geni
Exploring Networks of the Future

GENI

Exploring Networks of the Future

An introduction

GENI Project Office
November 2010
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
- GENI's evolving control framework
- How can you participate?

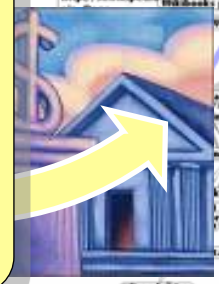
Global networks are creating extremely important new challenges

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

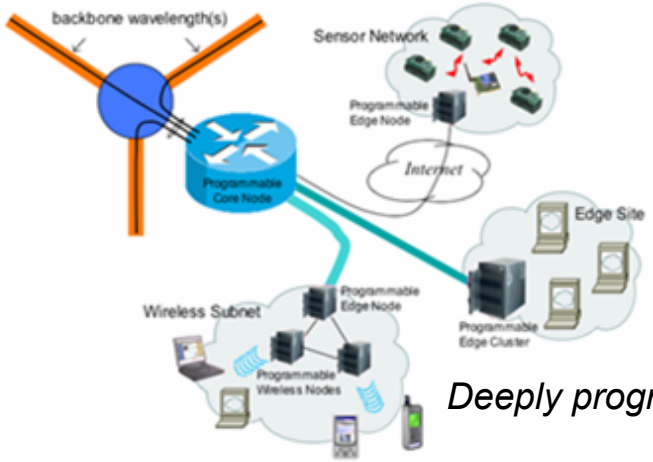
What is GENI?

- GENI is a virtual laboratory for **exploring future internets at scale**, now rapidly taking shape in prototype form across the United States
- GENI creates major opportunities to *understand, innovate, and transform* global networks and their interactions with society.
- GENI opens up new areas of research at the frontiers of network science and engineering, with significant potential for socio-economic impact.

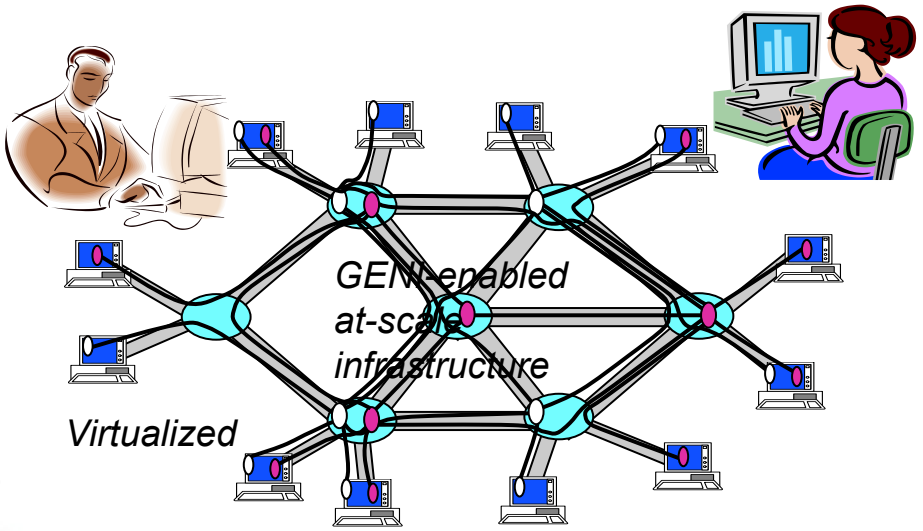
GENI is unique

- **GENI is enabling two classes of "at scale" experiments:**
  - **Controlled and repeatable** experiments, to help improve scientific understanding of complex, large-scale networks; and
  - **"In the wild" trials** of services that piggyback or connect to today's Internet and **engage large numbers of participants**.
  - With instrumentation and data archival / analysis tools for both
- GENI creates a smooth transition path from "innovative experiment" up to useful service at significant scale
- **GENI campuses and students "live in the future"** as early adopters of leading-edge research ideas

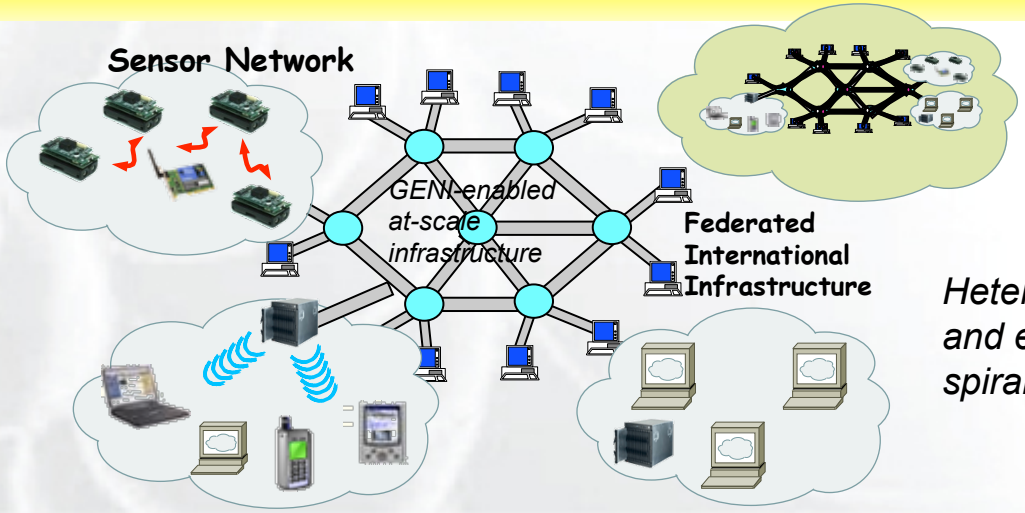
GENI Conceptual Design
Infrastructure to support at-scale experimentation



Deeply programmable



Programmable & federated, with end-to-end virtualized "slices"

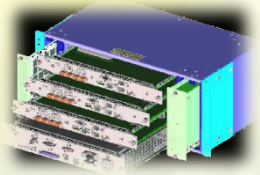


Heterogeneous, and evolving over time via spiral development

Enabling “at scale” experiments

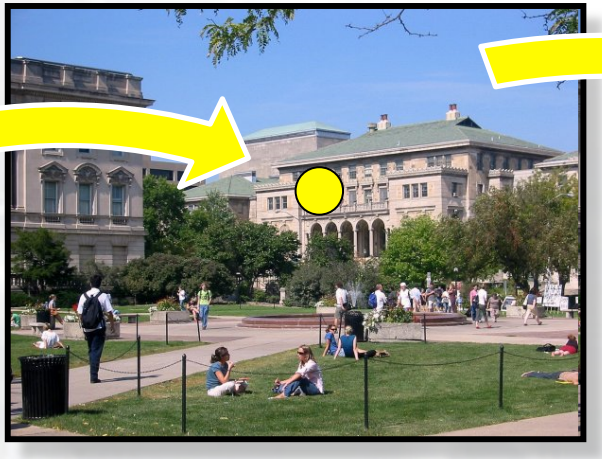
- **How can we afford / build GENI at sufficient scale?**
  - Clearly infeasible to build research testbed “as big as the Internet”
  - Therefore we are “GENI-enabling” testbeds, commercial equipment, campuses, regional and backbone networks
  - **Students are early adopters / participants in at-scale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

HP ProCurve 5400 Switch

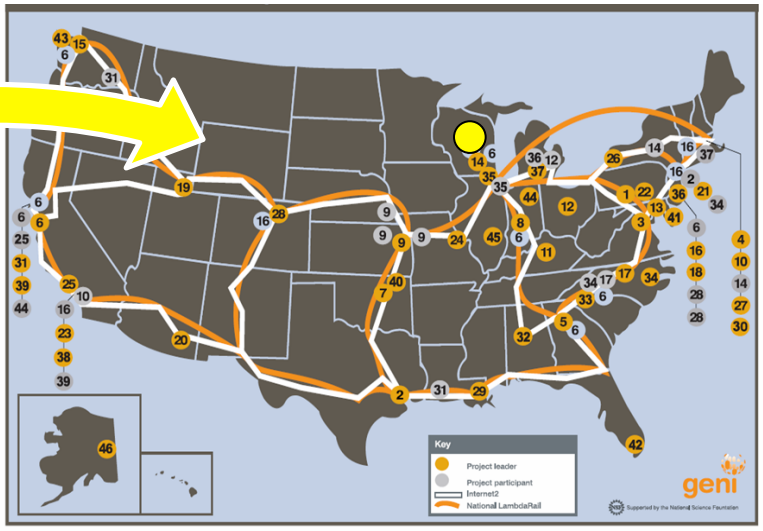


NEC WiMAX Base Station

GENI-enabled equipment



GENI-enabled campuses, students as early adopters



“At scale” GENI prototype

GENI is rapidly taking shape across the US

GENI-enabling testbeds, campuses, and backbones

BEN
Breakable Experimental Network
ORBIT
PLANETLAB
An open platform for developing, deploying, and accessing planetary-scale services
ProtoGENI
UIC
THE QUILT
PARISUNIVERSITAS
at&t
ARISTA
Battelle
ca
ciena
cisco
CNRI
FUJITSU
hp
invent
IBM
infinera
INTERNET2
JEFFREY HUNKER ASSOCIATES LLC
Technology • Government • Global business • Insight with impact
JUNIPER
NETWORKS
Microsoft
NETRONOME
nicira
NLR
light the future
NEC
Qwest
Radio Technology Systems
SPARTA

Outline

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- GENI's growing suite of infrastructure
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A bright idea

