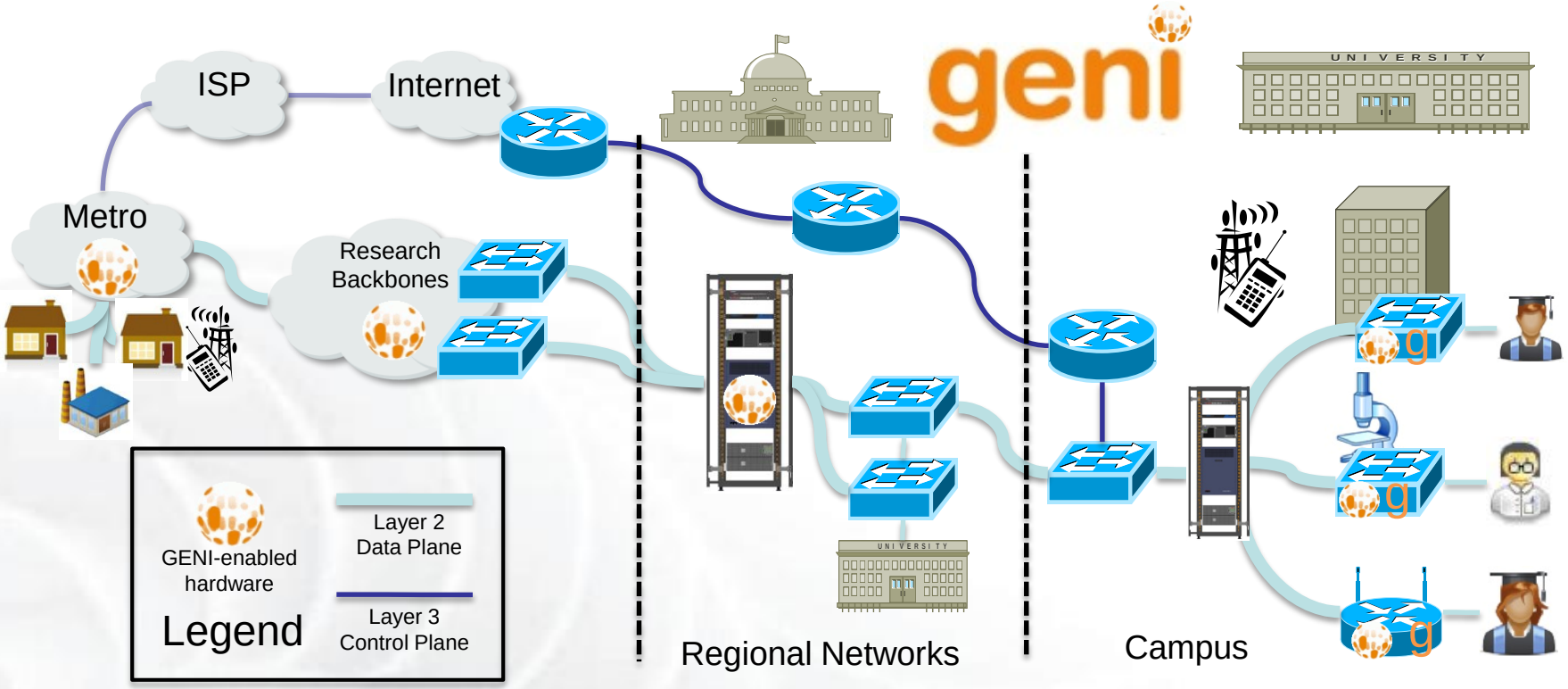
Looking forward
Growing to the “at scale” GENI

- Suggest 100-200 US campuses as target for “at scale”
  - Both academia and national labs
  - GENI-enable the campuses
  - Their students, faculty, staff can then “live in the future” using both today’s Internet and many experiments
  - Build out backbones, regionals, and shared clouds to support the campuses
- Grow via ongoing spiral development
  - Identify, understand, and drive down risks
  - Learn what is useful and what is not
  - Early GENI campuses can help later ones
- Transition to community governance

Envisioned architecture



- Flexible network / cloud research infrastructure
- Also suitable for physics, genomics, other domain science
- Support “hybrid circuit” model plus much more (OpenFlow)
- Distributed cloud (racks) for content caching, acceleration, etc.

