



GENI

Exploring Networks of the Future

GENI Engineering Conference 15
23 October 2012

www.geni.net

- GENI – Exploring future internets at scale
- The GENI Concept
- Building GENI
- GENI Experimenters
- GENI and US Ignite
- What's next for GENI?
- GENI: An experimenter's view

Global networks are creating extremely important new challenges

Science Issues

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



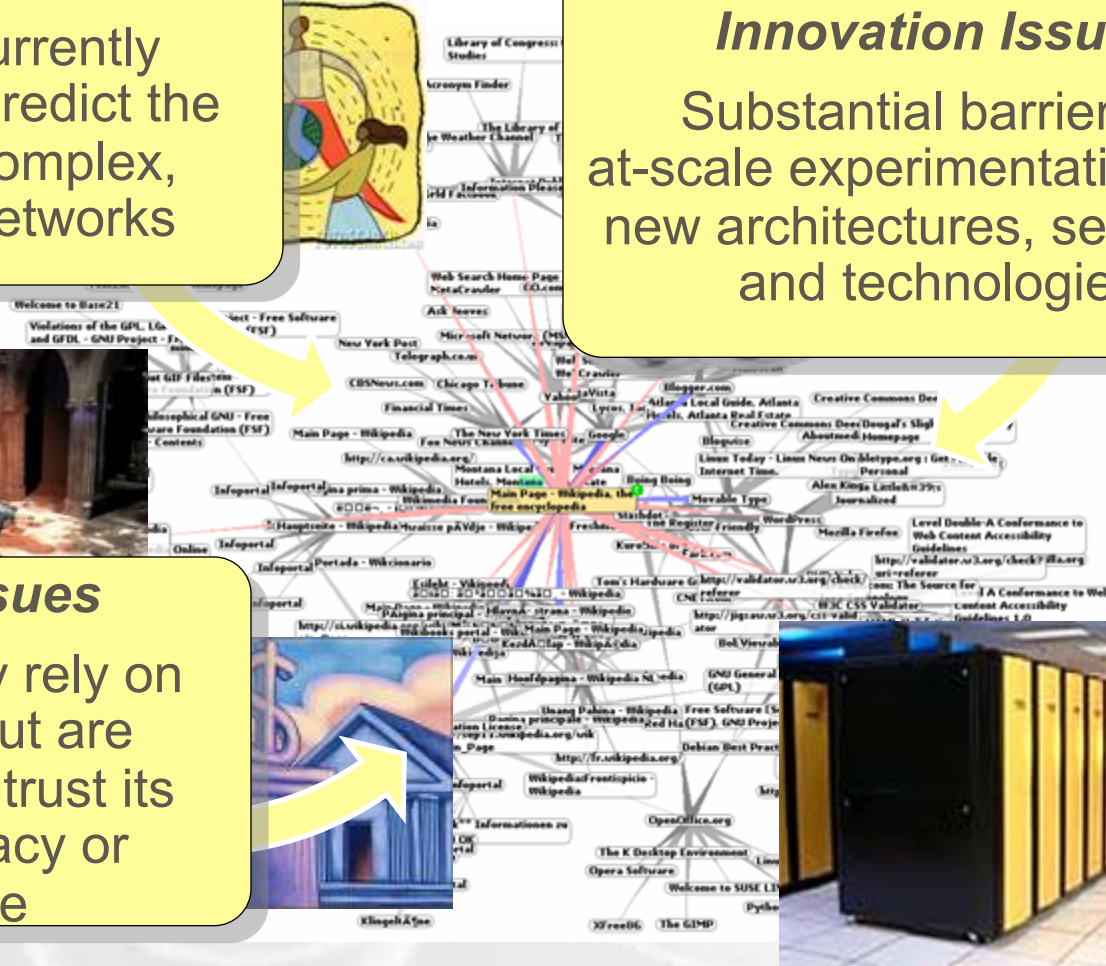
Innovation Issues

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



Society Issues

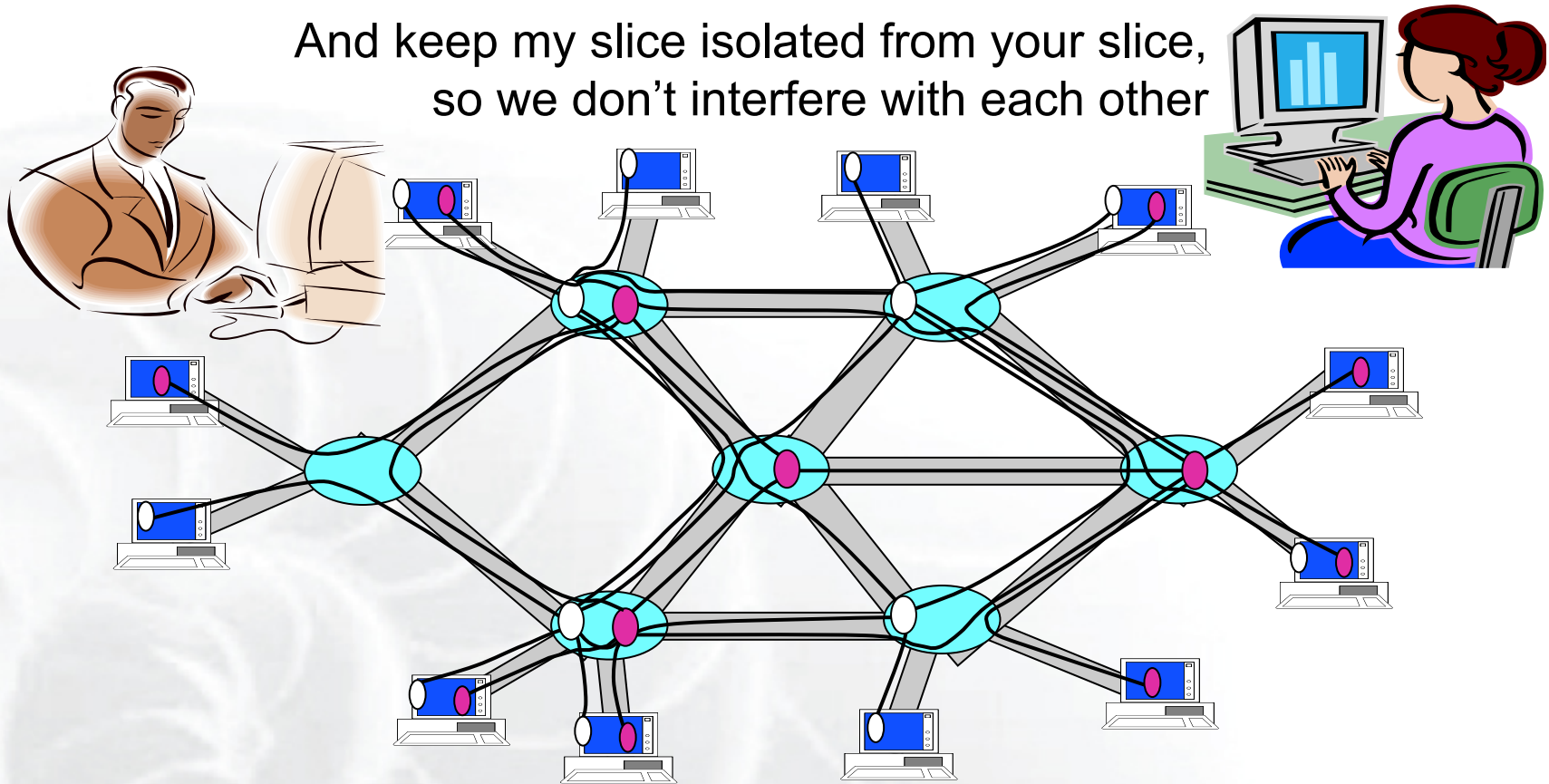
We increasingly rely on the Internet but are unsure we can trust its security, privacy or resilience



- GENI is a nationwide suite of infrastructure for “**at scale**” experiments in networking, distributed systems, security, and novel applications.
- 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

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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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!



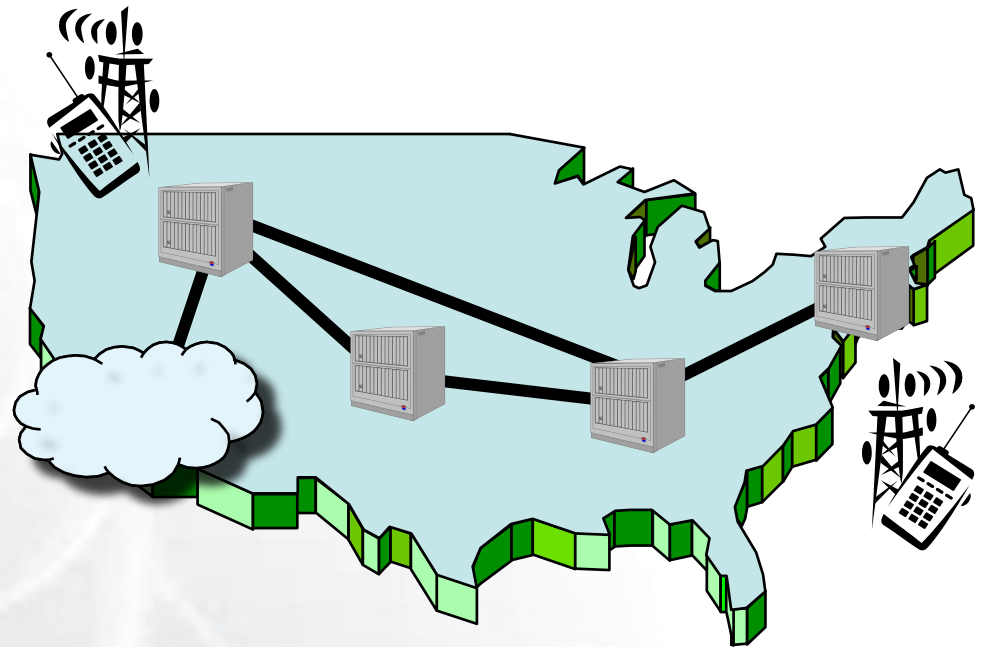
*That will never work! It won't scale!
What about security? It's impossible
to implement or operate! Show me!*



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.