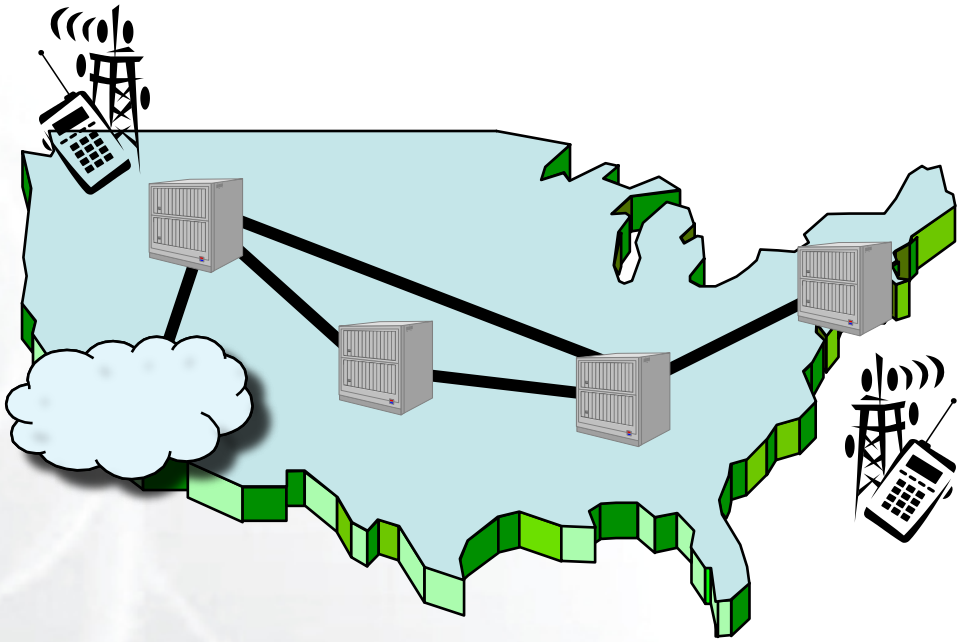
I have a great idea! The original Internet architecture was designed to connect one computer to another – but a better architecture would be fundamentally based on PEOPLE and CONTENT!

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 . . .



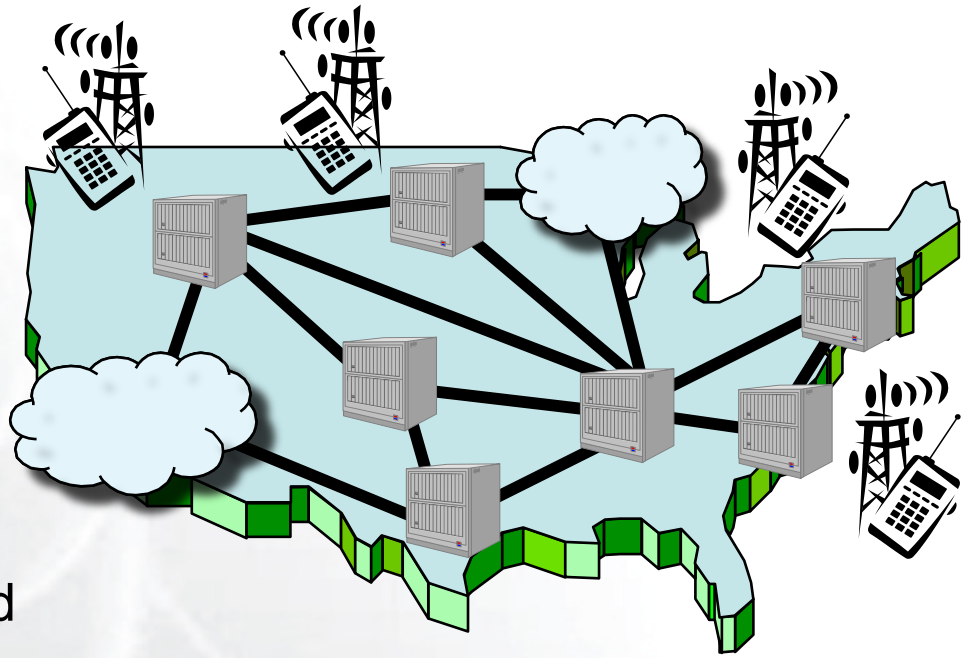
He uses a modest slice of GENI, sharing its infrastructure with many other concurrent experiments.

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 . . .



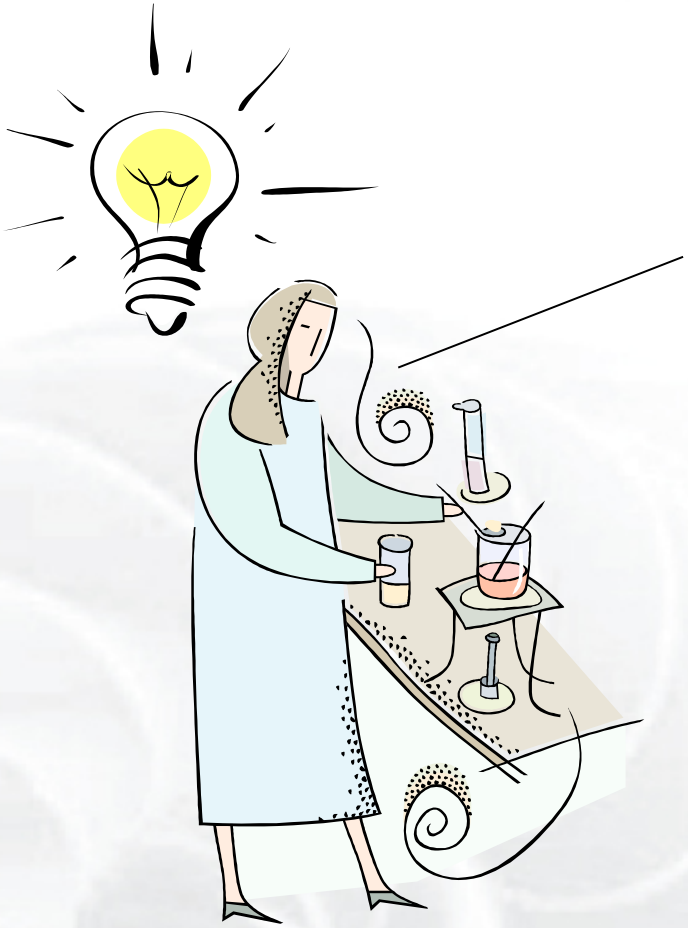
His slice of GENI keeps growing, but GENI is still running many other concurrent experiments.

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 . . .



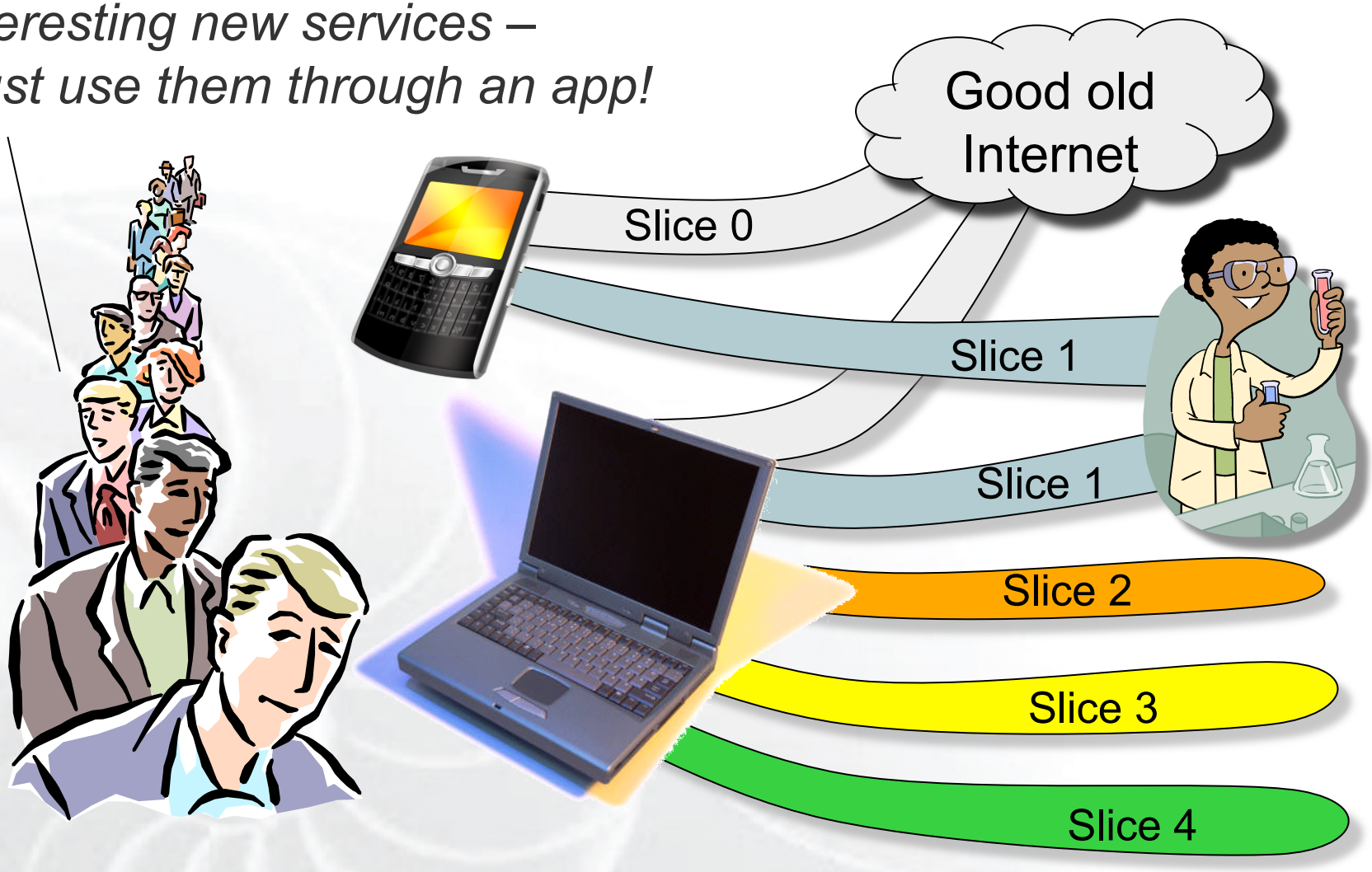
I have a great idea! If the Internet were augmented with a scalable control plane and realtime measurement tools, it could be 100x as robust as it is today . . . !

