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# GENI

Global Environment for Network Innovations

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**[www.geni.net](http://www.geni.net)**

Clearing house for all GENI news and documents



# Thank you Matt! and Karl!

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*There once was a Bishop from Davis . . .*

And also introducing . . .

➤ National Science Foundation

- ❑ Dr. Suzi Iacono
- ❑ Dr. Karl Levitt

➤ DARPA

- ❑ Dr. Mike VanPutte

➤ GENI Project Office

- ❑ Dr. Harry Mussman
- ❑ Dr. Vic Thomas



# GPO goals for this workshop

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- Engage the security community to play an active, central role in GENI's planning, prototyping, and early trial experiments (now rolling out as Spiral 1; first demos in March)
- Very concretely – encourage you to submit proposals for GPO Solicitation #2, due Feb. 20



# Outline

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- What is GENI?
- How we'll build it, how we'll use it  
(Two Comic Books)
- The GENI system concept
- GENI Spiral 1
- How can you participate?



# GENI supports Fundamental Challenges Network Science & Engineering (NetSE)

Science

Understand the complexity of  
large-scale networks

- Understand emergent behaviors, local-global interactions, system failures and/or degradations
- Develop models that accurately predict and control network behaviors

Network  
science and  
engineering  
researchers

Technology

Develop new architectures,  
exploiting new substrates

- Develop architectures for self-evolving, robust, manageable future networks
- Develop design principles for seamless mobility support
- Leverage optical and wireless substrates for reliability and performance
- Understand the fundamental potential and limitations of technology

Distributed  
systems and  
substrate  
researchers

Society

Enable new applications and new economies,  
while ensuring security and privacy

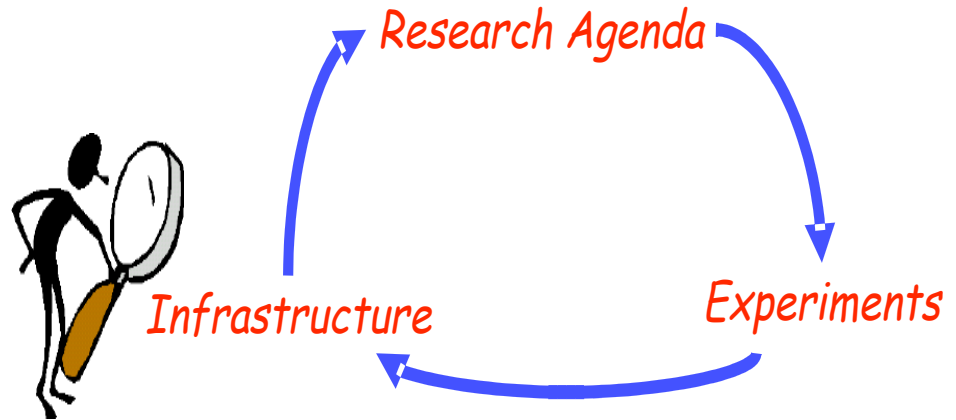
- Design secure, survivable, persistent systems, especially when under attack
- Understand technical, economic and legal design trade-offs, enable privacy protection
- Explore AI-inspired and game-theoretic paradigms for resource and performance optimization

Security,  
privacy,  
economics, AI,  
social science  
researchers



# Research Agenda to Experiments to Infrastructure

- Research agenda
  - Identifies fundamental questions
  - Drives a set of experiments to validate theories and models
- Experiments & requirements
  - Drives what infrastructure and facilities are needed
- Infrastructure could range from
  - Existing Internet, existing testbeds, federation of testbeds, something brand new (from small to large), federation of all of the above, to federation with international efforts
  - No pre-ordained outcome



## Existing Input

- Clark et al. planning document for Global Environment for Network Innovations
- Shenker et al. “I Dream of GENI” document
- Kearns and Forrest ISAT study
- Feigenbaum, Mitzenmacher, and others on Theory of Networked Computation
- Hendler and others in Web Science
- Ruzena Bajcsy, Fran Berman, and others on CS-plus-Social Sciences
- NSF/OECD Workshop “Social and Economic Factors Shaping the Future of the Internet”
- NSF “networking” programs
  - FIND, SING, NGNI



# “Our founders”

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## The GENI Planning Group and Many, Many Working Group Volunteers

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Larry Peterson, Princeton (Chair)  
Tom Anderson, Washington  
Dan Blumenthal, UCSB  
Dean Casey, NGENET Research  
David Clark, MIT  
Deborah Estrin, UCLA  
Joe Evans, Kansas  
Terry Benzel, USC/ISI

Nick McKeown, Stanford  
Dipankar Raychaudhuri, Rutgers  
Mike Reiter, CMU  
Jennifer Rexford, Princeton  
Scott Shenker, Berkeley  
Amin Vahdat, UCSD  
John Wroclawski, USC/ISI  
CK Ong, Princeton

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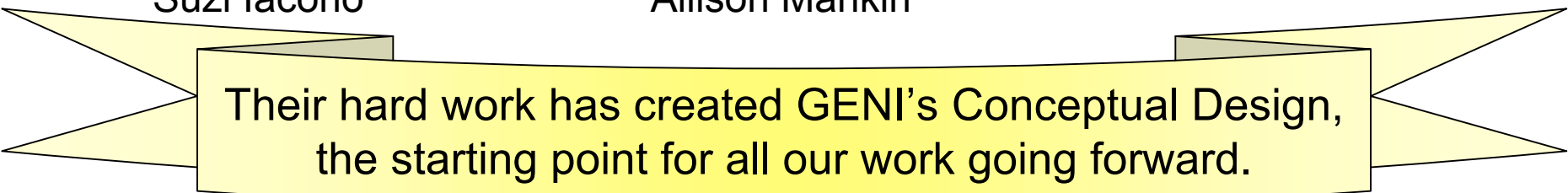
## And Within NSF

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Peter Freeman  
Debbie Crawford  
Larry Landweber  
Suzi Iacono

Guru Parulkar  
Darleen Fisher  
Cheryl Albus  
Allison Mankin

Ty Znati  
Gracie Narcho  
Paul Morton

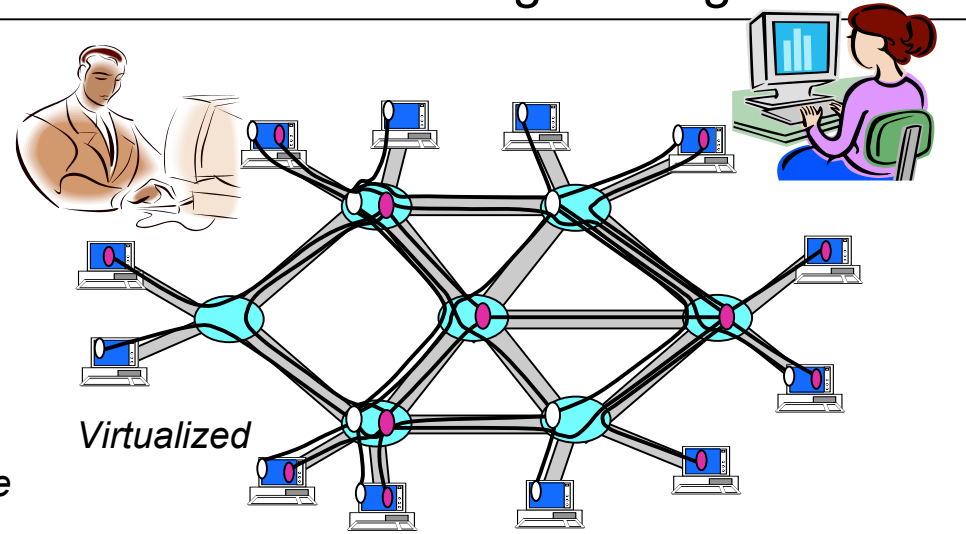
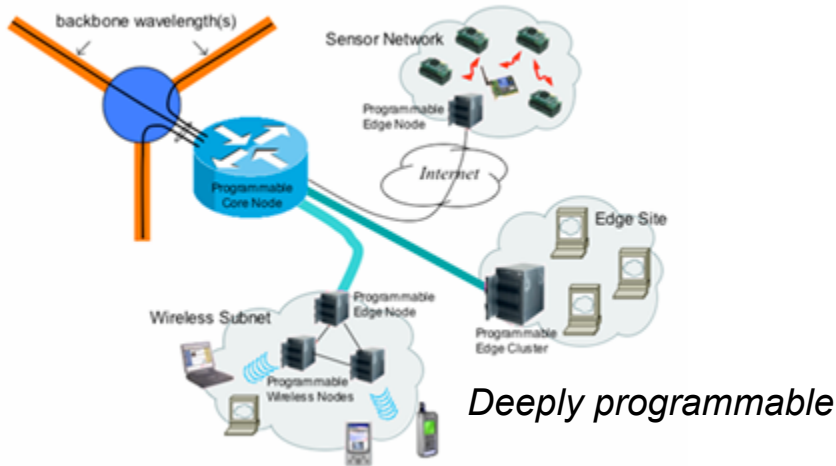
A yellow ribbon graphic with a black outline, featuring a central rectangular box with a drop shadow. The ribbon has pointed ends on the left and right sides.

Their hard work has created GENI's Conceptual Design,  
the starting point for all our work going forward.

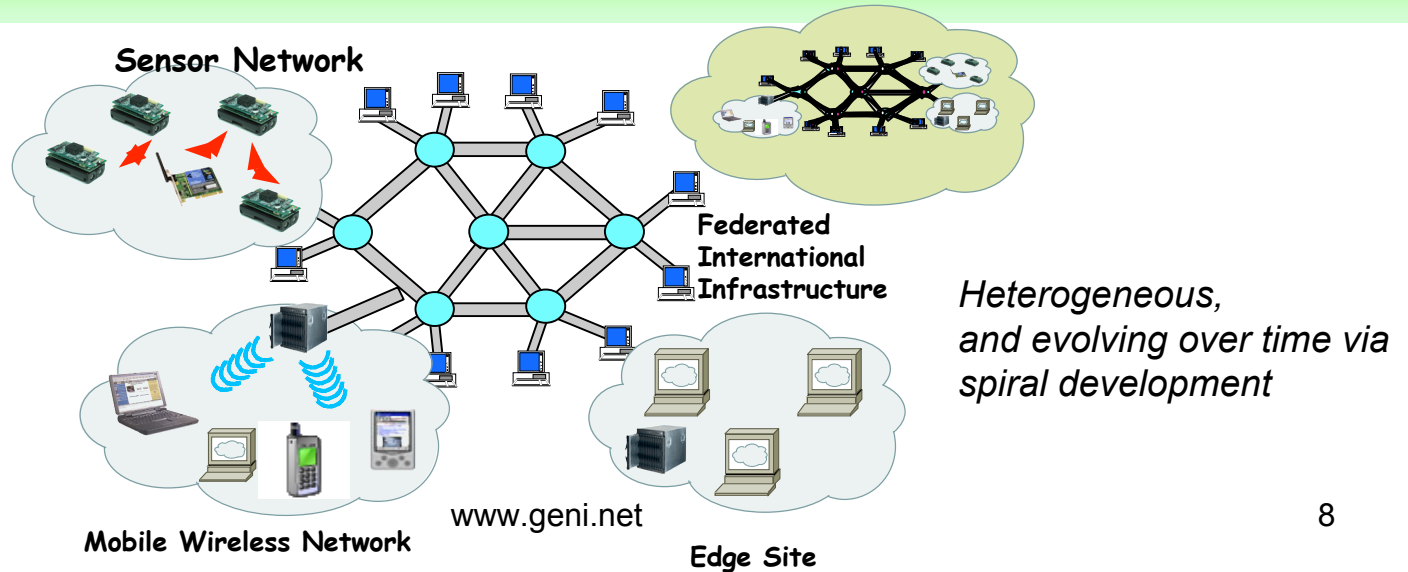


# The GENI Vision

A national-scale suite of infrastructure for long-running, realistic experiments in Network Science and Engineering



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







# Outline

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(Two Comic Books)
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# How We'll Use GENI

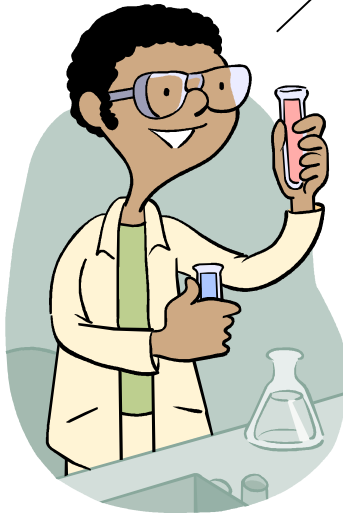
Note that this is the “classics illustrated” version – a comic book!