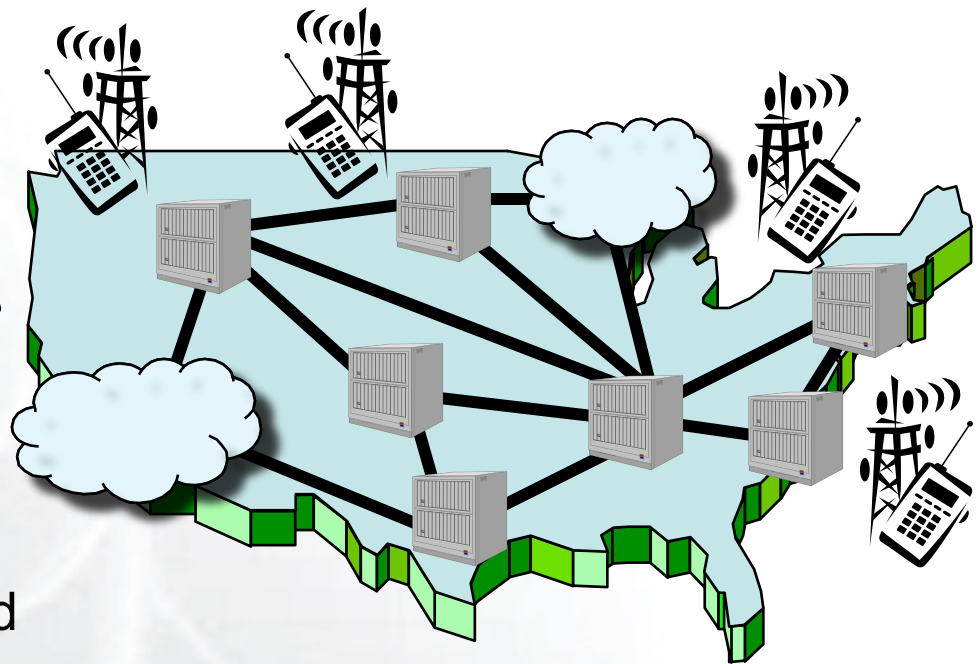
It turns into a really good idea

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



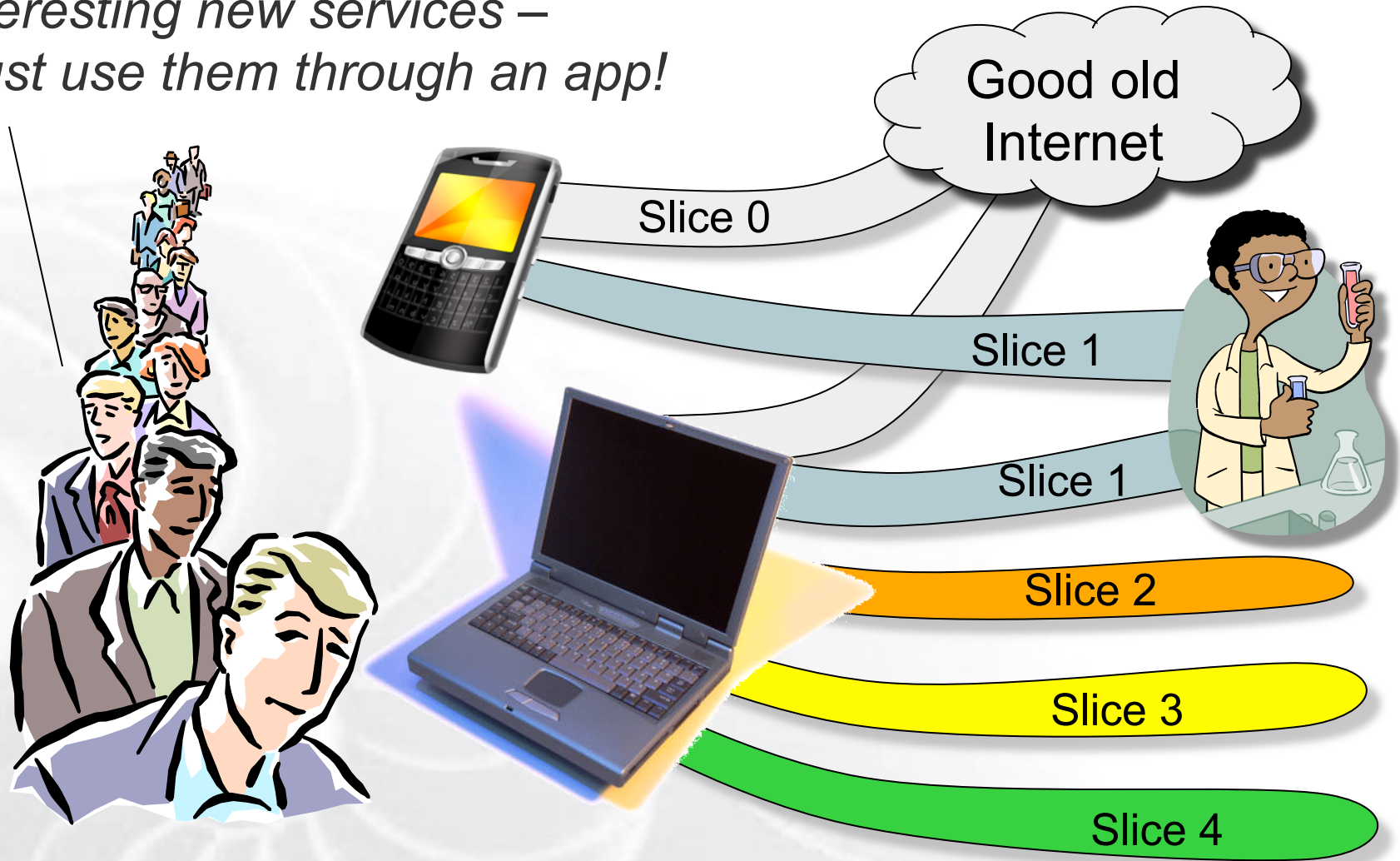
Location-based social networks are really cool!

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.

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

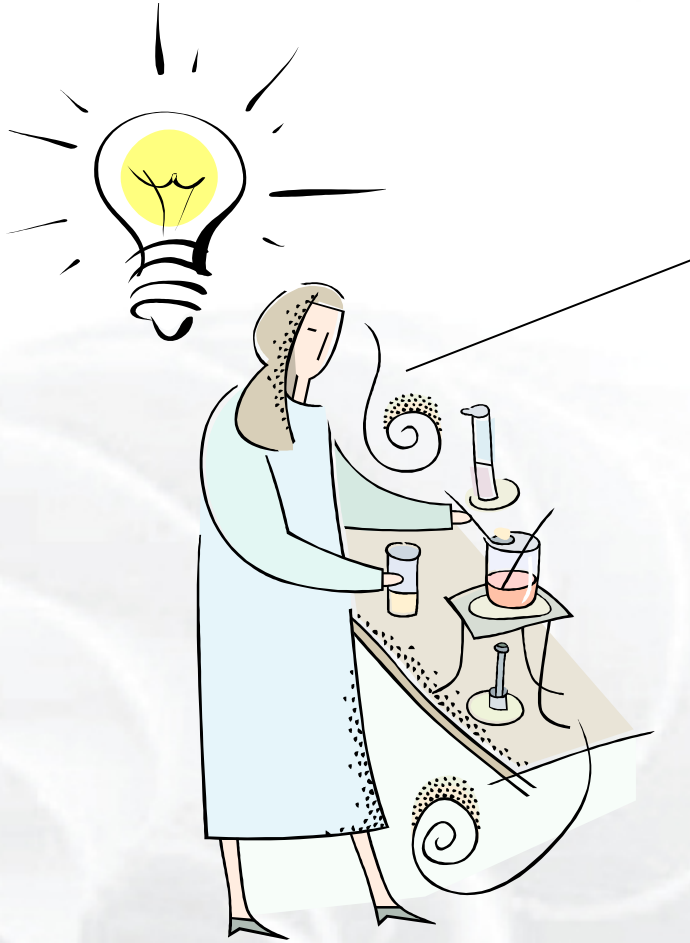


Experiment turns into reality

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.





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 !



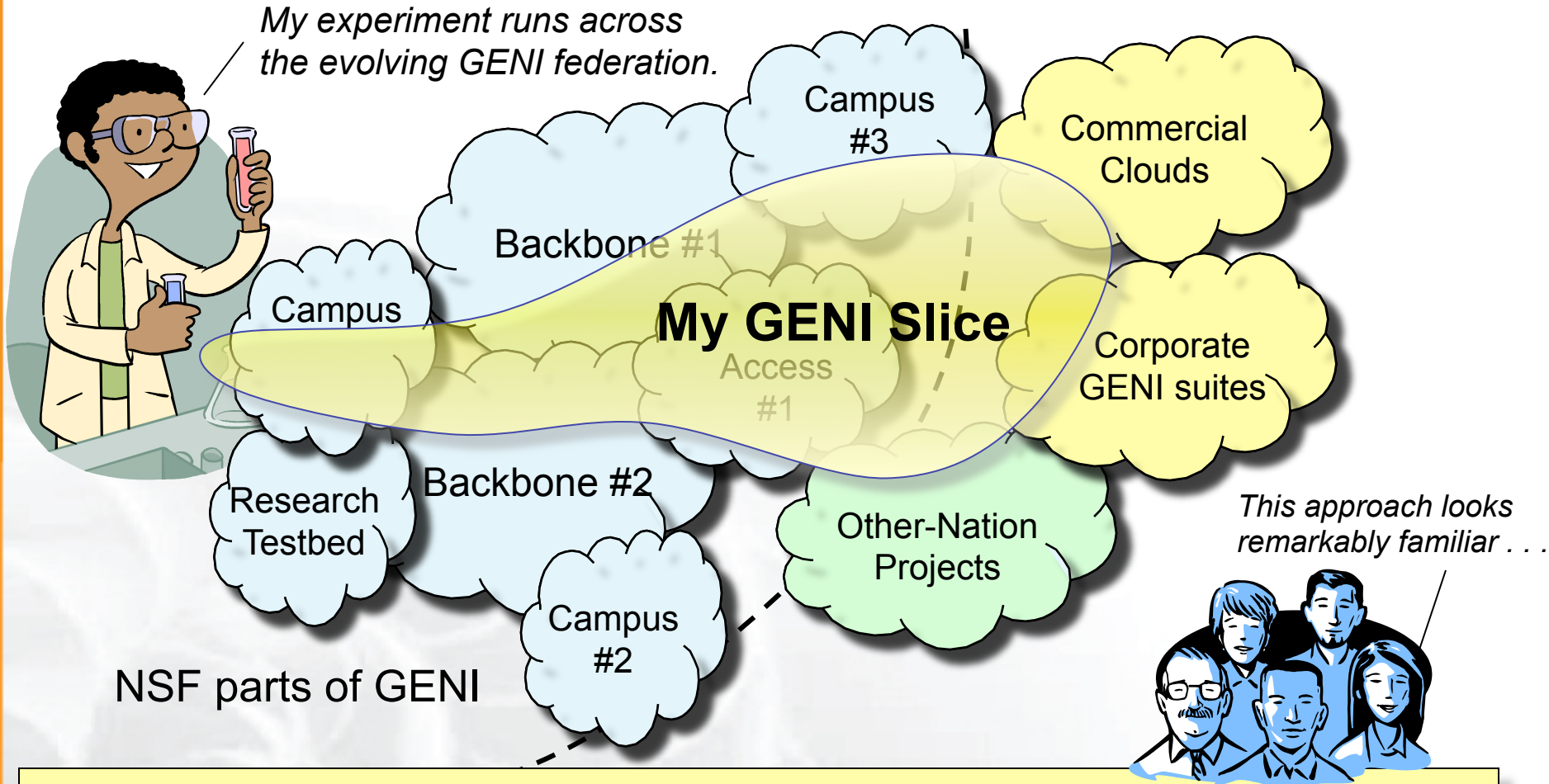
If you have a great idea, check out the **NSF CISE research programs for current opportunities.**

- 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!

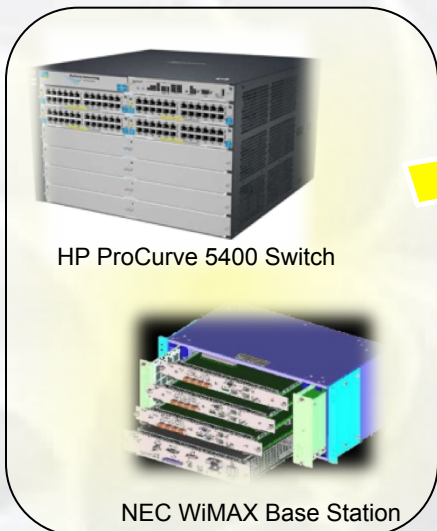
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GENI grows by “GENI-enabling” heterogeneous infrastructure

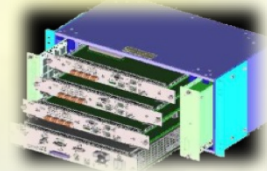


Goals: avoid technology “lock in,” add new technologies as they mature, and potentially grow quickly by incorporating existing infrastructure into the overall “GENI ecosystem”

- **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

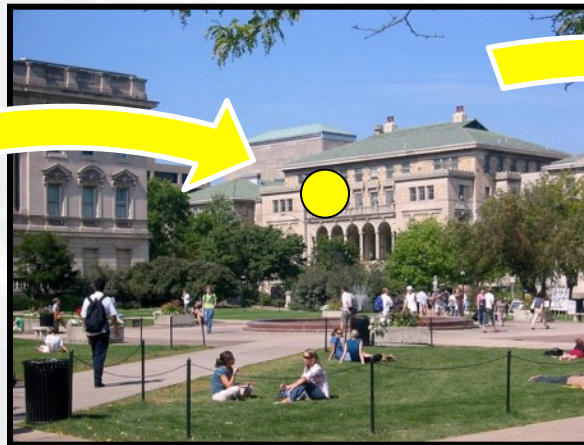


HP ProCurve 5400 Switch

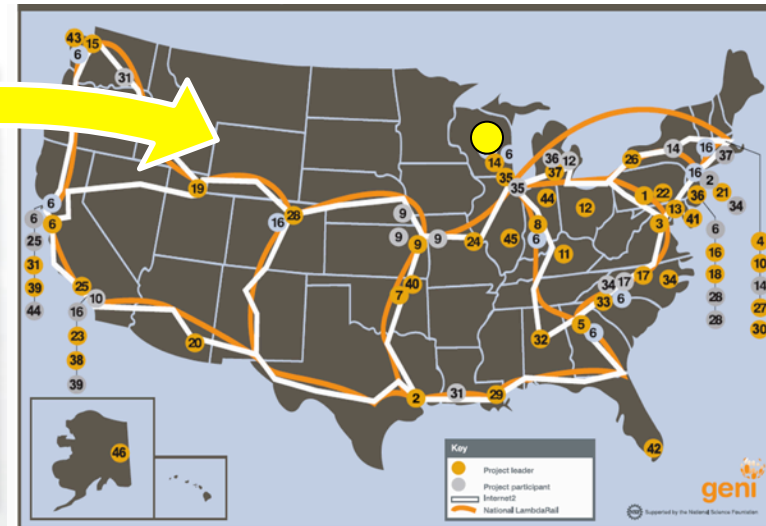


NEC WiMAX Base Station

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



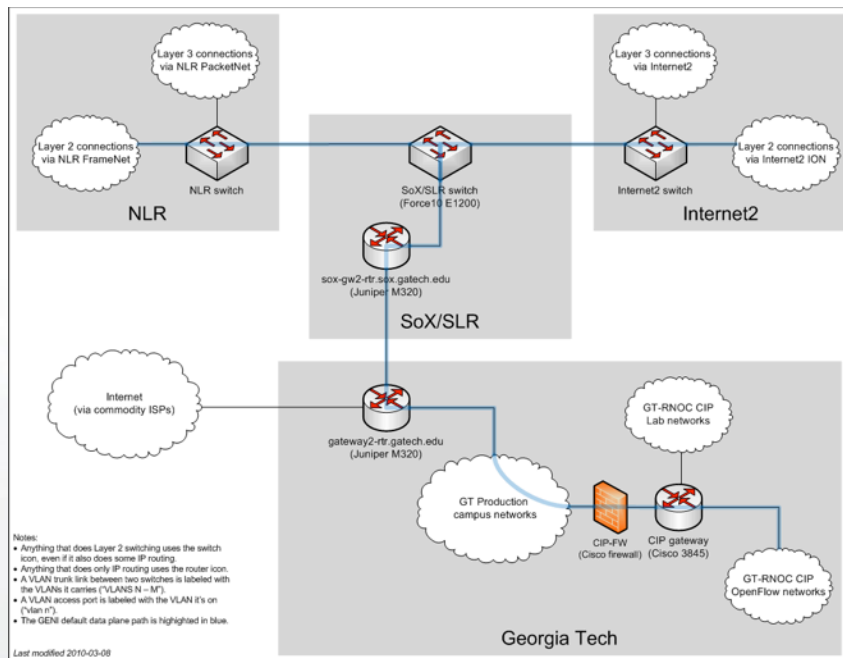
Ellen Zegura
PI



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

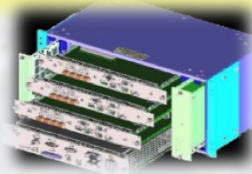
Trials of “GENI-enabled” commercial equipment