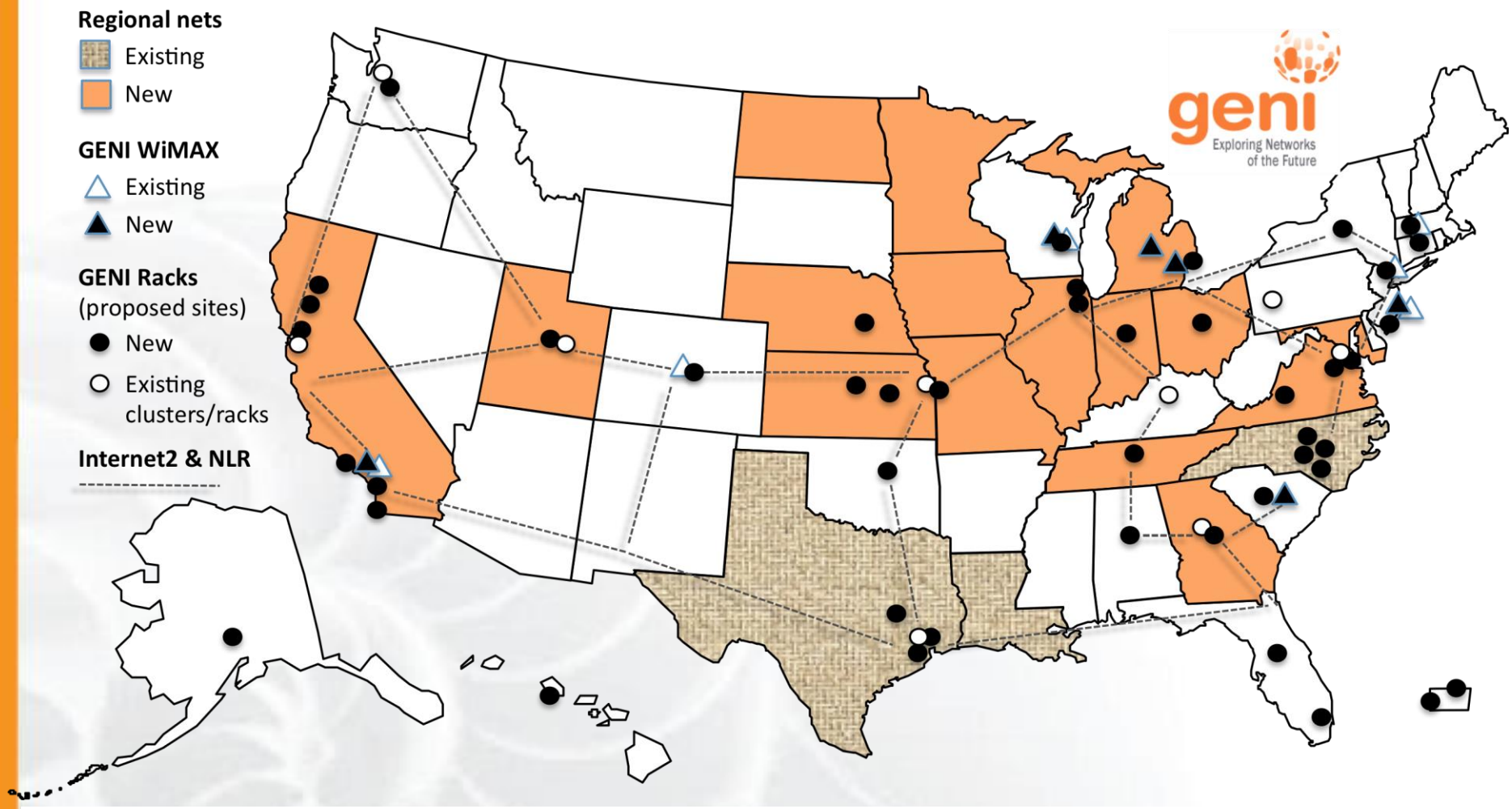
“Thickening up” GENI infrastructure

- GENI Solicitation 3
  - Add **GENI Racks** to 50-80 locations within campuses, regionals, and backbone networks
  - GENI-enable 5-6 **regional networks**
  - Inject more **OpenFlow** into Internet2 and NLR
  - More **WiMAX base stations** with Android handsets

