Research for Future Networking

Needs, Directions, and Facilities

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Outline

- The U.S. research context
- Challenges for the current Internet
- What is the U.S. approach?
- The GENI Facility
- The future (as we see it today)

CONTEXT

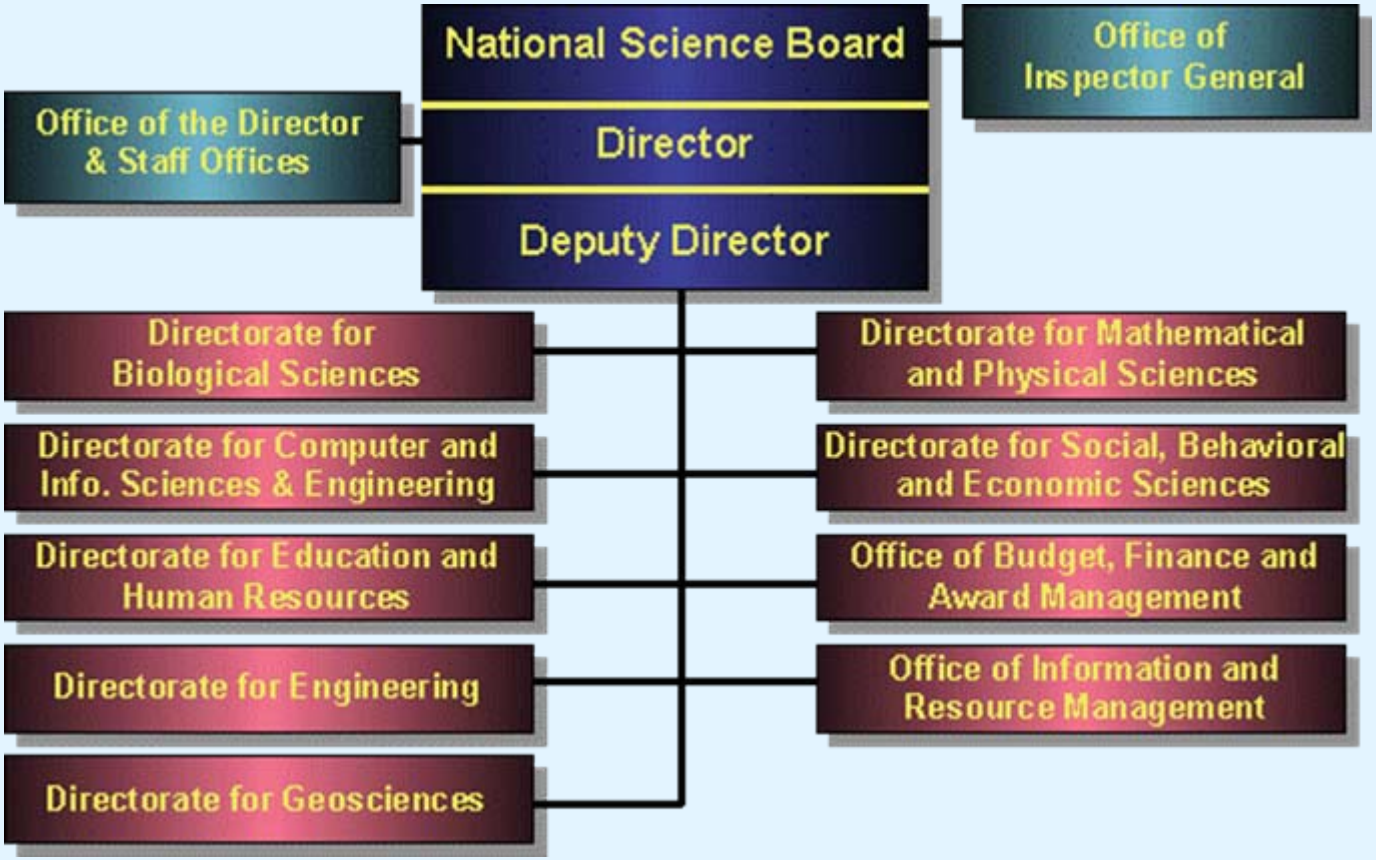
NSF Mission

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense

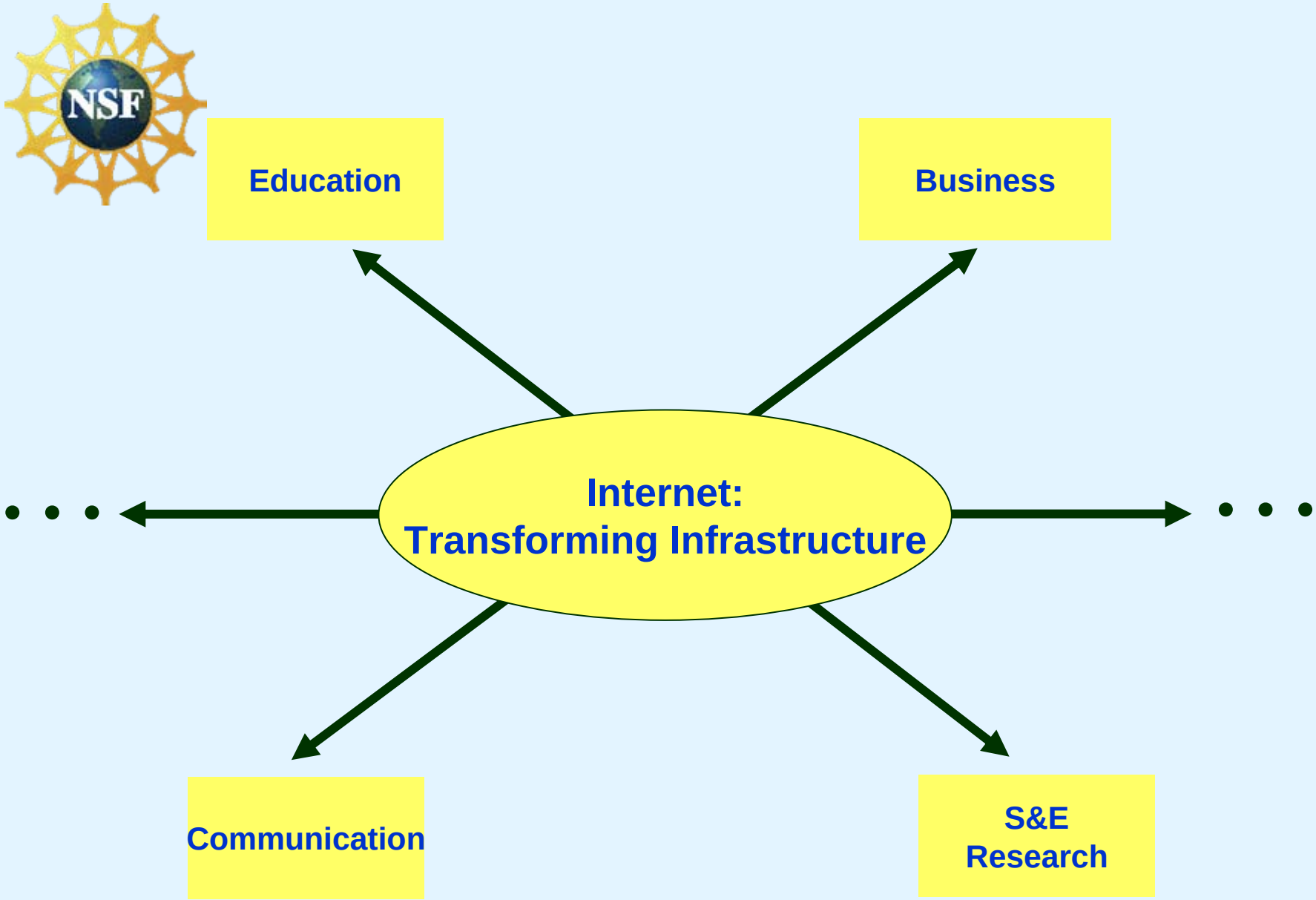
NSF

- Is the primary supporter of physical science and engineering research and education in U.S. universities
- No “classified” research
- Work is performed by faculty and students
- Focuses on fundamental and long-range research
- Integrates research and education
- Most work is independent of industry