HP ProCurve 5400 Switch



Juniper MX240 Ethernet Services Router



NEC WiMAX Base Station



HTC Android smart phone



Toroki LightSwitch 4810



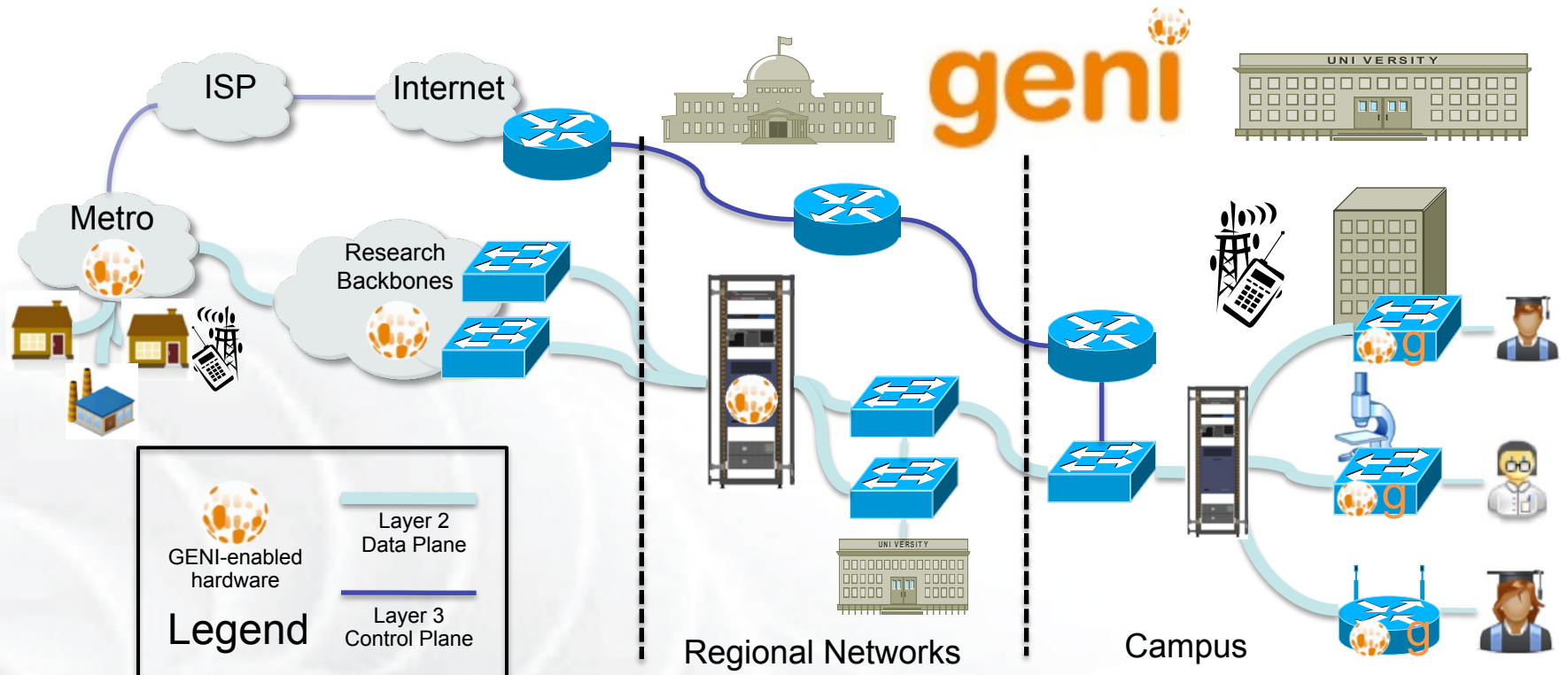
GENI racks



NEC IP8800 Ethernet Switch



Arista 7124S Switch





- 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.

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



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

Regional nets



-  Existing
-  New

GENI WiMAX

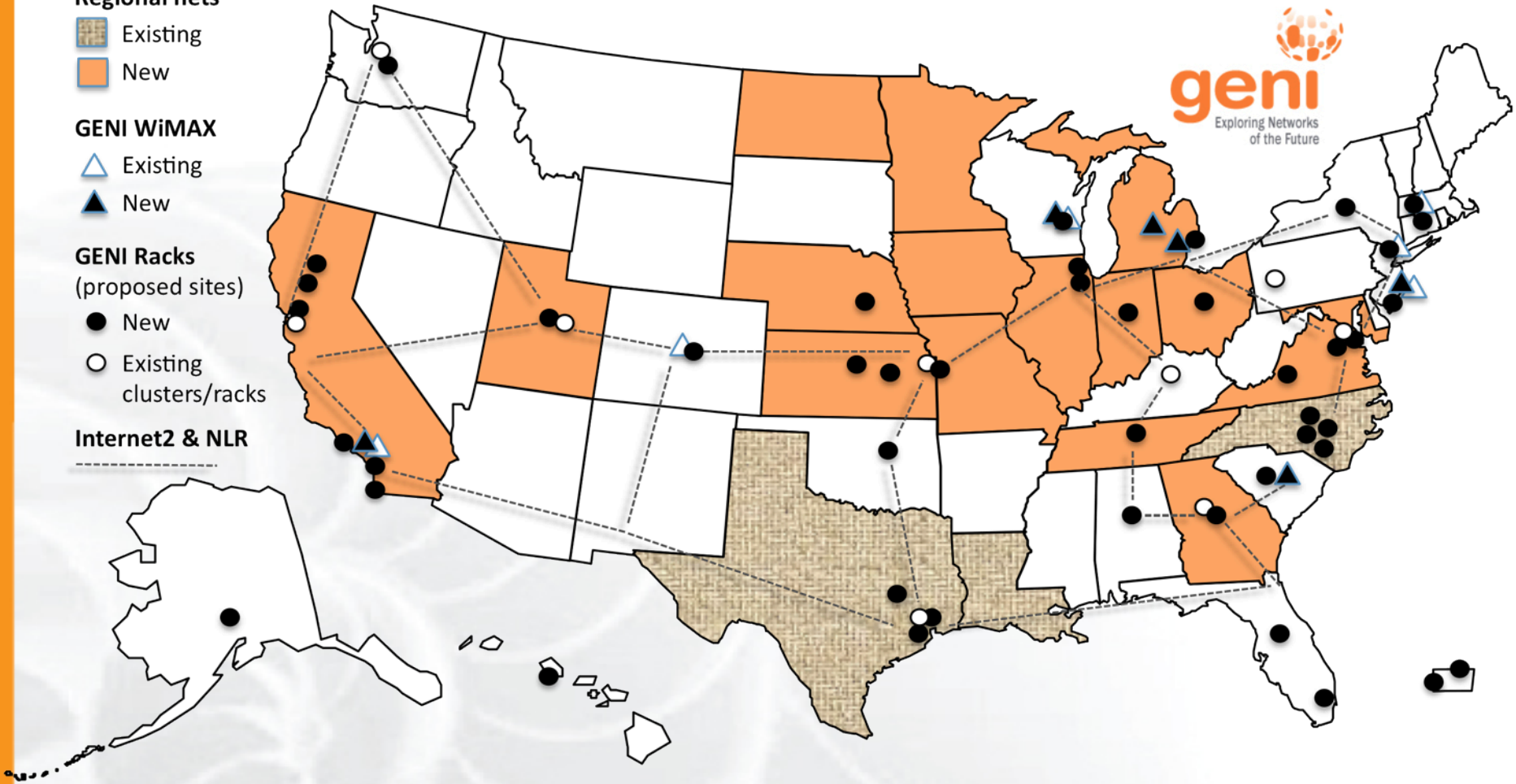
-  Existing
-  New

GENI Racks

(proposed sites)

-  New
-  Existing clusters/racks

Internet2 & NLR



(as proposed; actual footprint to be engineered)

- 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 !

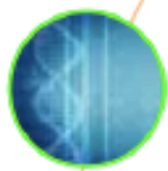
Note that this agreement does not exclude either party from additional collaborations.



