Challenges in Interdisciplinary Education for Embedded Systems

EMSOFT Education Day – October 11, 2003
Philadelphia

Dr. Helen Gill
CISE/C-CR
National Science Foundation

The National Science Foundation

- Independent agency, founded in 1950, funds peer-reviewed research spanning full spectrum of science and engineering
- Responsible for sustaining the Nation’s basic research and education enterprise
- Investments:
  - People
  - Ideas
  - Tools
- Research proposed by universities, not-for-profit research organizations
- Agency budget: $5.48 B (FY 2004 request)

2,000 Organizations (colleges and universities, schools, nonprofit institutions, and small businesses) receiving NSF funds each year
33,000 Proposals evaluated each year through NSF's competitive process of merit review
20,000 *Total* awards funded each year
10,000 *New* awards funded each year
50,000 Scientists and engineers who evaluate proposals for NSF each year
250,000 Proposal reviews done each year
37,000 Students supported by NSF Graduate Research Fellowships since 1952
213,000 People (researchers, post-doctoral fellows, trainees, teachers, and students) whom NSF directly supports

NSF Share of Basic Academic Research Investment
35% Physical sciences
44% Environmental sciences
42% Engineering
59% Mathematics
84% Computer science
65% Biology (non-health related)
100% Anthropology

NSF Today

- Office of the Director
  - **Director Rita Colwell**
  - **Deputy Director Joe Bordogna**
  - Office of Integrative Activities (OIA) - Nat Pitts
  - Office of Polar Programs (OPP) - Karl Erb
- Biological Sciences (BIO) - Mary Clutter
- ***Computer and Information Science and Engineering (CISE) - P.Freeman***
- Education and Human Resources (EHR) - Judith Ramaley
- Engineering (ENG) - John Brighton
- Geosciences (GEO) - Margaret Leinen
- Mathematics and Physical Sciences (MPS) - Michael Turner
- Social, Behavioral, and Economic Sciences (SBE) - Norman Bradburn

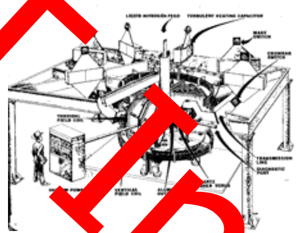
NSF Priority Areas

- **Nanoscale Science and Engineering** http://www.nsf.gov/od/lpa/priority/nano/start.htm
- **Biocomplexity in the Environment** http://www.nsf.gov/geo/ere/ereweb/fund-biocomplex.cfm
- **Information Technology Research** http://www.itr.nsf.gov/
- **Learning for the 21st Century Workforce**
- **Mathematical Sciences** http://www.nsf.gov/mps/divisions/dms/start.htm
- **Human and Social Dynamics** http://www.nsf.gov/pubs/2003/nsf03552/nsf03552.htm

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

Preface: a (fairly obvious) prediction about the Future of Physical and Engineered Systems

- Power generation and distribution
  - Deregulation, competition
  - Mix of generation technologies
    - Fossil fuels
    - Solar, wind
    - Hydrogen, fuel cells
    - Fusion?



- Future airspace
  - Airspace management
    - Free flight
    - UAVs
    - Critical Infrastructure Protection
  - Higher performance vehicles

- Health care
  - Infusion pumps, ventilators,…
  - EMT and ICU of the future
  - Triage and transport
  - Home care

- General transportation
  - Highway system technologies
  - Vehicle technologies
    - Hybrid engines, alternative fuels
    - Coordinated motor, braking, transmission
    - Continuously varying transmission control
    - ABS, regenerative braking, etc…

- Environmental monitoring
  - Global warming
  - Environmental observation instrumentation, control
- Agriculture and ecology
  - Herd health monitoring
  - Remote veterinary care
  - Crop condition monitoring
- Emergency response
  - Rescue robotics
  - Command and control

IT Inside

Photo Credits: Boeing, GM, Medtronics

Status Check: Embedded Systems for Science and Engineering

- Embedded systems, expanding scope (simple to complex, HW-SW to full system)
- IT multiplier for engineered system capability
- Risk set, reliance changes (e.g, critical infrastructures)
- Increasing assurance obligation
- Need for global interoperability, harmonization

End-to-end problems, but previously-separate research areas:

- Real-time embedded systems
- Control theory and engineering
- Networking
- Physical device and platform design
- Security and privacy
- Human-computer interaction
- Science and engineering research domains

Recent Hybrid and Embedded Systems Research at NSF

Software control frameworks

Discrete/switching

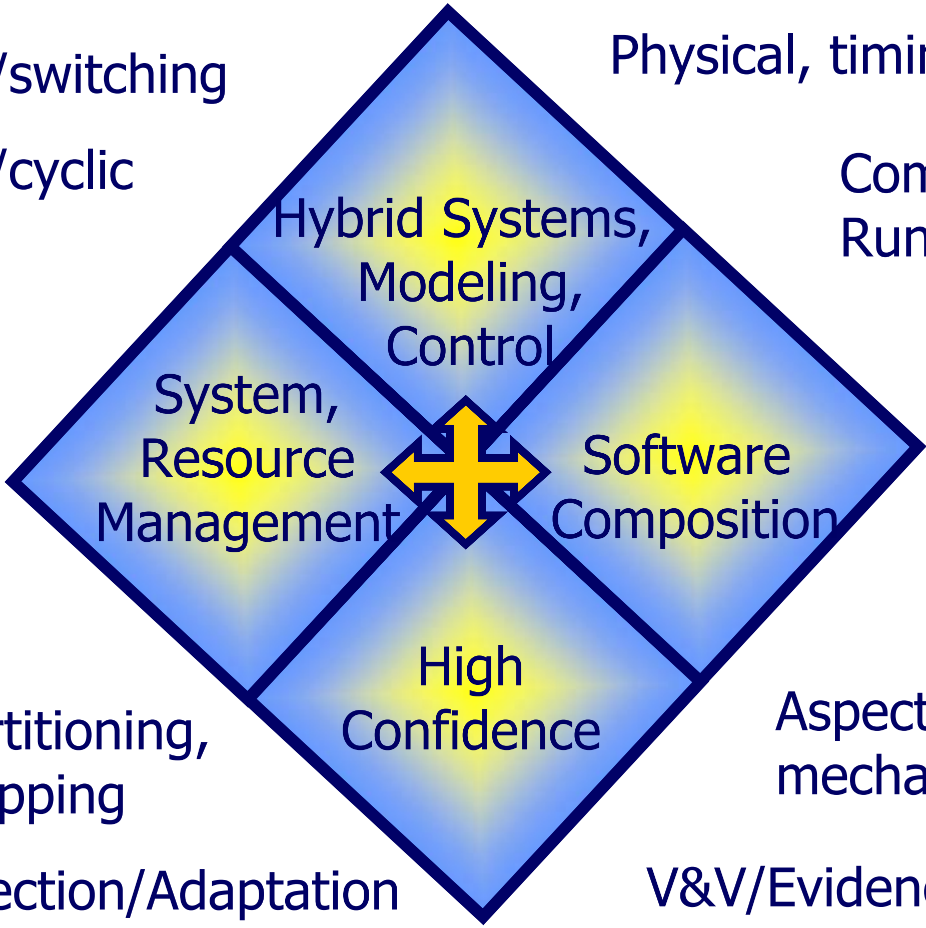
Physical, timing constraints

Continuous/cyclic

Computational model/ Runtime

Scheduling, Adaptation

Patterns, middleware



Algorithms, Protocols

Modularity, Synthesis

QoS

Partitioning, Mapping

Aspects & system software mechanisms/services

Security

Reflection/Adaptation

V&V/Evidence

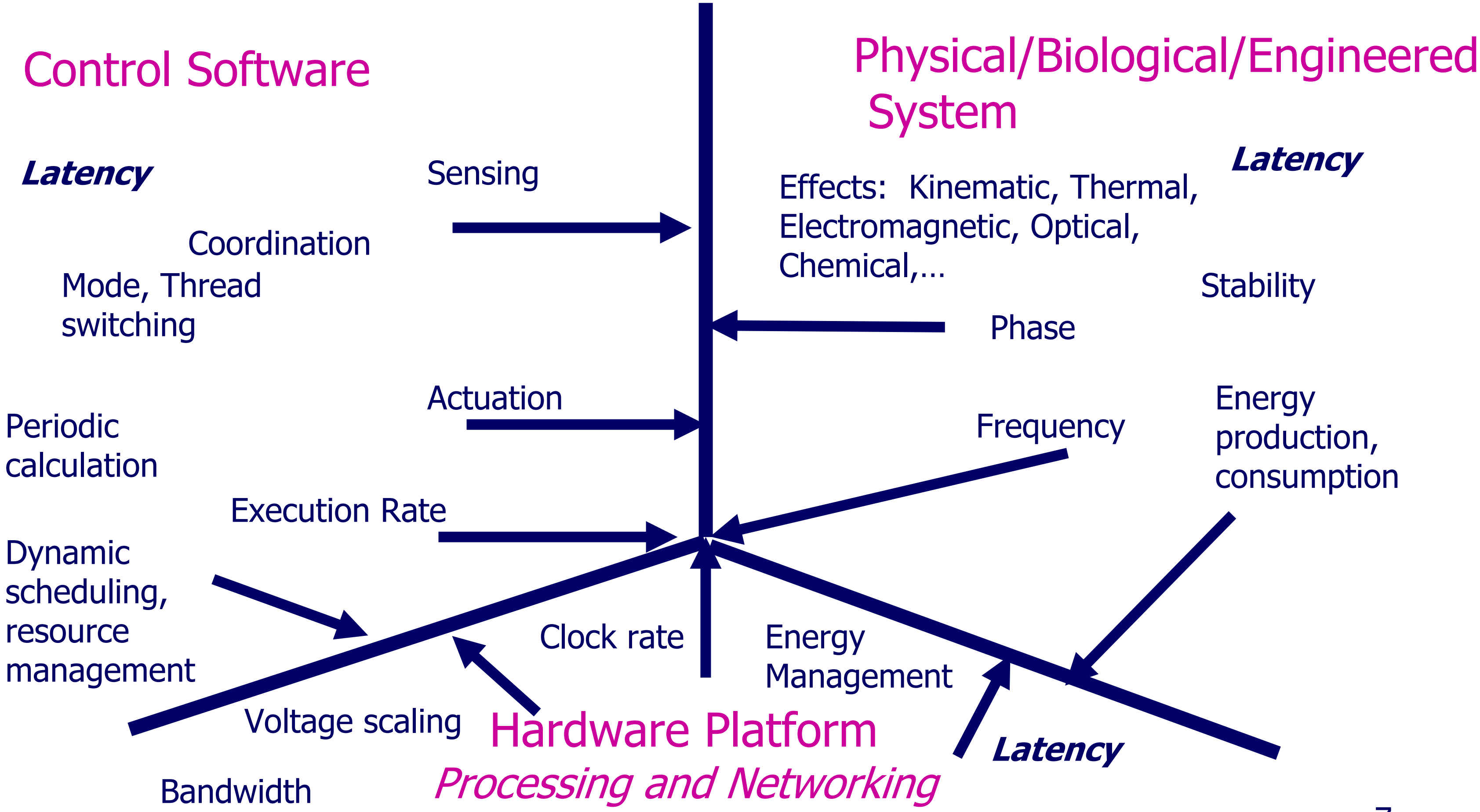
Networking

Certification

Distributed Systems

Embedded Software and System Control Perspective

Closing the loop around combined behaviors…



Current Educational Barriers

- Narrow CS and SE training, "algebra-physics gap"
  - Abstract view of software engineering problem
  - Narrow focus (e.g., real time, not systems)
  - De-emphasis, style of mathematics training, "engineering"
- Stove-piped (sub-) disciplines, perspectives
  - Domains (Inroads in virtual science)
  - Unintended consequences of many small research programs on graduate student training
- The pipeline
  - K-12
  - Undergraduate education
  - Graduate education
  - Non-traditional education
  - Tenure process
- More than half the population is not dealt in

A Key Topic: New Frontiers in Interdisciplinary Education

- Need: Workforce of the future is interdisciplinary
- Challenges
  - Preserve scientific growth of disciplines
  - Support evolving interdisciplinary foundations
- Opportunities/Examples
  - UC Berkeley, Vanderbilt: "A new Systems Science"
    - New science of logical, physical systems
    - Curriculum, summer schools, outreach
  - University of Pennsylvania, unified curriculum
    - Integration of math, engineering, computer science curricula
    - Student participation in interdisciplinary studies: biology, robotics