Please read the Network Science and Engineering Research Agenda to learn all about the community's vision for the research it will enable.

Your suggestions are very much appreciated!



# 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!*



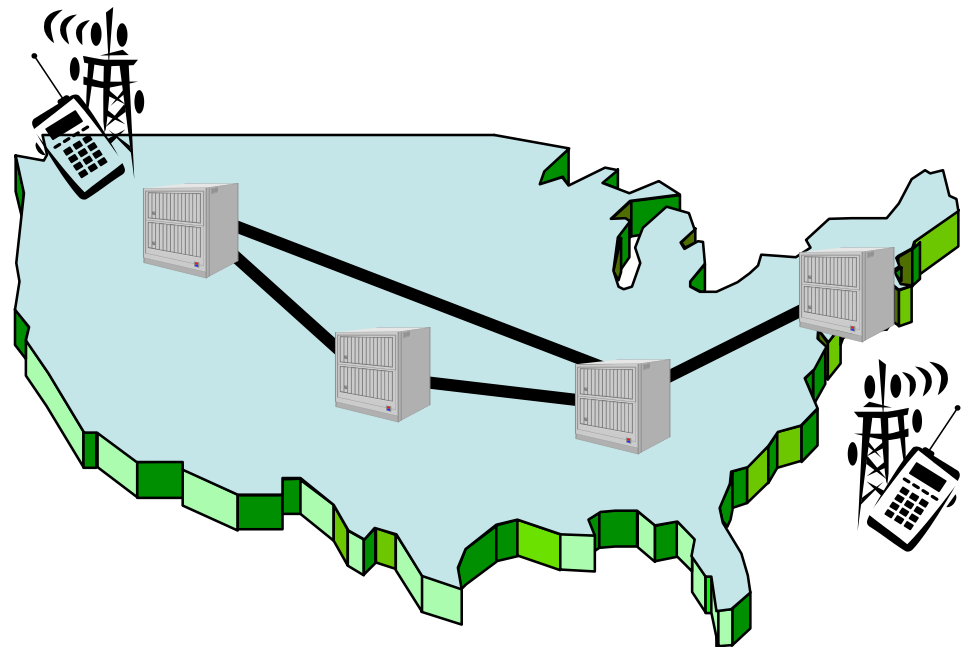


# Trying it out



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 clusters of CPUs and disks, 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.



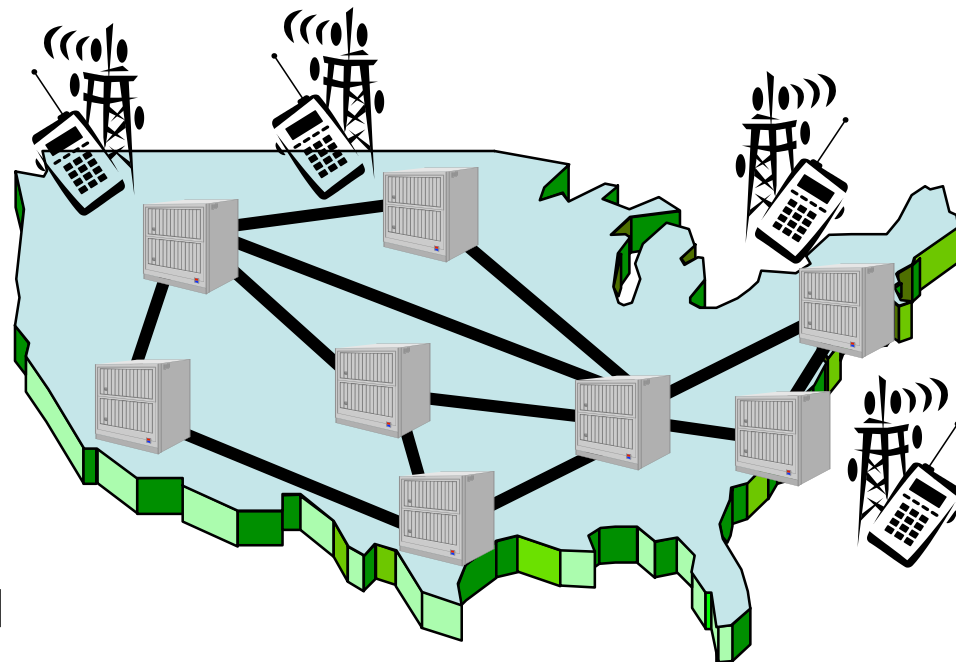
# It turns into a really good idea

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



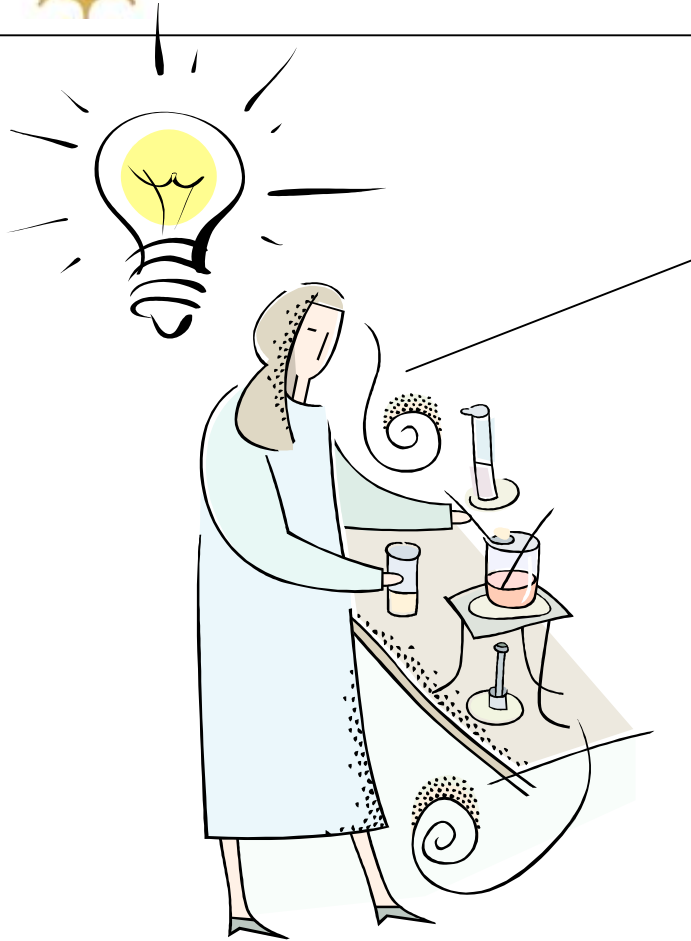
My experiment was a real success, and my architecture turned out to be mostly compatible with today's Internet after all – so I'm taking it off GENI and spinning it out as a real company.

*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 reliable 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 Network Science and Engineering** program.



# Moral of this story

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- GENI is meant to enable . . .
  - Trials of new architectures, which may or may not be compatible with today's Internet
  - Long-running, realistic experiments with enough instrumentation to provide real insights and data
  - 'Opt in' for real users into long-running experiments
  - Large-scale growth for successful experiments, so good ideas can be shaken down at scale
- A reminder . . .
  - GENI itself is not an experiment !
  - GENI is a suite of infrastructure on which experiments run

**GENI creates a huge opportunity for ambitious research!**





# How We'll Build GENI

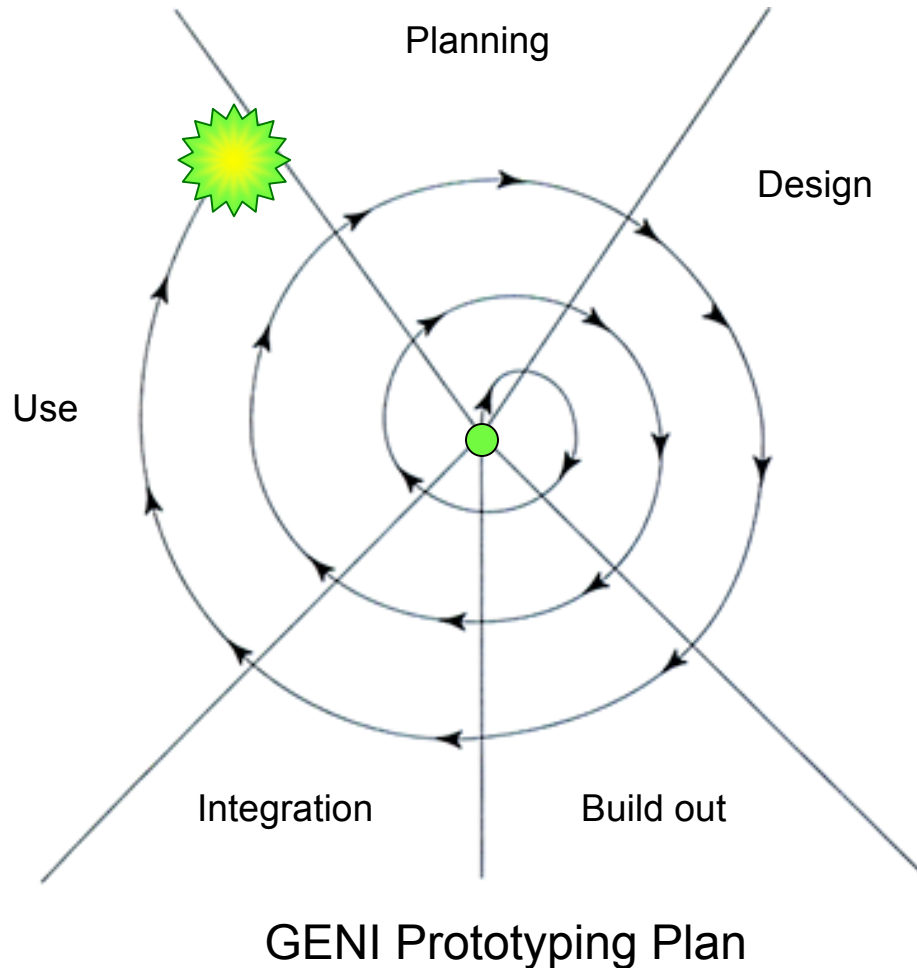
Note that this is the “classics illustrated” version – a comic book!

Please read the GENI System Overview and GENI Spiral 1 Overview for detailed planning information.



# Spiral Development

GENI grows through a well-structured, adaptive process



- An achievable **Spiral 1**  
Rev 1 control frameworks, federation of multiple substrates (clusters, wireless, regional / national optical net with early GENI 'routers', some existing testbeds), Rev 1 user interface and instrumentation.