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.

The (opt-in) user's view

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



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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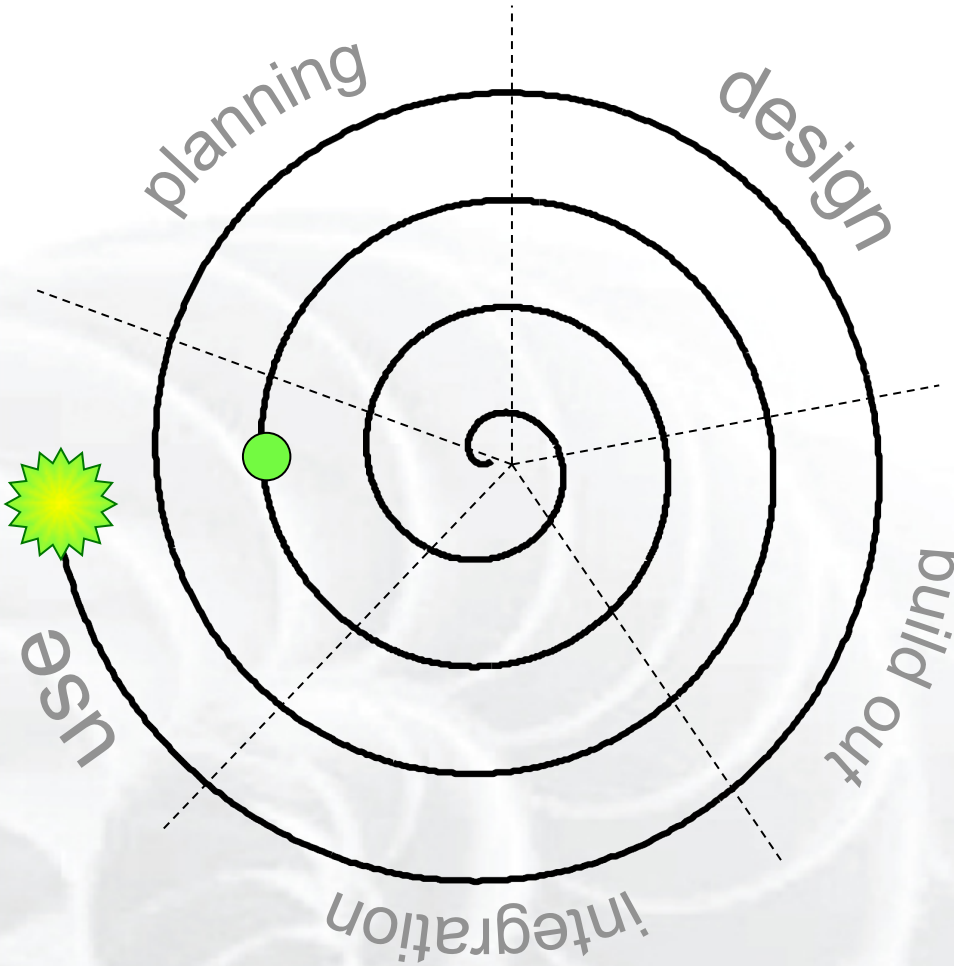
Spiral Development

GENI grows through a well-structured, adaptive process



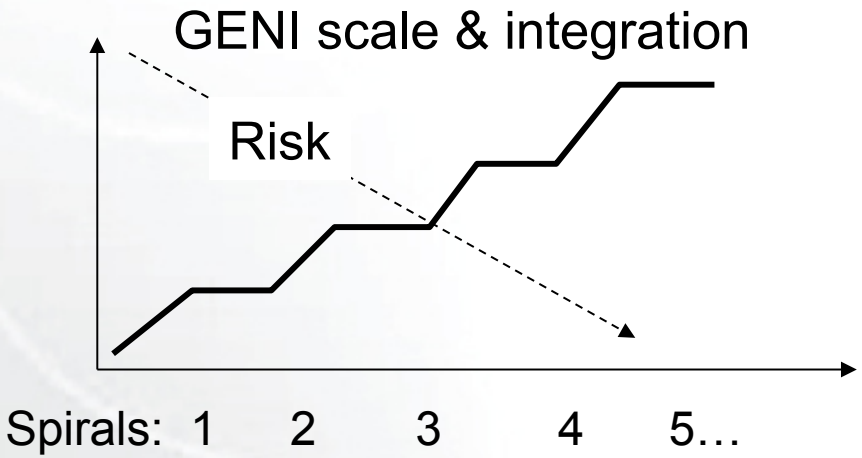
GENI Prototyping Plan

GENI Spiral 2

Early experiments, meso-scale build, interoperable control frameworks, ongoing integration, system designs for security and instrumentation, definition of identity management plans.

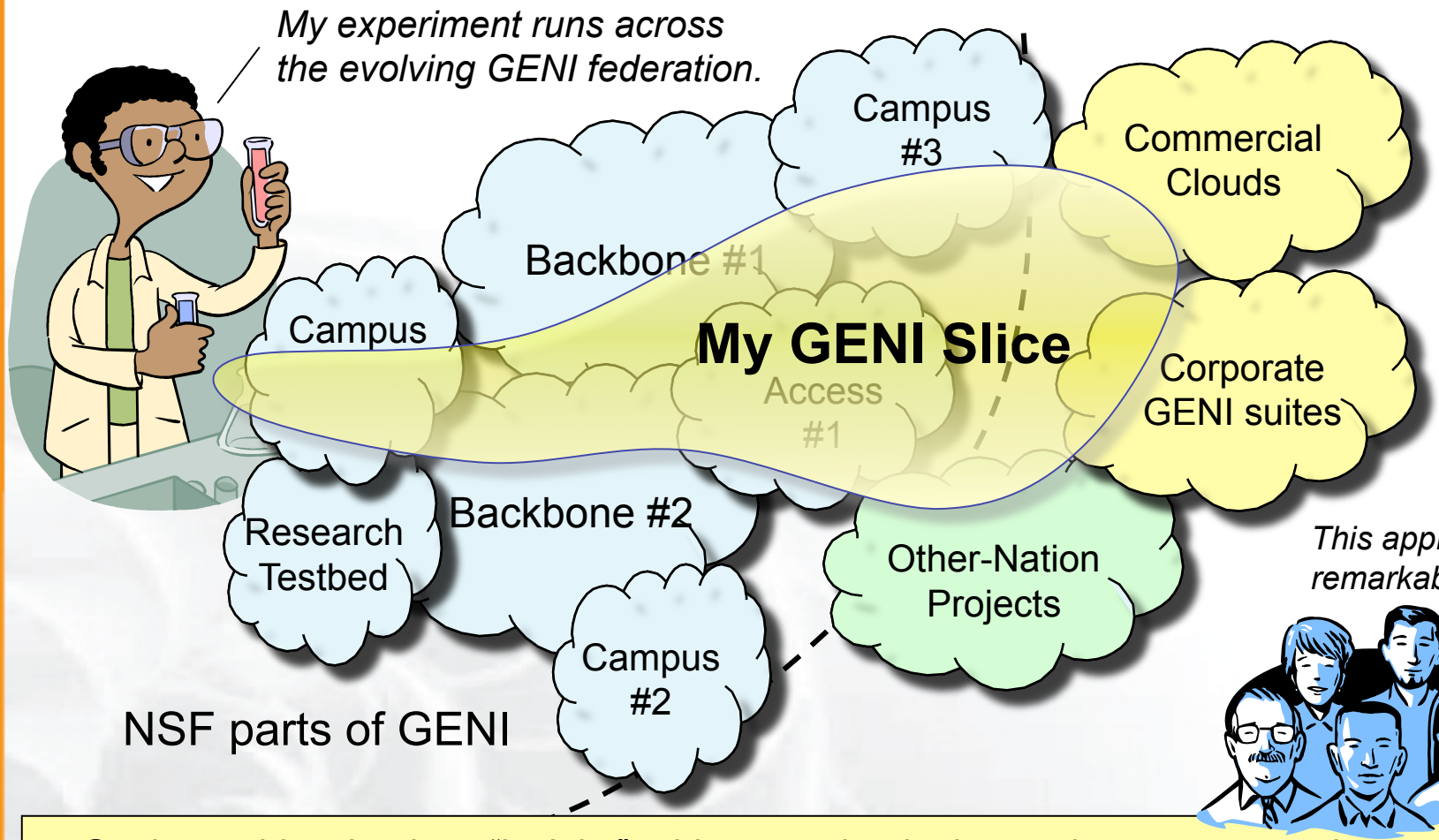
Envisioned **ultimate goal**

Large-scale distributed computing resources, high-speed backbone nodes, nationwide optical networks, wireless & sensor nets, etc.