Foundations for Progress

- Better- integrated science and engineering curricula
  - Mathematics, physics, computer science, engineering design
  - Emphasis on general education in science ("domains")
- Integration of research and education, e.g., through:
  - Challenge problems
  - Community-based, project-oriented R&E
- Laboratory-oriented research
  - Engineering
  - Experimental science
- Cyber Infrastructure
  - Equip laboratories
  - Enable interdisciplinary science
  - Research/development/use cycle

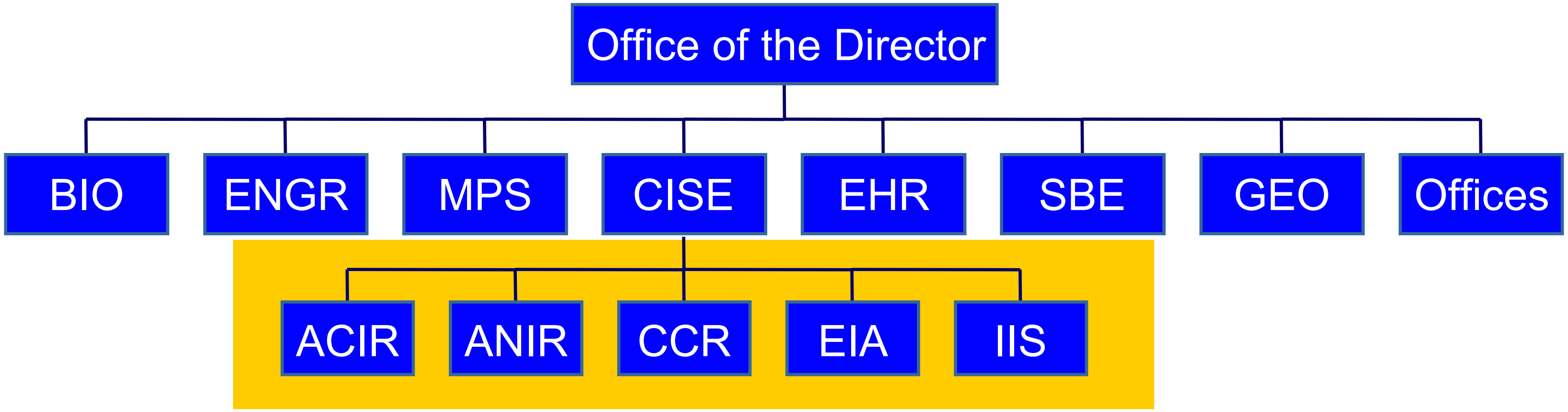
Means? A Sampler of Ideas

- The Integrated Day
- SIGBed leadership
- ACM/IEEE Curricula
- Textbook, monograph series
- Open Courseware projects
- Open Source Software projects
- Advanced Summer Schools
- A variety of superb conference tutorials (collect them?)