Courtesy of DOD

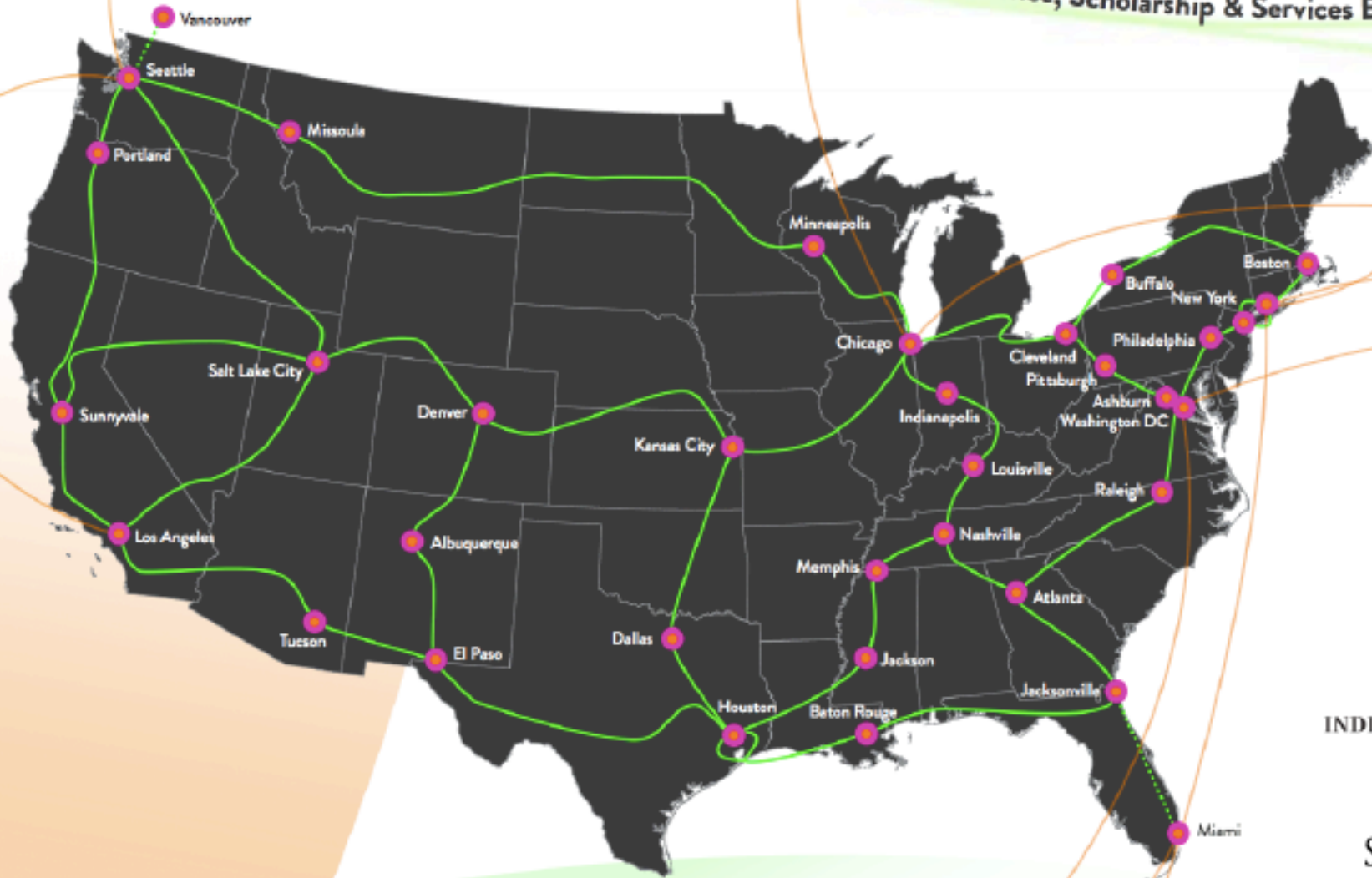


Courtesy of USGS



OS³E

The Open Science, Scholarship & Services Exchange



INDIANA UNIVERSITY

STANFORD UNIVERSITY

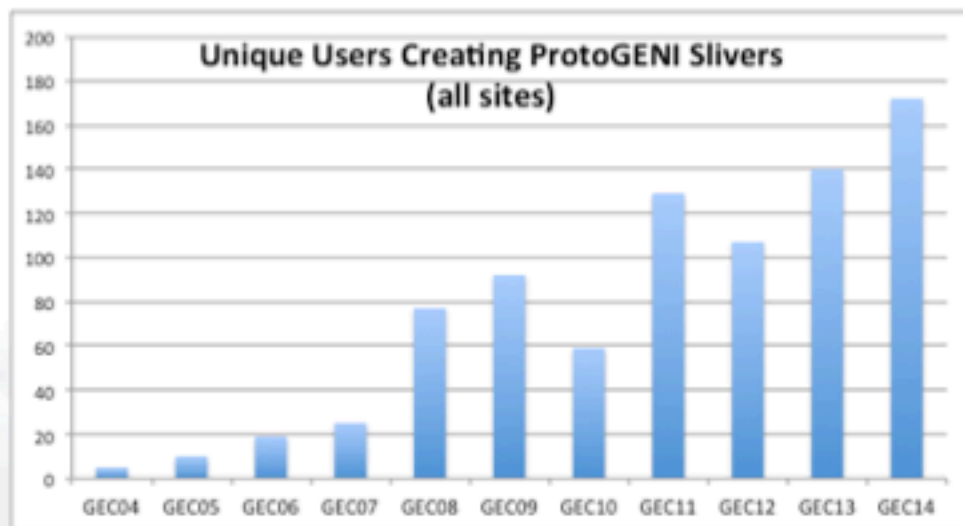
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- **GENI is gaining traction with experimenters.**
 - More experimenters are signing up for credentials.
 - More experimenters are actively using GENI.
- **Experienced experimenters are pushing up against some limits. They want access to more GENI resources.**
 - More deeply programmable sites
 - More compute resources
 - Long-lived slices



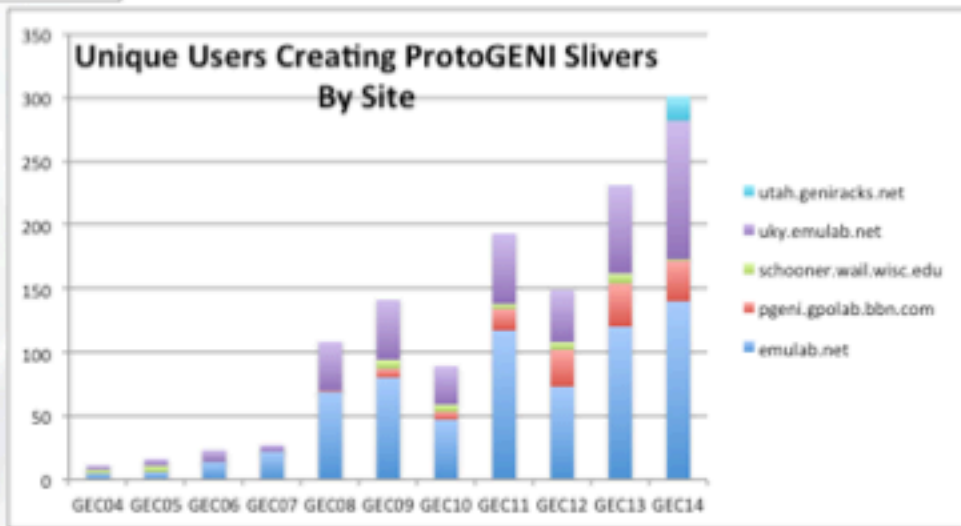
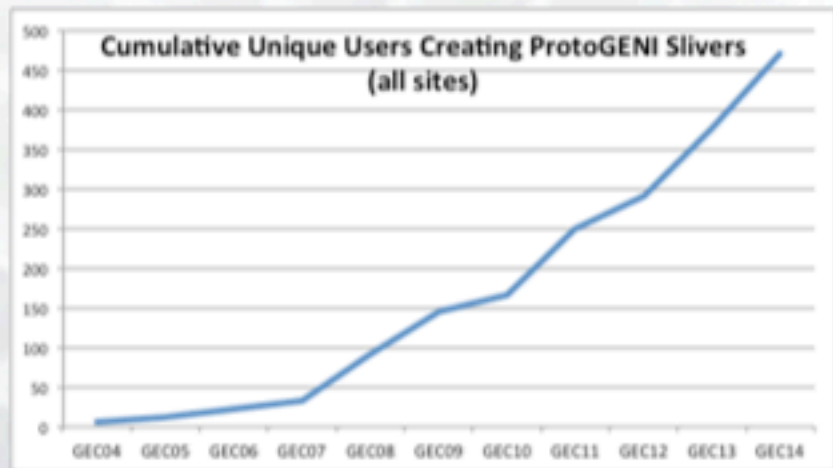
Planned GENI expansion significantly enhances experiment opportunities.

Growing number of experimenters

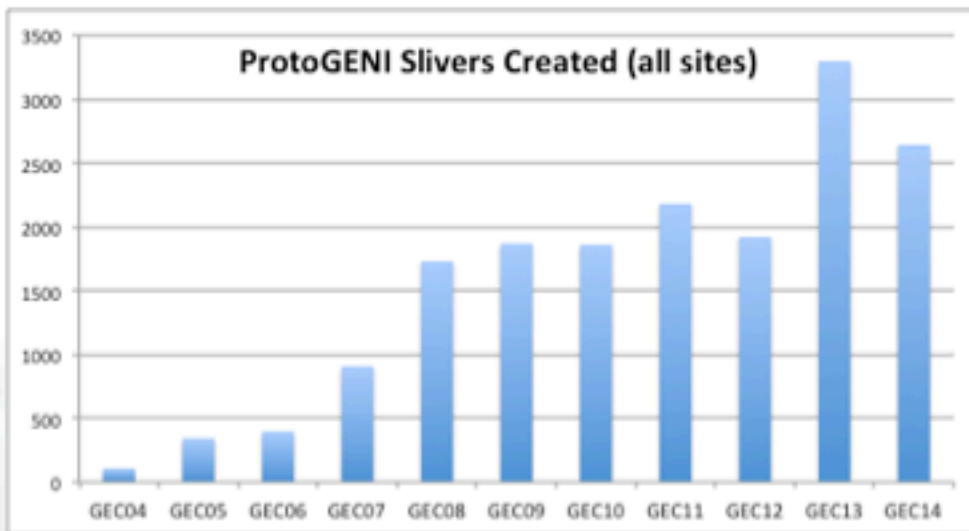


Notes

- ProtoGENI sites only (currently working on data from other GENI aggregates)
- Excludes test users and sites, includes tutorials
- Data as of 5 July 2012 (GEC14 period incomplete)

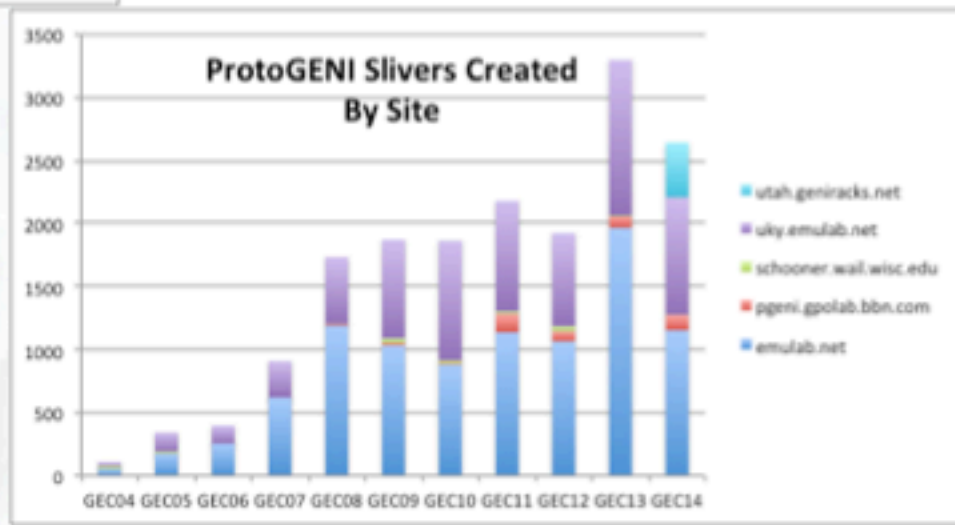
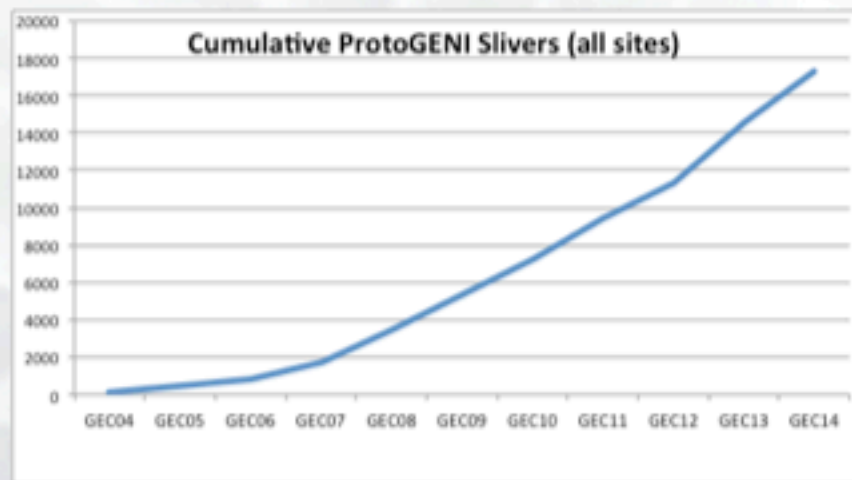


Growing number/size of experiments



Notes

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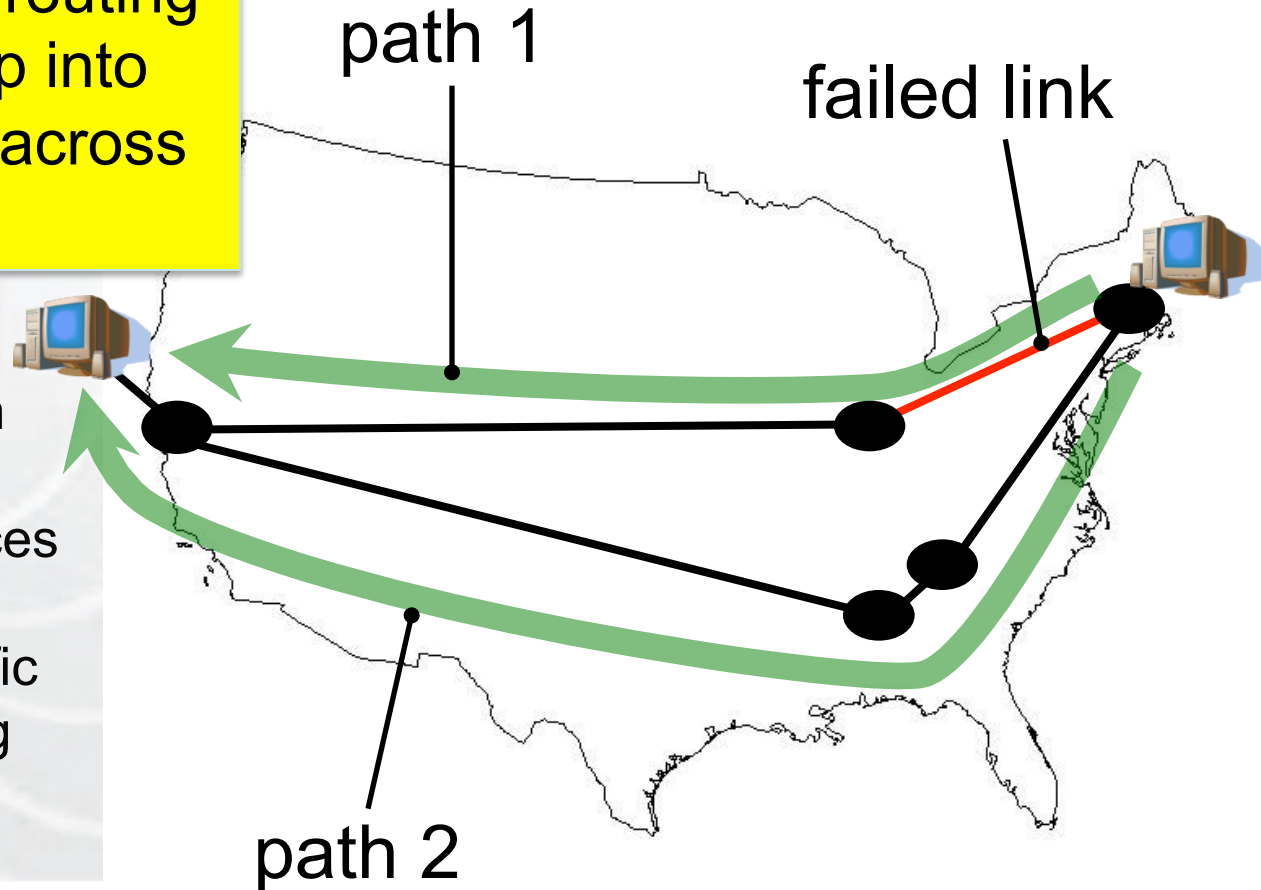