ExoGENI rack installation, 2/2012

GENI Racks serve as programmable routers, distributed clouds, content distribution nodes, caching or transcoding nodes, etc

Spiral 4 build-outs well underway
Growing GENI's footprint



(as proposed; actual footprint to be engineered)

GENI / Internet2 Agreement

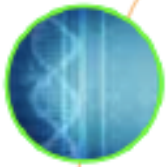
A major step towards campus expansion

- Collaboration to **implement national-scale infrastructure**
  - sliced and deeply-programmable
  - incorporating OpenFlow/SDN switches, GENI Racks, university datacenters, etc.
  - high-speed (10-100 Gbps initially)
- With software that supports shared use by faculty, students, and campus IT organizations
- Gradual migration from today's "prototype GENI" backbone in Internet2 to a real, production system
- Scaling to an envisioned goal of 100-200 GENI campuses

Opens the door for "at-scale" GENI !

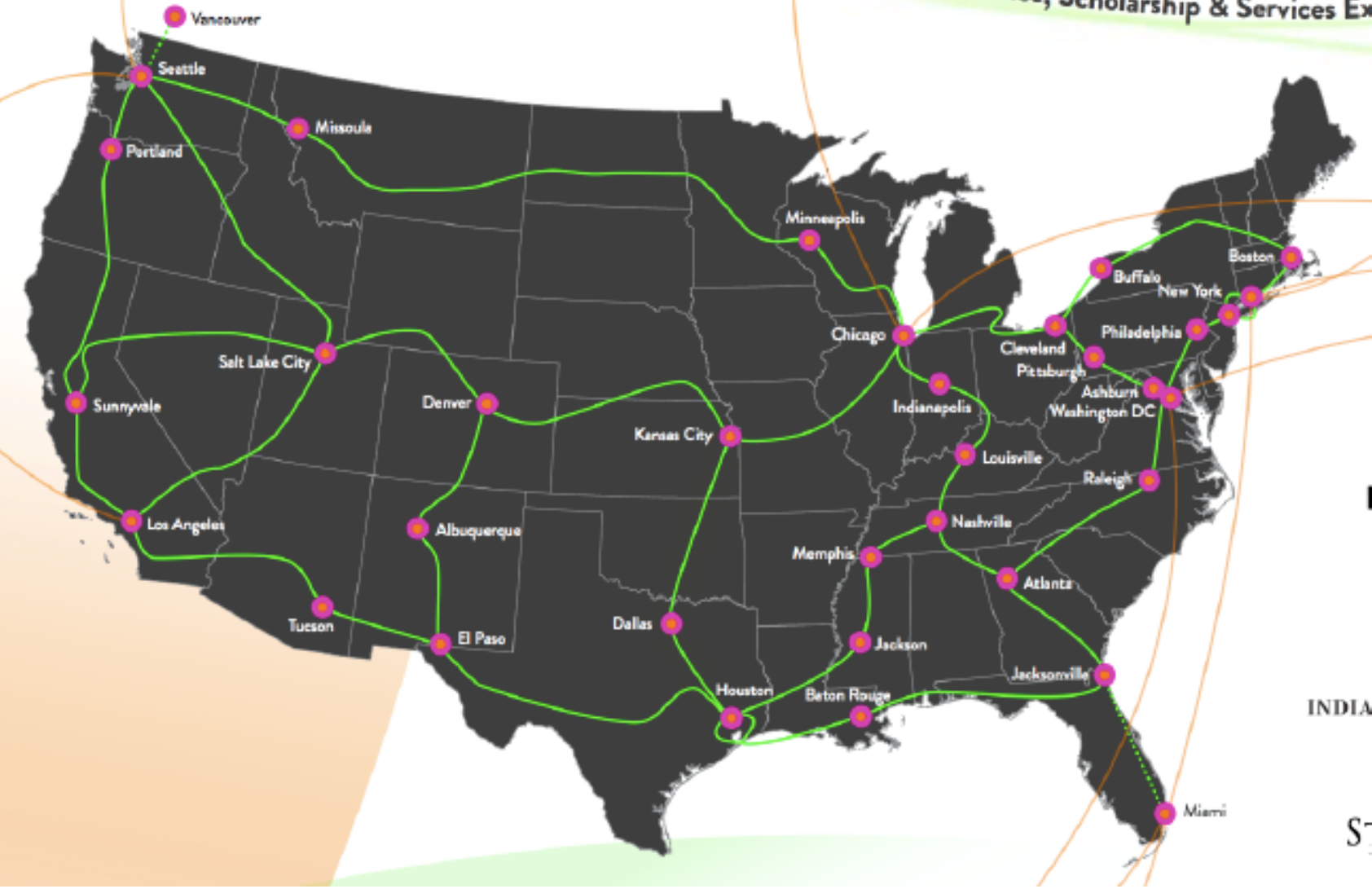
Note that this agreement does not exclude either party from additional collaborations.