National Science Foundation

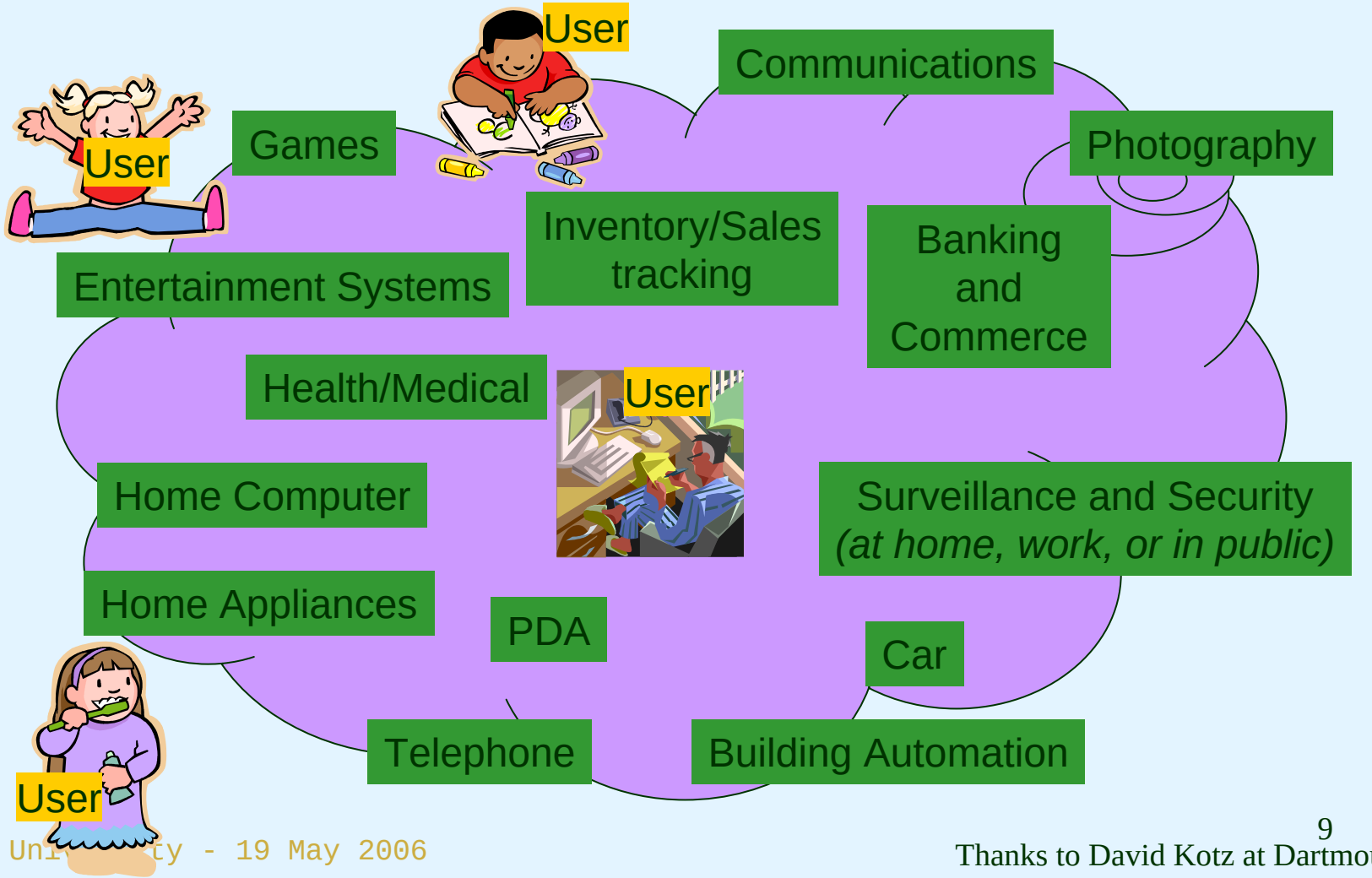


INTERNET CHALLENGES


Education
Business
Internet:
Transforming Infrastructure
Communication
S&E
Research

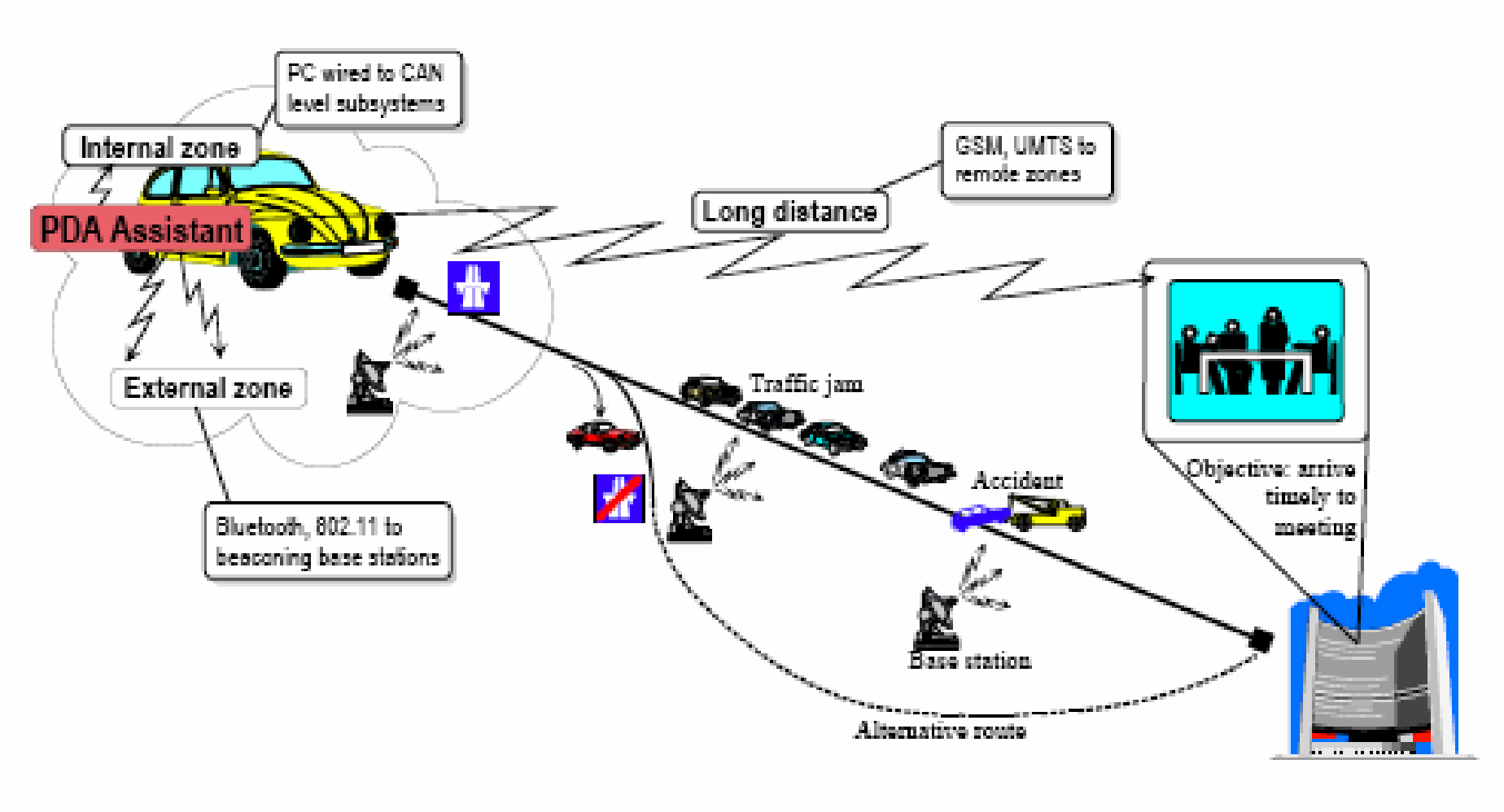
Digital Living *2010*

Tomorrow's users will be surrounded by pervasive devices, embedded sensors and systems… all connected to the Internet.