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"

Spiral 1 infrastructure examples

DRAGON core nodes
Mid-Atlantic Crossroads

WAIL, U. Wisconsin-Madison

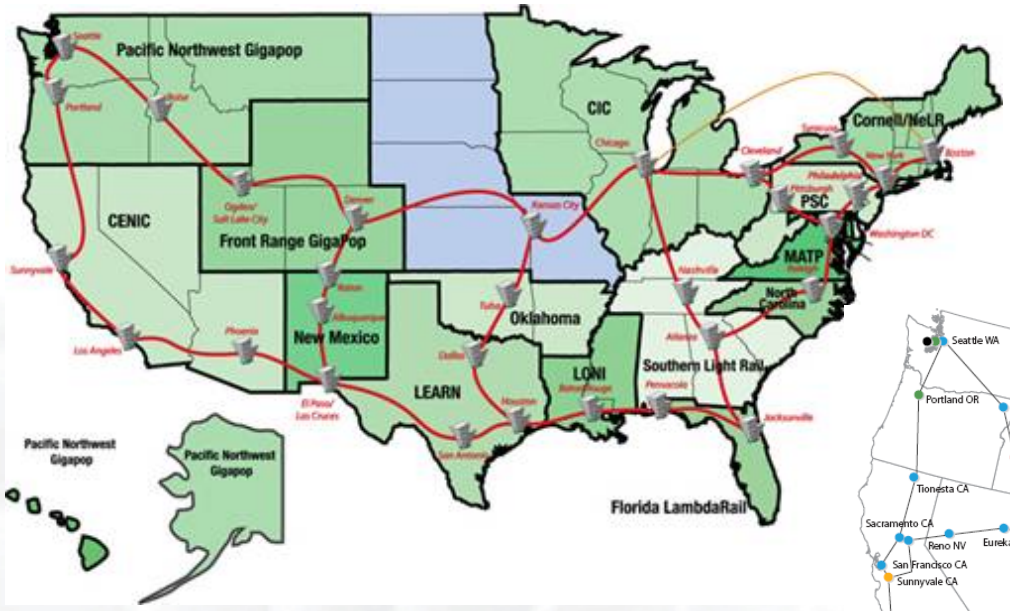
DieselNet, U. Mass Amherst

ViSE,
U. Mass Amherst

SPPs, Wash U.

ORBIT, Rutgers WINLAB

National LambdaRail and Internet2

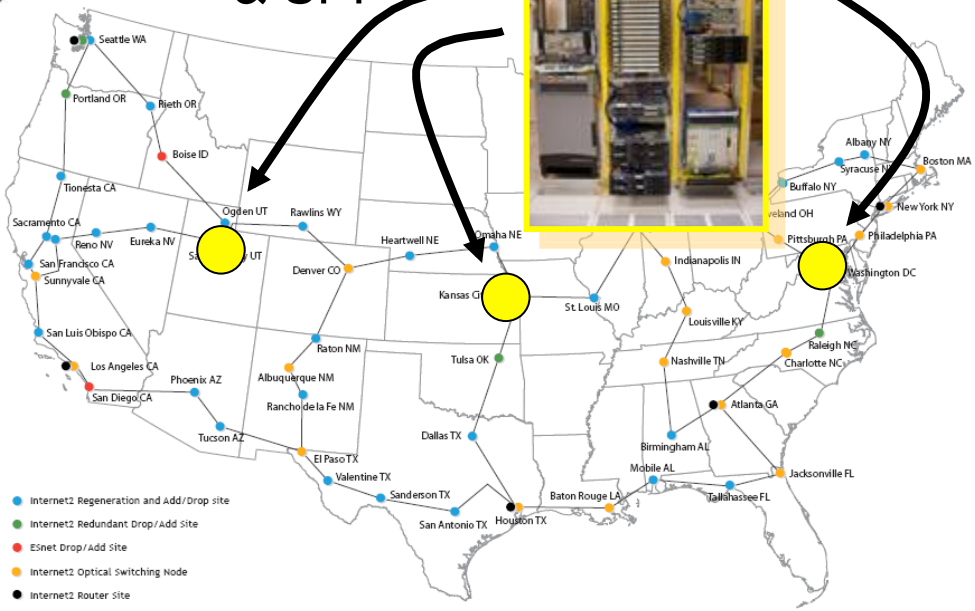


National LambdaRail

Up to 30 Gbps bandwidth

Internet2

ProtoGENI & SPP



Buildout for GENI prototyping within two national footprints to provide end-to-end GENI slices (IP or non-IP)

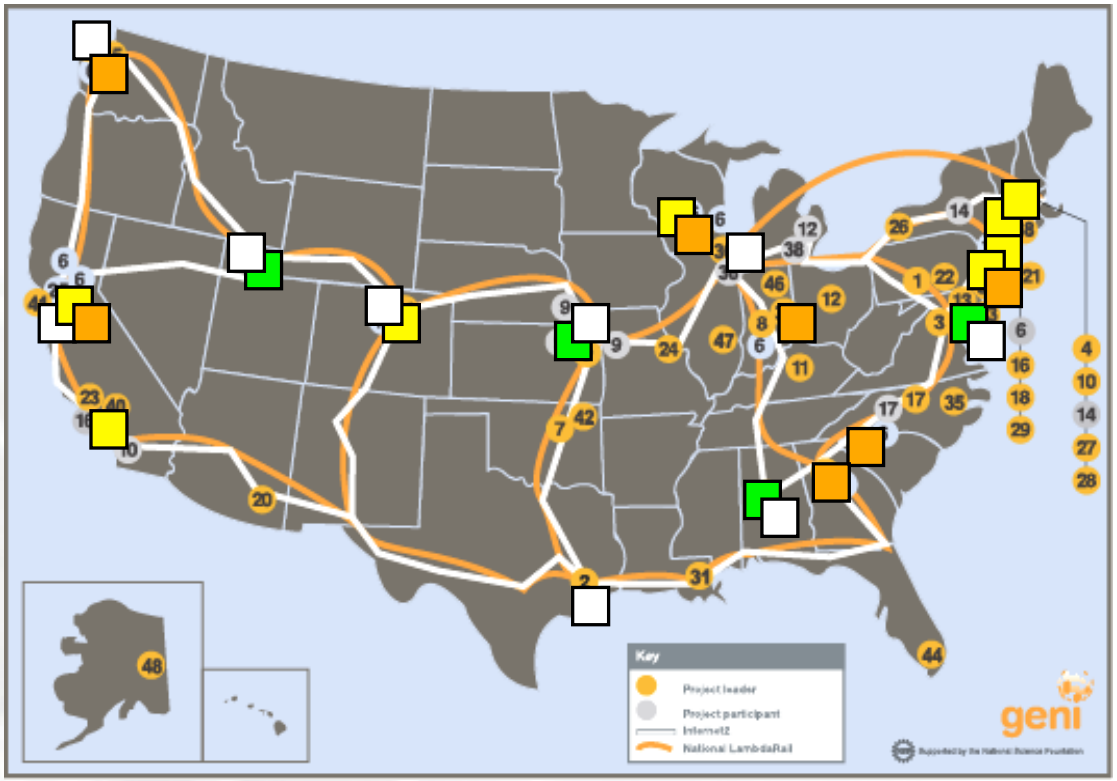
Spiral 2 infrastructure examples
Building the GENI Meso-scale Prototype

OpenFlow

Stanford
U Washington
Wisconsin
Indiana
Rutgers
Princeton
Clemson
Georgia Tech

ShadowNet

Salt Lake City
Kansas City
DC
Atlanta



WiMAX

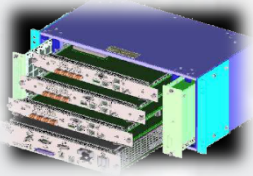
Stanford
UCLA
UC Boulder
Wisconsin
Rutgers
Polytech
UMass
Columbia

OpenFlow Backbones

Seattle
Salt Lake City
Sunnyvale
Denver
Kansas City
Houston
Chicago
DC
Atlanta

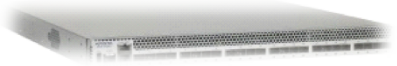
HP ProCurve 5400 Switch

Juniper MX240 Ethernet Services Router



NEC WiMAX Base Station

Toroki LightSwitch 4810



Arista 7124S Switch

NEC IP8800 Ethernet Switch

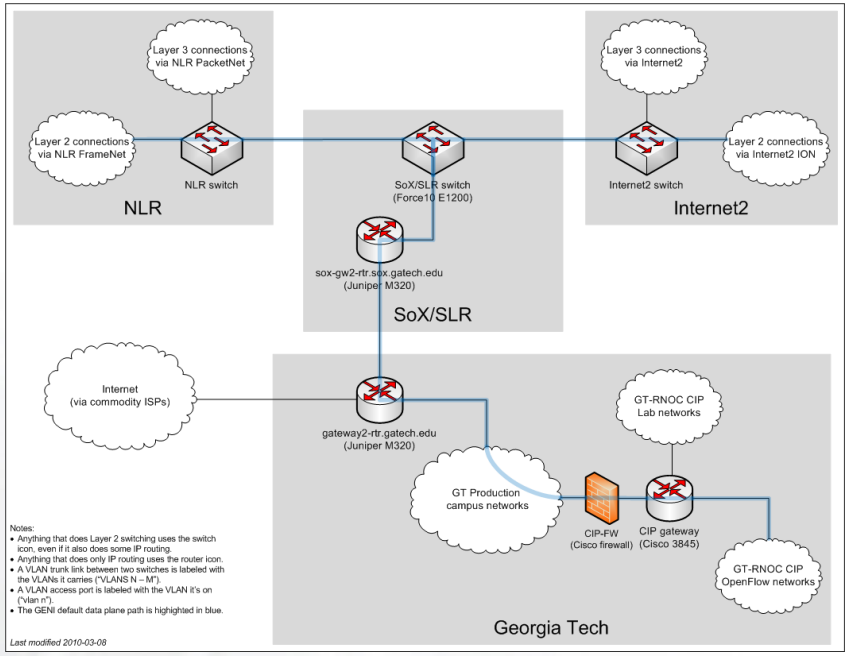
Campus GENI build-outs
Researchers teaming with campus IT staff

