COMPUTER AND INFORMATION SCIENCE AND ENGINEERING $620,560,000

The FY 2006 Budget Request for the Computer and Information Science and Engineering (CISE) Directorate is $620.56 million, an increase of $6.84 million, or 1.1 percent, over the FY 2005 Current Plan of $613.72 million.

Computer and Information Science and Engineering Funding

(Dollars in Millions)

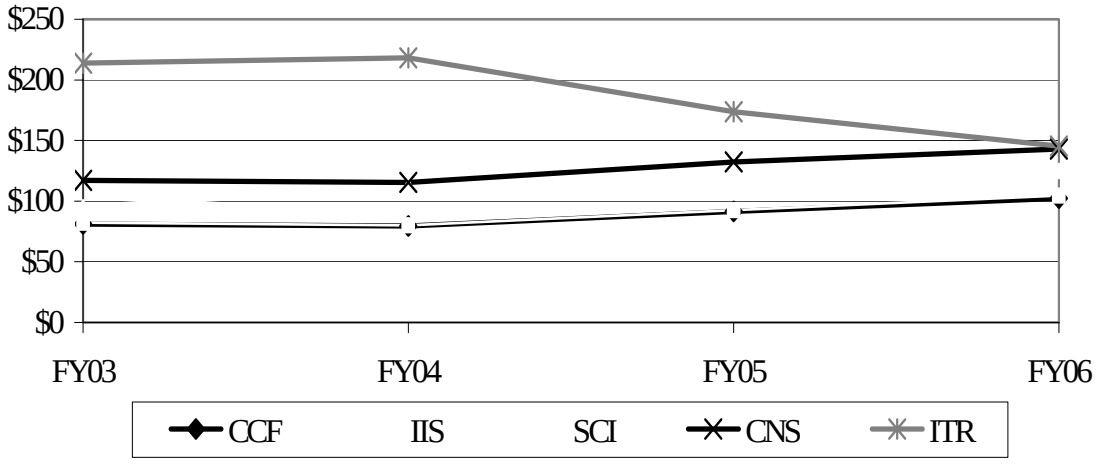
	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Computing and Communication Foundations (CCF)	79.59	91.41	102.53	11.12	12.2%
Computer and Network Systems (CNS)	115.40	132.39	142.96	10.57	8.0%
Information and Intelligent Systems (IIS)	80.02	92.54	104.67	12.13	13.1%
Shared Cyberinfrastructure (SCI)	112.29	123.60	124.96	1.36	1.1%
Information Technology Research (ITR)	218.07	173.78	145.44	-28.34	-16.3%
Total, CISE	$605.35	$613.72	$620.56	$6.84	1.1%

Totals may not add due to rounding.

The Computer and Information Science and Engineering Directorate (CISE) supports investigator-initiated research in all areas of computer and information science and engineering; guides the development, deployment, and management of cutting-edge national computing and information infrastructure for all science and engineering research and education; and contributes to the education and training of future generations of computer scientists and engineers.

CISE Subactivity Funding

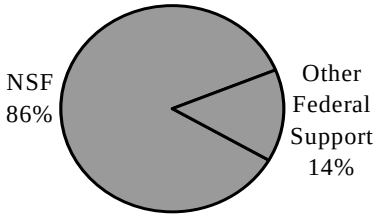
(Dollars in Millions)



Note: CISE subactivities have been reorganized; crosswalk data prior to FY 2003 are not available. The chart indicates that, with the completion of the ITR priority area, CISE ITR investments are being redirected to prominent IT research challenges and opportunities in core CISE activities in CCF, CNS and IIS.

RELEVANCE

Federal Support for Basic Research in Computer & Information Science & Engineering at Academic Institutions



CISE is the principal source of federal funding for university-based basic research in computing disciplines, providing the vast majority - 86 percent - of total federal support in this area. The CISE Directorate also plays a leadership role in the multi-agency Networking and Information Technology Research and Development (NITRD) program, chairing many of the working groups that promote interagency coordination.

