NETWORKING AND INFORMATION TECHNOLOGY R&D

The National Science Foundation is a primary federal agency supporting the Networking and Information Technology Research and Development (NITRD) program. All of the awards made by both the Directorate for Computer and Information Science and Engineering and the Office of Cyberinfrastructure enrich NSF's NITRD portfolio, with all of the agency's directorates making contributions in some way. Additionally, NSF makes research, education or research infrastructure investments in every NITRD Program Component Area (PCA). As in society at large, computing and information technology plays an increasingly important and expansive role in the agency's science and engineering award portfolio; in FY 2009, NITRD represents approximately 16% of the agency's budget.

Networking and Information Technology Research and Development Funding
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request
Biological Sciences	$83.50	$83.50	$86.15
Computer and Information Science and Engineering	526.69	534.53	638.76
Engineering	11.20	19.20	28.01
Geosciences	14.56	15.56	18.98
Mathematical and Physical Sciences	73.70	70.89	73.72
Social, Behavioral and Economic Sciences	12.47	13.47	15.05
Office of Cyberinfrastructure	182.42	185.33	220.08
Subtotal, Research and Related Activities	$904.54	$922.48	$1,080.75
Education and Human Resources	3.91	9.00	9.50
Total, NITRD Request	$908.45	$931.48	$1,090.25

Totals may not add due to rounding.

NSF's FY 2009 Request continues strong support for the NITRD program. A number of promising new activities will help ensure that the agency's NITRD portfolio remains vibrant and focused on the scientific frontier, most notably the agency's enhanced investment of $100.0 million in Cyber-enabled Discovery and Innovation (CDI) and $20.0 million in Science and Engineering Beyond Moore's Law (SEBML).

CDI investments will create new computational concepts, methods, models, algorithms, and tools that promise a wave of innovations in science and engineering and in the public and private sectors for years to come. SEBML investments will lead to the new hardware, architectures, algorithms, and software needed to address challenges in computing systems, such as efficient input and output, data storage and internal communications, and reduction of energy dissipation, as well as optimizing computing power.

The NITRD Request of $1,090.25 million supports fundamental research and education and cyberinfrastructure deployment in:

- High-end computing infrastructure and applications (HEC I&A) involving advanced computer systems, applications software, and related infrastructure, critical to cutting-edge discovery across all scientific and engineering fields;
- High-end computing research and development (HEC R&D) activities to optimize the performance of today's high-end computing systems and to develop future generations of systems to meet critical needs;
- Cyber security and information assurance (CSIA) focusing on improving the ability of computing and information systems to prevent, resist, respond to, or recover from actions or events that compromise

or threaten the availability, integrity, or confidentiality of data, of the systems themselves, or of related services;
- Human-computer interaction and information management (HCI&IM) to increase the benefit of computer technologies to humans, particularly the science and engineering R&D community;
- Large-scale networking (LSN) for high-performance networking R&D in leading-edge networking technologies, services, and enhanced performance;
- High-confidence software and systems (HCSS) for systems and verification technologies to assure computer-based system safety, dependability, and correctness;
- Software design and productivity (SDP) leading to fundamental advances in concepts, methods, techniques, and tools for software design; and
- Social, economic, and workforce aspects of IT and IT workforce development (SEW) focusing on the nature and dynamics of IT impacts on technical and social systems, interactions between people and IT devices and capabilities, and workforce development needs.

NSF's Assistant Director for CISE is co-chair of the NITRD Subcommittee of the National Science and Technology Council's Committee on Technology. In addition, NSF works in close collaboration with other NITRD agencies and participates at the co-chair level in seven of the eight PCA Coordinating Groups.

NITRD Priorities in FY 2009

NSF is emphasizing investments in the following areas of NITRD in FY 2009:

Large Scale Networking ($95.79 million): CISE will continue support for activities for the Networking Technology and Systems (NeTS) program, including the Future Internet Design (FIND) program which focuses on revolutionary network architectures for the future.

Cybersecurity and Information Assurance ($87.55 million): NSF will continue to fund research on cybersecurity foundations, network security, and systems software that supports the objectives of the *Federal Plan for Cyber Security and Information Assurance Research and Development*. Emphasis will be placed on usability, privacy, and theoretical foundations. Support will continue for several centers, including one devoted to the scientific exploration of new technology that will radically transform the ability of organizations to design, build, and operate trustworthy information systems for critical infrastructure, and one investigating software architectures, tamper-resistant hardware, cryptographic protocols and verification systems as applied to electronic voting systems.