Nick Feamster
PI

Ellen Zegura

Russ Clark,
GT-RNOC

Ron
Hutchins,
OIT



- OpenFlow in 2 GT-RNOC lab bldgs ***now***
- OpenFlow/BGPMux coursework ***now***
- Dormitory trial
- Access control, authentication focus

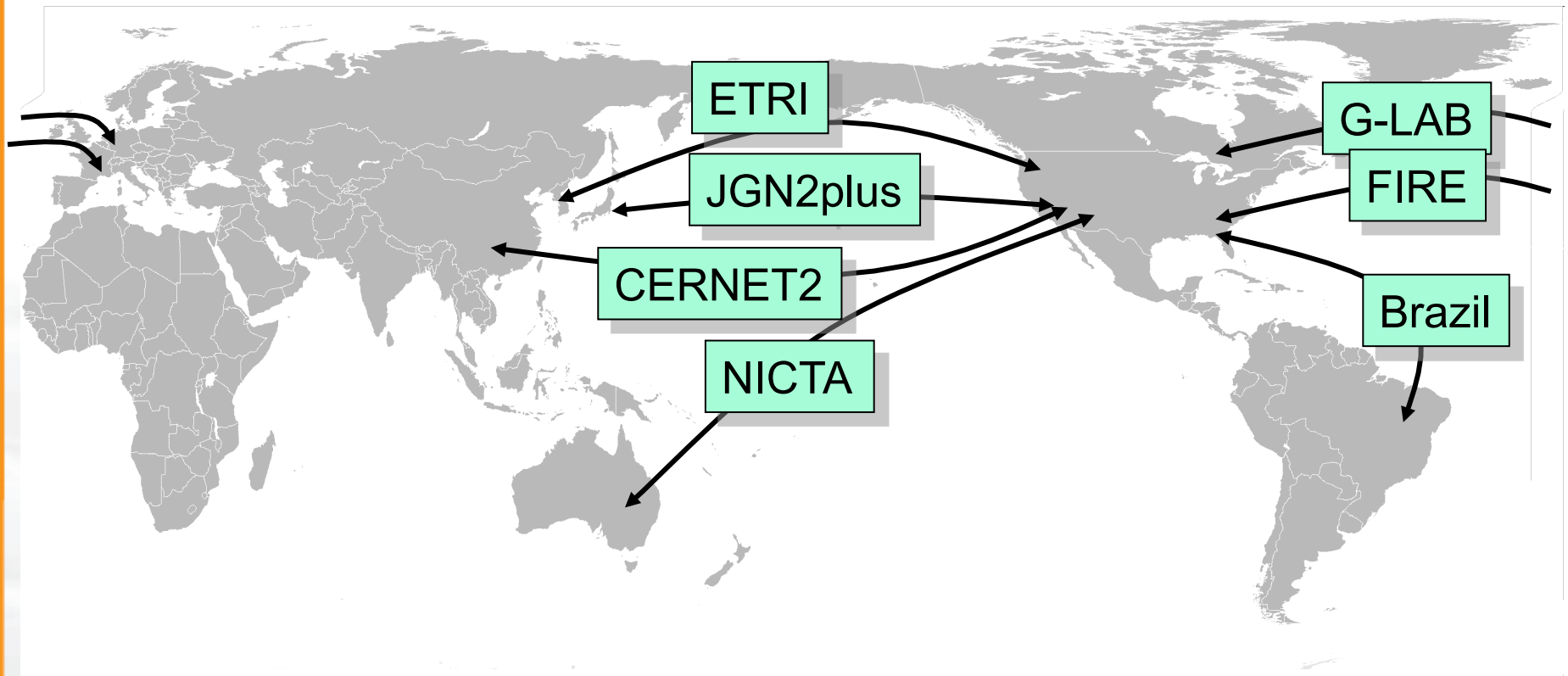
How are we "GENI-enabling" campuses?

OpenFlow

WiMAX

GENI racks

These are exciting times all around the world!



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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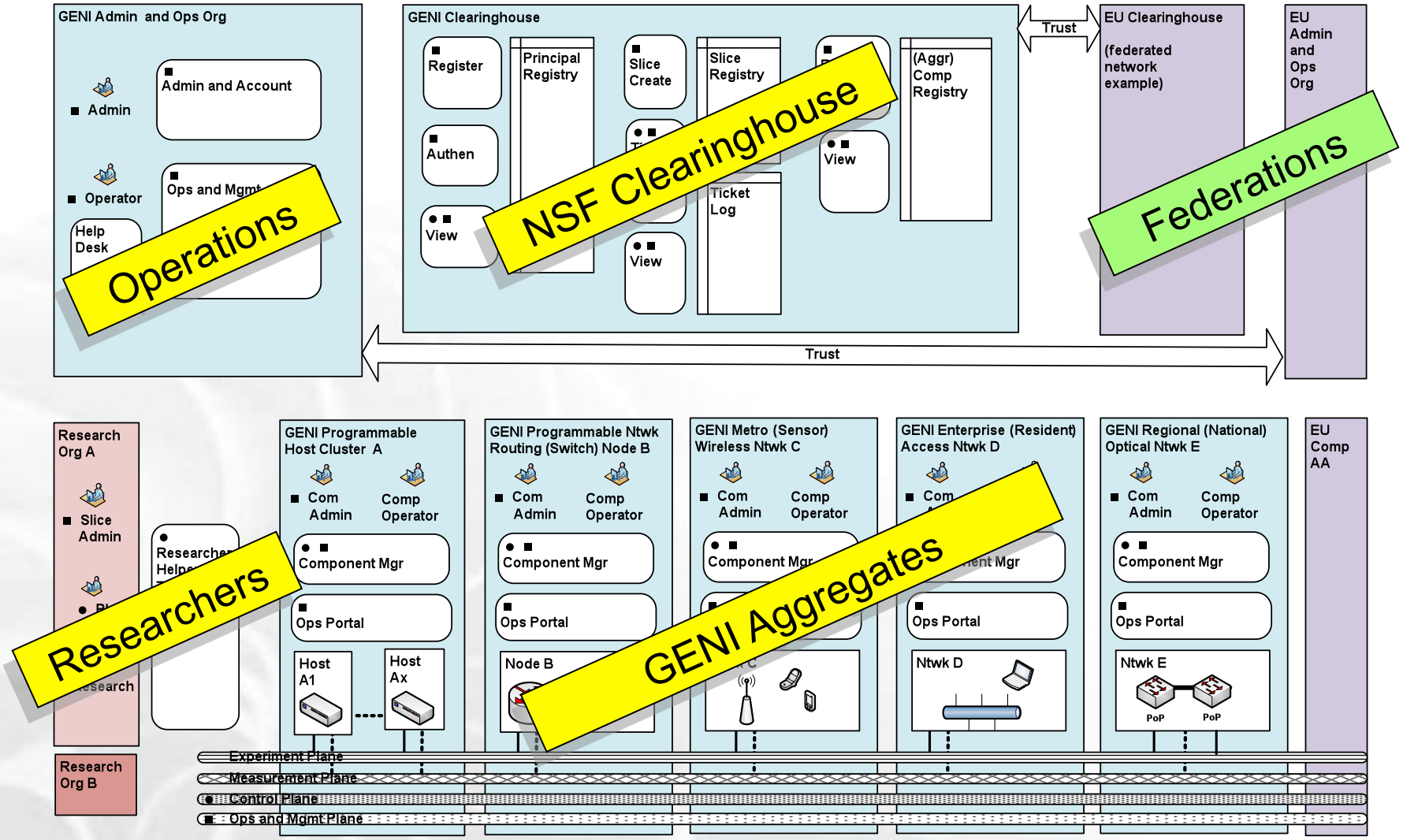
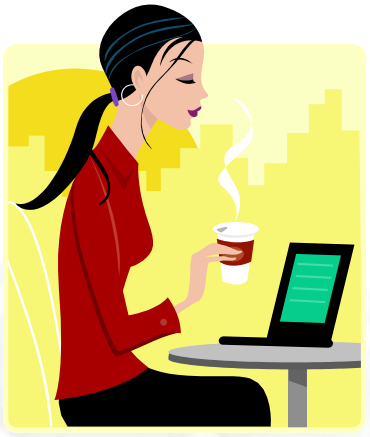
GENI System Diagram (simplified)



Resource discovery

Aggregates publish resources, schedules, etc., via clearinghouses



Researcher

What resources can I use?