Consistent with the Administration's NITRD priority, in FY 2006 CISE will continue to support innovative IT research and education activities, promoting advances in new software, hardware, systems, and algorithms. Informed by the recommendations of the High End Computing Revitalization Task Force (HEC-RTF), these investments include funds targeted to the development of new HEC Hardware and software architectures. CISE will also focus on building research capacity in areas foundational to homeland security, such as cyber security, machine translation, artificial intelligence, computer vision, and technologies for collaboration and information retrieval. This is consistent with the interagency Homeland Security R&D priority. CISE will continue to contribute to the National Nanotechnology Initiative, supporting exploratory and interdisciplinary work on novel nano-based devices and architectures that promise to form the basis of future computing and communication systems.

In FY 2006, CISE will continue to capitalize on the positive outcomes of the agency's former Information Technology Research (ITR) priority area. ITR, an NSF-wide priority area from FY 2000 to FY 2004, spurred innovative research, permitted work on realistic-scale problems, and built strong bridges between computing and other fields. ITR outcomes have led to the emergence of a new CISE "core", with a greater focus on inter- and cross-disciplinary research and education activities. In FY 2006, support will continue for projects of varying size and scope, including single investigators, research teams, and center-scale activities.

As a result of the essential and growing role of computing in society, the number of new scientific opportunities and challenges presented by the field far exceeds CISE's ability to fund them. While CISE has always received many more quality proposals than can be funded, as a consequence of growth in the field proposal funding rates have declined dramatically in recent years. In FY 2004, proposal funding rates in some CISE programs dropped precipitously to levels significantly below the NSF average.

Increased CISE funding in FY 2006 will focus on addressing the most prominent challenges and opportunities of information technology, while at the same time addressing the need to increase proposal funding rates.

Summary of Major Changes by Division *(Dollars in Millions)*

CISE FY 2005 Current Plan……. $613.72

Computing and Communication Foundations +$11.12

Increased support will lead to the development of revolutionary software and hardware architectures that improve the raw performance of computing systems, potentially by orders of magnitude and contribute to the improved security, reliability, and manageability of computing systems. In addition, increased support will lead to new understanding of both the limits and optimal methods of computation and communication in our increasingly mobile and interconnected world. The accompanying graphic, demonstrates the self-assembly of DNA-based structures, which have promise to form the basis of future generations of computing architectures.

Computer and Network Systems +$10.57

Increased funding will support projects that promote the systematic redesign of current network systems, a pressing challenge since the Internet as we currently know it is fast reaching the limits of its capacity and capability. Available funds in CNS will also support the development of sensor systems that can greatly improve our ability to predict, detect and respond to natural disasters. CNS will also increase support for projects aimed at making significant breakthroughs in the design and implementation of systems software. Improving the security of computing and communications systems is of vital importance and is an essential component in the Division's programs.

Information and Intelligent Systems +$12.13

Increased support will promote advances in Science and Engineering Informatics, informing the development of information tools and technology that permit the effective collection, representation and analysis of very large collections of scientific data that further promotes discovery. It will also enable increased funding rates and build research capacity in areas foundational to homeland security such as machine translation, artificial intelligence, computer vision and robotics.

Shared Cyberinfrastructure +$1.36

Support will continue to be provided for the Extensible Terascale Facility and other cyberinfrastructure resources, tools and services to meet the needs of the national science and engineering community. Efforts to build a base for the future expansion of cyberinfrastructure will also continue to be supported.

Information Technology Research -$28.34

In FY 2006, funds are moved from the ITR subactivity to the CCF, CNS, and IIS Divisions to support emerging scientific opportunities in the CISE core and to increase core funding rates.

Subtotal, Changes +$6.84

FY 2006 Request, CISE……...….. $620.56

Summary of Major Changes in Directorate-wide Investments *(Dollars in Millions)*

CISE FY 2005 Current Plan……. $613.72

Trustworthy Computing: +$5.0

Computers, especially those that are networked, reside at the heart of systems on which people now rely, both in critical national infrastructures and in their homes, cars, and offices. Today, many of these systems are far too vulnerable to cyber attacks that can inhibit their function, corrupt important data, or expose private information.

To respond to these challenges, CISE established a new program in FY 2004 called Cyber Trust to complement ongoing cyber security research and education investments made in the core CISE programs. In FY 2006, focused investments in Cyber Trust and the core CISE programs will: target basic research aimed at making computing systems more secure; develop improved understanding of the human, organizational, legal, and economic contexts in which trusted computing systems are developed and operated; and strengthen education for those who will create such systems and for those who will configure, operate, investigate, and use the systems produced.