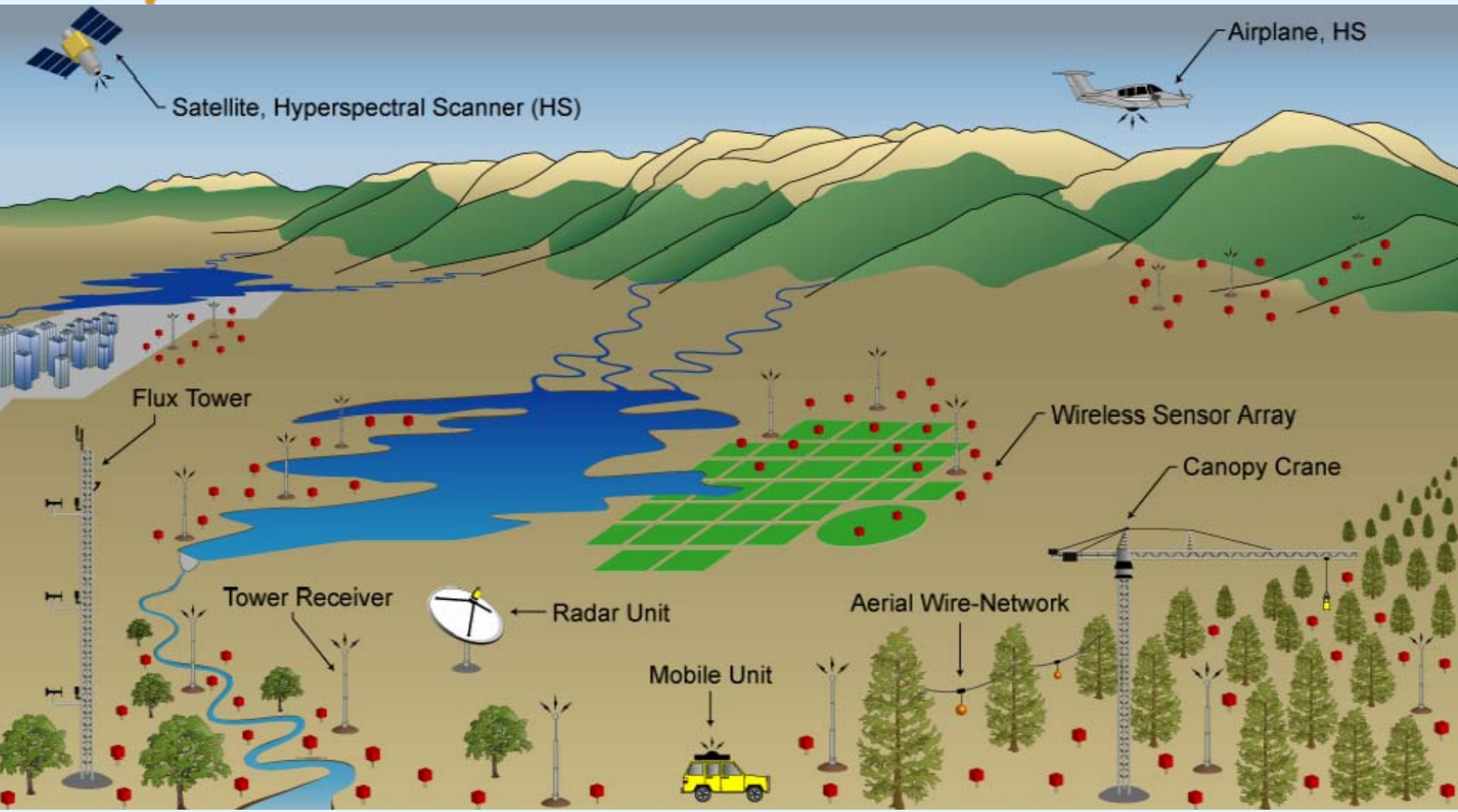
Thanks to David Kotz at Dartmouth

Networked Embedded Systems



Thanks to Paulo Verssimo

NEON: National Ecological Observatory Network



Network Centric Critical Infrastructures

Transportation

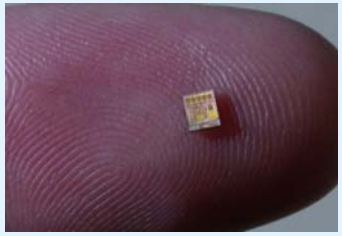
Essential Utilities

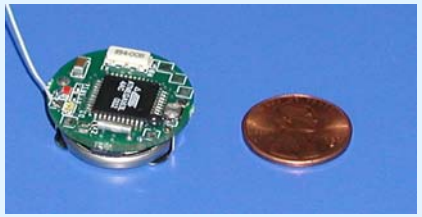
Telecommunications
Banking & Finance

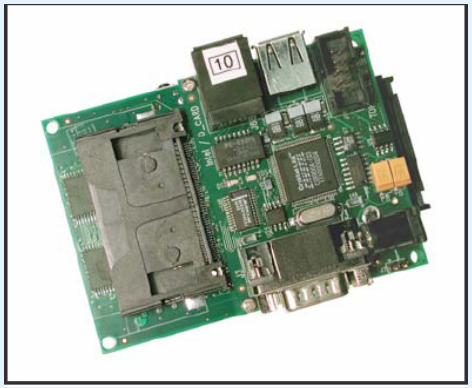
Images from Google Image

Sensors and Sensor Networks

New Machines







New Environments
New Applications

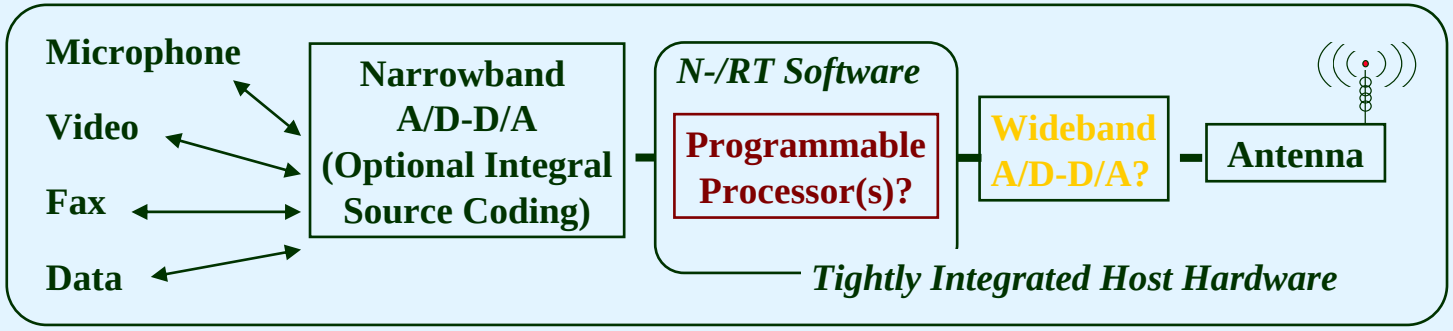
New Scale

Billion to trillion devices!

Images from Google Image Search

Software Radios

- Software Radio
  - Wide operational frequency supports use of multiple bands
  - Multiple waveforms in a single hardware unit provides interoperability
- Impact
  - Dynamic spectrum management helps prevent interference
  - Adaptable to local & current situation; flexible frequency use provides opportunities for quality of service
  - Rapid deployment and service creation
  - Enables new network architectures through flexible & dynamic connectivity



- Systems and networking issues remain unexplored and unexploited!