High-End Computing R&D ($91.49 million): NSF's new investment, Science and Engineering beyond Moore's Law, will focus on revolutionary new computing hardware technologies, as well as related programming models, languages and tools, all of which promise to inform the computing systems of the future. OCI and CISE will support the development of simulation, optimization and analysis tools that exploit the potential of petascale computing to advance the frontiers of scientific and engineering research.

High-End Computing Infrastructure and Applications ($298.43 million): Continuation of the acquisition of a high performance computing system in OCI is included at an annual level of $50.0 million. Several NSF directorates will increase their investments in this PCA to capitalize on the growing importance of cyberinfrastructure in furthering their research and education goals. For example, MPS and ENG will increase activity in modeling and simulation of complex systems; development of numerical

algorithms and software implementations that push the boundaries of computing infrastructure; and use of the grid computing infrastructure.

MPS will strengthen support of research and education activities that contribute to and utilize the Virtual Astronomical Observatory, a federation of astronomical data bases. Support of other databases and digital libraries also will increase. MPS will support enhanced participation of remote access to instrumentation and increased connection of institutions that are distant from each other, such as a minority institution and its partner.

ENG will increase support of virtual organizations to leverage distributed physical experimentation, data collection, modeling and analysis capabilities using high-end computing and large scale networking infrastructures. ENG will also increase activity in modeling and simulation of complex systems; development of numerical algorithms and software implementations that push the boundaries of computing infrastructure; and use of the grid computing infrastructure.

BIO will invest in activities to broaden access to and usability of high performance computing resources in the biological sciences. Current biology applications claim substantial HPC computing resources that are narrowly focused in specific areas of biology. With increasing availability of large amounts of diverse data from plant, animal and microbial genomics to ecosystems modeling, additional areas of biology will likely require expanded access to and development of HPC resources.

GEO will continue to support state-of-the-art computing systems and data management services at the National Center for Atmospheric Research (NCAR). Part of this high performance computing environment, the Climate Simulation Laboratory (CSL), helps keep the U.S. at the forefront of 21st century climate science.

High Confidence Software and Systems ($67.62 million): As part of the CDI investment, CISE will support research on software for tomorrow's complex cyber-physical systems, such as smart automobiles, sensor nets for environmental monitoring, and embedded medical devices, and similarly in mobile, portable, and pervasive computing devices, such as cell phones, digital cameras, flexible displays, RFIDs, multi-media multi-modal handhelds, and household robots.

ENG will increase support of novel cyber-physical systems that combine the physical sensing and actuation functions with the computing and control functions into tightly-coupled high confidence systems.

Human Computer Interaction and Information Management ($266.52 million): The multidisciplinary CDI emphasis will focus on creation of new knowledge from digital data, including novel algorithms, data mining, and dimension reduction methodologies, new visualization methods to enhance human cognition, and innovative technologies to address data confidentiality, privacy, security, provenance, and regulatory issues.

NSF's new investment, Adaptive Systems Technology (AST), will support multidisciplinary research to generate creative pathways and natural interfaces between human and physical systems that will revolutionize the development of novel adaptive systems.

NSF will focus increased attention on the issues of federation, preservation, curation, and access to large, heterogeneous collections of scientific data and information. High capacity data management and high capacity computing are increasing challenges for a growing number of research communities. OCI will

develop activities for a robust and resilient national and global digital data framework for preservation and access to the resources and products of the digital age. OCI will invest in data, modeling paradigm and software interoperability in the area of virtual organizations.

ENG's investment in this area will focus on creating new pathways to connect researchers with each other and with state-of-the-art experimental facilities. ENG will also invest in curation of data generated by the large number of geographically dispersed sensors that will be used for real-time control of complex systems.

BIO's investments in this area will facilitate discovery through tools that integrate the published literature with the expanding universe of digital data collections, expand capacity for understanding through virtual environments that provide an intuitive display of the complex networks of interactions among organisms and their environments, and make it practical for scientists to search vast collections of biological images simply and quickly.

Software Design and Productivity ($70.81 million): CISE will support research on the scientific and engineering principles for developing software for tomorrow's complex cyber-based systems. Advances in software foundations, including new computational models, techniques, languages, tools, metrics, and processes for developing and analyzing software for these complex systems, will be pursued.