Cyberinfrastructure-Computational Science, High End Computing, and Information Integration: +$12.96

The practice of science and engineering at the research frontier is being transformed by increasingly powerful and pervasive information technology, as described in the 2003 Report of the NSF Advisory Committee on Cyberinfrastructure (*Revolutionizing Science and Engineering through Cyberinfrastructure*). The 2004 Report of the High-End Computing Revitalization Task Force further noted that most currently available hardware, software, systems, and algorithms are focused mainly on business applications only suitable for smaller-scale scientific and engineering problems. These systems do not meet the high-end supercomputing needs of the science and engineering community.

In FY 2006, CISE will promote advances in cyberinfrastructure through focused research investments that include: building complex software and tools for high-end computing architectures; developing multi-scale analysis methods in computational science; and developing more sophisticated tools and technologies to support the analysis and management of scientific data and information.

Continued CISE leadership and investments in the development and deployment of a pervasive and persistent cyberinfrastructure, including HEC systems essential to the work of the national science and engineering community, are also planned for FY 2006. These investments draw upon strong interdisciplinary partnerships of computer scientists and scientists in other domains and will leverage the outcomes generated by CISE cyberinfrastructure research investments.

Finally, CISE funds will explore promising new approaches to prepare current and future generations of scientists and engineers to exploit cyberinfrastructure to advance their research and education agendas.

Broadening Participation in Computing: +$10.00

The growing influence of computing in society coupled with declining enrollments in computing fields demands a significant national effort aimed at increasing the number of young people entering and remaining in the computing field. This increase must occur across all segments of the population, but it is particularly important among those groups that historically have not participated at high rates: women, persons with disabilities, and minorities. The under participation of these groups causes a loss of opportunity for individuals, a loss of talent to the workforce, and a loss of diverse perspectives and creativity in shaping the future of technology. This CISE-wide emphasis aims to develop and implement innovative models for recruiting, mentoring, and retaining students from underrepresented communities in post secondary programs in computing disciplines.

Reductions in other CISE programs -$21.12

Funds previously available for IT research and education broadly, are targeted in FY 2006 to the IT priorities described above.

Subtotal, Changes +$6.84

FY 2006 Request, CISE……...….. $620.56

PRIORITY AREAS

In FY 2006, CISE will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Nanoscale Science and Engineering, Mathematical Sciences, and Human and Social Dynamics.

CISE Investments in NSF Priority Areas
(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Biocomplexity in the Environment	8.01	8.00	3.00	-5.00	-62.5%
Nanoscale Science and Engineering	17.56	18.48	5.00	-13.48	-72.9%
Mathematical Sciences	2.18	2.29	2.29	0.00	0.0%
Human and Social Dynamics	3.00	3.00	3.00	0.00	0.0%

Biocomplexity in the Environment: A total of $3.0 million will focus on environmental system synthesis, integration of observing systems, and computational challenges in biodiversity and ecosystem informatics. Prior CISE investments in Biocomplexity in the Environment have stimulated new research activities in the CISE core. Consequently, in FY 2006 CISE is redirecting funds previously invested in Biocomplexity in the Environment to related core activities such as Science and Engineering Informatics in IIS.

Nanoscale Science and Engineering: A total of $5.0 million will continue support for projects that advance the adoption of nano-devices and systems in computing applications. Prior CISE investments in Nanoscale Science and Engineering have stimulated new research activities in the CISE core. Consequently, in FY 2006 CISE is redirecting funds previously invested in Nanoscale Science and Engineering to related core activities such as Emerging Models and Technologies for Computation in CCF.

Mathematical Sciences: A total of $2.29 million will emphasize interdisciplinary research and education bridging IT and mathematical disciplines, with focus on algebraic and geometric algorithms, algorithms for scalable scientific computations and algorithms for visualization.

Human and Social Dynamics: A total of $3.0 million will expand research in areas such as augmented cognition and the exploration of new interfaces and tools that allow people to make informed and rational decisions in spite of human limitations and biases.