NSF Update

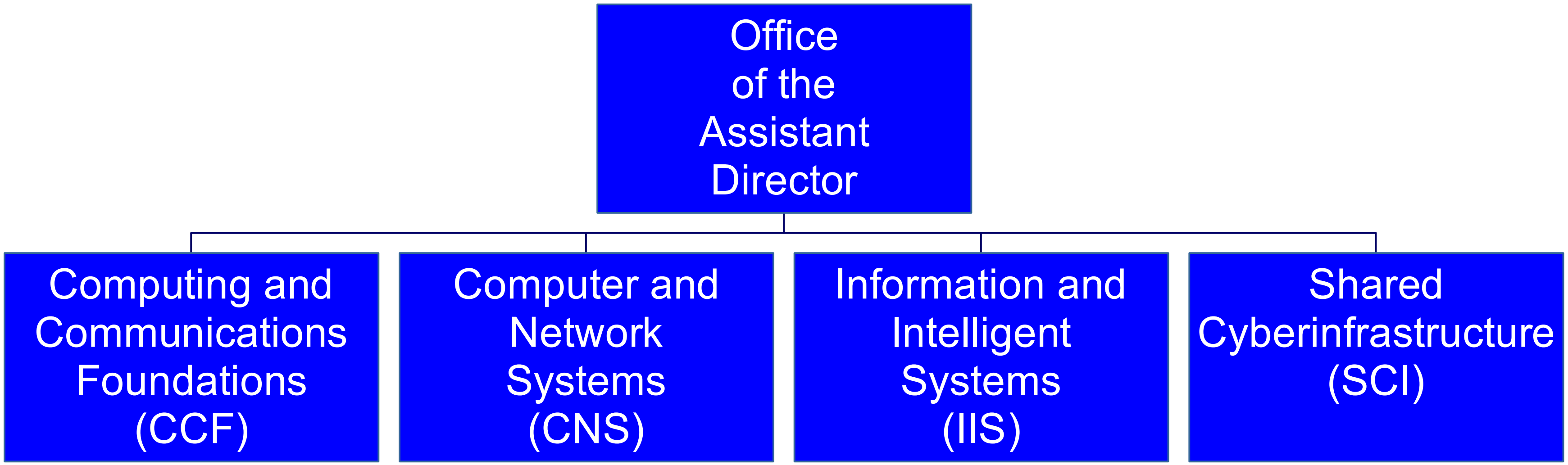
http://www.nsf.gov

Organization: NSF's Alphabet Soup Today (Yesterday?)



CISE Proposed Reorganization: Strategic Objectives

- Realign divisions for coherence and to mirror the field
- Cluster similar programs
- Support cross-cutting themes
- Build on success of ITR to invigorate the CISE core



CISE Reorganization: Goals

- Increase productivity and efficiency for investigators and program officers
- Increase grant size and duration
- Sharpen focus of CISE programs
- Increase agility in the CISE organization
- Integrate education and research
- Broaden participation in CISE activities

Key Concept: Clusters

- Comprehensive activity in a coherent area of research and education
- Teams of Program Officers and Staff working closely with the community
- Initially: groups of existing programs
- Eventually: one program per cluster

Computing and Communication Foundations (CCF)

- Formal and mathematical foundations
  - Computer science theory; numerical computing; computational algebra and geometry; signal processing and communication
- Foundations of computing processes and artifacts
  - Software engineering; software tools for high-performance computing; programming language design; compilers; computer architecture; graphics and visualization
- Emerging models for technology and computation
  - Computational biology; quantum computing; nano-scale computing; biologically inspired computing

Information and Intelligent Systems (IIS)

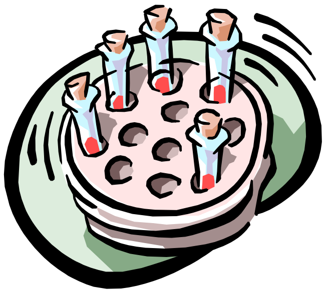
- Systems in context
  - Human computer interaction; educational technology; robotics; computer-supported cooperative work; digital government
- Understanding, inference, & data
  - Databases; artificial intelligence; text, image, speech, and video analysis; information retrieval; knowledge systems
- Data-driven science
  - Bioinformatics; geoinformatics; cognitive neuroscience; …

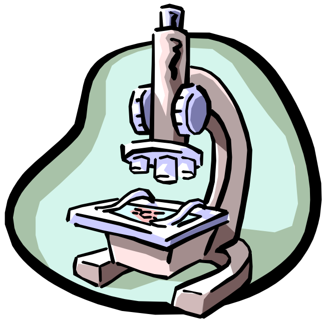
Computer and Network Systems (CNS)

- Computer systems
  - FY04: Programs in distributed systems; embedded and hybrid systems; next-generation software systems
  - FY05: single program with fall deadline
- Network systems
  - FY04: single program with spring deadline; general topics and focus areas
  - FY05: single program with fall deadline
- Computing research infrastructure
  - FY04: current infrastructure programs (RI, RR, MII)
  - FY05: single program with (next) summer deadline
  - Ongoing: Major Research Instrumentation (MRI)

Shared Cyberinfrastructure (SCI)

- Infrastructure Development
  - Creating, testing, and hardening next-generation deployed systems
- Infrastructure Deployment
  - Planning, construction, commissioning and operations





Key Concept: Themes

- Focused areas of research that cut across clusters and divisions
- Address scientific and national priorities
- Have program announcements and funds
- Examples:
  - Cybertrust
  - Education and workforce
  - Science of design
  - Information integration

Cybertrust Theme

- Vision: A society in which
  - Computing systems operate securely and reliably
  - Computing systems protect sensitive information
  - Systems are developed and operated by a well-trained and diverse workforce
- Research on foundations, network security, systems software, and information systems
- Integrated education and workforce activities
- Program announcement being created