GENI Clearinghouse

These

Components

Aggregate A
University campus

Components

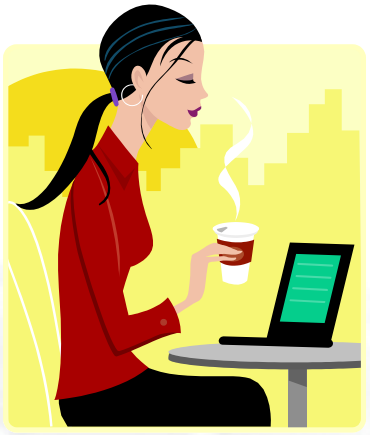
Aggregate B
Backbone Net

Components

Aggregate C
Metro Wireless

Slice creation

Clearinghouse checks credentials & enforces policy
Aggregates allocate resources & create topologies



Create my slice

GENI Clearinghouse

Components

Components

Components

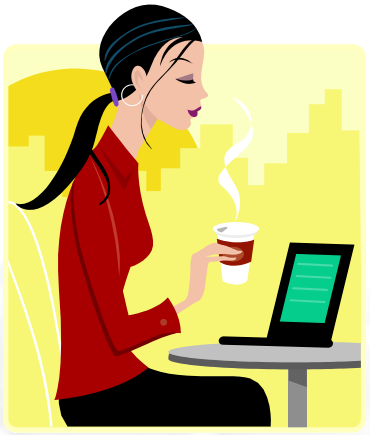
Aggregate A
University campus

Aggregate B
Backbone Net

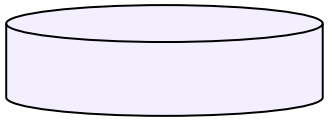
Aggregate C
Metro Wireless

Experimentation

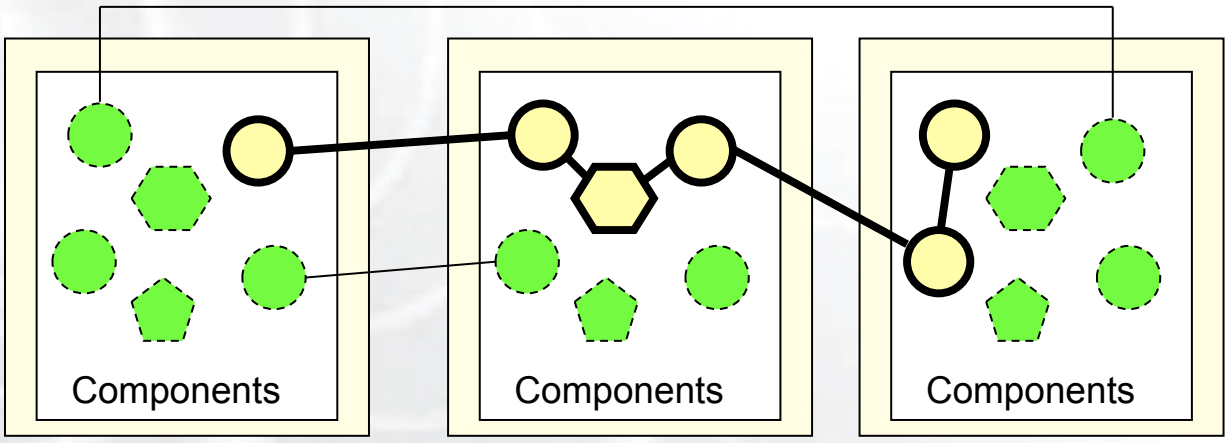
Researcher loads software, debugs, collects measurements



Experiment – Install my software, debug, collect data, retry, etc.



GENI Clearinghouse



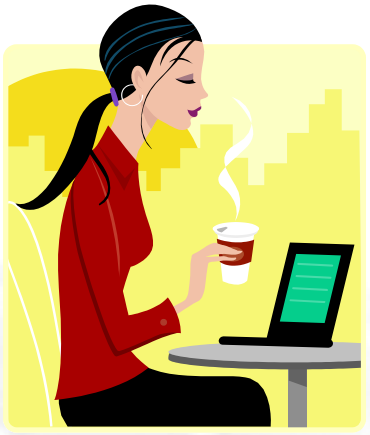
Aggregate A
University campus

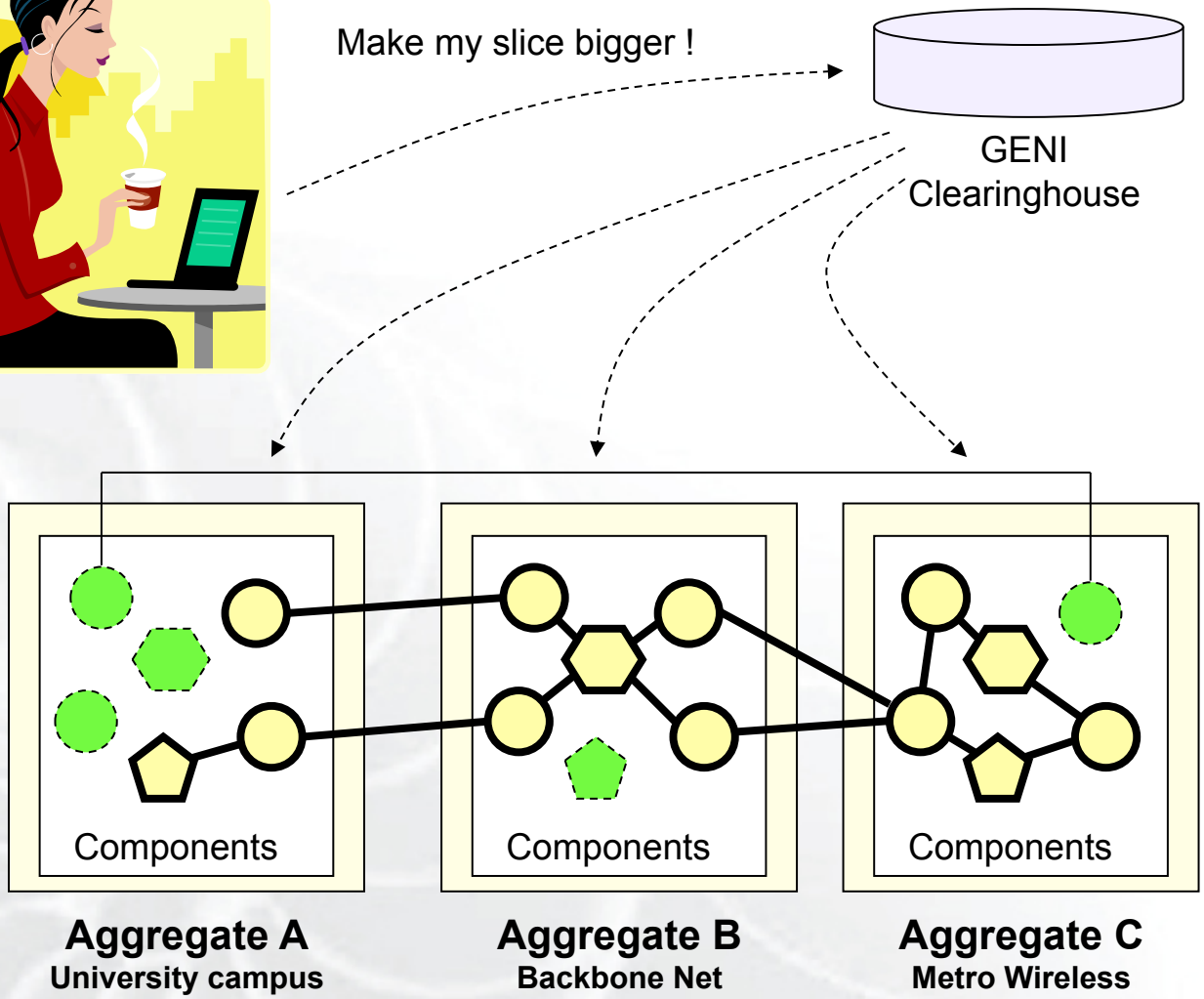
Aggregate B
Backbone Net

Aggregate C
Metro Wireless

Slice growth & revision

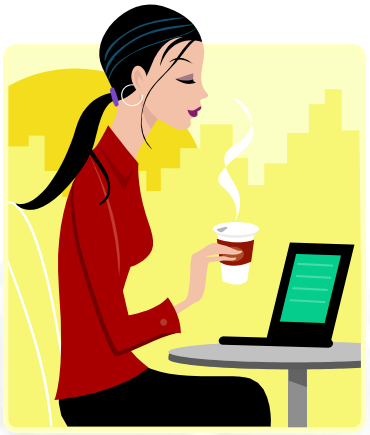
Allows successful, long-running experiments to grow larger





Federation of Clearinghouses

Growth path to international, semi-private, and commercial GENIs



Make my slice even bigger !