QUALITY

CISE maximizes the quality of the R&D it supports through the use of a competitive, merit-based review process. The percent of research funds that were allocated to projects that undergo external merit review was 96 percent in FY 2004, the last year for which complete data exist.

To ensure the highest quality in processing and recommending proposals for awards, CISE convenes Committees of Visitors (COVs), composed of qualified external evaluators, to review each program every three years. These experts assess the integrity and efficiency of the processes for proposal review and

provide a retrospective assessment of the quality of results of NSF's investments. In FY 2005, CISE will oversee the COV for ITR and for the SCI Division. COVs planned for FY 2006 include those for the CCF, CNS, and IIS Divisions.

CISE also receives advice from the Advisory Committee for Computer and Information Science and Engineering (CISEAC) on such issues as: the mission, programs, and goals that can best serve the scientific community; how CISE can promote quality graduate and undergraduate education in the computer and information science and engineering sciences; and priority investment areas in computer and information science and engineering research. The CISEAC meets twice a year with members volunteering their time to serve on subcommittees for three additional days per year. Members from both academe and industry represent a cross section of the computer and information science and engineering field, with representatives from many different sub-disciplines within the field. The CISEAC includes a balanced representation of women, underrepresented minorities, and individuals from a range of geographic regions.

PERFORMANCE

NSF's FY 2006 budget is also aligned to reflect funding levels associated with the Foundation's four strategic outcome goals and the ten investment categories highlighted in the FY 2003-2008 Strategic Plan. These categories were designed as a mechanism to better enable assessment of program performance and to facilitate budget and performance integration.

Computer and Information Science and Engineering

By Strategic Outcome Goal and Investment Category

(Dollars in Millions)

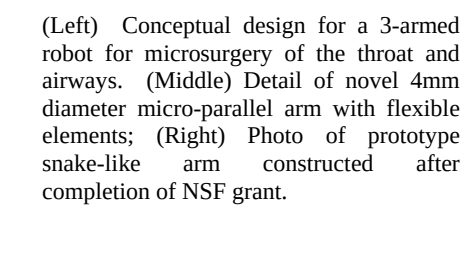
	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
People					
Individuals	48.89	44.55	46.55	2.00	4.5%
Institutions	7.67	7.95	7.95	-	-
Collaborations	0.92	2.50	20.92	18.42	736.8%
	57.48	55.00	75.42	20.42	37.1%
Ideas					
Fundamental Science and Engineering	409.42	409.39	396.40	-12.99	-3.2%
Science and Technology Centers	4.00	4.00	4.00	-	-
Capability Enhancement	0.95	1.45	1.70	0.25	17.2%
	414.37	414.84	402.10	-12.74	-3.1%
Tools					
Facilities	111.16	121.26	114.50	-6.76	-5.6%
Infrastructure and Instrumentation	14.66	14.66	20.58	5.92	40.4%
Polar Tools, Facilities and Logistics	-	-	-	-	-
Federally-Funded R&D Centers	-	-	-	-	-
	125.82	135.92	135.08	-0.84	-0.6%
Organizational Excellence	7.68	7.96	7.96	-	-
Total, CISE	$605.35	$613.72	$620.56	$6.84	1.1%

Totals may not add due to rounding.

CISE will continue its commitment to education, training, and increasing diversity within the computing field; an increase of almost $18 million in PEOPLE collaborations reflect this commitment and represents growing CISE investments in the Broadening Participation in Computing (BPC) and Cyberinfrastructure CI-TEAM programs. Prominent IT research challenges and opportunities in the core CISE Divisions of CCF, CNS and IIS are also targeted in FY 2006. At the same time, the FY 2006 Request seeks to increase funding rates and to emphasize crosscutting research and education opportunities in computing.

Recent Research Highlights

Cooperative Steady-Hand Augmentation of Human Skill in Micromanipulation Tasks. The primary focus of this research is on development of a cooperatively controlled 'steady hand' robot for microsurgery and other fine manipulation tasks, research exploring and extending the steady hand paradigm, and application of the system for prototypical microsurgical tasks in areas such as ophthalmology and otology. Researchers at John Hopkins University have conceived of and begun prototyping a new class of highly dexterous robotic devices suitable for minimally-invasive microsurgical procedures in the throat and airways, as well as for other precise, multi-handed tasks in confined spaces.