OS³E

The Open Science, Scholarship & Services Exchange



INTERNET2®

INDIANA UNIVERSITY

STANFORD UNIVERSITY

GENI campus expansion

Dr. Larry Landweber, U. Wisconsin

- **"GENI-enabled" means . . .** OpenFlow + GENI racks, plus WiMAX on some campuses

- **Current GENI campuses** Clemson, Colorado, Columbia, Georgia Tech, Indiana, Princeton, Kansas State, NYU Poly, Rutgers, Stanford, UCLA,U MA Amherst, U Washington, U Wisconsin
- **CIO Initiative - 19 campuses** Case Western, Chicago, Colorado, Cornell, Duke, Florida International, U Kansas, Michigan, NYU, Purdue, Tennessee, U FLA, University of Houston, UIUC, U MA Lowell-Amherst, Utah, Washington, Wisconsin
- **Rapidly growing waitlist**

Ramping up experimenter workshops and training sessions for IT staff

Network Engineers “boot camp” on the day before this GEC, organized by Larry Landweber and given by Matt Davy and Steve Wallace, Indiana University

- GPO funding 3 workshops / year by Indiana University
- Goal: train IT staff on OpenFlow and (when available) GENI racks
- At GEC 12 in Kansas City:

Case Western Reserve	Cornell
Duke	Florida International
NYU	Purdue
Univ Chicago	Univ DC
Univ Florida	Univ Houston
UIUC	Univ Colorado
Univ Kansas (Lawrence)	Univ Massachusetts, Lowell
Univ Massachusetts, Amherst	Univ Michigan
Univ Tennessee, Chatanooga	Univ Utah
Univ Washington	Univ Wisconsin, Madison