GENI Clearinghouse

Federated Clearinghouse

Components

Aggregate A
University campus

Components

Aggregate B
Backbone Net

Components

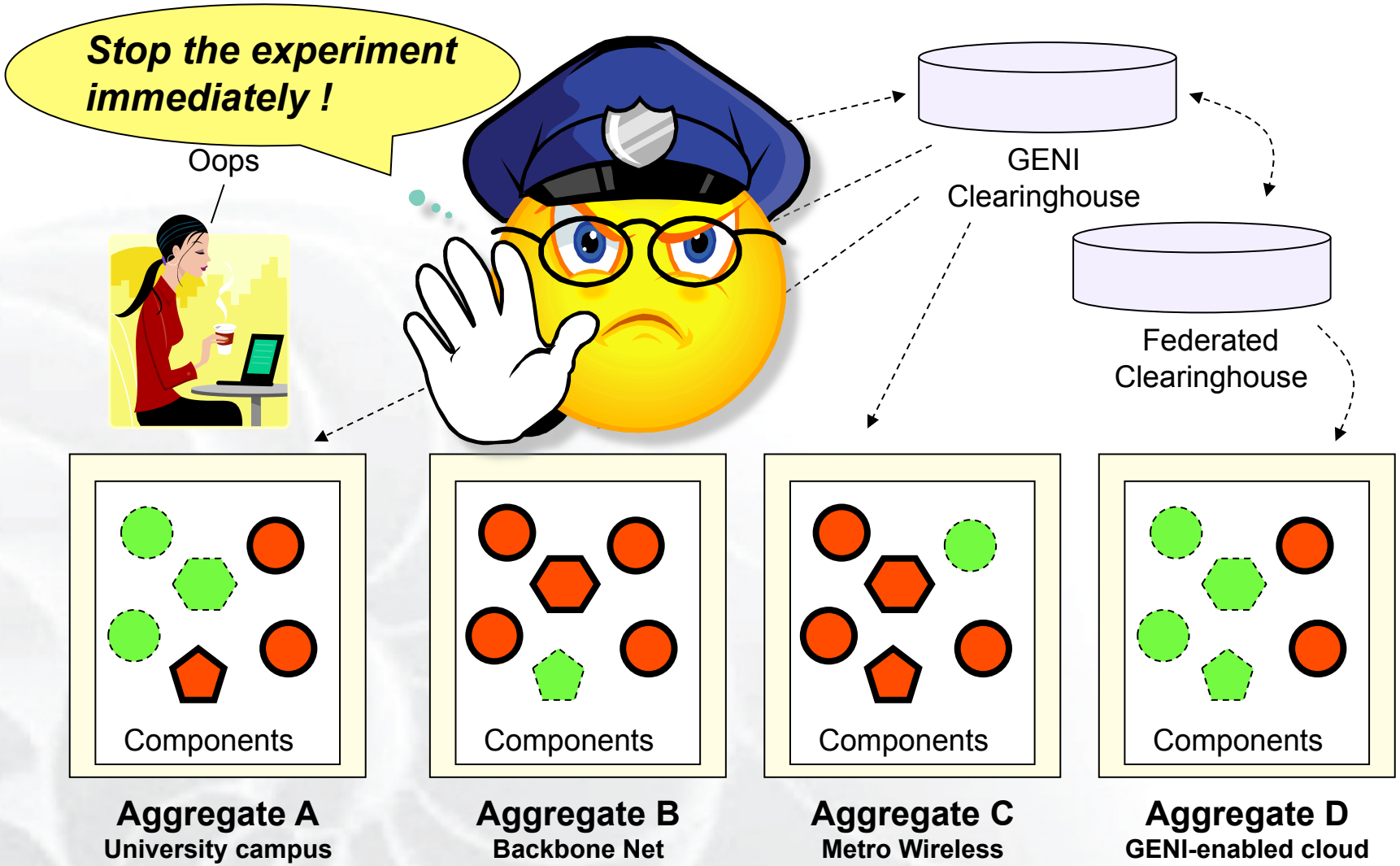
Aggregate C
Metro Wireless

Components

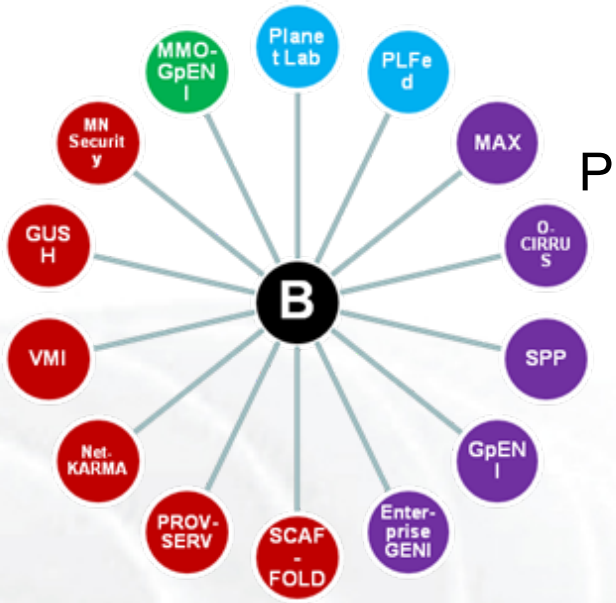
Aggregate D
GENI-enabled cloud

Operations & Management

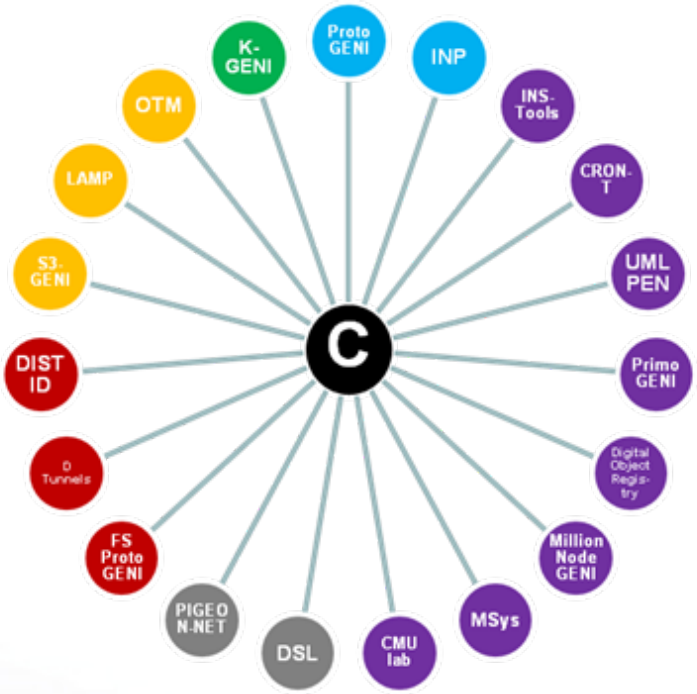
Always present in background for usual reasons
Will need an 'emergency shutdown' mechanism



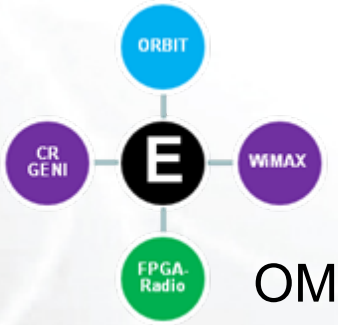
Spiral 2 Control Framework Teams



PlanetLab

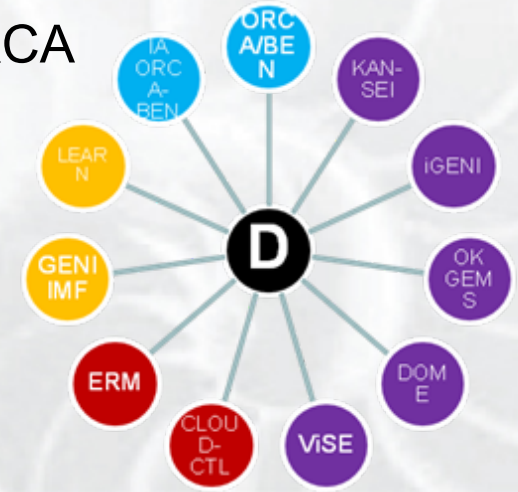


ProtoGENI



OMF

ORCA



KEY

Instrumentation & Measurement	Control Framework	Tools & Services
Experiment	Study	Aggregate