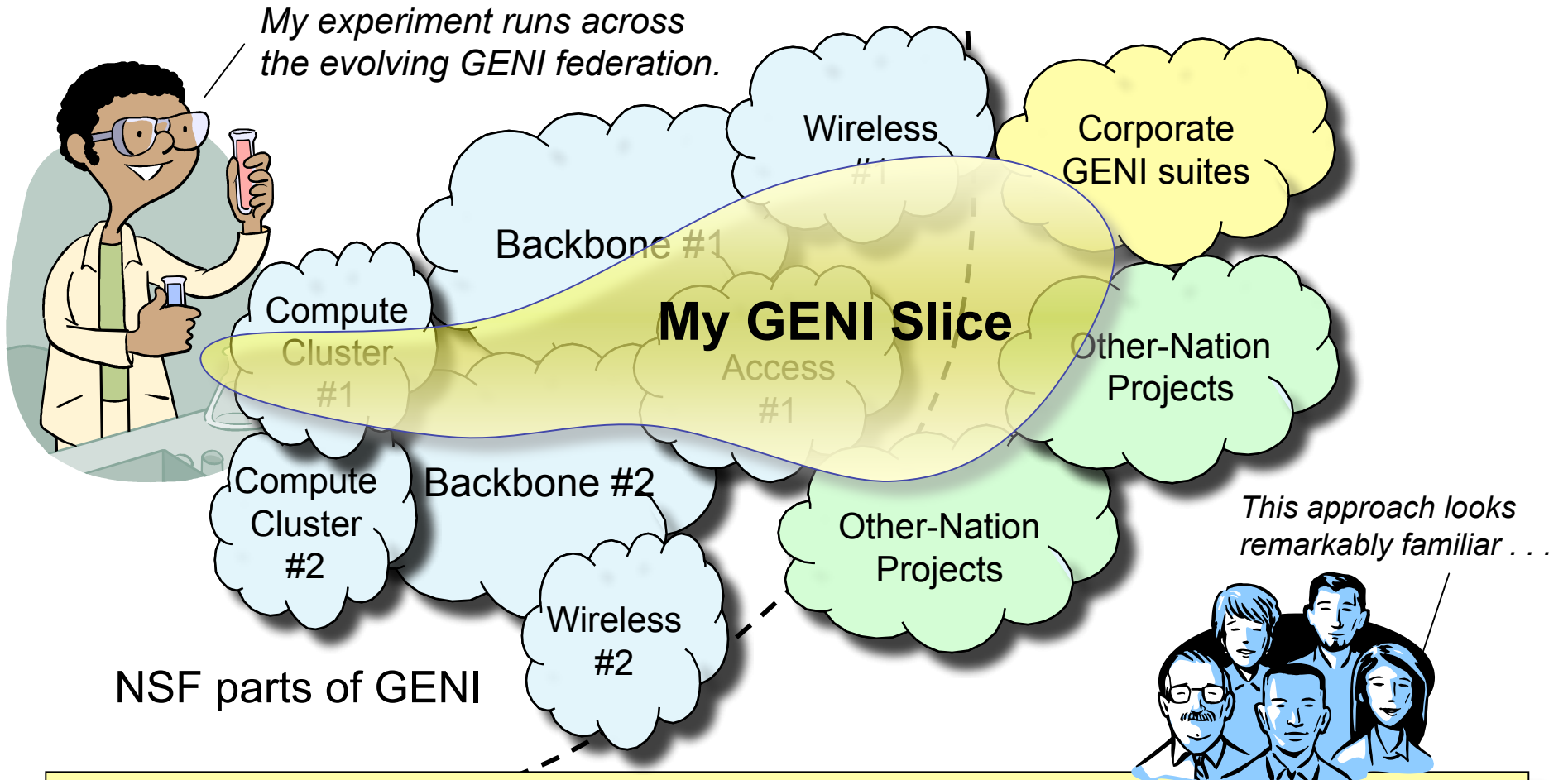
- **Envisioned ultimate goal**  
Example: Planning Group's desired GENI suite, probably trimmed some ways and expanded others. Incorporates large-scale distributed computing resources, high-speed backbone nodes, nationwide optical networks, wireless & sensor nets, etc.

- **Spiral Development Process**  
Re-evaluate goals and technologies yearly by a systematic process, decide what to prototype and build next.



# Federation

GENI grows by “gluing together” 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”



# Outline

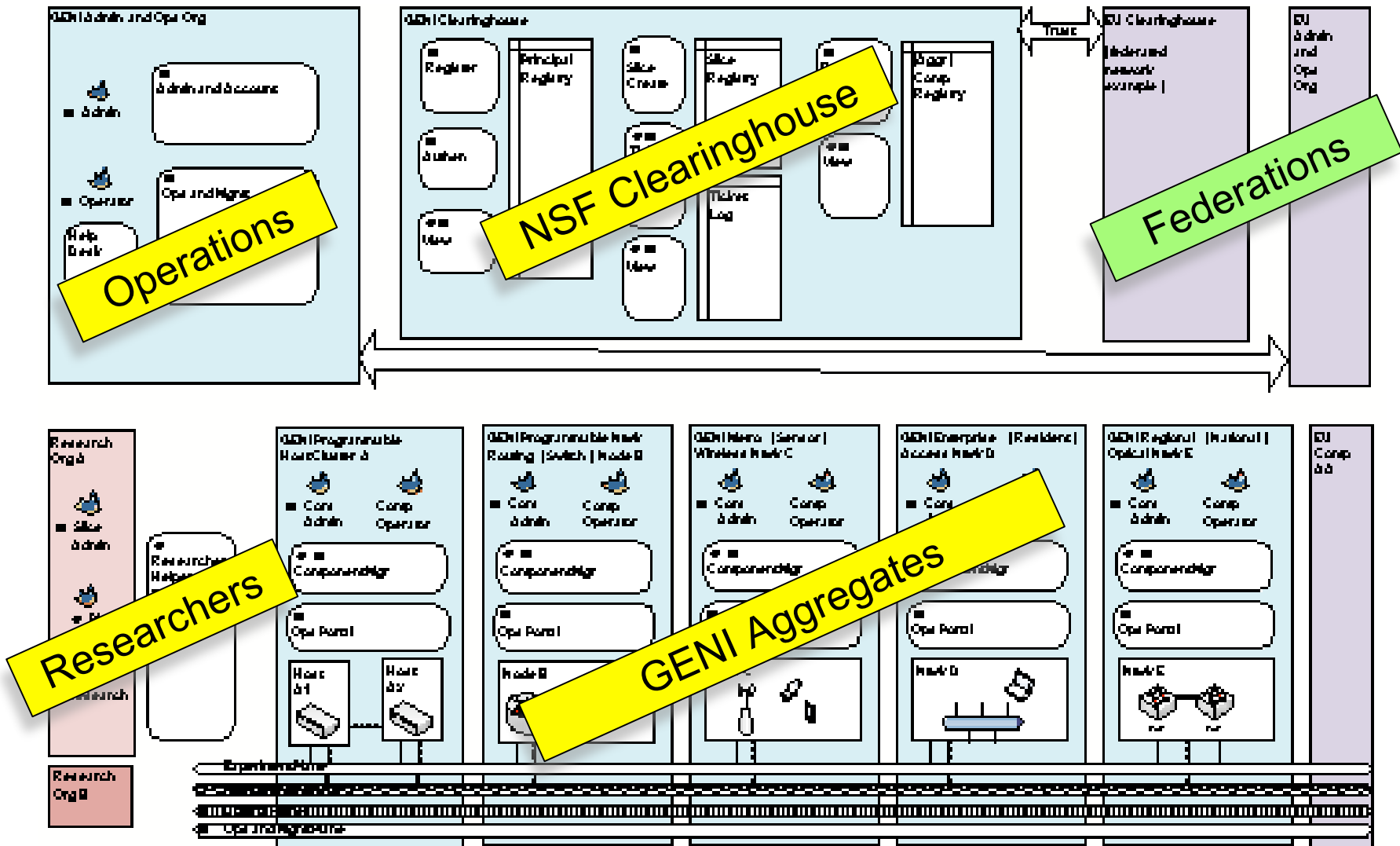
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# GENI System Decomposition (simplified)

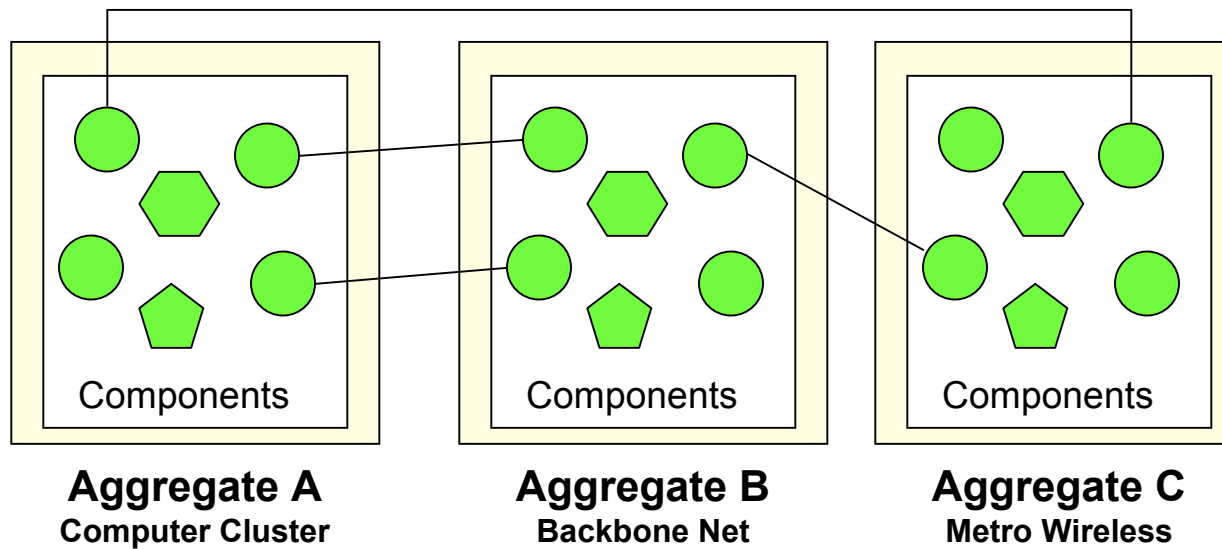
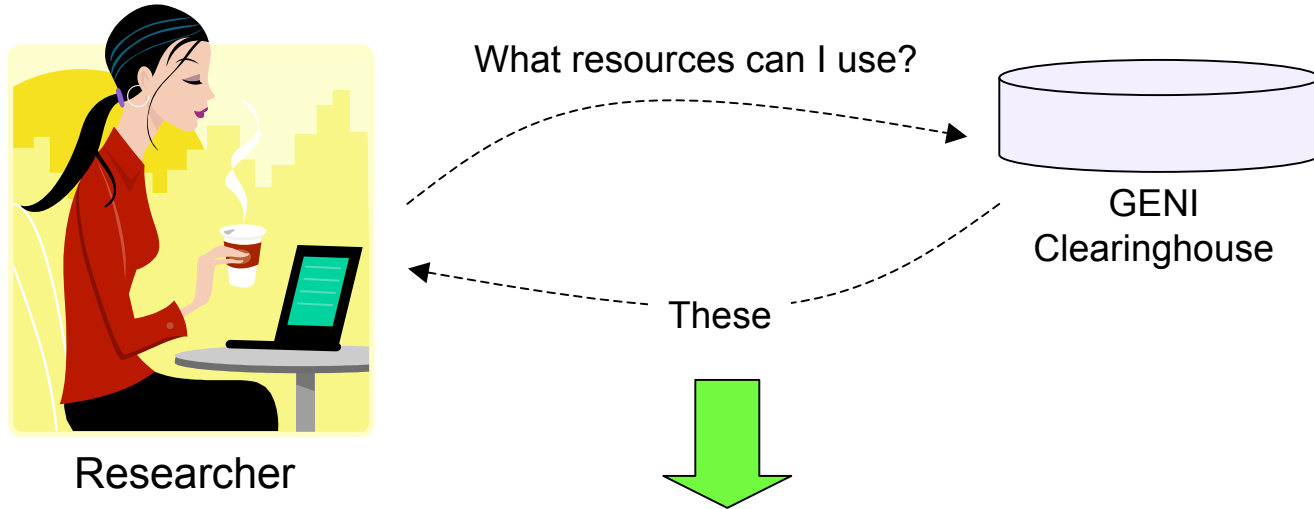
## Engineering analysis drives Spiral 1 integration