- 35 additional schools have expressed interest and are on waitlist

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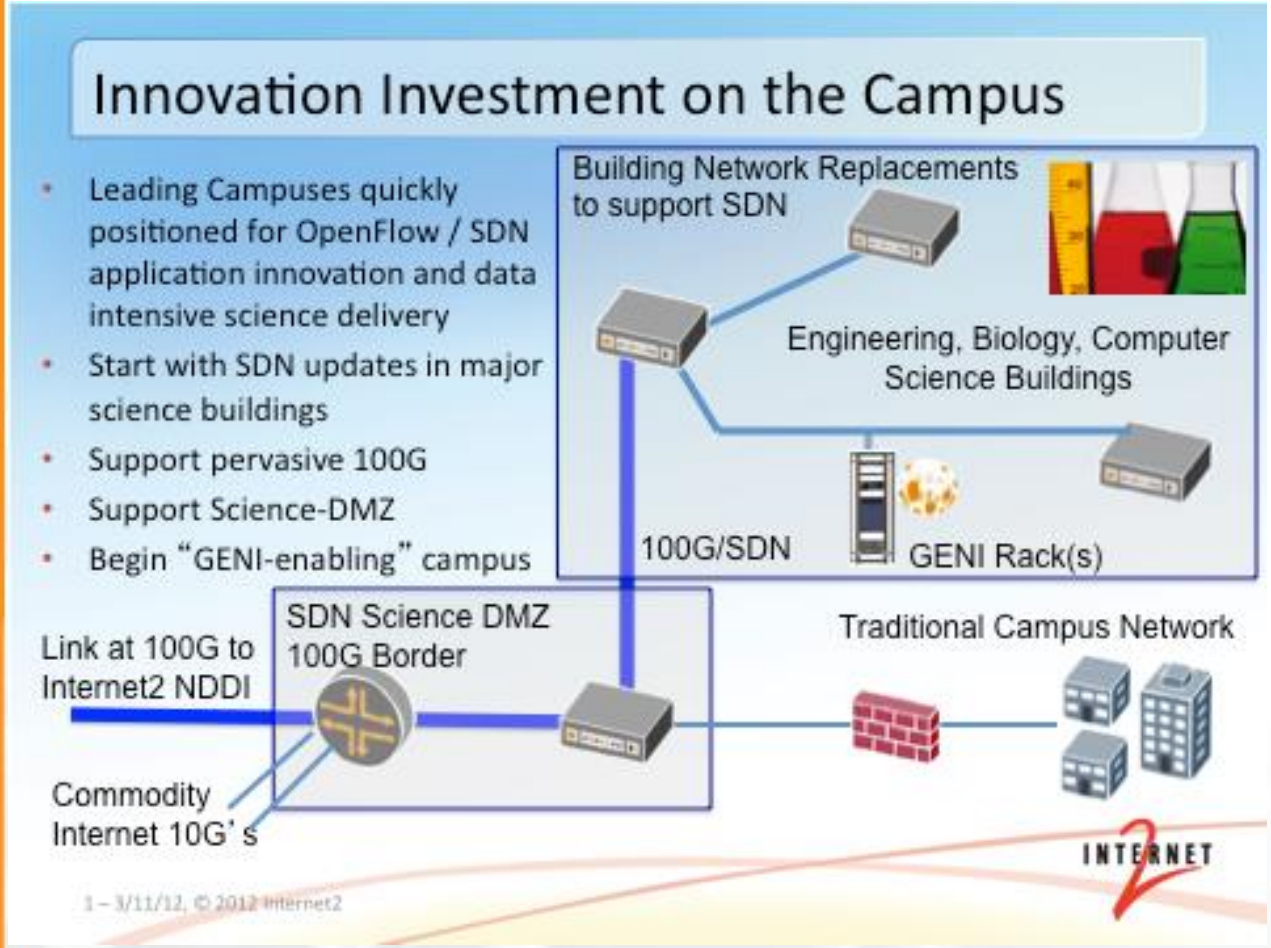
GENI and NSF Cyberinfrastructure



- GENI fits into the "campus bridging" architecture, eg:
  - Layer 2 circuits / VLANs stitch campuses into larger GENI
  - perfSONAR funded as basis of GENI measurements
  - InCommon for identity management
- Extensive PI overlap with SC and COI communities
- Joint SC / GENI demos