Cyber Trust

- Improved ability to reason about system trustworthiness
  - logic applied to critical property specification/verification
  - assurance evidence development and maintenance
  - managing knowledge about system properties
- Methods and tools for next generation infrastructure
  - programming languages that preclude flaws
  - design methods for trustworthy systems
- Composition / decomposition methods
  - factoring systems into components with specified trustworthiness requirements
  - combining components with known/unknown properties and reasoning about the result

Education and Workforce Theme

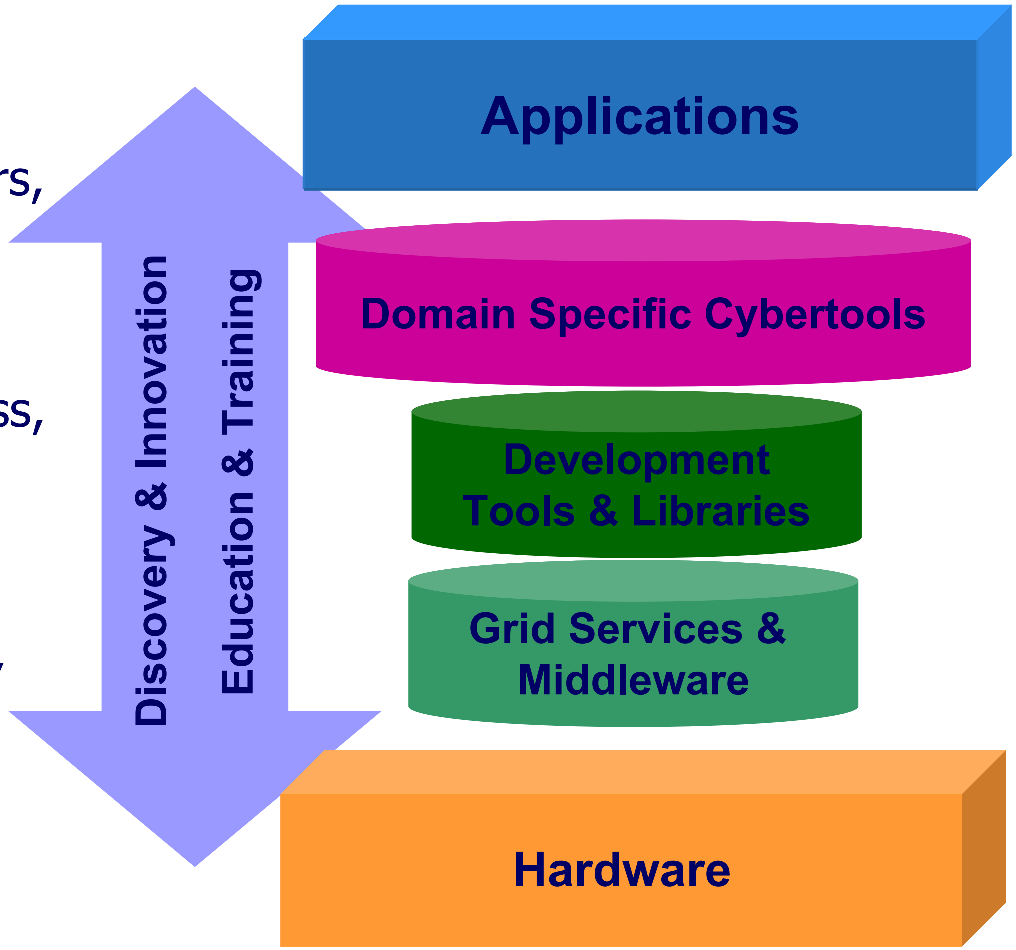
- Goal
  - Much greater integration of education and workforce development with research projects
- Fiscal Year 04
  - Research/Education program: CRCD/EI (late fall)
  - Workforce program: ITWF (late fall)
  - Increased synergy with research programs (e.g., cybertrust)
- Fiscal Year 05
  - One program with education, workforce, and integration
- Ongoing
  - numerous cross-directorate programs

Status and Proposed Plans

- October 2003
  - Start operating with new divisions
- FY 2004
  - Transition year, with lots of changes
  - Last year of ITR (and it will be different)
- FY 2005
  - Full implementation of new organization
  - Beginning of Cyberinfrastructure activity