# Resource discovery

Aggregates publish resources, schedules, etc., via clearinghouses

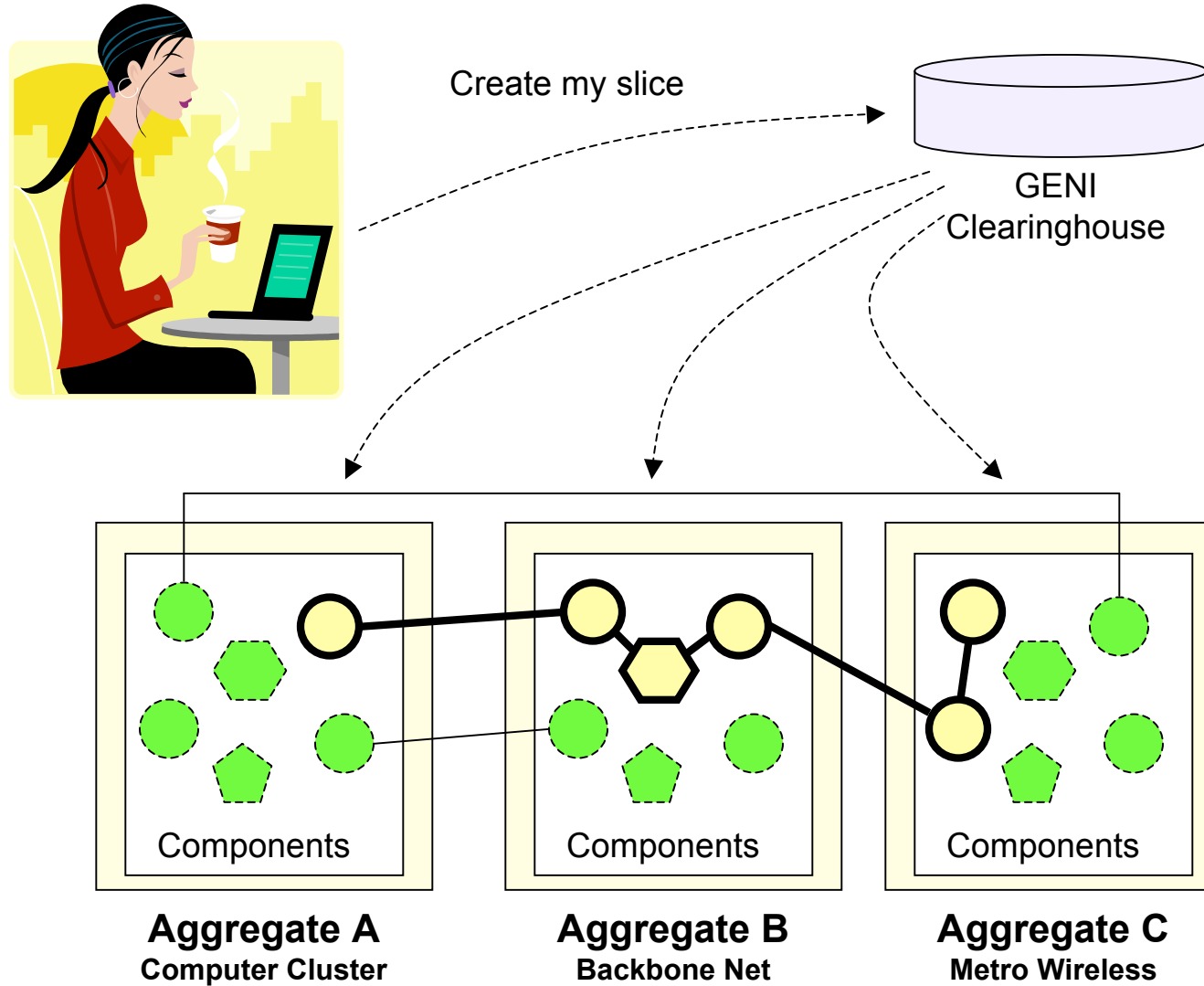




# Slice creation

Clearinghouse checks credentials & enforces policy

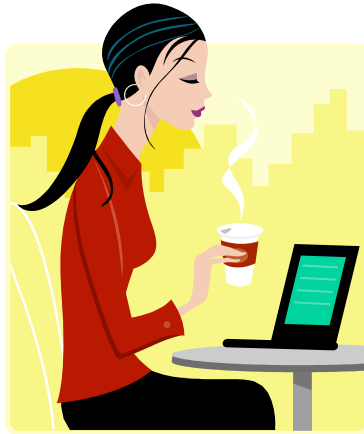
Aggregates allocate resources & create topologies



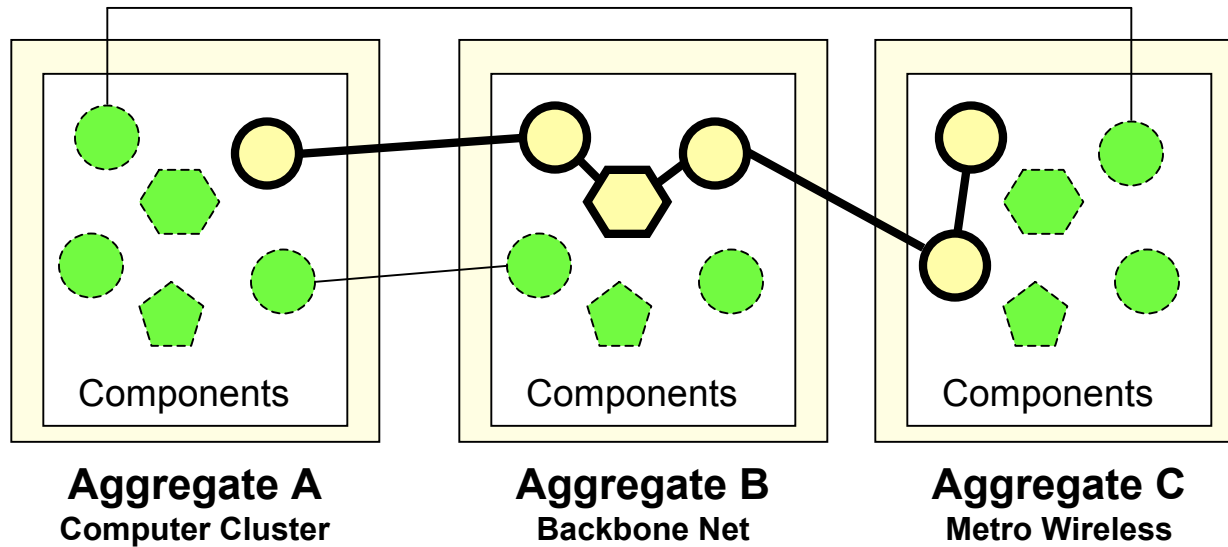
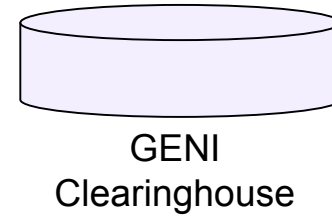


# Experimentation

Researcher loads software, debugs, collects measurements



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

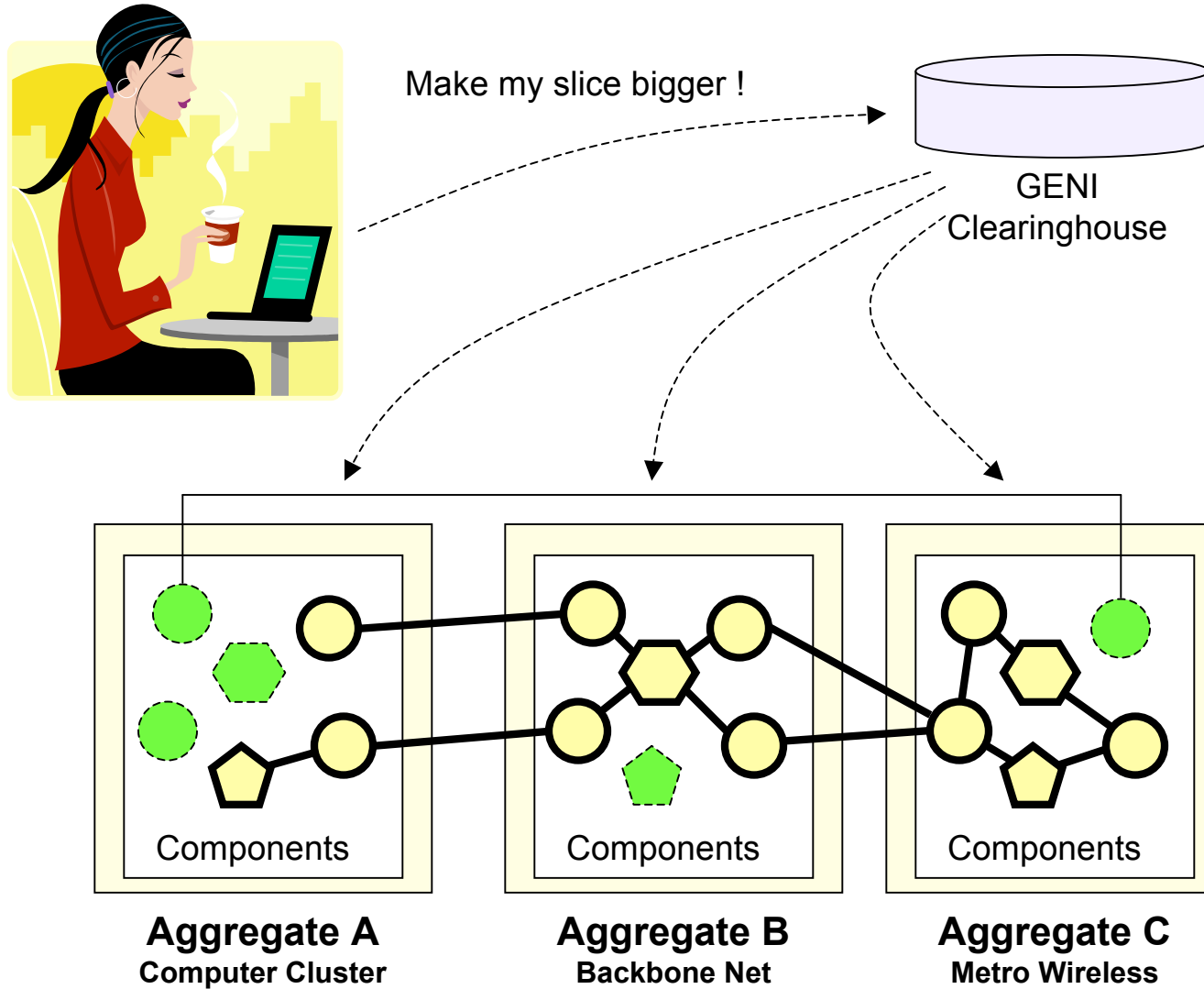






# Slice growth & revision

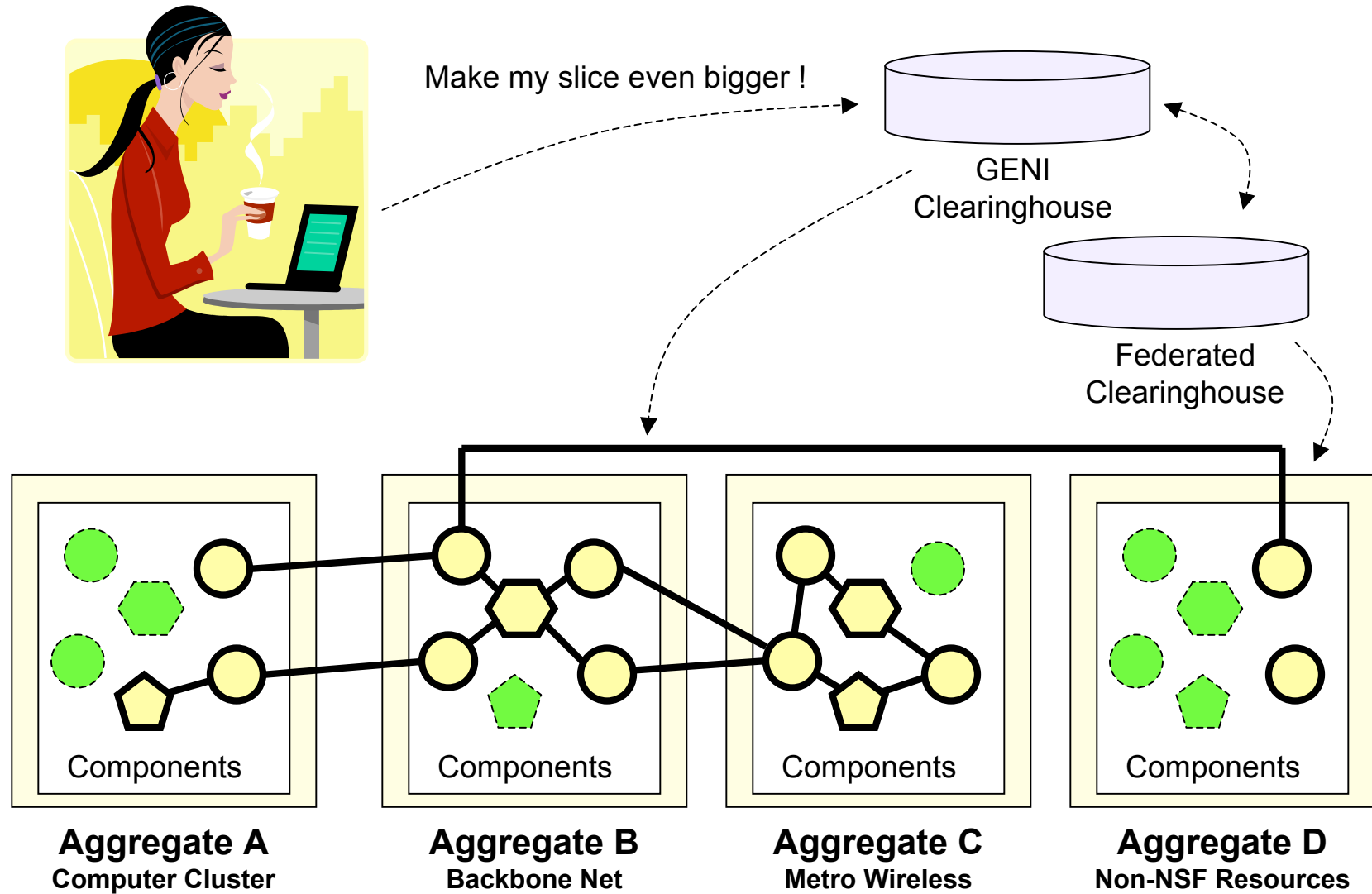
Allows successful, long-running experiments to grow larger