ENG will invest in developing new algorithms and software that can efficiently scale to the petascale levels. ENG will also invest in virtual organizations to enhance the productivity of researchers by providing them access to computational tools, specialized facilities and observational data from anywhere in the world.

BIO, through its Biological Databases and Informatics program, will promote new ways of enabling science through the use of cyberinfrastructure, including new visual programming environments and integrated information systems that allow an entire community of experts to contribute simultaneously to understanding genome dynamics.

Social, Economic and Workforce ($112.04 million): Through CDI, NSF will support investments that infuse computational thinking into computing education at all levels and in all fields of science and engineering.

CISE will continue support to revitalize undergraduate education in computing through the CPATH program, begun in FY 2006. The CPATH vision is of a U.S. workforce with the computing competencies and computational thinking skills imperative to the Nation's health, security and prosperity in the 21st century. CISE also continues to support the Broadening Participation in Computing program, aimed at significantly increasing the number of students who are U.S. citizens and permanent residents receiving post secondary degrees in the computing disciplines.

OCI will support activities in cyberlearning that will pursue new opportunities for using cyberinfrastructure as a platform for providing effective online laboratory experiences to students and teachers. In collaboration with partners across NSF, OCI will support creative explorations and demonstrations of the use of cyberinfrastructure to integrate research with education, the development of innovative technologies that will facilitate the integration of research and education, and research on how educators and students interact with cyberinfrastructure along with exploring novel uses of cyberinfrastructure.

BIO will strengthen IT capabilities in all biological sub-disciplines through support for postdoctoral fellowships in bioinformatics; integrative graduate programs that combine training in biology and computer sciences (via the NSF-wide IGERT program); undergraduate summer institutes in bioinformatics through the interagency Bioengineering and Bioinformatics Summer Institutes program; and other mechanisms.

EHR will continue to study the impact of IT on educational practice, new approaches to using technology in education, application and adaptation of technologies to promote learning in a variety of fields and settings, and the effects of technology on learning, and efforts that advance teaching and learning opportunities in nanotechnology and/or cyberinfrastructure.

NITRD by Program Component Area
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request
Large Scale Networking	$83.50	$82.55	$95.79
Cybersecurity and Information Assurance	68.25	68.08	87.55
High End Computing R&D	64.68	78.57	91.49
High End Computing Infrastructure and Applications	275.43	257.42	298.43
High Confidence Software and Systems	52.40	56.63	67.62
Human-Computer Interaction and Info Management	219.34	234.82	266.52
Software Design and Productivity	51.00	54.81	70.81
Social/Economic/Workforce	93.85	98.60	112.04
Total, NITRD Request	$908.45	$931.48	$1,090.25

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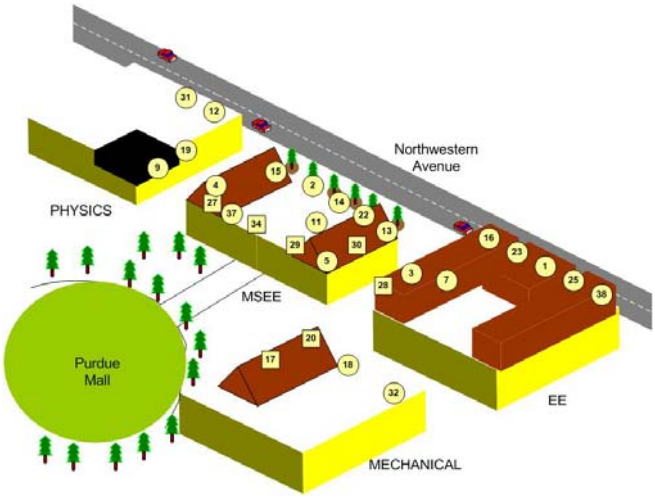
Recent Research Highlights

► **Solving the "Last Mile Problem":** Small businesses and homes, representing the "last-mile problem" in telecommunications, stand to benefit from research being conducted at Purdue University on wireless mesh networks. Researchers are developing a high-performance mesh-network control plane designed to provide very-high data rates and low delays to end-users in a cost-effective manner. The large-scale development of such networks could pave the way for new broadband services such as high-definition video-conferencing, high-speed rural Internet access, distance education to the home, easy remote assistance for the disabled and sick, etc. This is a unique opportunity for the clean slate design of mesh networks, since these networks are not currently constrained by the shackles of legacy systems. An understanding