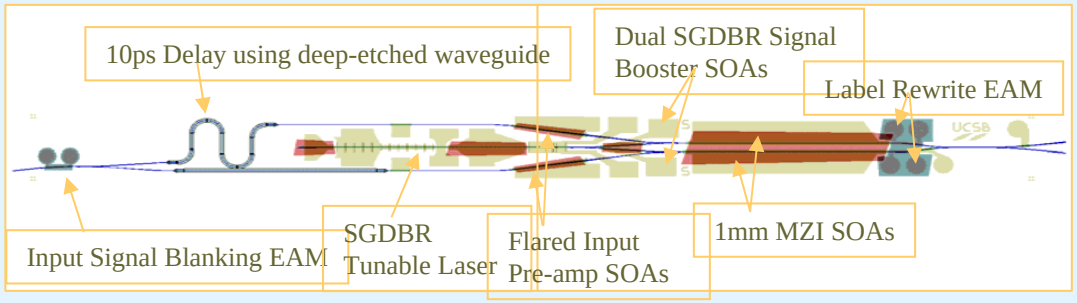
Thanks to Joe Evans

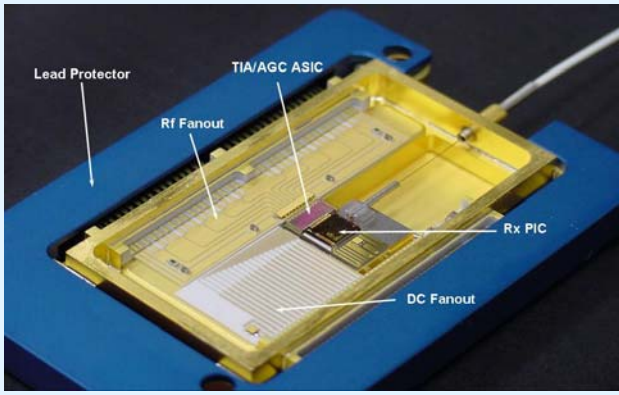
Mobile Wireless Devices

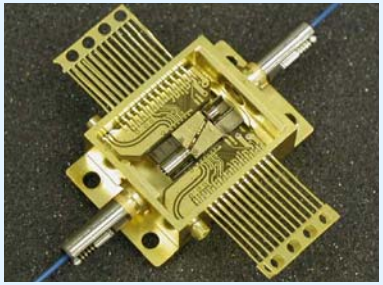
- Each one is an end-node on the network
- 2B+ cell phones sold every year
- Range of mobility
- Data, VOIP, IPTV, …

Images from Google Image

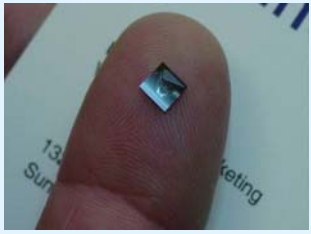
Photonics Integration



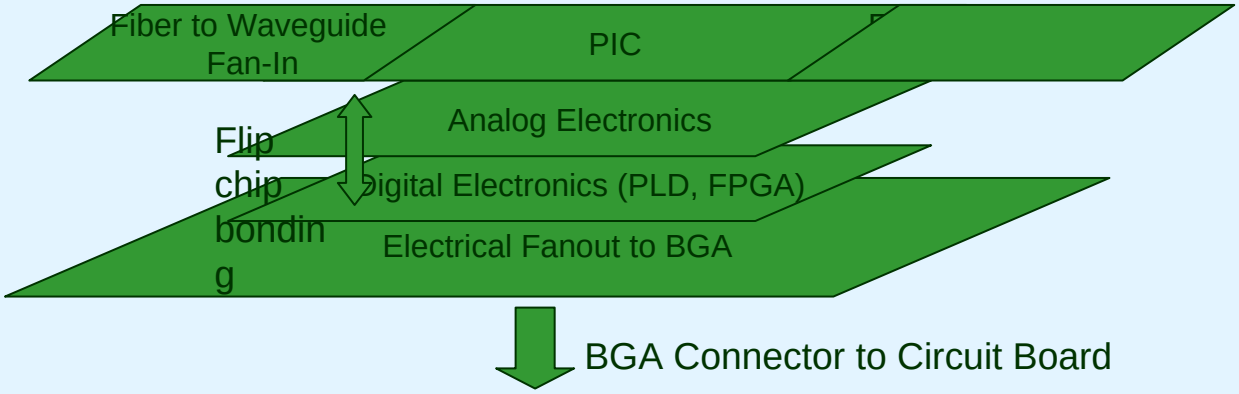




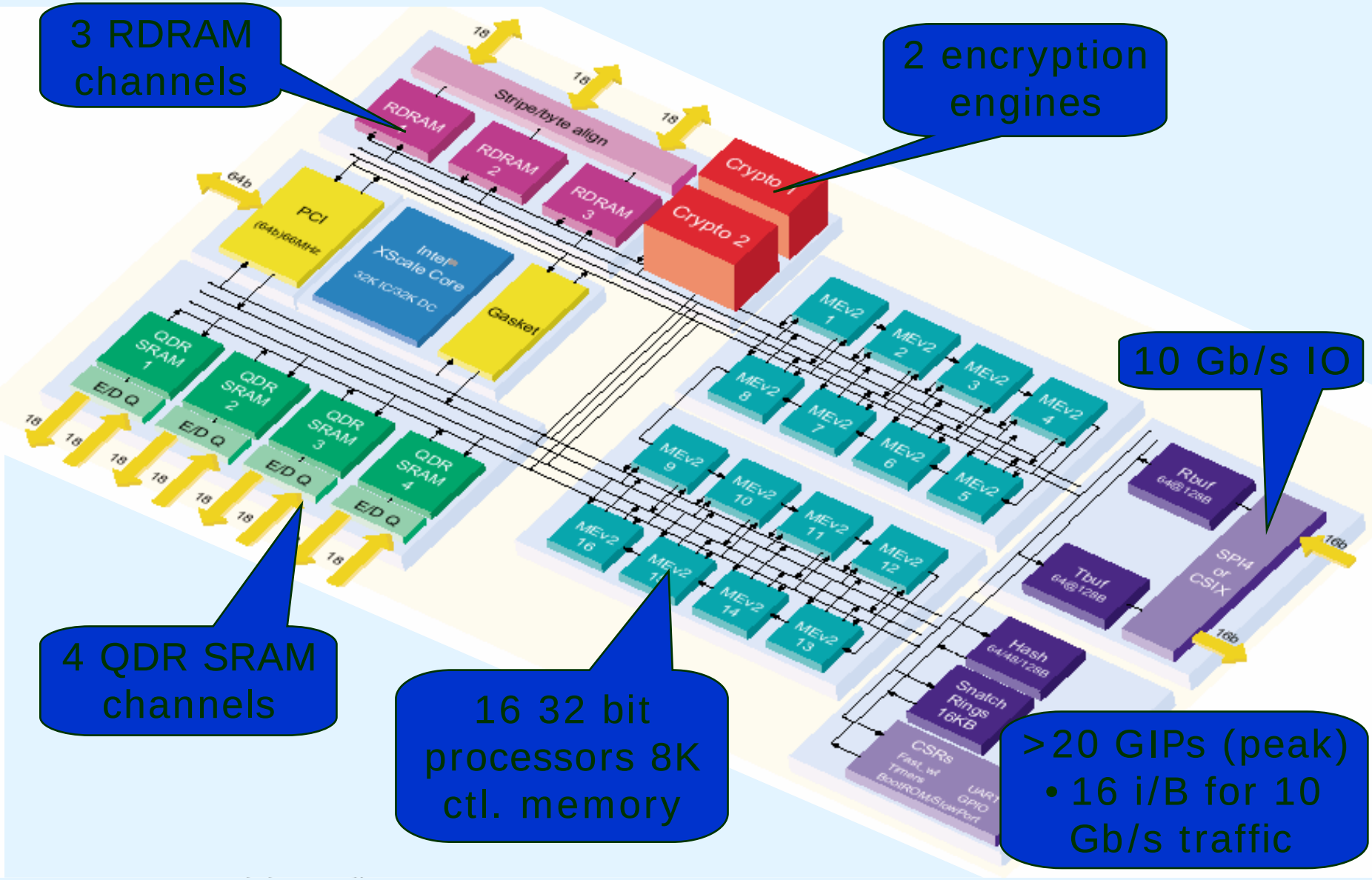
Dan Blumenthal
UCSB



Vinod Khosla talk
http://www.kpcb.com/



System on a Chip: IXP 2850



Thanks to Jon Turner

And many more

- Mapping the physical world into virtual world
- Large scale data grid and vast personal data
- Pervasive computing with mobile wireless
- Disaster recovery
- S&E Applications

And others that we cannot guess today

Challenges

- Increasing dependence of society on the Internet
- Fundamental limitations of current Internet architecture
  - Security, robustness, manageability, quality of service, etc.
  - At the limit of its extensibility
- New opportunities enabled by
  - Disruptive technologies: sensors, mobile wireless, photonics…
  - New classes of applications in all areas of activity
- Need to establish robust, experimental, scientifically validated methodologies for network and distributed systems research

Issues with the Internet

- Security
- Robustness
- Scaling
- Mobile wireless and sensor networks
- New technologies

There are fundamental issues with the current architecture and many of its mechanisms that cannot be fixed incrementally and with additional engineering workarounds.