Resilient Routing in the Pathlet Architecture

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

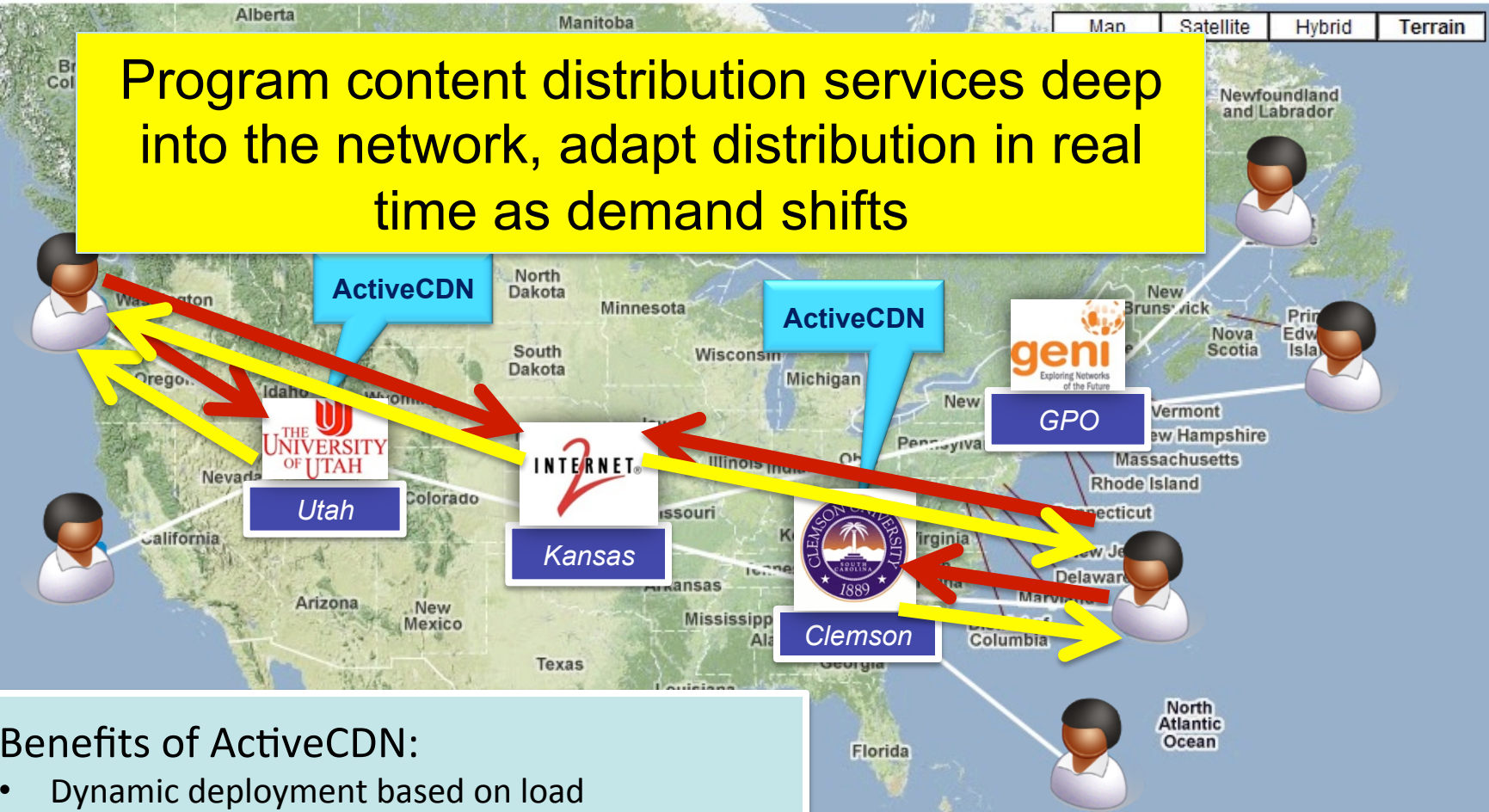
Deploy innovative routing architecture deep into network switches across the US

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





Program content distribution services deep into the network, adapt distribution in real time as demand shifts



- 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

David Irwin et al



UMASS
AMHERST



Revolutionizing our ability to observe, understand, predict and respond to hazardous weather events



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

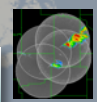
Nowcast images for display

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

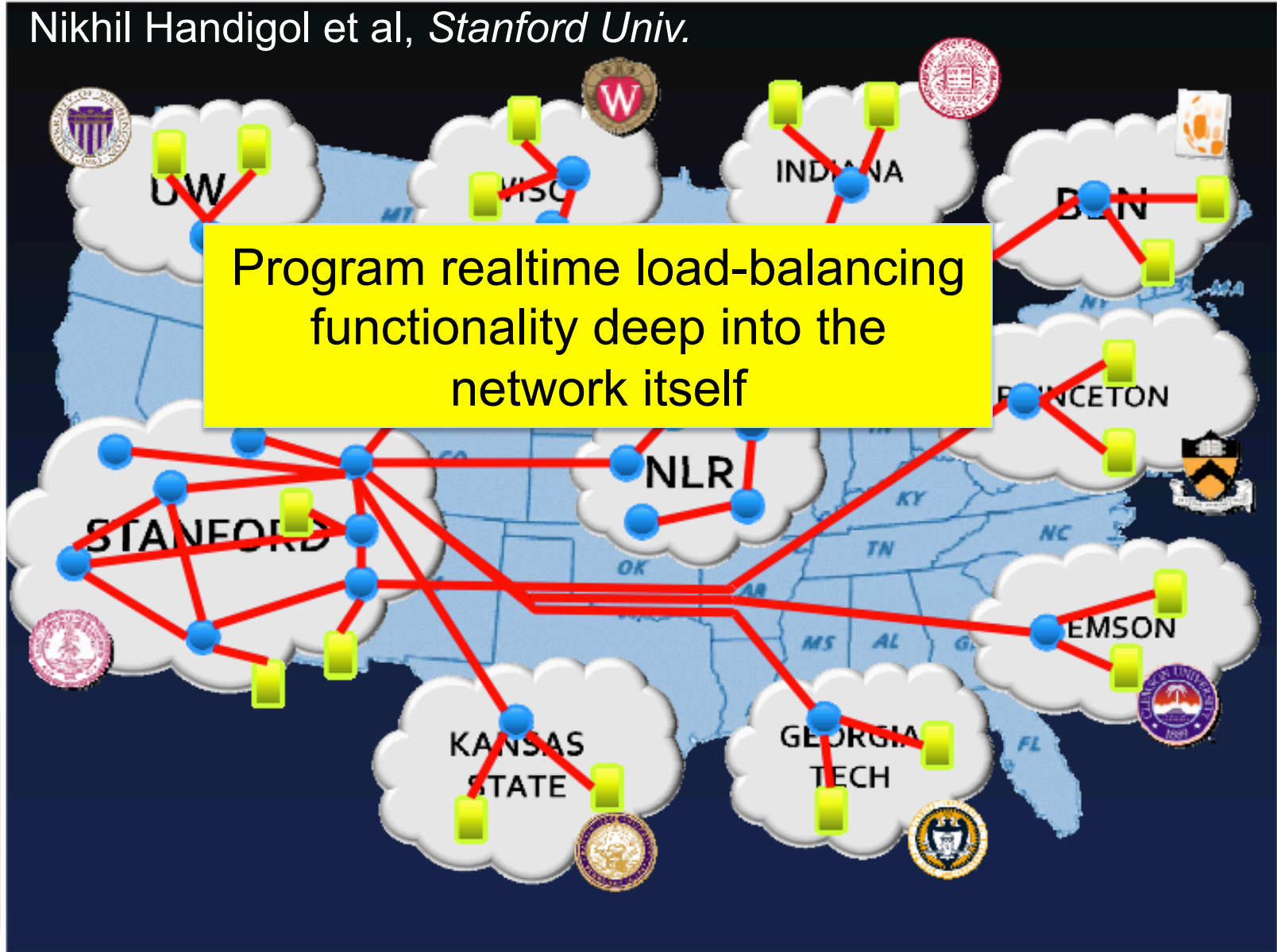
Multi-radar NetCDF Data



Nowcast Processing



Nikhil Handigol et al, *Stanford Univ.*



- **Kaiqi Xiong, RIT**
 - First GENI Research and Educational Experiment Workshop
- **Jeannie Albrecht, Williams**
 - Curricula for Undergraduate Courses in Distributed Systems
 - before GEC 14 (Boston)
- **Nick Feamster, GA Tech**
 - “Living lab”
 - Being planned
- **ACM SIGCOMM 2012**
 - Workshop on Hot Topics in Software Defined Networking
- **ICC 2012**
 - Workshop on Software Defined Networks (SDN'12)
- **ICCCN 2012**
 - Track on Network Architectures and Clean-Slate Designs
- **TridentCom 2012**
 - Testbeds, Experimentation and Innovation for the Future Internet

Special issue on Future Internet Testbeds –
Computer Networks, James P. G. Sterbenz et al, eds.

1st GENI research and educational experiment workshop (GREE2012)

- At GEC13 (Los Angeles), March 15-16

GREE-SC2012 at RIT in May/June

- 4.5 days of tutorials, advice, one-on-one support, and project coding
- Eighteen attendees plus camp staff
 - Ten grants from ~30 applicants, plus eight self-funded
- Participants continue projects with an eye towards submission to GREE2013.



Next camp: June 2013 at UConn, Storrs, CT.

For info: Kaiqi Xiong <kxxics@rit.edu> or help@geni.net

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- US Ignite is an initiative to spark the development of **gigabit applications and services**
- **in areas of national priority:** advanced manufacturing, health, education, energy, economic development, transportation, and public safety/emergency preparedness
- **on an ultra high speed, deeply programmable, and sliceable network testbed.**