# Federation of Clearinghouses

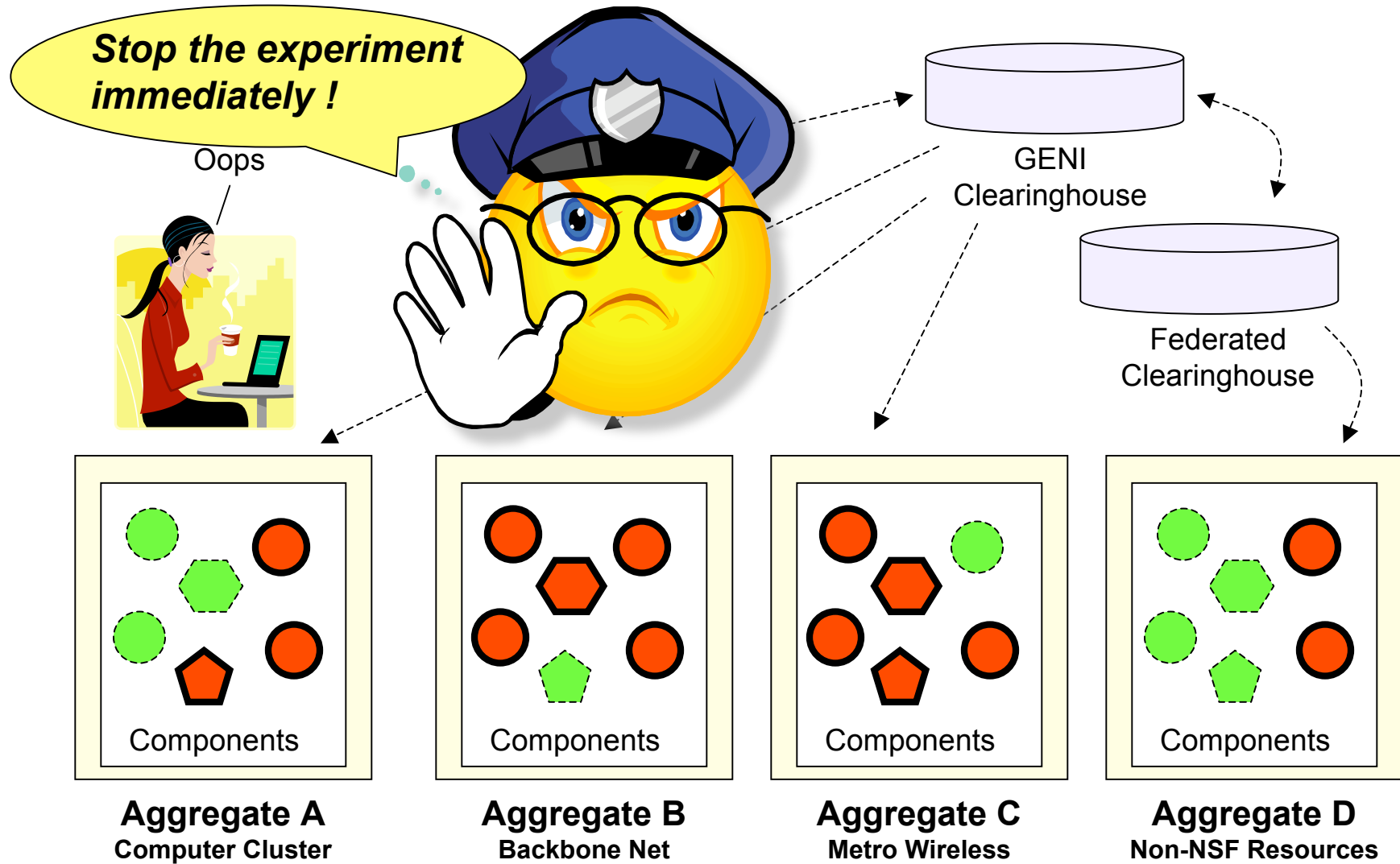
Growth path to international, semi-private, and commercial GENIs





# Operations & Management

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





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# GENI Spiral 1 has now begun!

First results expected in 6-12 months

## GENI Project Office Announces \$12M for Community-Based GENI Prototype Development

July 22, 2008

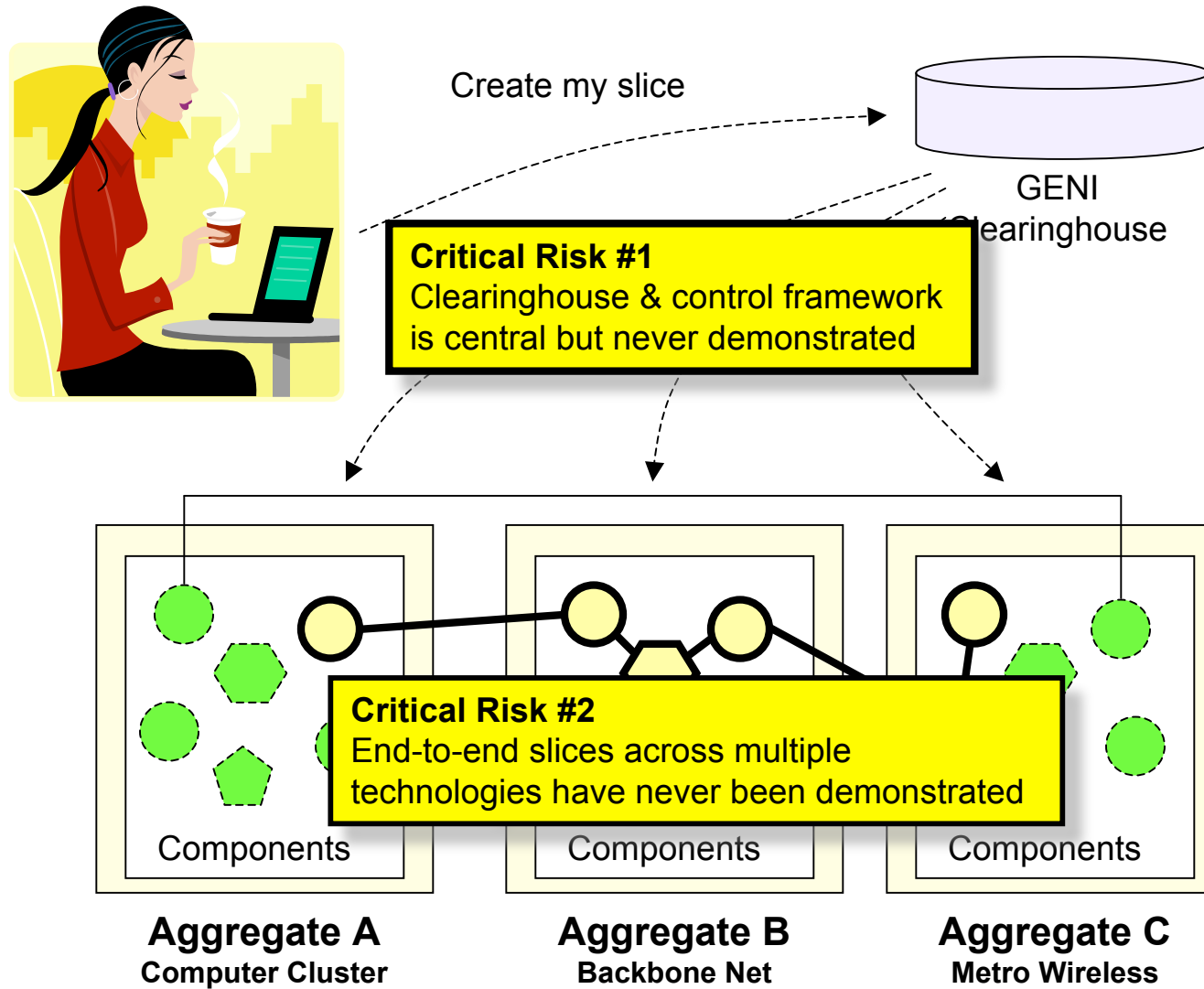
The GENI Project Office, operated by BBN Technologies, an advanced technologies solutions firm, announced today that it has been awarded a **three year grant worth approximately \$4M a year** from the US National Science Foundation to perform GENI design and risk-reduction prototyping.

The funds will be used to contract with **29 university-industrial teams** selected through an open, peer-reviewed process. The first year funding will be used to **construct GENI Spiral 1, a set of early, functional prototypes** of key elements of the GENI system.



# GENI's Critical Technical Risks

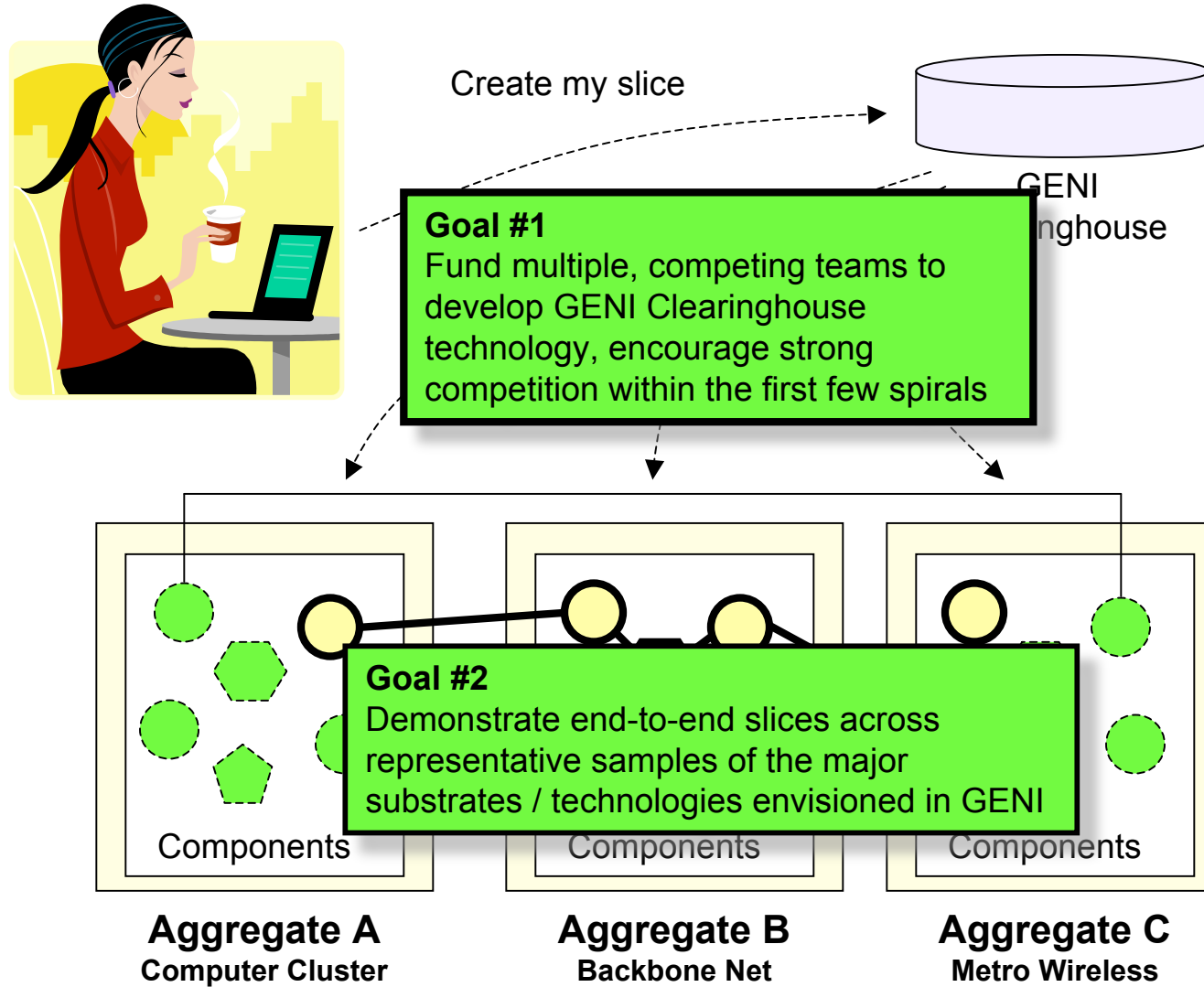
These risks drive the Prototyping Goals for GENI Spiral 1