Our goal: ensure GENI compatibility with next-gen research infrastructure

Growing GENI interactions with ESNET and DREN

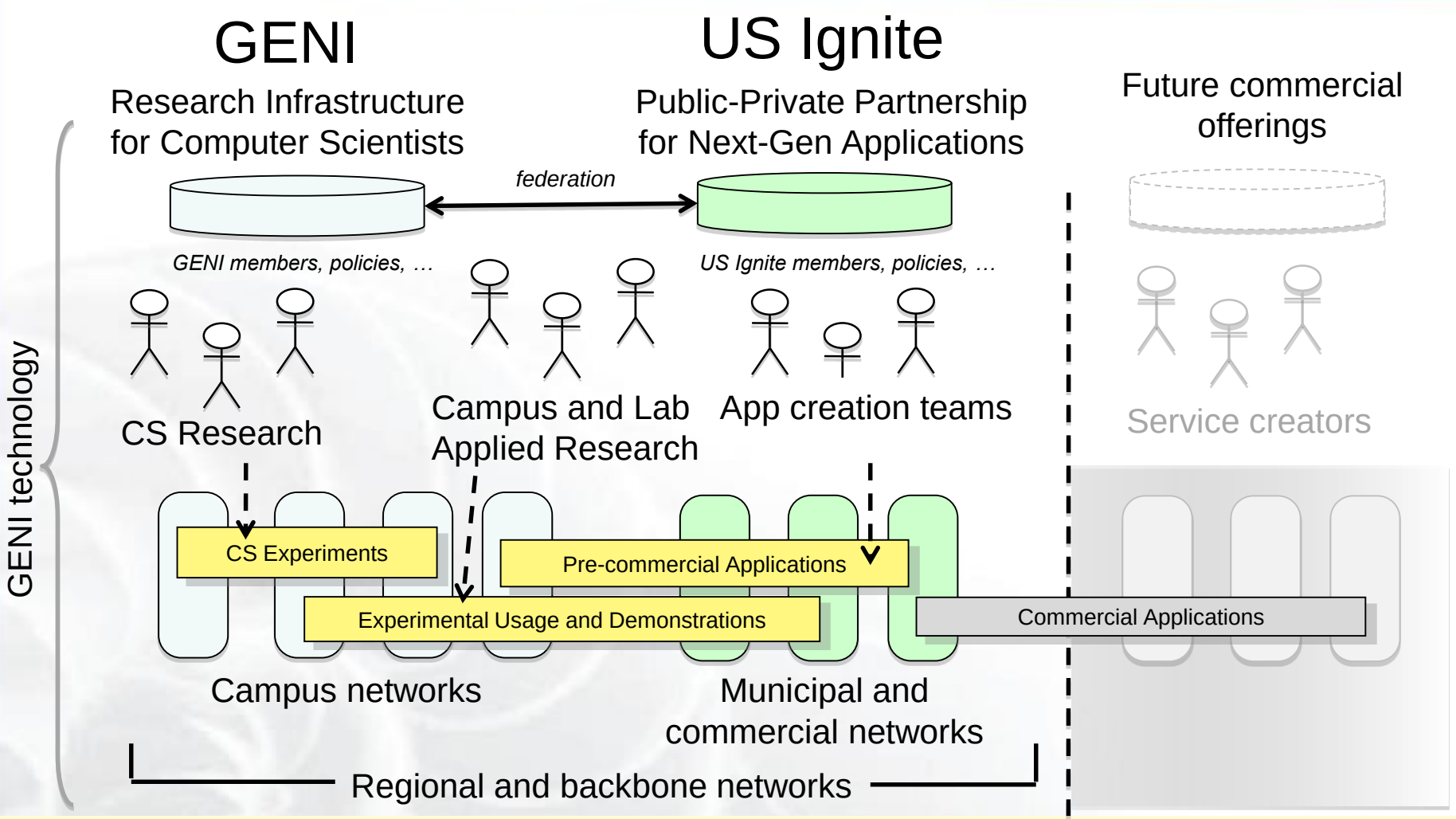
- ESNET
  - Shared interest in OpenFlow & GENI Racks
  - Also dynamic circuits, “cloud,” etc.
  - LBNL joined HP’s GENI Rack proposal
  - Potential for protocol accelerators, perfSONAR, …
- DREN
  - Shared interest in OpenFlow & GENI Racks
  - They plan to purchase switches, buy GENI racks, etc
  - Preliminary discussions with West Point, NPS, ARL
- Possible “peering” concept
  - ESNET and DREN would not be “parts” of GENI
  - Conceptually they could be Layer2 / SDN / GENI Rack peers
  - Still too early to say