White House Launch – US Ignite



Dr. John Holdren
President's Science Advisor



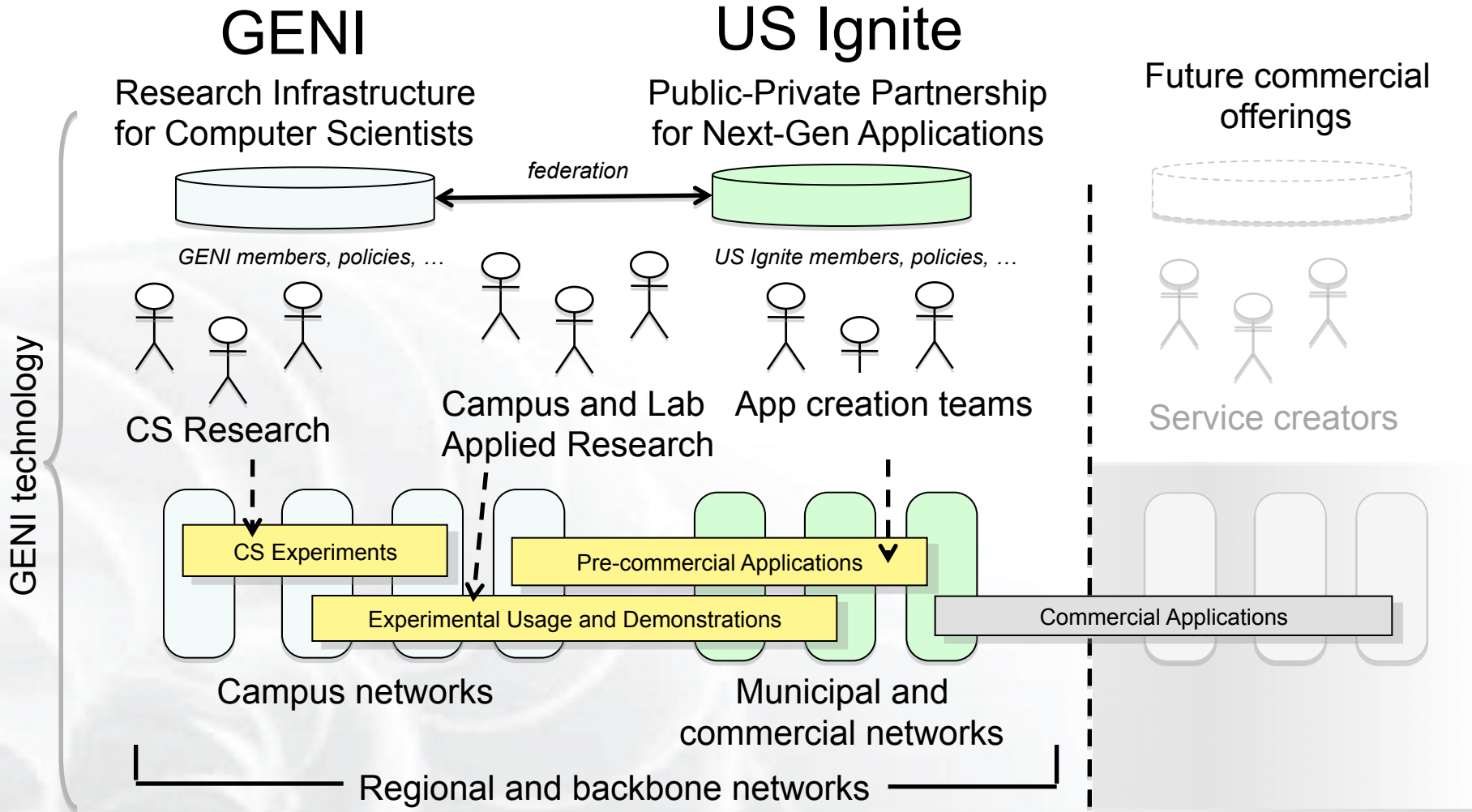
Dr. Subra Suresh
Director, NSF



Dr. Julius Genachowski
Chairman, FCC



June 14, 2012

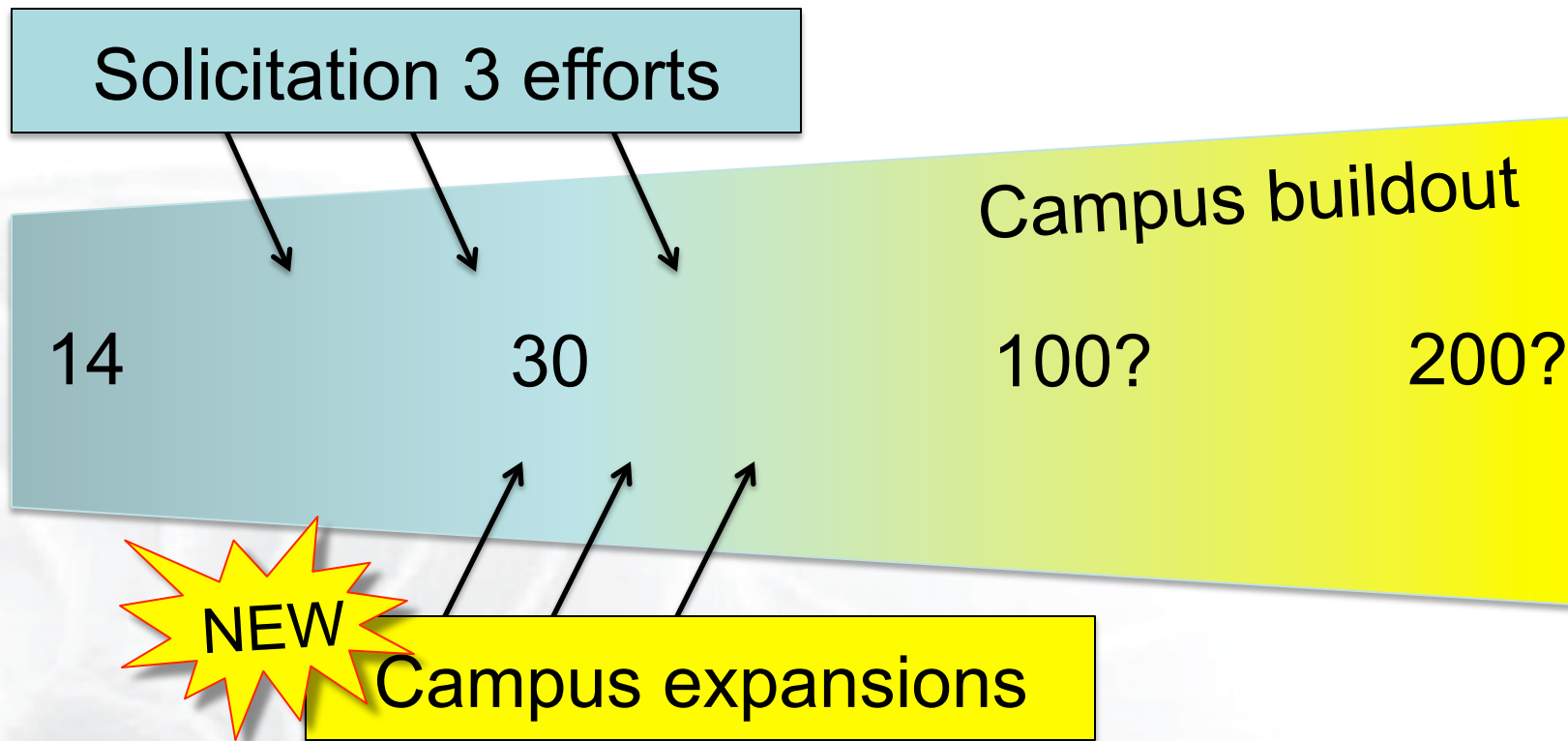


US Ignite is a new organization that will promote advanced applications and infrastructure leveraging GENI research and technologies.

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Growing GENI to 100-200 campuses

GENI racks, OpenFlow, WiMAX, training, ops



GENI racks, OpenFlow, WiMAX, training, ops



Spiral development . . .



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

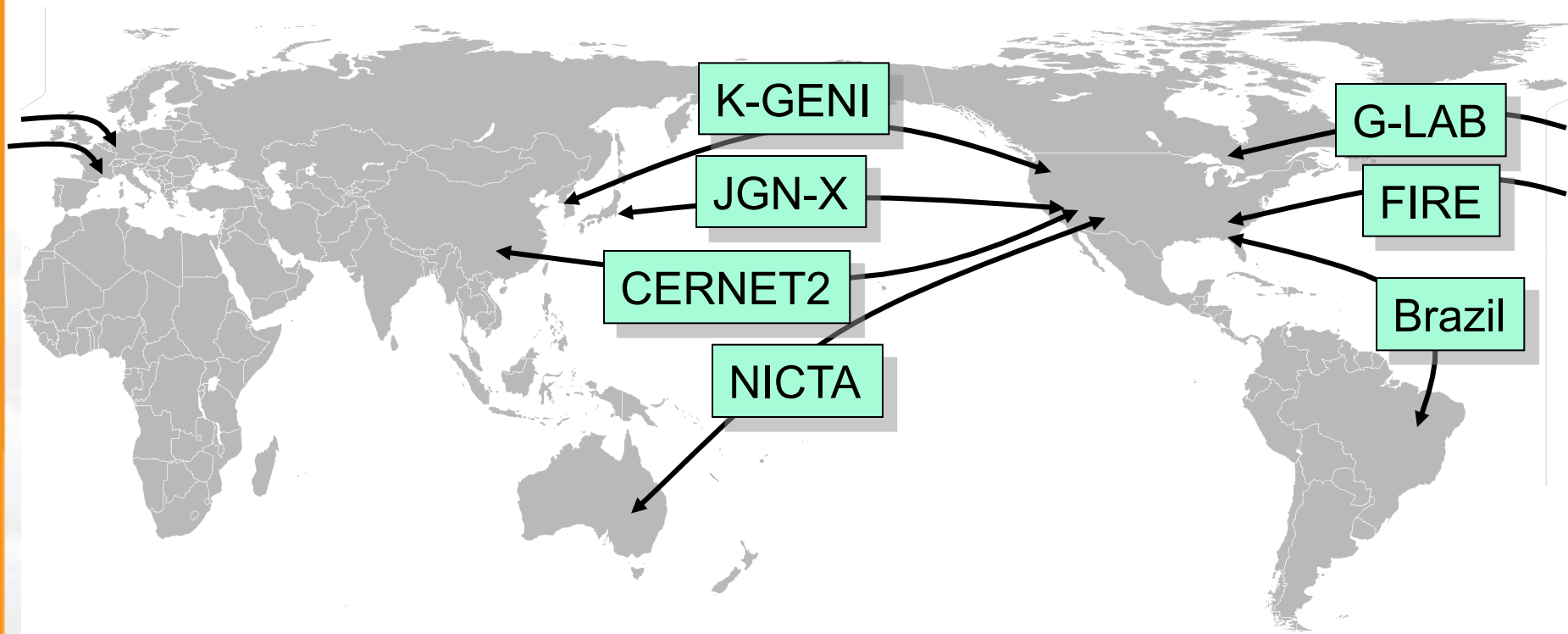


Network Engineers “boot camp” organized by Larry Landweber and given by Matt Davy and Steve Wallace, Indiana University

- 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, Chattanooga	Univ Utah
Univ Washington	Univ Wisconsin, Madison

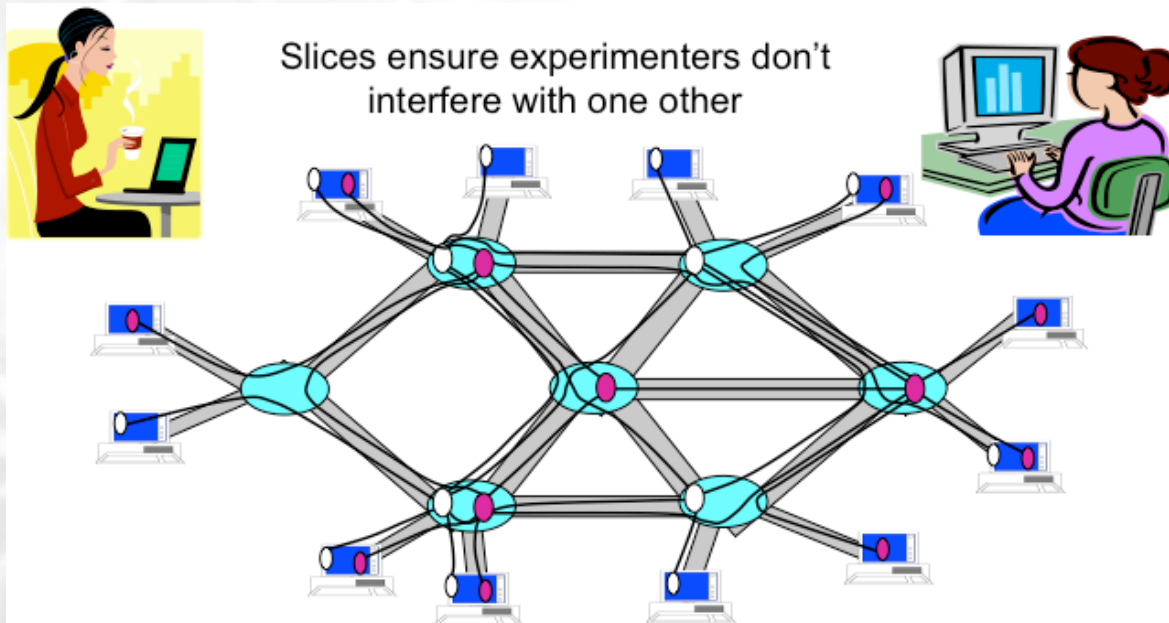
- 35 additional schools have expressed interest and are on waitlist



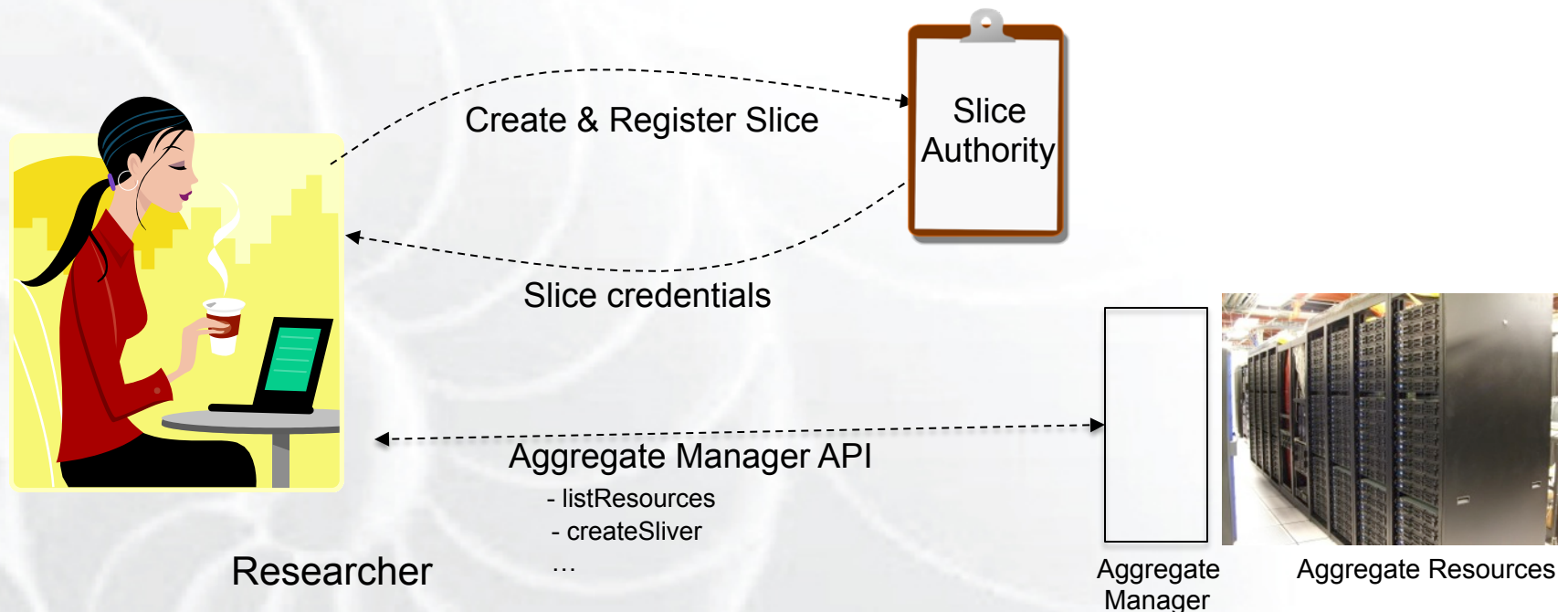
The GENI project is actively collaborating with peer efforts outside the US, based on equality and arising from direct, “researcher to researcher” collaborations.