Transportation

Critical Infrastructure

Internet Not Ready for Its Future Roles

Telecommunications

Banking & Finance

Images from Google Image

The Future Internet

Must

- **Be worthy of our society's trust**
  - **Even for managing and operating critical infrastructures**
- **Provide a bridge between physical and virtual worlds**
  - **Via instrumented and managed sensorized physical environment**
- **Support pervasive computing**
  - **From wireless devices to supercomputers**
  - **From wireless channels to all optical light-paths**
- **Enable further innovations in S&E research**
  - **Seamless access to networked instruments, supercomputers, storage, etc**
- **Create a social world in which we would want to live**

U.S. APPROACH

- Our opportunity is to:
  - Develop new architectures, technologies, and policies
  - Experiment under realistic conditions

Leading to a solid scientific base for future networking and distributed systems that overcome these limitations.

US Approach to the Challenges

- Our response is:
  - Serious experimentation at scale with new architectures, technologies, and policies
  - The GENI project, which envisions and will implement this type of experimentation

Research is the primary driver

Future Internet Design (FIND)

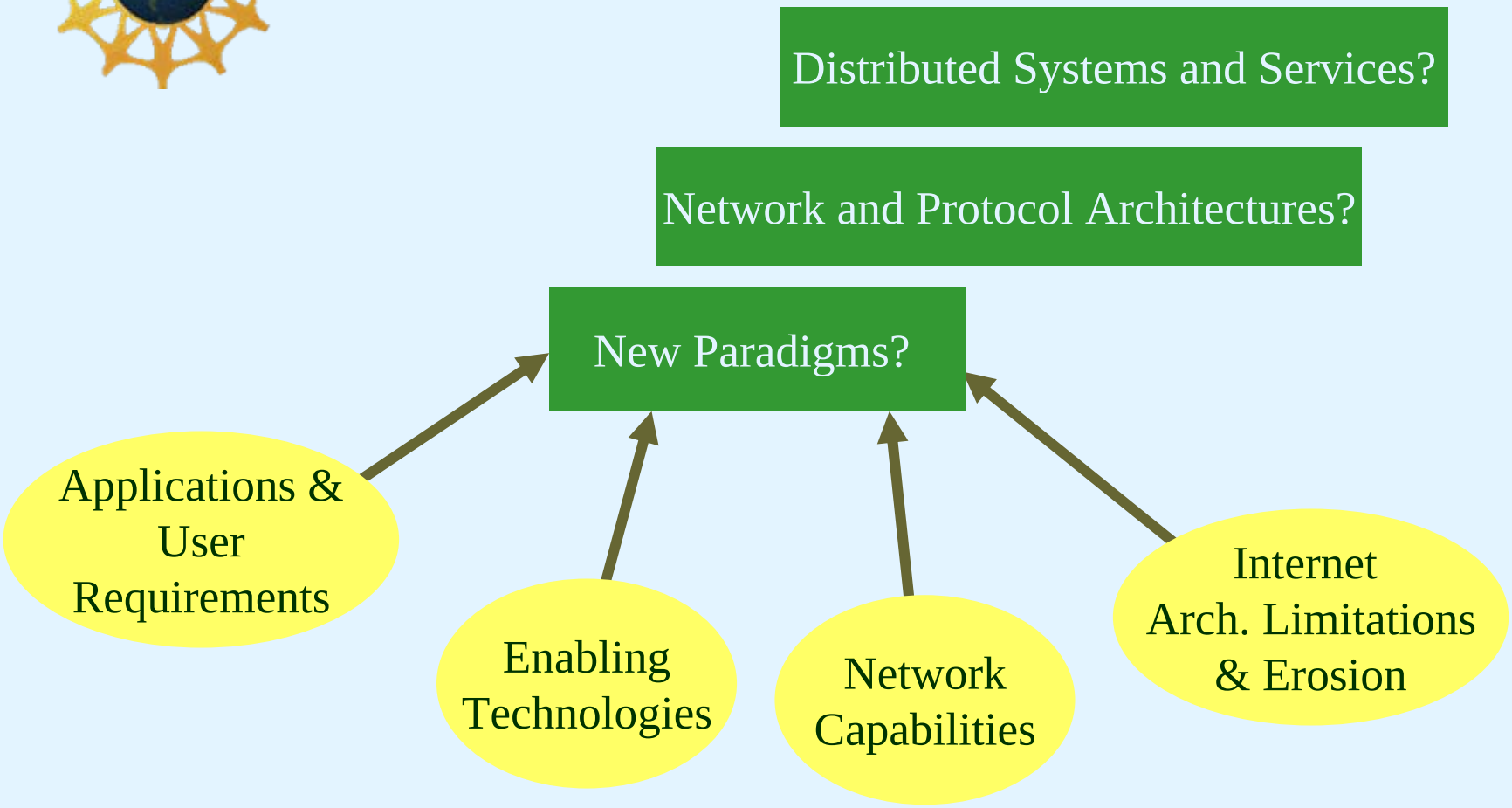
Creating the Internet you want

in 10, 15, 20 years

GENI (Global Environment for Networking Investigations) Project

- Research -- Refocus existing programs
  - **NeTS => FIND focus area**
  - **Cyber Trust (CT)**
  - **Computer Systems Research (CSR)**
  - **Computing Research Infrastructure (CRI)**
  - …
- GENI Experimental Facility
  - **Not funded yet**
  - **Exploring different possibilities**
  - **Planning activities underway**

Future Internet?



Need a clean-slate approach

NeTS and FIND

- NeTS Solicitation: Four Focus Areas
  - **Networking of Sensor Systems (NOSS)**
  - **Programmable Wireless (ProWin)**
  - **Networking Broadly Defined (NBD)**
  - **Future Internet Design (FIND)**
- FIND
  - **About end to end network architecture & design**
  - **Not about individual technologies or subnetworks**

Example Research Challenges

Security and Robustness	Pervasive Computing w/ Mobility	Bridging Physical and Cyberspace	Autonomic Networking

GENI-enabled research

Impact: Trustworthy & reliable information access	**Impact:** Seamless information access any where and any time	**Impact:** Access information about physical world in real time	**Impact:** Information access in dynamic and challenging environments

Scope of Research

- Core mechanisms
- Theoretical foundations
- Security and robustness
- Privacy and accountability
- Manageability and usability
- Economic viability
- Communications during crises
- High-level conceptualization
- Support for applications design
- Large-scale storage management
- Social needs

Networking and distributed systems broadly defined

Focus of FIND

- Can we reinvent the Internet so that it can
  - Retain its strengths
  - Support new technologies such as mobile wireless, sensors, optical networks
  - Enable new class of applications and services made possible by new technologies
  - Be secured, robust, manageable, evolvable, service-oriented, …
  - Promote economic viability of different players