DInfo-Subs | GMOC | REG OPT

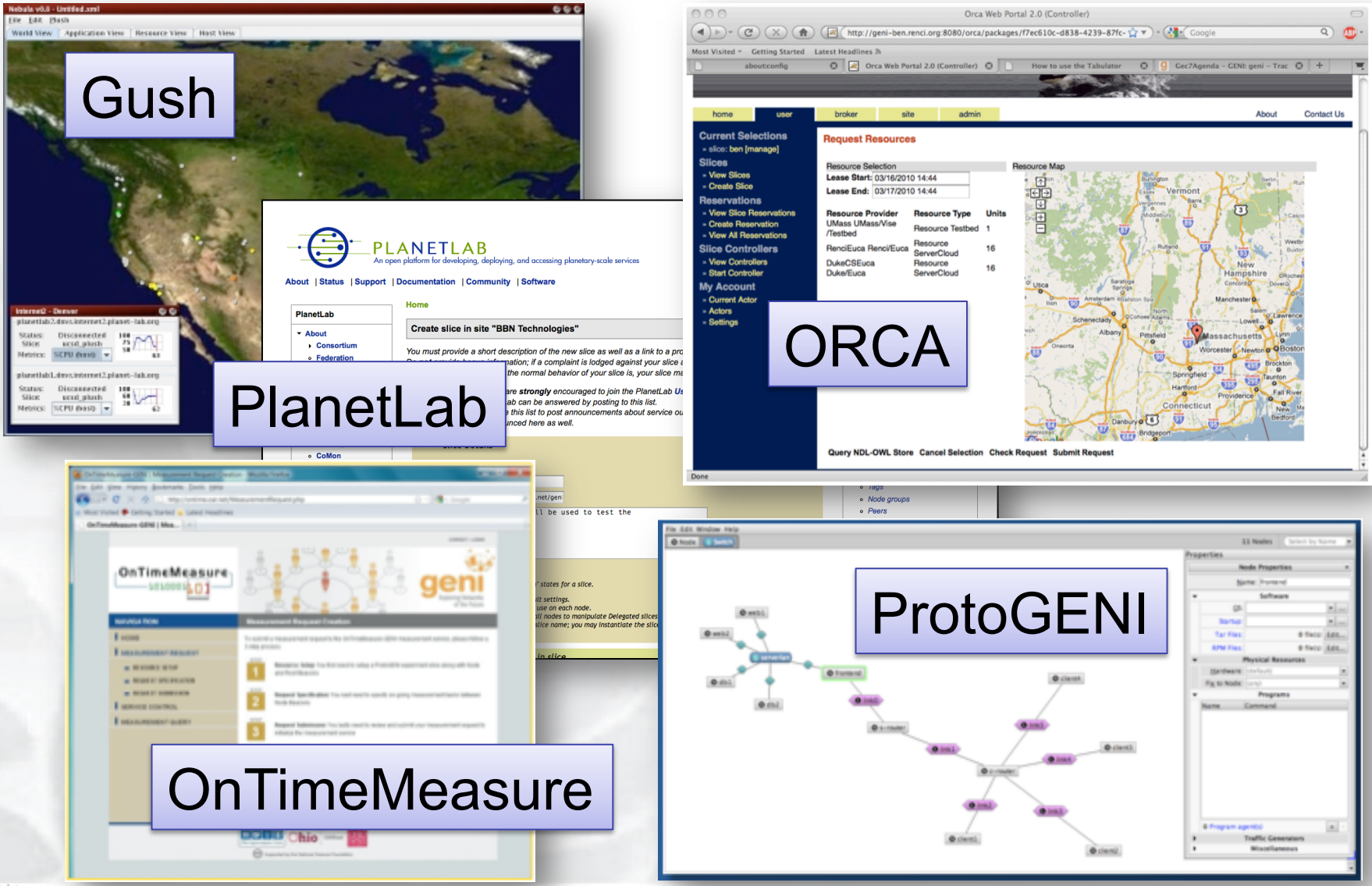
CMUDP | SEC-POL | DSN-HIVE

GENI 4YR | SEC ARCH | DMeas

LEFA | Att-GENI | EXP-SEC

A researcher's view of GENI

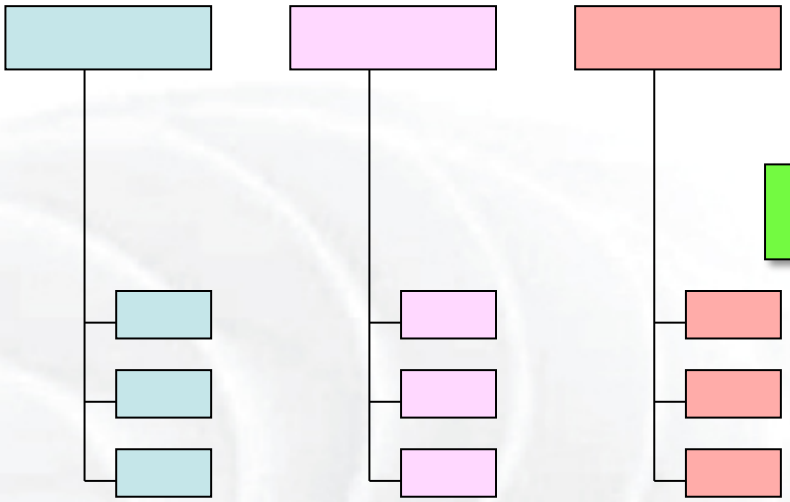
Some familiar tools, plus some new tools



Control framework interoperability
via the GENI Aggregate Manager API 1.0

Spiral 1: tightly coupled

Control frameworks / Clearinghouses

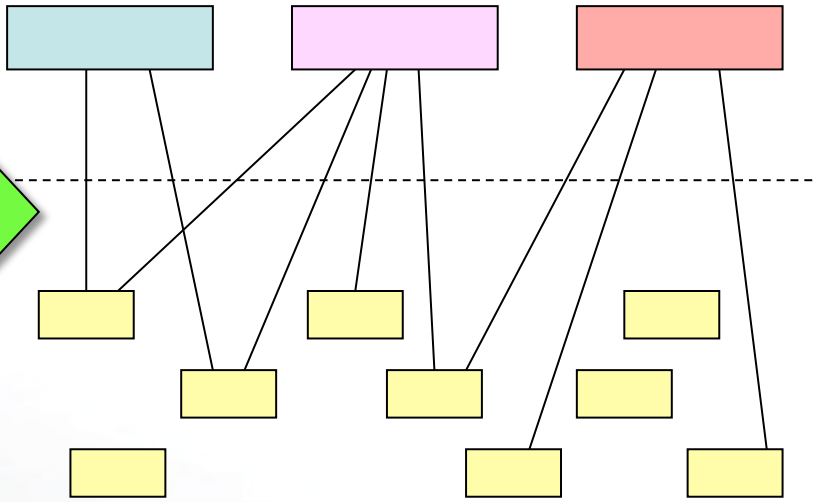


Aggregates

Each aggregate was tightly linked to exactly one cluster and control framework

Now: open & interoperable

Control frameworks / Clearinghouses



Aggregates

"GENI AM API" lets you mix and match aggregates with control frameworks

PlanetLab, ProtoGENI, OpenFlow are now interoperable – more to follow

Ramping up to GENI Operations

- As experiments ramp up . . .
  - Operations need to begin (on a limited scale)
- Experimenters will drive GENI Spiral 3
  - Easy-to-use experiment design tools
  - Measurement, archival, and analysis tools
  - Help desks, training courses, online materials

Outline

- GENI – Exploring future internets at scale
- Introducing GENI: an example
- GENI's growing suite of infrastructure
- GENI's evolving control framework
- How can you participate?

Want to run an experiment?

- **Shakedown experiments in progress**
  - "The brave pioneers"
- **GENI Experimenters Workshop -** Princeton, June 29-30, 2010
  - Co-chaired by Jennifer Rexford and Guru Parulkar
  - 54 researchers participated (pairs of prof + student)
  - Dozens of quick-turn proposals submitted to NSF
  - Excellent experimental research starts ramping up in early fall
- **CISE "Future Internet Architectures" program**
  - "stimulate innovative and creative research to explore, design, and evaluate trustworthy future Internet architectures"
  - "design and experiment with new network architectures and networking concepts"
  - "proposals must describe plans to prototype and evaluate the proposed architectures; this may require the construction of new artifacts or the use of research infrastructure like GENI or the NCR (National Cyber Range)"

Talk to NSF CISE or Mark Berman, GPO (mberman@bbn.com)

GENI Tutorials and Workshops

- Researcher-led, “hands on” sessions
  - **Nick Feamster**, Bringing Internet Connectivity to Your GENI Experiment
  - **Rob Ricci**, ProtoGENI tutorial
  - **Timothy Ficarra**, Network Experimentation with UMLPEN
  - **Jon Turner**, Experimental Networks Using the Supercharged PlanetLab Platform
  - **Martin Swany**, GENI Instrumentation and Measurement Systems
  - **Srini Seetharaman**, OpenFlow tutorial
  - **Giovanni Pau**, Designing a Vehicular Network Testbed
  - **Tom Henderson**: ns-3 Tutorial

Want to give a tutorial? What are we missing?

Want to affiliate your infrastructure?

- If so, you will become a new GENI "aggregate"
  - You own / operate your aggregate, and "affiliate" into GENI
  - You make (some of) your resources available for experiments
  - Examples: testbeds, campuses, regionals and backbone networks, commercial providers, . . .
- Three actions needed on your part
  - Download GENI API software, modify to reflect your infrastructure resources and local policies
  - Connect to GENI, ideally at Layer 2 but otherwise via GRE tunnel
  - Agree to GENI policies, sign MOUs, join GENI operations
- Reminder: GENI is still a really early prototype!

If interested, contact Heidi Dempsey (hdempsey@bbn.com)

Want to help design GENI?

- All design, prototyping, & development is performed by the research community (academia & industry)
  - Working Groups, open to all
    - The locus for all GENI technical design
    - Patterned on the early IETF
    - Discuss by email, create documents, meet 3x per year
    - Each led by Chair(s), plus a professional System Engineer
- Openness is emphasized
  - Design process is open, transparent, and broadly inclusive
  - Open-source solutions are strongly preferred
  - Intellectual property is OK, under no-fee license for GENI use
- GPO is fair and even-handed

Current hot topics in GENI design

- GENI racks and “distributed cloud” technology
- Instrumentation and measurement architecture
- Resource specifications (rspecs)
- Mechanisms and policy for user opt-in
- End-to-end stitching mechanisms
- How should operations work?

GENI Engineering Conferences

Meet every 4 months to review progress together

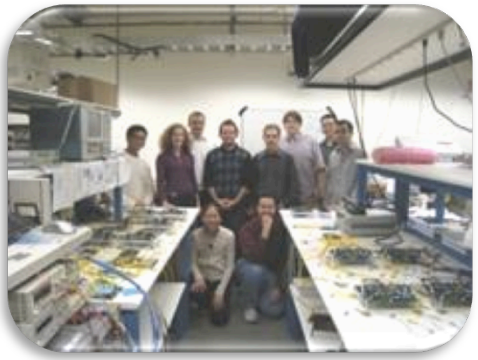
- **10th meeting, open to all:**
  March 1-3, 2011, Puerto Rico
  - Team meetings, integrated demos, Working Group meetings
  - Tutorials and workshops
  - **Travel grants** to US academics for participant diversity

GENI is a huge opportunity - Get involved!

ViSE Team

PlanetLab Team

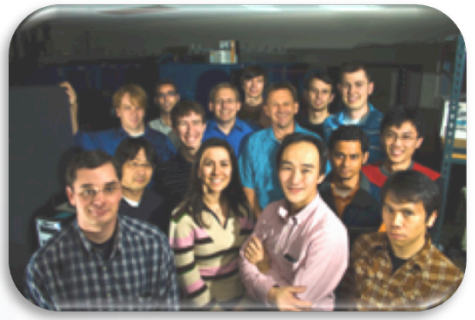
ERM Team



ORCA/BEN Team

GUSH Team

Enterprise GENI Team



GPO points of contact

- Experiments . . . Mark Berman: mberman@bbn.com
- Prototyping . . . Aaron Falk: afalk@bbn.com
- Campus CIOs . . . Heidi Dempsey: hdempsey@bbn.com
- Industry . . . Chip Elliott: celliott@bbn.com

www.geni.net