(Left) Conceptual design for a 3-armed robot for microsurgery of the throat and airways. (Middle) Detail of novel 4mm diameter micro-parallel arm with flexible elements; (Right) Photo of prototype snake-like arm constructed after completion of NSF grant.

The mechanical architecture of these robots consists of a snake-like unit and a modular detachable parallel unit that attaches at the tip of the snake-like unit. The snake-like unit uses a novel design utilizing multiple continuous backbones for its actuation. The parallel manipulation unit uses flexible links to accurately manipulate the payload in a small workspace and eliminates the need for small mechanical joints. All these features support the down-size scalability of these designs to diameters smaller than 5 mm – a critical dimension beyond which standard designs of snake-like units and parallel robots for payload manipulation becomes extremely expensive and mechanically complicated. These smaller diameters are needed for many surgical applications.

ITR: Learning-Centered Design Methodology: Meeting the Nation's Need for Computational Tools for K-12 Science Education (Engineering Scaffolded Work Environments). The University of Michigan's Center for Highly-Interactive Computing in Education (HI-CE) has designed, classroom-tested, and freely-distributed a suite of educational applications for handheld computers through ITR funding. They have recorded over 100,000 downloads of this software over the past two years. Of the 12 educational applications ranked by eSchool News, nine were produced under ITR funding at HI-CE. In effect, HI-CE software enables educators to take handheld computers designed for business and repurpose them for use in K-12.

Under supplemental Research Experiences for Teachers (RET) funding, HI-CE investigators have worked with over a dozen K-12 teachers across the country to develop curricular materials that provide science and math teachers with concrete ways in which to use HI-CE's software on handheld computers. Moreover, HI-CE software is used in the curricular examples in many books published for K-12 about handheld computers. From basic research to commercialization, with nationwide, free distribution in between, this effort has demonstrated how a University-based project can "fill the pipeline" with cutting-edge, provocative technology.

Cardiovascular Informatics. Sudden heart attacks remain the leading cause of death in the U.S. Since the majority of sudden cardiac deaths occur in people with no prior symptoms, there is an urgent need for

computational tools to assist in screening for the conditions that underlie these cardiac events. Researchers at the University of Houston are developing advanced computer vision technology for a variety of applications, including assisting with the diagnosis of coronary heart disease. Patients who already present risk factors undergo an intravascular ultrasound procedure that is capable of analyzing in detail any plaques present in coronary blood vessels. In particular, those plaques that are considered vulnerable (i.e., likely to rupture and cause a heart attack) have been found to encourage the growth of new microvessels in their vicinity. These microvessels are small vessels and are generally difficult to detect. However, using the contrast-enhanced intravascular ultrasound acquisition technique developed by researchers at the University of Houston, evidence of their presence can be detected.

Recovery Oriented Computing. The time required to restart a system after failure continues to be a major concern for systems that must be continuously available. Safety-critical systems are particularly affected by a lengthy interval for recovery and restart.

In an innovative NSF CAREER research project, Armando Fox, Assistant Professor, Stanford University, earned recognition as one of *Scientific American* magazine's 50 outstanding young scientists for 2003. Dr. Fox has generalized the concept of "recovery through rebooting" to "micro-reboot" individual components of existing applications, significantly improving their availability with no application changes and no a priori knowledge of application structure. Dr. Fox successfully demonstrated that a technique called "statistical-anomaly based failure detection" finds and localizes faults in these applications. While traditional techniques typically leave systems in unpredictable states, this research pursues a new design philosophy called Crash-Only Software. A crash-only system or component can be safely and predictably crashed at any time using mechanisms orthogonal to the component itself, allowing rebooting to be safely used as a recovery mechanism from many fault types. The ultimate goal is self-managing systems technology for future reliable distributed systems.

The graph on the left shows recovery via traditional reboot. The graph on the right shows recovery via micro-reboot. Note that the troughs are much smaller.

Data Mining for Detecting Network Intrusions. Novel data mining based anomaly detection techniques developed under NSF support have been incorporated in the Minnesota Intrusion Detection System (MINDS) that help cyber security analysts detect intrusions and other undesirable activity in real life networks.