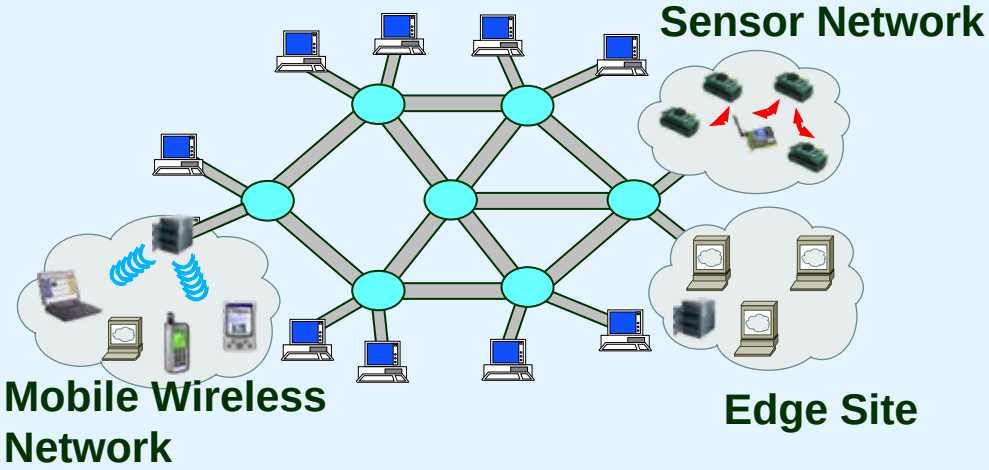
What is Different This Time?

- Clean-slate approach
  - **To overcome Internet ossification**
  - **Research not constrained by the features of the current Internet**
- A comprehensive coordinated effort
  - **Ability to try different approaches (We do not have a preconceived idea of what they are)**
- Ability to experiment at scale
  - **With real users and applications**

THE GENI FACILITY

(Global Environment for Networking Innovation)

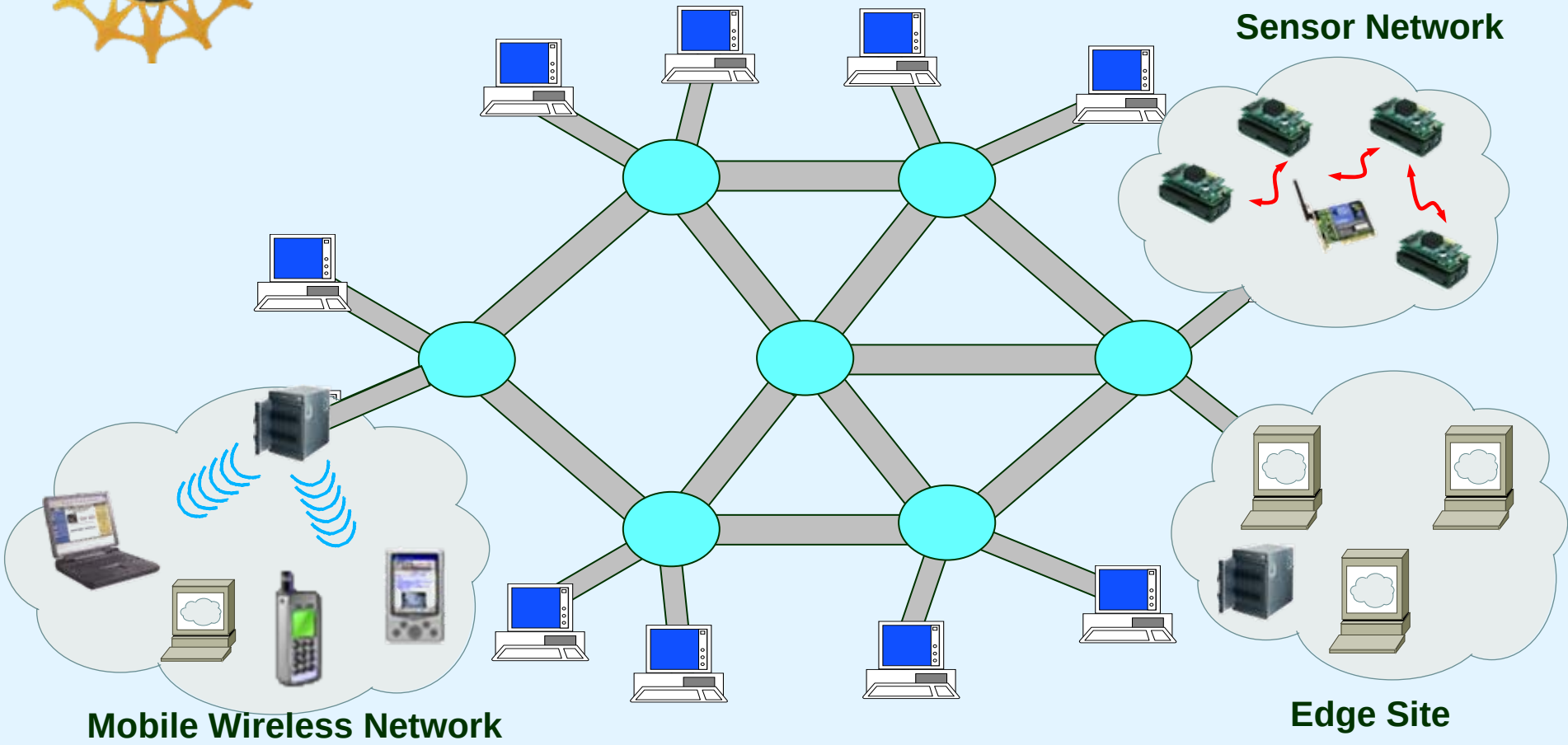
GENI is an advanced, flexible, programmable instrument for networking and distributed systems research.



GENI Will Allow

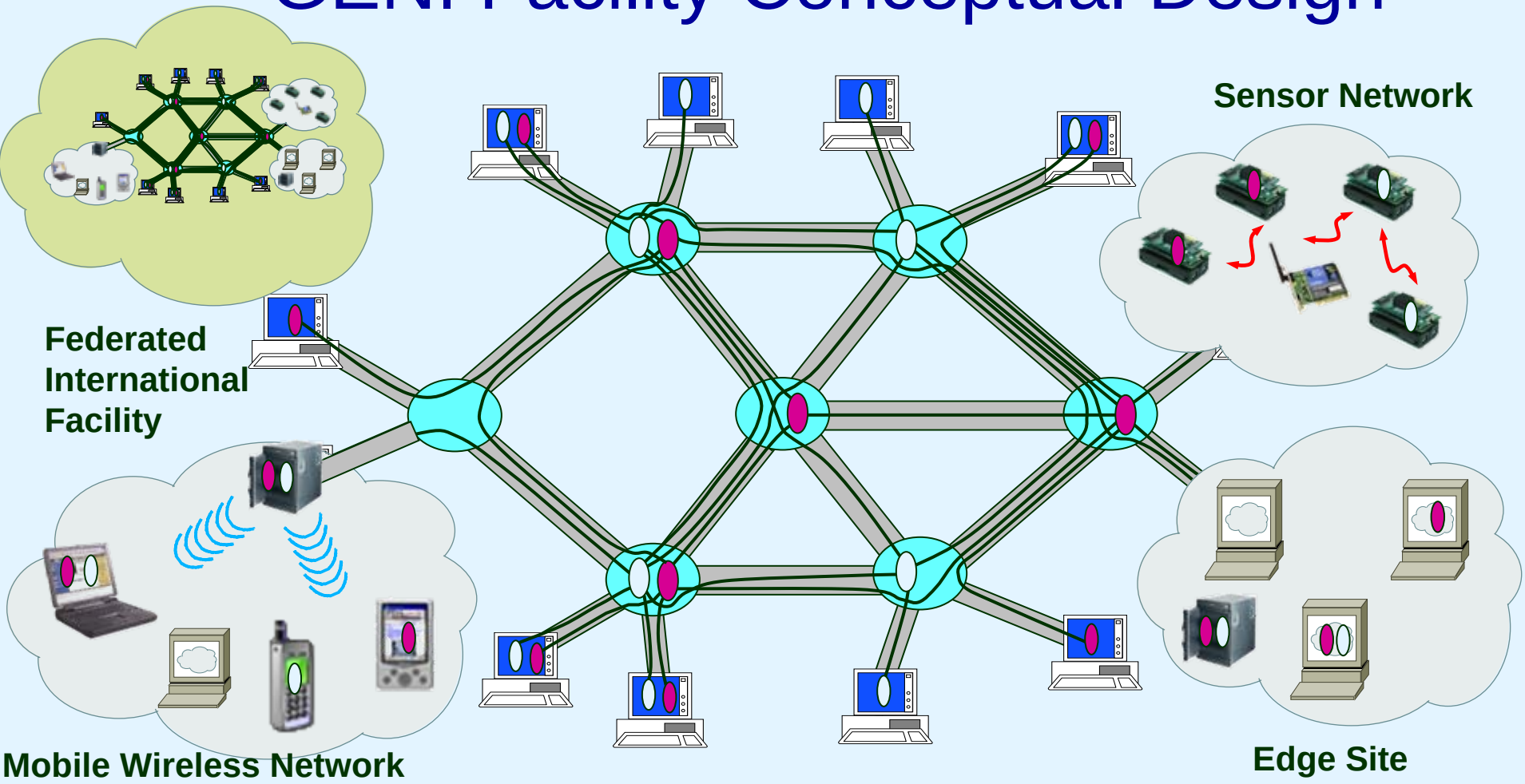
- Experimentation with complex systems to provide deeper understanding of their dynamics, stability, evolvability, emergent behaviors, and more.
- Evaluation of alternative networking architectures.
- Exploration of the competing goals a network architecture must meet.
- Evaluation of different services.