GENI and US Ignite

- Very strong interest from 6 US cities
  - Chattanooga, Cleveland, Lafayette LA, Philadelphia, Salt Lake City region, Washington DC
  - Their citizens will be able to “live in the future”
- Cities can be GENI-enabled very rapidly
  - We have visited all 6 cities for surveys, discussions
  - GENI rack, OpenFlow, and Layer 2 connectivity appear quite feasible
  - Can be federated into GENI very quickly
- Can support experimental, gigabit applications in GENI slices through cities
  - Creates **tremendous** new research opportunities

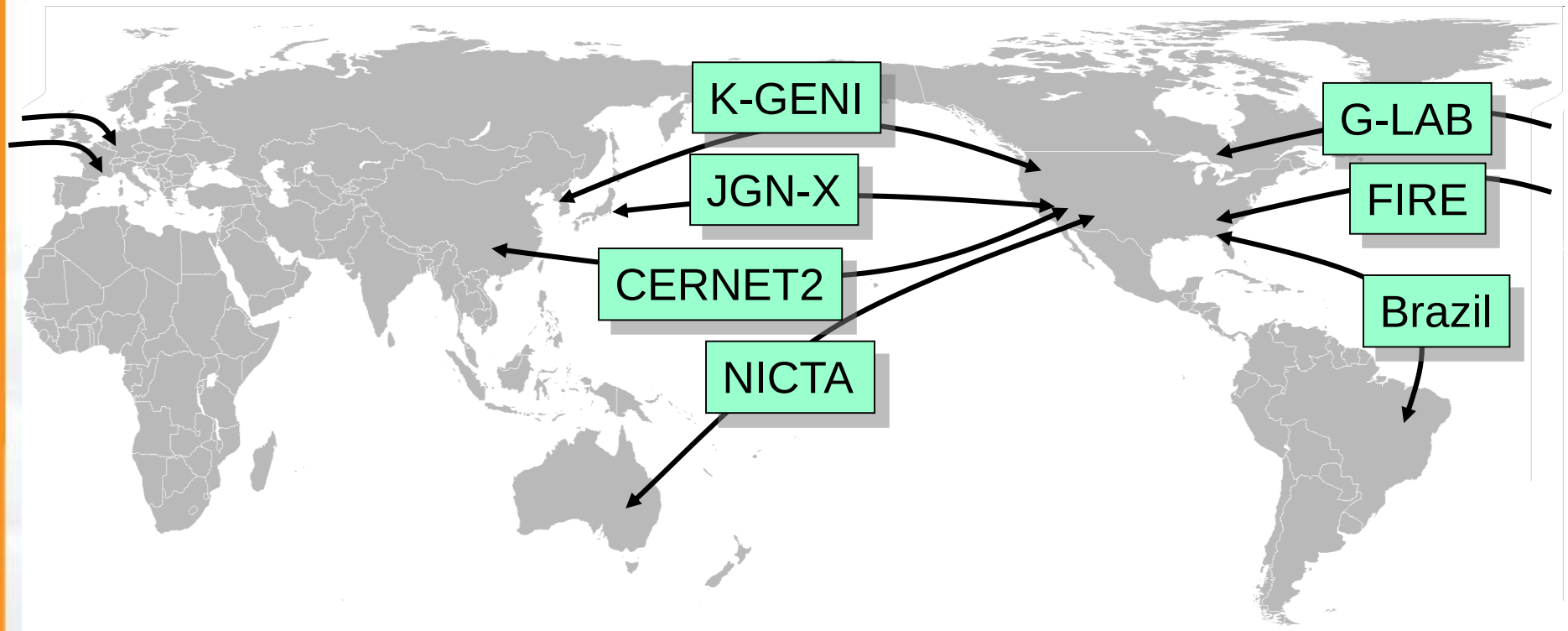
GENI / US Ignite interactions

Bridging CS Experiments to Next-Gen Applications in Cities



US Ignite is a new organization that will promote advanced applications and infrastructure leveraging GENI research and technologies.

GENI's international peers



The GENI project is actively collaborating with peer efforts outside the US, based on equality and arising from direct, "researcher to researcher" collaborations.