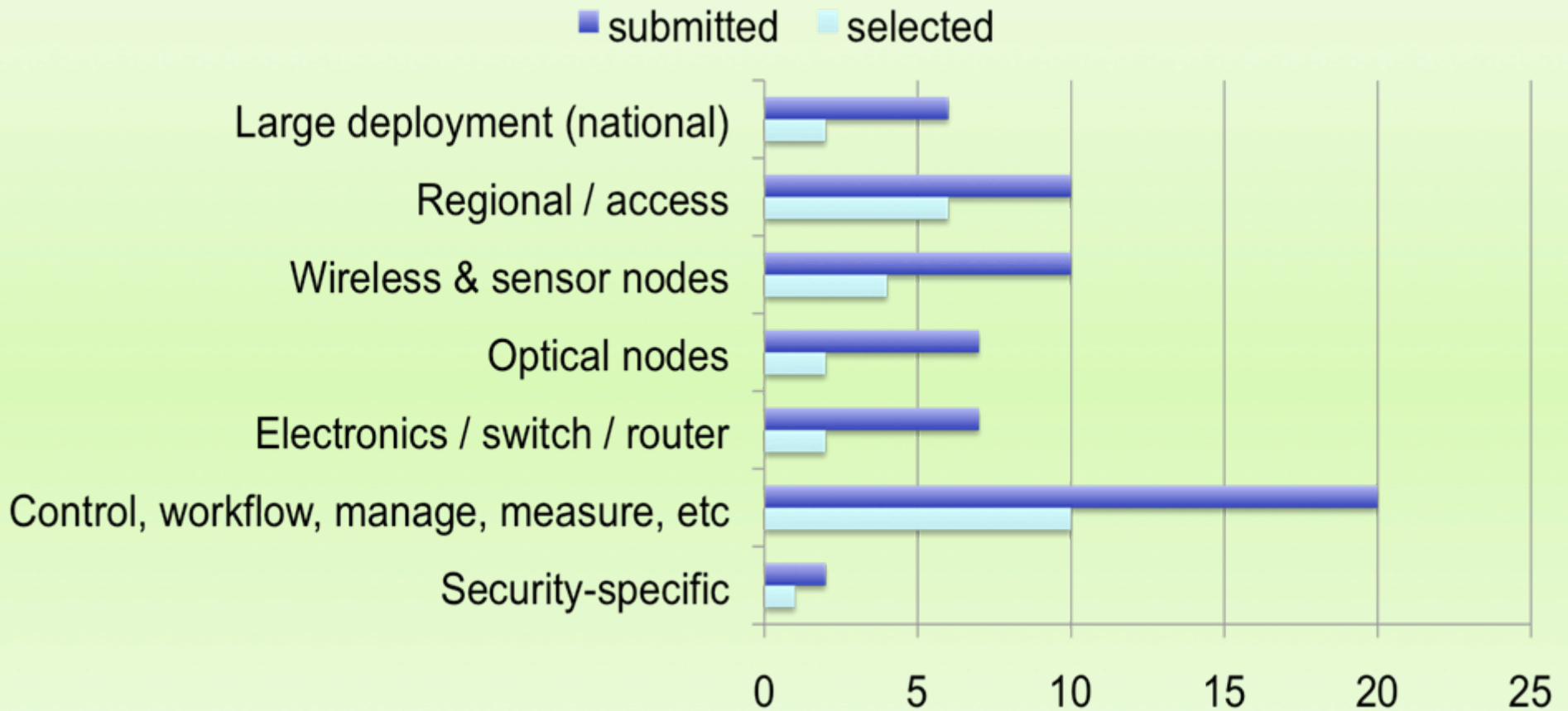
# Key Goals for GENI Spiral 1

Drive down the critical technical risks in GENI's concept





# 1<sup>st</sup> GENI Solicitation – proposal areas

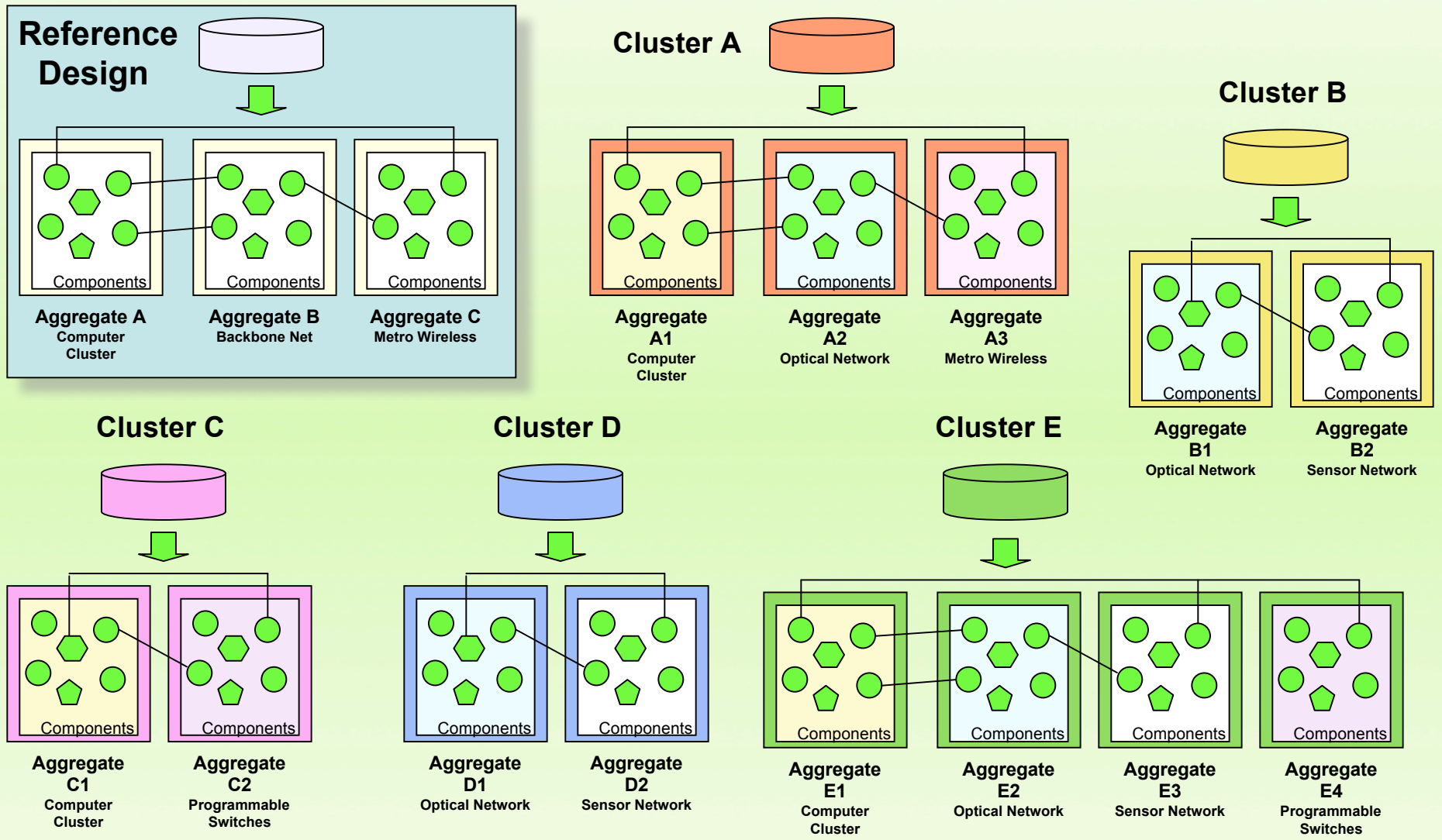






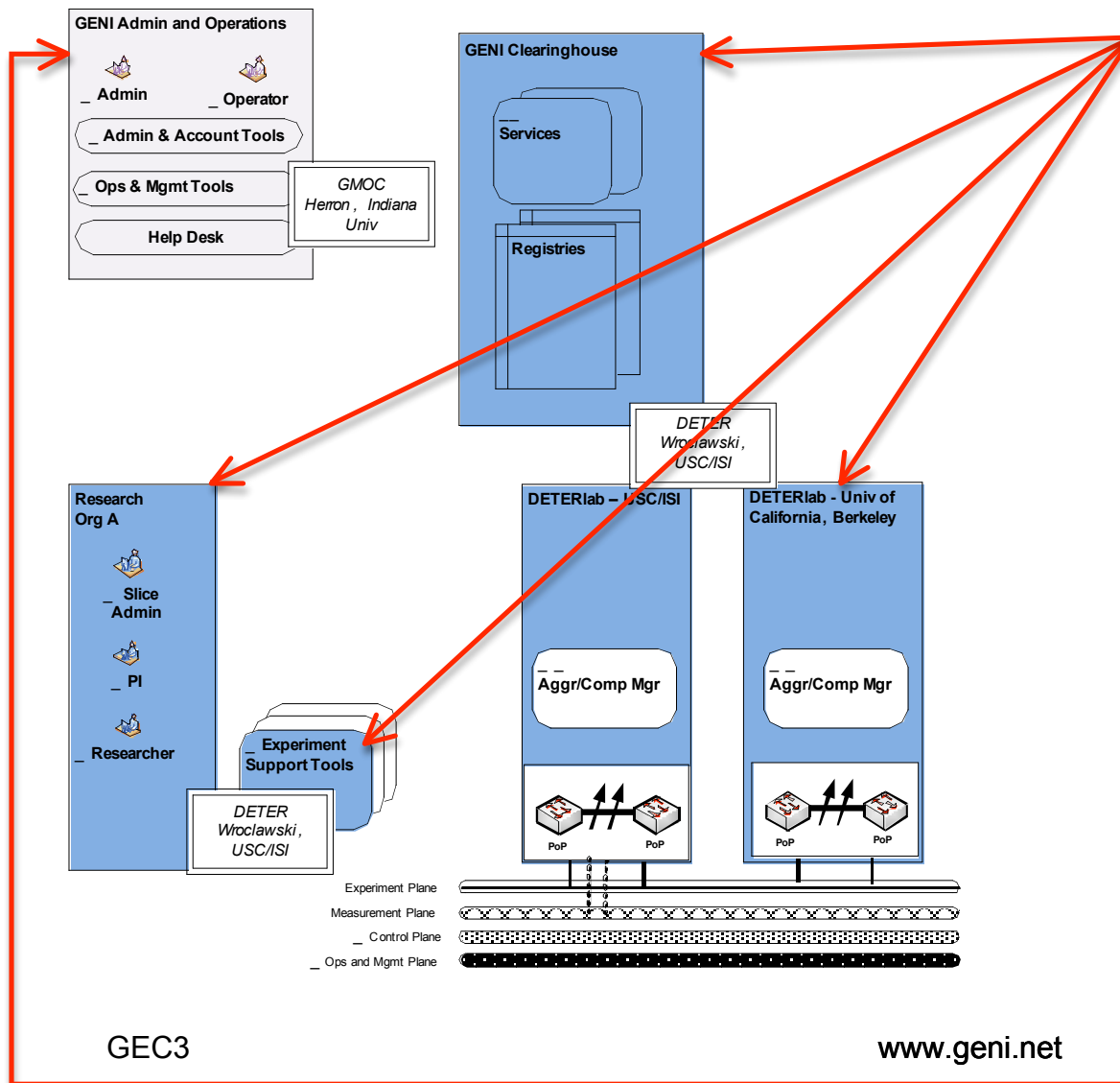
# Spiral 1 integration and trial operations