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- Slice: Abstraction for a collection of resources capable of running experiments
 - An experiment uses resources in a slice
 - Slices isolate experiments
 - Experimenters are responsible for their slices

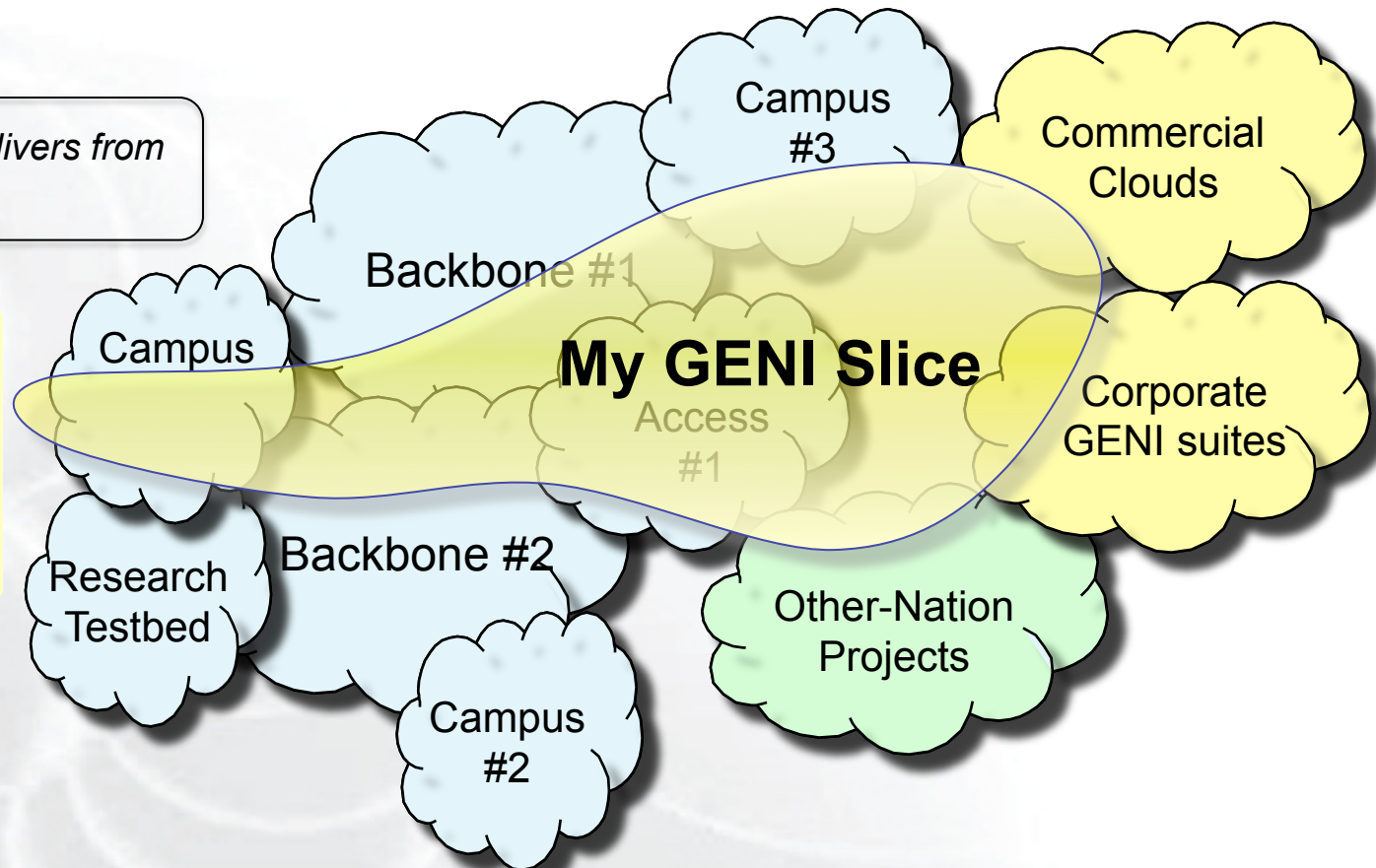


- **Slice authority:** Creates and registers slices
 - GENI slice authorities: PlanetLab, ProtoGENI, GPO Lab
- **Aggregate:** Provides resources to GENI experimenters
 - Typically owned and managed by an organization
 - Examples: PlanetLab, Emulab, GENI Rack on various campuses
 - Aggregates implement the GENI AM API



- Sliver: One or more resources provided by an aggregate
 - E.g. Bare machines, virtual machines, VLANs

My slice contains slivers from many aggregates.

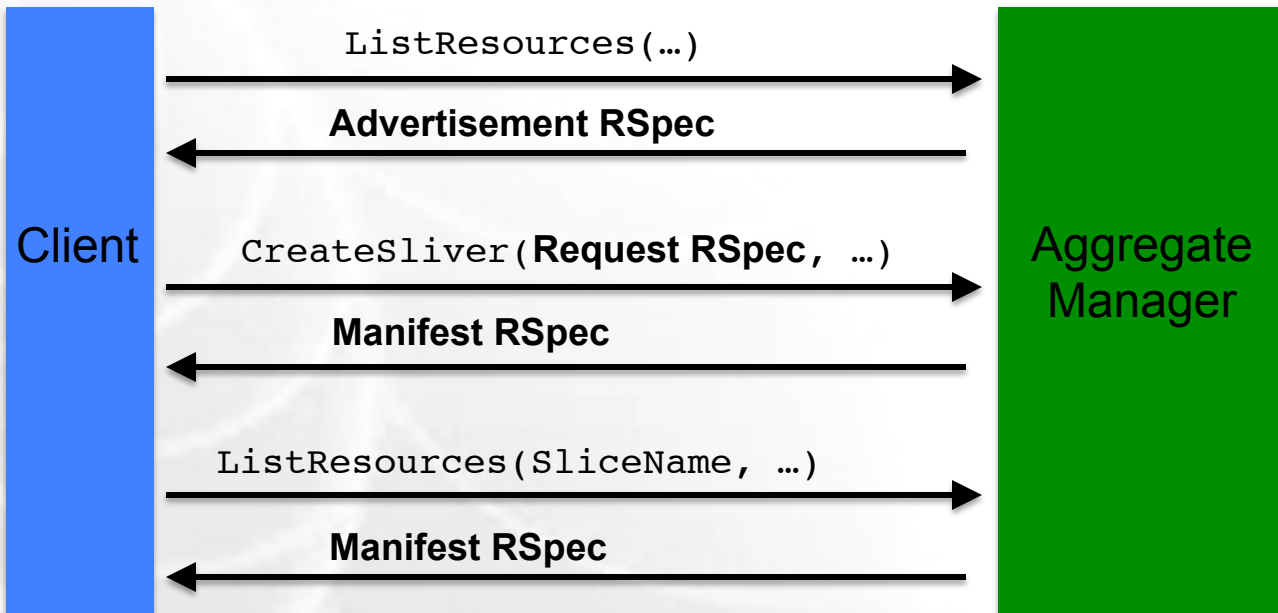
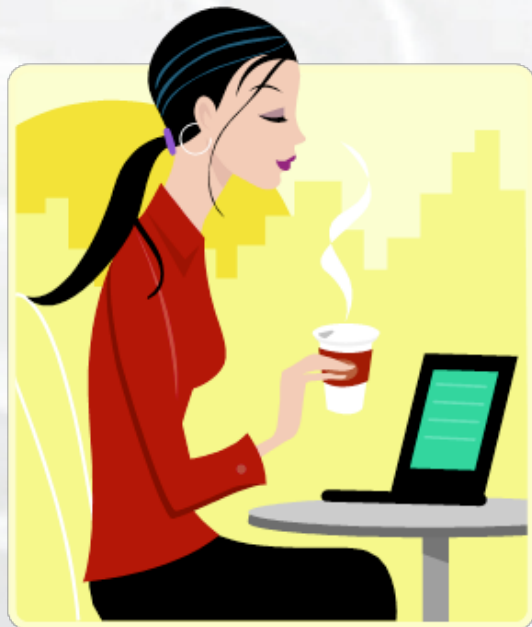


- RSpecs: Lingua franca for describing and requesting resources
 - “Machine language” for negotiating resources between experiment and aggregate
 - Experimenter tools eliminate the need for most experimenters to write or read RSpec

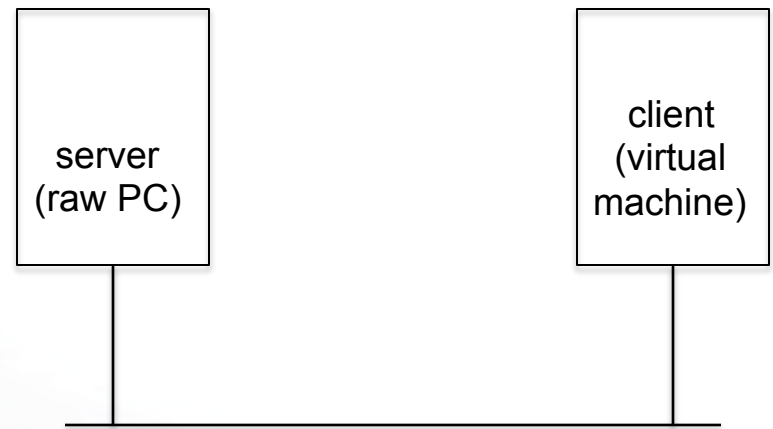
```
<?xml version="1.0" encoding="UTF-8"?>
<rspec xmlns="http://www.protogeni.net/resources/rspec/2"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.protogeni.net/resources/rspec/2
    http://www.protogeni.net/resources/rspec/2/request.xsd"
  type="request" >
  <node client_id="my-node"
    exclusive="true">
    <sliver_type name="raw-pc" />
  </node>
</rspec>
```

RSpec for requesting a single node

- Advertisement RSpec: What does an aggregate have?
- Request RSpec: What does the experimenter want?
- Manifest RSpec: What does the experimenter have?



- Demo
 - Create a slice
 - Create a sliver at one aggregate
 - One computer (raw PC), one VM, connected by a LAN
 - Install and run software on the machine and VM
 - View output of software
 - Delete sliver
- Experimenter tool: Flack



- Launch Flack
- Log in
- Create slice
- Use Flack canvas to draw topology
- Create sliver
- Verify sliver creation was successful



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Flack

Submit introslice1: Submitted v14.42

introslice1

View ▼

Add Resources

Get Status

utahemulab.cm ▼

Get Silver Status: Ready

Slices New

Show

All

introslice1

Managers Add

Show/Hide

- bbn-pgeni.cm
- beelab.cm
- cis.flu.edu.cm
- cmulab.cm
- cron.loni.org.cm
- ETRI-CM1.cm
- genicloud.hplabs.sa
- jonlab.cm
- mygeni.cm
- plc.sa
- shadowgeni.cm
- ukgeni.cm
- usp_protojeni.cm
- utahemulab.cm