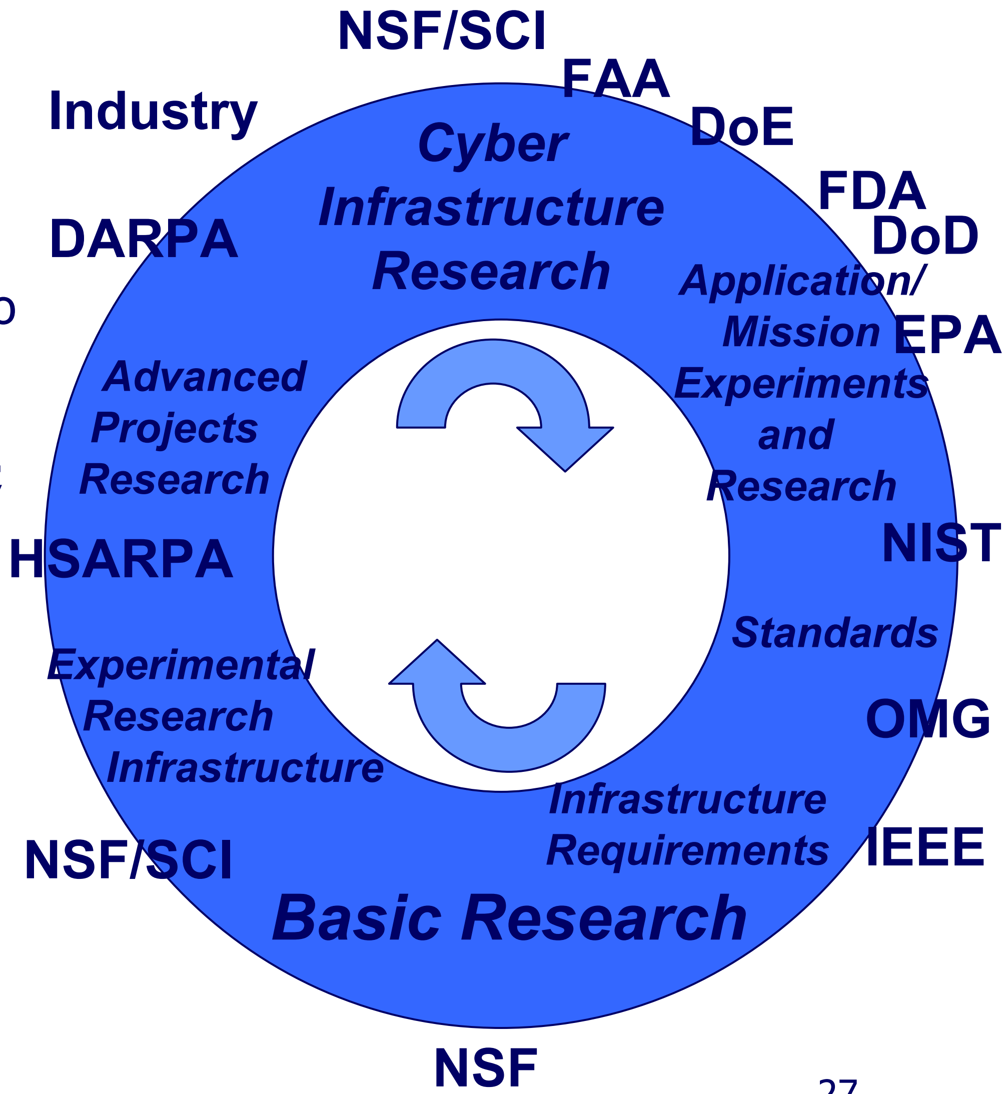
Deployed Cyber Infrastructure

- Computational engines (supercomputers, clusters, workstations, small processors, …)
- Mass storage (disk drives, tapes, …)
- Networking (including wireless, distributed, ubiquitous)
- Digital libraries/data bases
- Sensors/effectors
- Software (operating systems, middleware, domain specific tools/platforms for building applications)
- Services (education, training, consulting, user assistance)



In 10 Years, a CI that is

- Rich in resources, comprehensive in functionality, and ubiquitous;
- Easily usable by all scientists and engineers, from students to emertii;
- Accessible anywhere, anytime needed by authenticated users;
- Interoperable, extendable, flexible, tailorable, and robust;
- Funded by multiple agencies, states, campuses, and organizations;
- Supported and utilized by educational programs at all levels.



Thank you!