Five competing control frameworks, wide variety of substrates





# Cluster A Integration (uses TIED/DETER control framework)



## DETER Trial Integration

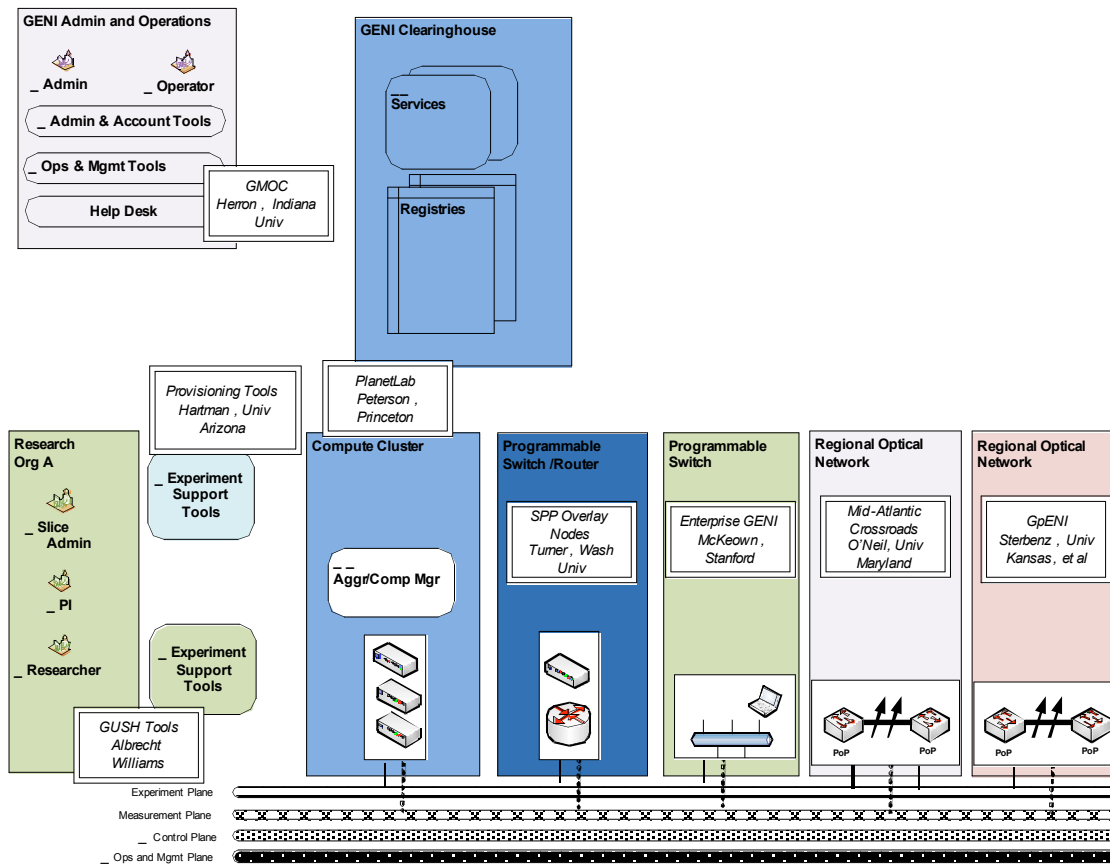
- DETER security testbed
- Emphasis on federation
- Clearinghouse, CM
- 100+ nodes at ISI, UC Berkley

## GMOC

- Global Research NOC (Indiana)



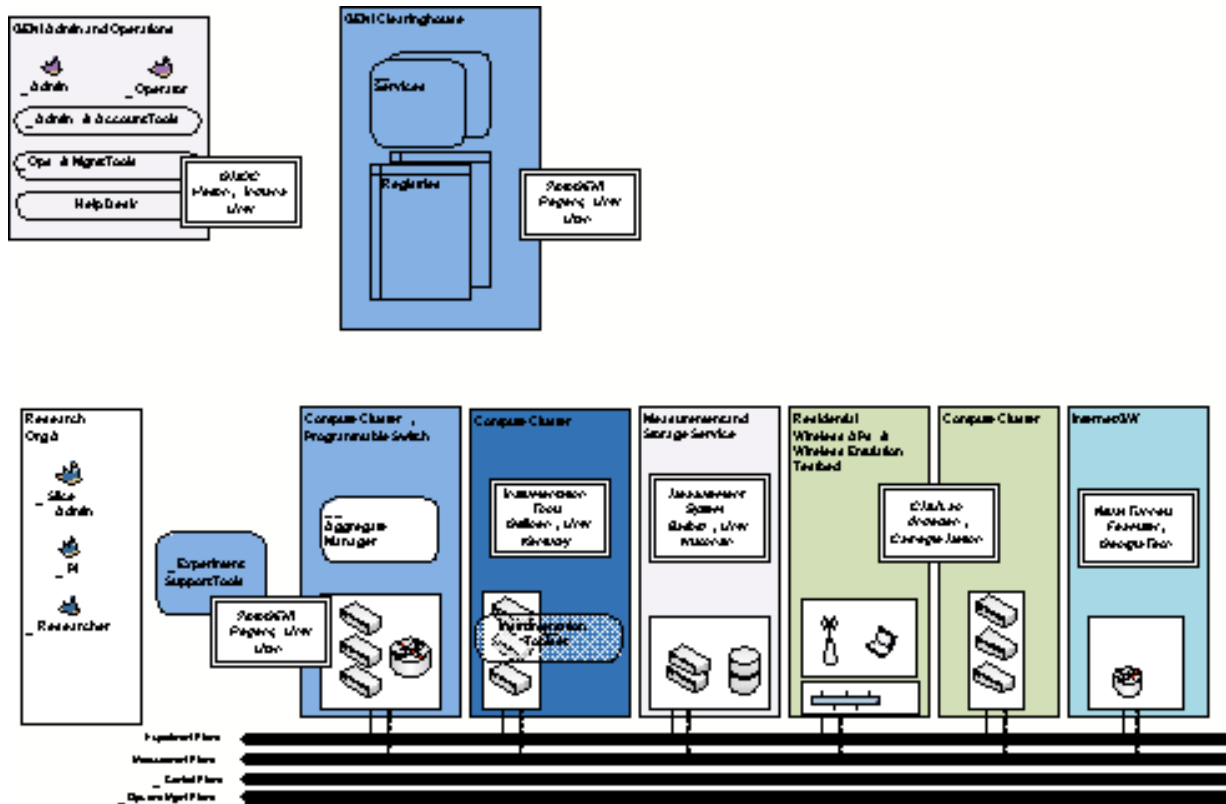
# Cluster B Integration (uses PlanetLab control framework)



- PlanetLab
  - Clearinghouse, CM
  - 800+ nodes
  - VINI (virtual topologies)
- Enterprise GENI
  - GENI VLANs on enterprise nets
- SPP Overlay Nodes
  - Programmable routers
- GUSH Tools
  - Experiment design tools
- Provisioning Service
  - Slice & experiment management tools
- Mid-Atlantic Crossroads
  - Regional network with VLAN control plane
- GpENI
  - Regional network with sliceable optics & routers
- GMOC



# Cluster C Integration (uses ProtoGENI/Emulab Control Framework)



## ProtoGENI

- Clearinghouse, CM
- Emulab resources
- (370+ nodes)

## CMULab

- Home Wireless APs
- Emulab cluster
- Wireless emulation testbed

## Instrumentation Tools

- UK Edulab (compute/store)

## Measurement System

- GIMS prototype

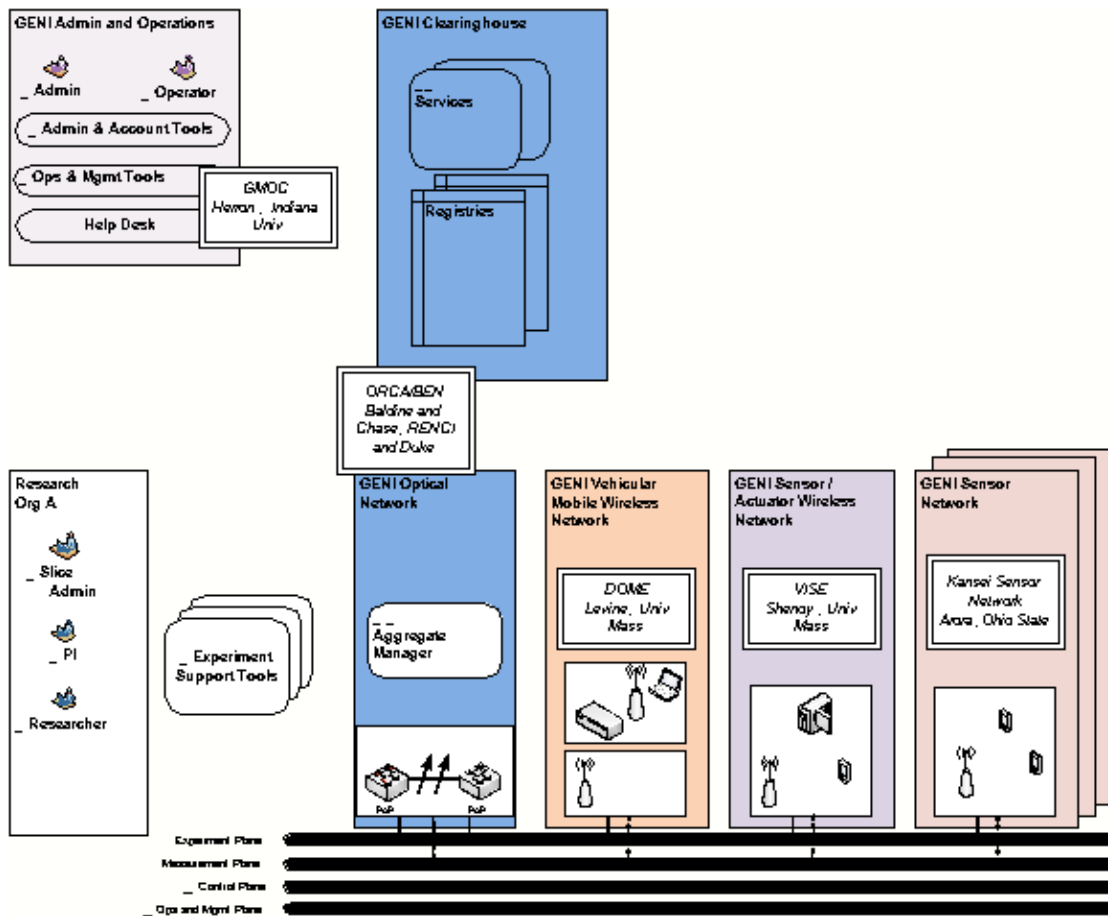
## Virtual Tunnels

- Dynamic tunnel tools
- BGP distribution tools

- GMOC



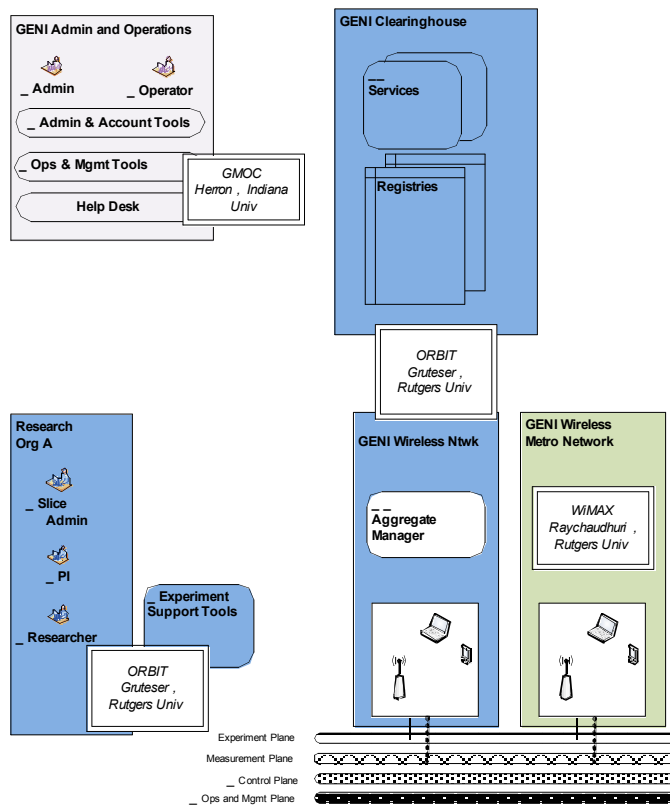
# Cluster D Integration (uses ORCA Control Framework)