server ❌ i

pc554.emulab.net:22
excl, raw-pc
FEDORA10-STD
=> pc554

Lan ❌ i

client ❌ i

pc533.emulab.net:37178
sh.emulab-openvz
=> pc533

5h 49m

Extend 2 Hours ▼

Delete

Submit

Preview Request RSPEC for Introslice 1

Download in other formats:
[Plain Text](#)

```
<rspec type="request" xsi:schemaLocation="http://www.geni.net/resources/rspec/3 http://www.geni.net/resources/rspec/3/request.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://www.geni.net/resources/rspec/3">
  <node client_id="server" component_manager_id="urn:publicid:IDN+emulab.net+authority+cm" exclusive="true">
    <sliver_type name="raw-pc">
      <disk_image name="urn:publicid:IDN+emulab.net+image+emulab-ops//FEDORA10-STD"/>
    </sliver_type>
    <services>
      <execute command="sudo /local/install-script.sh" shell="sh"/>
      <install install_path="/local" url="http://www.gpolab.bbn.com/experiment-support/HelloGENI//hellogeni-install.tar.gz"/>
    </services>
    <interface client_id="server:if0" />
  </node>
  <node client_id="client" component_manager_id="urn:publicid:IDN+emulab.net+authority+cm" exclusive="false">
    <sliver_type name="emulab-opensvz"/>
    <services>
      <execute command="sudo /local/install-script.sh" shell="sh"/>
      <install install_path="/local" url="http://www.gpolab.bbn.com/experiment-support/HelloGENI//hellogeni-install.tar.gz"/>
    </services>
    <interface client_id="client:if0" />
  </node>
  <link client_id="Lan">
    <component_manager name="urn:publicid:IDN+emulab.net+authority+cm"/>
    <interface_ref client_id="server:if0"/>
    <interface_ref client_id="client:if0"/>
    <property source_id="server:if0" dest_id="client:if0"/>
    <property source_id="client:if0" dest_id="server:if0"/>
  </link>
</rspec>
```





```

<rspec type="manifest" ...>
  <node client_id="server" component_manager_id="urn:publicid:IDN+emulab.net+authority+cm" exclusive="true"
    component_id="urn:publicid:IDN+emulab.net+node+pc554" sliver_id="urn:publicid:IDN+emulab.net+sliver+95506">
    <sliver_type name="raw-pc">
      <disk_image name="urn:publicid:IDN+emulab.net+image+emulab-ops//FEDORA10-STD"/>
    </sliver_type>
    <services>
      <execute command="sudo /local/install-script.sh" shell="sh"/>
      <install install_path="/local" url="http://www.gpolab.bbn.com/experiment-support/HelloGENI//hellogeni-install.tar.gz"/>
      <login authentication="ssh-keys" hostname="pc554.emulab.net" port="22" username="vthomas"/>
    </services>
    <interface client_id="server:if0" component_id="urn:publicid:IDN+emulab.net+interface+pc554:eth2" sliver_id="urn:publicid:IDN
+emulab.net+sliver+95509" mac_address="0024e87a46fb">
      <ip address="10.10.1.1" type="ipv4"/>
    </interface>
  </node>
  <node client_id="client" component_manager_id="urn:publicid:IDN+emulab.net+authority+cm" exclusive="false"
    component_id="urn:publicid:IDN+emulab.net+node+pc533" sliver_id="urn:publicid:IDN+emulab.net+sliver+95505">
    <sliver_type name="emulab-openvz"/>
    <services>
      <execute command="sudo /local/install-script.sh" shell="sh"/>
      <install install_path="/local" url="http://www.gpolab.bbn.com/experiment-support/HelloGENI//hellogeni-install.tar.gz"/>
      <login authentication="ssh-keys" hostname="pc533.emulab.net" port="37178" username="vthomas"/>
    </services>
    <interface client_id="client:if0" component_id="urn:publicid:IDN+emulab.net+interface+pc533:eth2" sliver_id="urn:publicid:IDN
+emulab.net+sliver+95510" mac_address="0262331adfd4">
      <ip address="10.10.1.2" type="ipv4"/>
    </interface>
  </node>
  <link client_id="Lan" sliver_id="urn:publicid:IDN+emulab.net+sliver+95508" vlantag="310">
    <interface_ref client_id="server:if0" component_id="urn:publicid:IDN+emulab.net+interface+pc554:eth2" sliver_id="urn:publicid:IDN
+emulab.net+sliver+95509"/>
    <interface_ref client_id="client:if0" component_id="urn:publicid:IDN+emulab.net+interface+pc533:eth2" sliver_id="urn:publicid:IDN
+emulab.net+sliver+95510"/>
    <property source_id="server:if0" dest_id="client:if0"/> <property source_id="client:if0" dest_id="server:if0"/>
  </link>
</rspec>

```

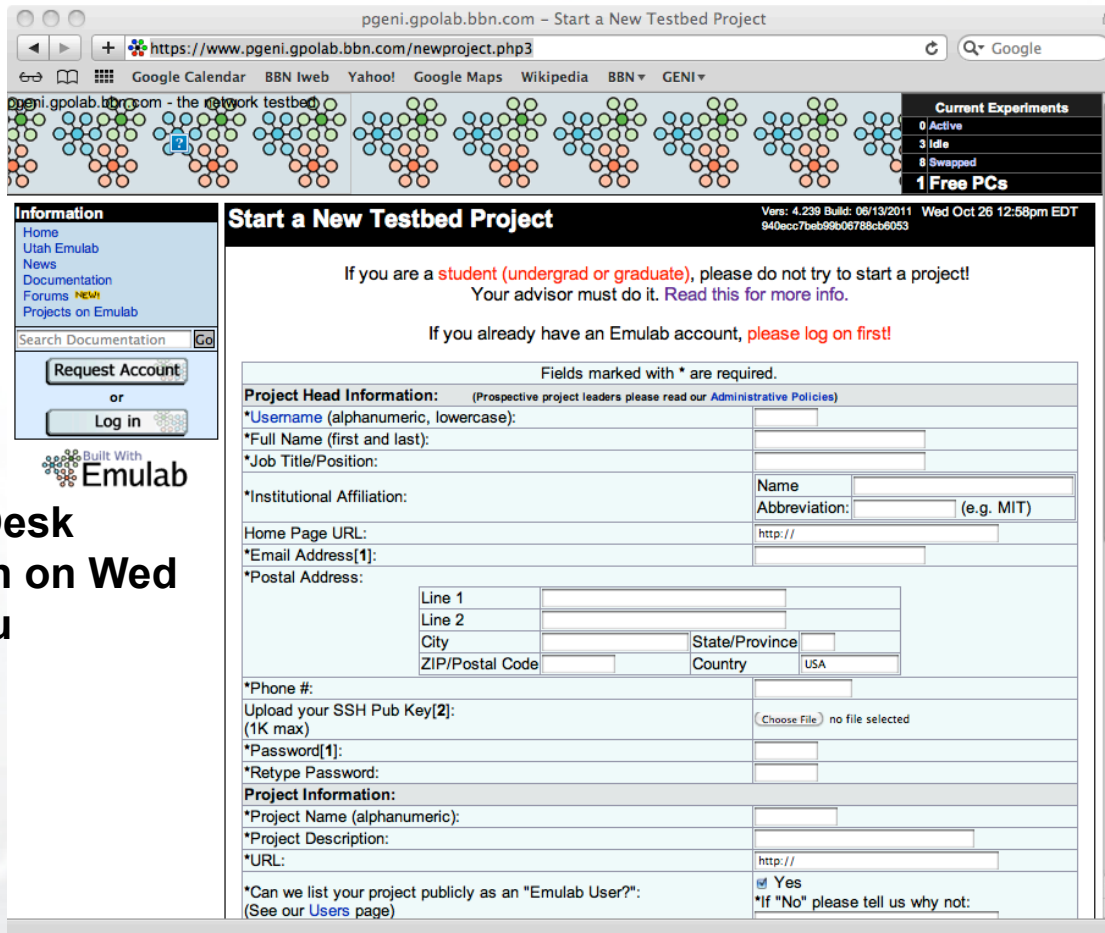
- Log in
- Create a slice
- Add resources (slivers) to the slice
- Install software on resources
- Run experiment

- Not shown in this demo
 - Instrumentation and measurement
 - More experiment control (start, stop, barrier synchronization, etc)

- Tutorials on the GENI wiki
 - Look for the  icon on the GENI wiki and then click on  for tutorials
- Participate in the hands-on tutorials at the GEC
- Get a GENI account today!



At the GEC: - Experimenter Help Desk
 - Experimenter drop-in on Wed
 - Coding sprint on Thu

Online: <https://www.pgeni.gpolab.bbn.com/newproject.php3>

Email: help@geni.net

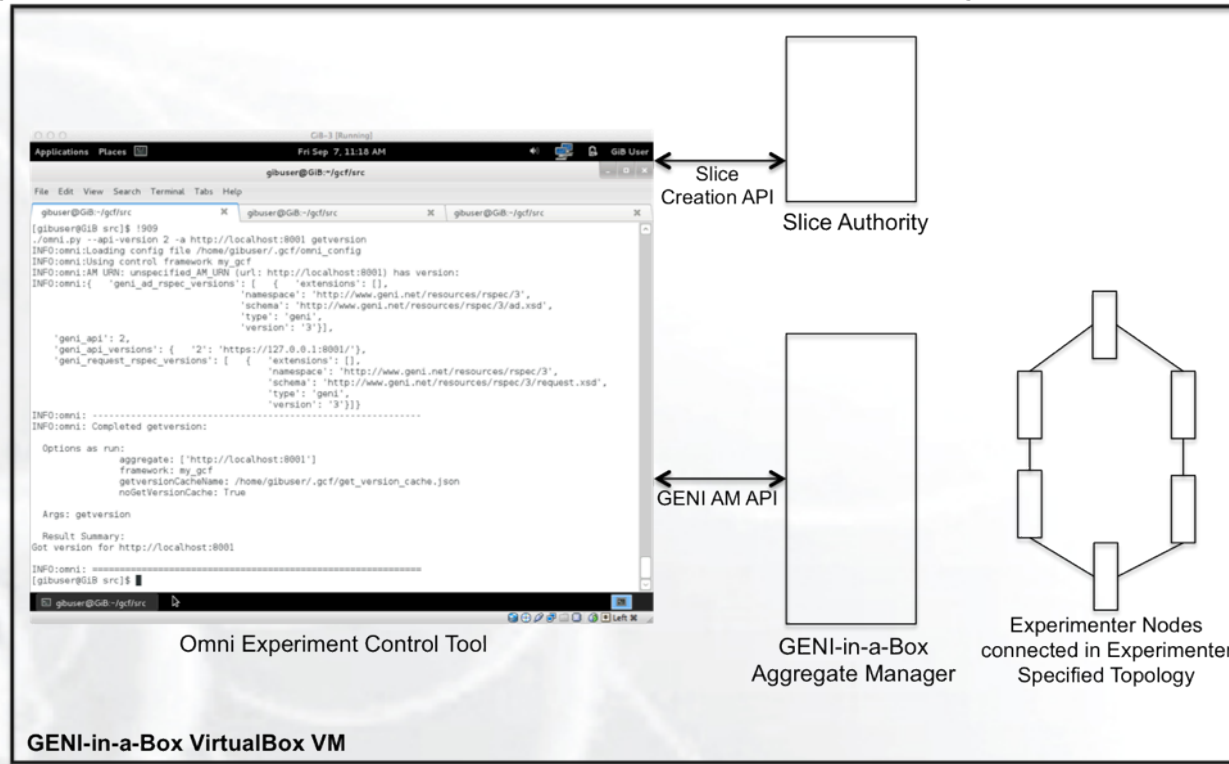
Student accounts need to be approved by a professor.

Participate in the Hands-On Tutorials

	Tue 10/23			Wed 10/24			Thu 10/25			
7:30-8:30	Breakfast	★ Newcomer Breakfast		Breakfast			Breakfast	★ Newcomer Breakfast	7:30-8:30	
8:30 – 10:00	▲ I&M: GIMI and GEMINI Design Topics	OPEN	★ Tutorial: Intro to GENI and Experiment Lifecycle	Plenary (A)			★ Tutorial: GIMI	▲ Program-mable Networks & GENI	★ Tutorial: WiMAX	8:30 – 9:45
10:30 – noon	▲ Campus / Experiment Topics in Monitoring and I&M	OPEN	★ Tutorial: Flack & InstaGENI	Plenary (B)			▲ Experimenters Roundtable			9:45 – 11:00
Noon – 1:00	Lunch			Lunch			Lunch			11:30 – noon
1:00 – 2:30	● ▲ Experiment Lifecycle Tools	▲ Aggregate Topics: AM API Rspecs Stitching	★ Tutorial: GEMINI	● GENI Clearinghouse and Portal	● Tutorial: Advanced GENI Topologies with Omni	★ Tutorial: ExoGENI	● ▲ Coding Sprint	OPEN	OPEN	1:00 – 2:30
3:00 – 5:00	OPEN	★ Tutorial: Intro to Omni	★ Tutorial: GEMINI (cont'd)	▲ GENI Racks at Campuses and Regionals	★ ● Experimenters Drop-In Help Session	● ▲ WiMAX Campus and Experiment Update	● ▲ Coding Sprint	OPEN	OPEN	3:00 – 5:00
5:30 – 7:30	Demo Night			BoF Dinners (Info on web site.) Times TBA			<p>Why are you at GEC? These symbols will help you identify sessions of interest to you.</p> <ul style="list-style-type: none"> ★ Learn GENI basics: suitable for new experimenters. ● Broaden GENI knowledge or improve experiment skills. ▲ Participate in and influence GENI development. 			

GPO Office Hours

- Try out GENI without getting an account
 - A GENI slice authority and aggregate that runs on your computer!
- Move your experiment to GENI when you are ready



Demo at Experimenter Roundtable (or ask me for one)

- Participate in the tutorials
 - Stop by the Experimenter Help Desk if you don't have the VM with tutorial software
- Don't be shy to ask for help
 - At the tutorials
 - Stop by the Experimenter Help Desk
 - Staffed during the breaks today and tomorrow
 - Drop in to the Experimenter Help Session
 - Tomorrow at 3pm
 - Walk into Coding Sprint
 - Email help@geni.net

GENI Engineering Conferences

We welcome your participation in GENI

- **16th meeting, open to all:
19-21 March 2012, University of Utah**
 - Planning & discussion for experimenters, software, infrastructure
 - Tutorials and workshops
 - **Travel grants** to US academics for participant diversity