Facility Design Concepts



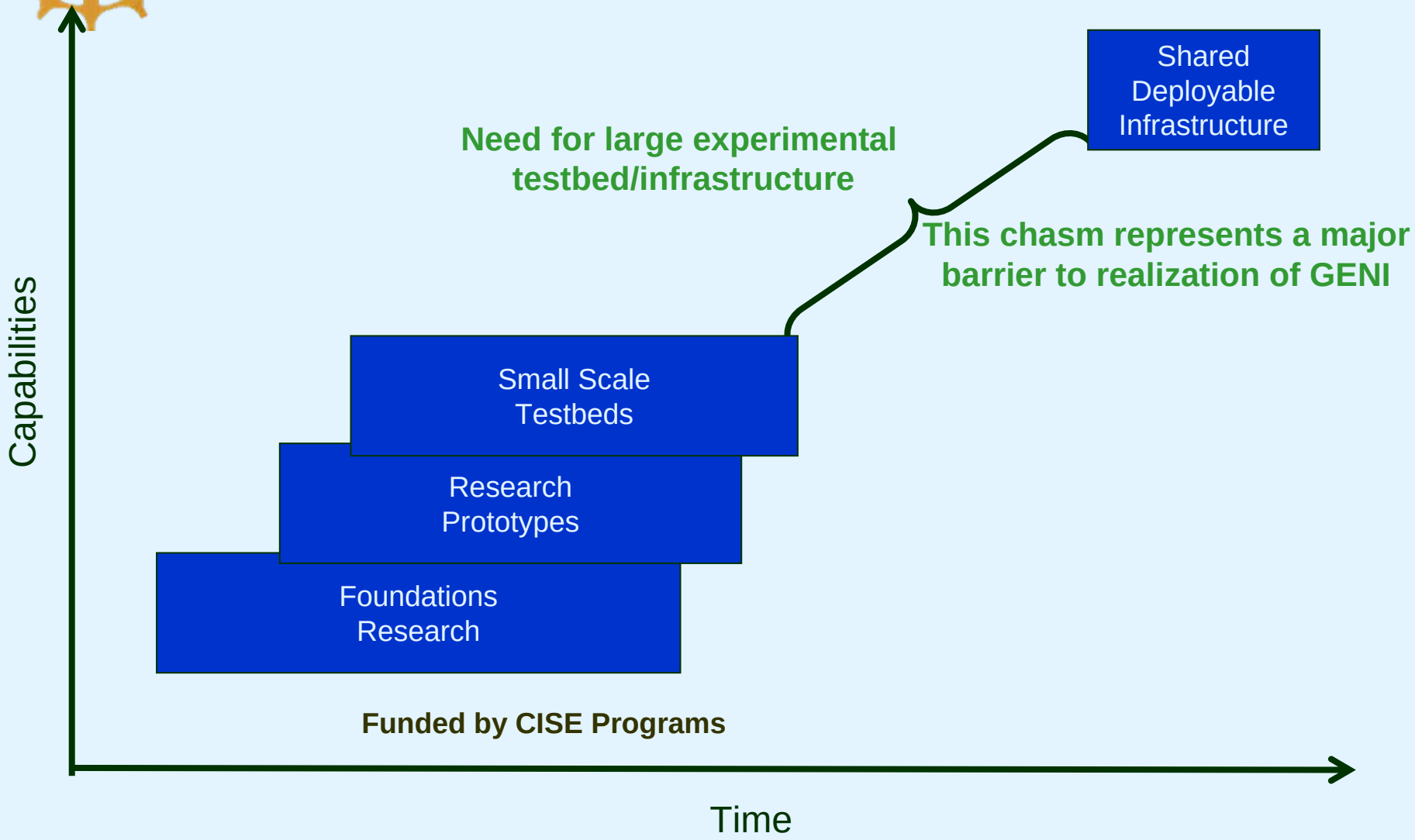
Slicing, Virtualization, Programmability

GENI Facility Conceptual Design



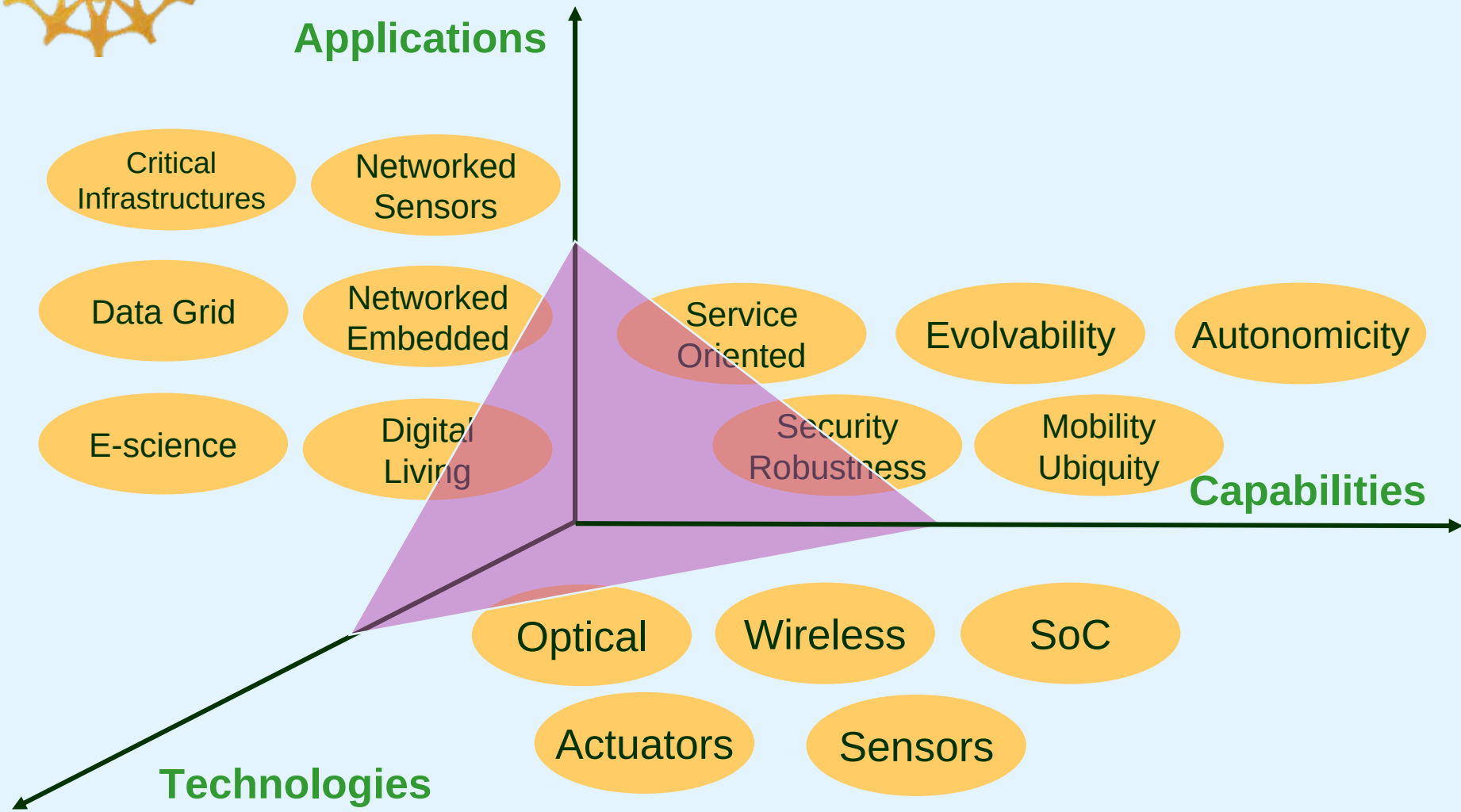
Slicing, Virtualization, Programmability