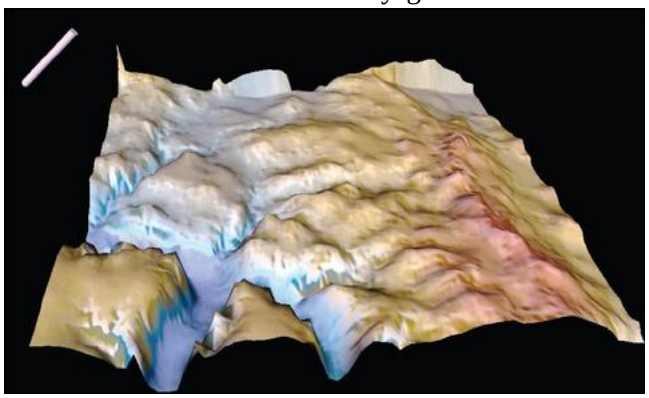
The Mesh@Purdue mesh network testbed has been extended to consist of 32 nodes, each with dual 802.11a/b radios. *Credit: Saumitra Das, Purdue University.*

of performance limits may finally provide answers to the "last mile" problem, resulting in a quantum advance in the ability to provide critical broadband services and applications to millions of end-users. Thus, the research has the potential to further increase the competitive edge that the U.S. holds in telecommunications. (CISE)

► **Development of a New Generation of Miniature Search and Rescue Robots:** Researchers have developed a miniature robot "scout" that can obtain reconnaissance and surveillance data in areas that pose significant risk to human beings or are unreachable in any other way. The robots have been designed to withstand repeated impact, which means that they can be thrown into position as well as be deployed from remote-controlled unmanned aerial vehicles. A number of these robots were delivered to the U.S. military for operation in Iraq and Afghanistan, where they are deployed in advance of ground forces, giving soldiers more time to think and react. A less expensive version of the robot, eROSI, has been used in a variety of educational, research, and outreach programs, including a robotics camp for middle school students from underrepresented groups. (CISE)

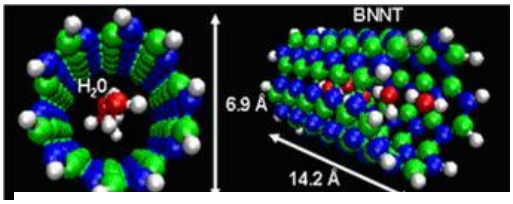
Top Right: A highly resilient robot "Scout" is displayed. Below Right: Students working with two eROSIs, the educational version of the "Scout." *Credit: Center for Distributed Robotics, University of Minnesota.*

► **Modeling 3-D Geologic Structures in a Multisensory Virtual Environment:** Three-dimensional surfaces form the basis of many geoscientific tasks. An NSF-funded project aims to create natural and intuitive ways for scientists to interact with these surfaces, while simultaneously presenting additional data to them. The first prototype uses a force-feedback device to feel the surface with a "virtual fingertip" and to shape it by deforming it via a virtual tool. When touching the surface, various types of force effects are generated, such as hardness or friction. In addition, a sound is generated that conveys additional data about the current point of contact based on its elevation. The virtual fingertip can also be used as a deformation tool to change the shape of the surface, which acts like a rubber skin. (CISE)



A 3-D surface (terrain) model, the color indicates elevation and pitch: blue = low to red = high. *Credit: Chris Harding, Virtual Reality Applications Center, Iowa State University.*

► **Computational Discovery of Boron Nitride Nanotubes as Water Channels:** Development of bio-inspired devices is of critical importance towards developing next generation sensors, computing elements, drug discovery, bio-batteries and many other applications. Because of their superior electrical, mechanical, thermal, and chemical properties, carbon nanotubes are being investigated to create biomimetic sensors and water channels. Using advanced computational tools, researchers have shown that the water transport properties of boron nitride nanotubes (BNNTs) can be superior to those of carbon nanotubes. These results take us one step



Water permeation through a boron nitride nanotube (BNNT). The diameter of the BNNT is 6.9 Å and length of the BNNT nanotube is 14.2 Å. *Credit: N. R. Alura.*

closer towards realizing synthetic versions of aqua-porin water channels. Even though boron nitride nanotubes have been shown to possess many excellent physical properties, including thermal and mechanical properties, their water transport properties were previously unknown. (CCF)