- ORCA/BEN
  - ORCA resource leasing software
  - Metro-Scale Optical Testbed (BEN)
- VISE
  - CASA (radar, video, weather sensors)
- Kansei Sensor Network
  - Wireless sensor network arrays
  - 3 federated sites each w/~100 sensor nodes
- Diverse Outdoor Mobile Environment (DOME)
  - Programmable nodes with radios on city busses
- GMOC



# Cluster E Integration (uses ORBIT control framework)



- ORBIT
  - Heterogeneous testbed control, management, & measurement software
  - WINLAB wireless testbeds resources (400+ sensor nodes)
  - NICTA (Australia) wireless outdoor traffic testbed
- WiMAX
  - Open, programmable WiMAX base station
- GMOC



# Generous Donations to GENI Prototyping Internet2 and National Lambda Rail



## National Lambda Rail

Up to 30 Gbps nondedicated bandwidth

**Internet2**  
10 Gbps dedicated bandwidth



**40 Gbps capacity for GENI prototyping on two national footprints  
to provide Layer 2 Ethernet VLANs as slices (IP or non-IP)**



Currently in the works

## Prototyping GENI through campuses

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- August Meeting at O'Hare
  - Thanks to EduCause (Mark Luker, Garret Sern)
  - Stimulated by Larry Landweber
- CIOs from 11 major research universities
  - Berkeley, Clemson, GA Tech, Indiana, MIT, Penn State, Rice, U. Alaska, UIUC, UT Austin, U. Wisconsin
- Discussions of representative GENI prototypes
  - Nick McKeown, Stanford (OpenFlow)
  - Arvind Krishnamurthy, UW (Million Node GENI)
  - GPO Staff
- Near-term GENI / CIO activities
  - How to “GENI-enable” campus IT infrastructure
  - Coordinated policy for handling side-effects of network research (Larry Peterson, Helen Nissenbaum)





# GENI Spiral 1

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- Provides the very first, national-scale prototype of an interoperable infrastructure suite for Network Science and Engineering experiments
- Creates an end-to-end GENI prototype in 6-12 months with broad academic and industrial participation, while encouraging strong competition in the design and implementation of GENI's control framework and clearinghouse
- Includes multiple national backbones and regional optical networks, campuses, compute and storage clusters, metropolitan wireless and sensor networks, instrumentation and measurement, and user opt-in
- Because the GENI control framework software presents very high technical and programmatic risk, the GPO has funded multiple, competing teams to integrate and demonstrate competing versions of the control software in Spiral 1

Nothing like GENI has ever existed; the integrated, end-to-end, virtualized, and sliceable infrastructure suite created in Spiral 1 will be entirely novel.



# Outline

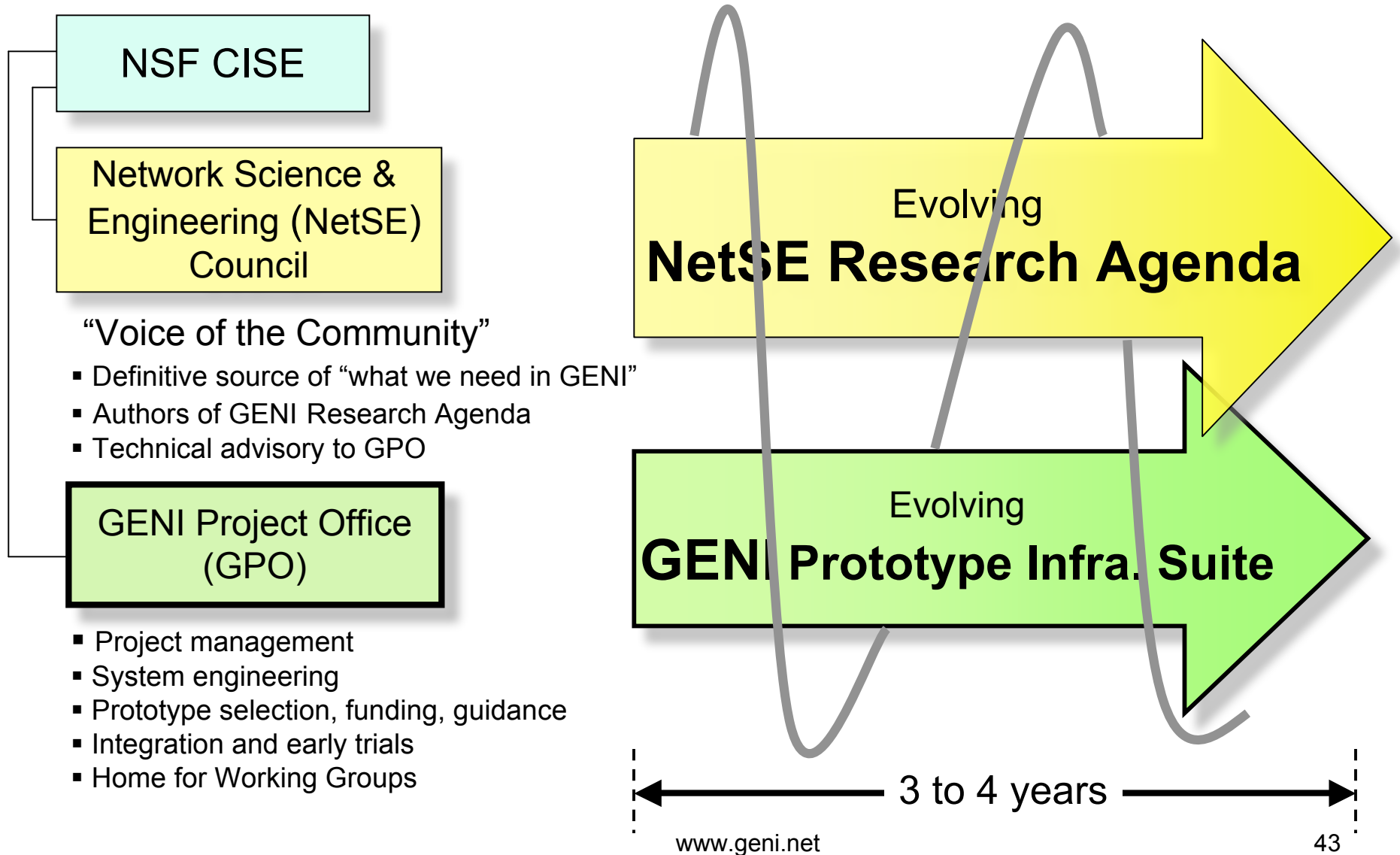
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# GENI in Context

Supports the Evolving NetSE Research Agenda





# NetSE Council



Ellen Zegura (Chair)



Tom Anderson (UW)



Joe Berthold (Ciena)



Charlie Catlett (Argonne)



Mike Dahlin (UT Austin)



Chip Elliott (GPO)



Joan Feigenbarum (Yale)



Stephanie Forrest (UNM)



Jim Hendler (RPI)



Michael Kearns (U.Penn)



Ed Lazowska (UW)



Peter Lee (CMU)



Larry Peterson (Princeton)



Jennifer Rexford (Princeton)



Alfred Spector (Google)

And not shown . . .

Roscoe Giles  
Helen Nissenbaum



## GENI is being Designed & Built by the Community Via an Open, Transparent, & Fair GPO Process

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- All design, prototyping, & construction will be performed by the research community (academia & industry)
- 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 will be fair and even-handed
  - BBN brings no technology to the table
  - BBN does not intend to write any GENI software, nor does it envision bidding on any prototyping or construction activities (but “never say never”)
  - If BBN does create any GENI technology, it will be made public at no cost



## Working Groups drive GENI's Technical Design

Meet every 4 Months to Review Progress Together

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- **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 in person
  - Each led by Chair(s), plus a professional System Engineer
- **GENI Engineering Conferences**, open to all who fit in the room
  - Held at regular 4-month periods
  - Held on / near university campuses (volunteers?)
  - All GPO-funded teams required to participate
  - Systematic, open review of each Working Group status (all documents and prototypes / trials / etc.)
  - Also time for Working Groups to meet face-to-face
  - Results in prioritized list for next round of prototype funding areas (priorities decided by NetSE and GPO)



# GENI Working Groups (WGs)

Open to all, participate via **geni.net** email lists

*Shaded areas pose major security / privacy challenges*

- **Substrates**

All hardware, real-estate, facilities, etc., required for the GENI infrastructure suite (including optical networks, wireless, computers, etc.)

- **Control Framework with Federation**

Written definitions of the core GENI mechanisms for providing experimental control of a node or collection of nodes. The very earliest version must incorporate federation.

- **Experiment Workflow**

Tools and mechanisms by which a researcher designs and performs experiments using GENI. Includes all user interfaces for researchers, as well as data collection, archiving, etc.

- **User Opt-In**

How do “real users” (not researchers) participate in GENI experiments. Includes both mechanisms and considerations such as privacy, etc.

- **Operations, Management, Integration, and Security**

How do operators provision, operate, manage, and trouble-shoot GENI? Includes all mechanisms for integrating and securely operating the GENI infrastructure suite.





# GENI Engineering Conferences

Meet every 4 months to review progress together

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- **4th meeting March 31-April 2, 2009, Miami, open to all**
  - Team meetings, integrated demos, Working Group meetings
  - Also discuss GPO solicitation, how to submit a proposal, evaluation process & criteria, how much money, etc.
  - **Travel grants** to US academics for participant diversity
- **Subsequent Meetings, open to all who fit in the room**
  - Held at regular 4-month periods
  - Held on / near university campuses (volunteers?)
  - All GPO-funded teams required to participate
  - Systematic, open review of each Working Group status (all documents and prototypes / trials / etc.)
  - Also time for Working Groups to meet face-to-face
  - Discussion will provide input to subsequent spiral goals





# GPO Solicitations

Academic-industrial teams favored but not required

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- **Second solicitation active – proposals due Feb. 20 !**
- What kinds of proposals do we solicit?
  - Analyses & idea papers
  - Prototypes of high-risk GENI technology
  - Integrations and trials of prototypes
- How are proposals judged?
  - Merit review
  - Joint academic / industrial teams are favored but not required
  - Open source will be favored but not required  
(**IP licenses on [www.geni.net](http://www.geni.net)**)



## GENI Solicitation 2 – Proposals due Feb. 20

- Overview
  - Solicitation issued December 2008
  - Proposals due February 20, 2009
  - Total funds ~ \$3.5 M / yr for 3 years, as always subject to availability of funds
  - Existing / new GENI participants both welcome
- Strong preference given to . . .
  - Joint Academic / Industrial teams
  - Active participation of campus / regional infrastructure providers (e.g., letter from campus CIO)
- Main solicitation interests
  - Security design and analysis for GENI
  - Experimental workflow prototypes
  - Instrumentation and measurement prototypes
  - Early tries at international federation
  - Other good ideas

**[www.geni.net](http://www.geni.net)**

Solicitation and background information



# GENI is a Huge Opportunity

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- **GENI is an unbelievably exciting project for the community**
  - Our research community has changed the world profoundly. GENI opens up a space to do it again.
- **We believe the whole community will build GENI together**
  - Our vision is for a very lean, fast-moving GPO, with substantially all design and prototyping performed by academic and industry research teams.
- **GENI Spiral 1 is now underway !**
  - within a GENI project framework that is open, transparent, and broadly inclusive.

**[www.geni.net](http://www.geni.net)**

Clearing house for all GENI news and documents