Case for GENI



THE FUTURE
(as we see it)

Looking Ahead



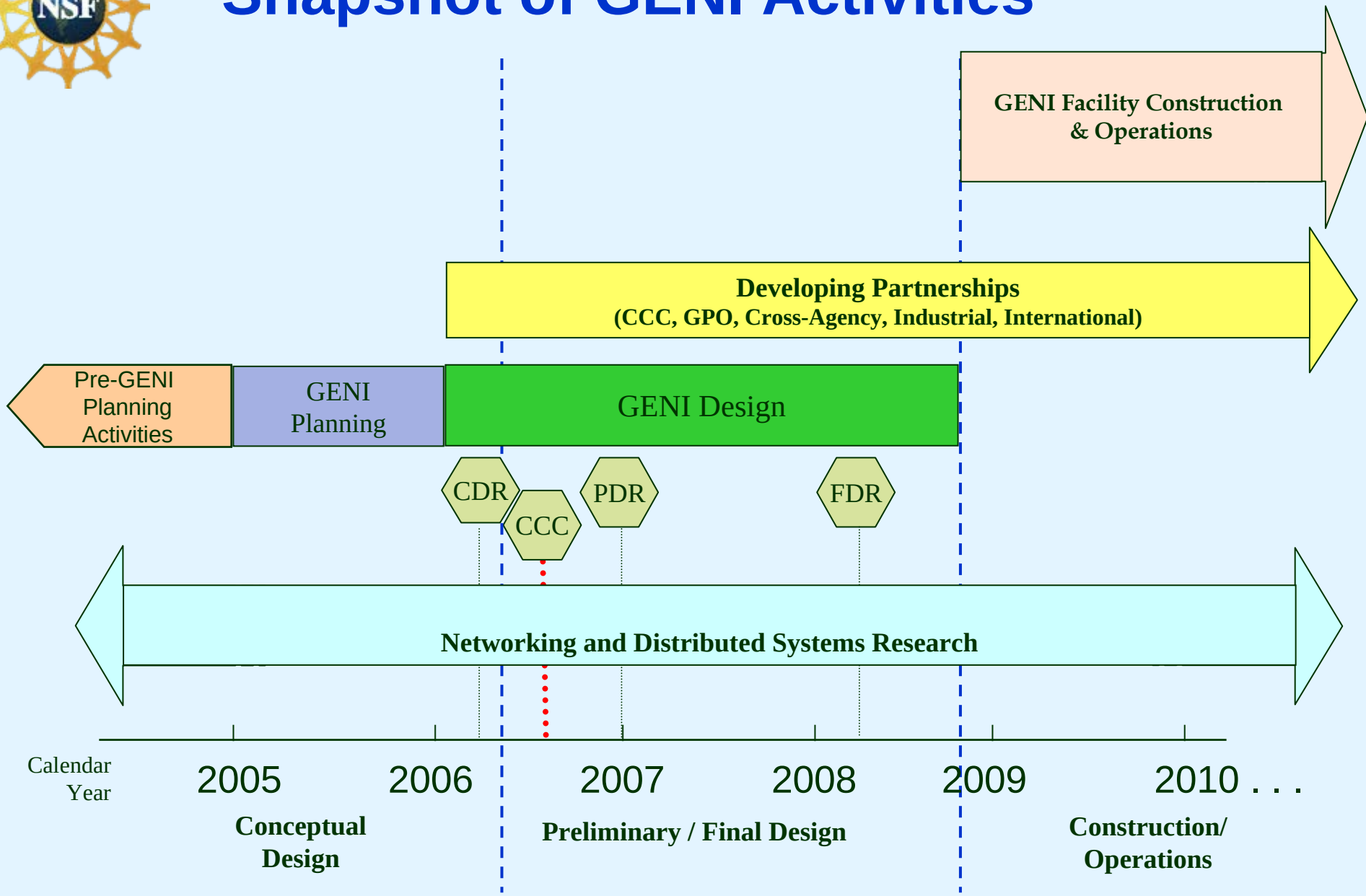
International Partnerships are Important

- Help define facility scope
- Build national partner facilities to complement U.S. GENI facilities and capabilities
- Share facilities with researchers in all partner countries
- Encourage collaborative international research projects and experiments

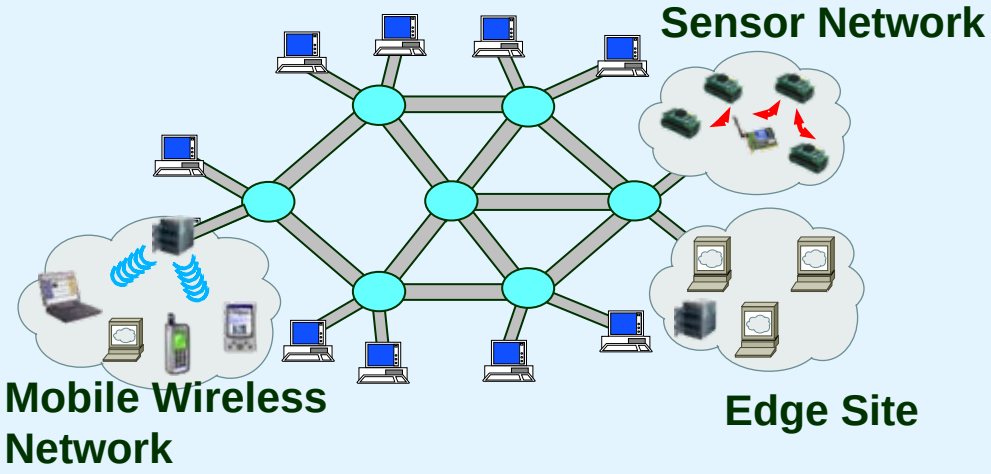
Industry Partnerships are Important

- Help to refine R&D objectives
- Become a member in the GENI consortium
- Provide leading-edge technology for use in GENI
- Contract (or subcontract) to build the facility
- Conduct collaborative research with universities
- Benefits to partnering
  - Accelerate the transfer of academic research results to commercial products
  - Enable a national/international “proving ground” for new technology

Snapshot of GENI Activities



GENI is an advanced, flexible, programmable instrument for networking and distributed systems research.



Summary

- Internet impacted the world in a way few inventions have before.
- A solid scientific foundation for future networking and distributed systems is essential.
- Urgent and important need to reinvent the Internet.
- GENI is a compelling facility in support of this opportunity.
- The result may be even greater and far-reaching than the invention of the current Internet.

Contact Information

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Visit the GENI web site at:
http://www.nsf.gov/cise/geni/

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