MINDS is being used at the Army Research Laboratory (ARL) Center for Intrusion Monitoring and Protection (CIMP) and at the University of Minnesota to successfully detect novel intrusions, policy violations, and insider abuse that cannot be identified by widely used signature-based tools such as Snort. MINDS allows cyber security experts to quickly analyze massive amounts of network traffic, as they only need to evaluate the most anomalous connections identified by the system. Further summarization of these anomalous connections using association pattern analysis helps in understanding the nature of cyber attacks, as well as in creating new signatures for use in intrusion detection systems. The underlying techniques have applicability in many areas beyond cyber security, such as financial and health care fraud detection.

Prototype Leadership-Class Supercomputer Up and Running. Nearly half of the new XT3 "Red Storm" system at the Pittsburgh Supercomputing Center (PSC), more than 1,000 processors providing roughly five teraflops of capability, were installed and running in PSC's machine room by the end of December, 2004. The XT3 architecture is based on the "Red Storm" system developed at the Sandia National Laboratories. The PSC system will soon provide 10 teraflops of capability for NSF science and engineering research and education.

Applications already running on the new system include storm forecasting, earthquake modeling, quantum chromodynamics, cosmology and numerical relativity. A quantum materials science application, LSMS, shows per-processor performance on the XT3 more than twice that of LeMieux, PSC's existing terascale computer system. Other application areas expected to benefit significantly from the PSC XT3 system include molecular dynamics modeling of complex biological systems, modeling of cellular microphysiology, fluid dynamics and turbulence, blood flow, climate modeling, and network simulation and modeling.

Ten racks of XT3 containing nearly 1,000 AMD Opteron processors stand side-by-side in PSC's machine room at the Westinghouse Energy Center, Monroeville, PA.

Other Performance Indicators

The tables below show the change in the number of people benefiting from CISE funding, and trends in the award size, duration and number of awards.

Number of People Involved in CISE Activities

	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate
Senior Researchers	4,200	4,400	4,420
Other Professionals	1,400	1,200	1,210
Postdoctorates	500	500	600
Graduate Students	4,700	4,800	4,870
Undergraduate Students	810	1,000	1,150
Total Number of People	11,610	11,900	12,250

CISE Funding Profile

	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate
Statistics for Competitive Awards:			
Number	1,064	1,050	1,050
Funding Rate	16%	17%	19%
Statistics for Research Grants:			
Number of Research Grants	823	900	905
Funding Rate	14%	15%	16%
Median Annualized Award Size	$119,734	$116,000	$116,000
Average Annualized Award Size	$175,474	$165,000	$165,000
Average Award Duration, in years	3.2	3.0	3.0

COMPUTING AND COMMUNICATION FOUNDATIONS $102,530,000

The FY 2006 Request for the Division of Computing and Communication Foundations (CCF) is $102.53 million, an increase of $11.12 million, or 12.2 percent, over the FY 2005 Current Plan of $91.41 million.

Computing and Communication Foundations Funding
(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Computing and Communication Foundations	**$79.59**	**$91.41**	**$102.53**	**$11.12**	**12.2%**
Major Components:					
Research & Education Grants	75.59	87.41	98.53	11.12	12.7%
Science and Technology Centers	4.00	4.00	4.00	0.00	0.0%

About CCF:

CCF is organized into three clusters: Theoretical Foundations, Foundations of Computing Processes and Artifacts, and Emerging Models and Technologies for Computation. Within and across these clusters, CCF supports research and education activities that explore the foundations of computing and communication devices and their usage. Research and education projects supported promote advances in computing and communication theory, algorithms for computer and computational sciences, architecture and design of computers and software, and investigations of revolutionary computing paradigms such as bio-inspired computing. CCF projects also integrate education with research to prepare future generations of computer science and engineering professionals.

In FY 2004, the CCF Division at NSF received over 1,800 proposals, including considerably more high quality proposals than could be funded. In fact, the CCF funding rate was only 18 percent, six percent below the NSF average. Within the FY 2005 Current Plan, approximately 50 percent of CCF funding is already committed to grants made in previous years. A portfolio that includes a "mortgage" of approximately 50 percent for ongoing grants allows CCF to maintain a funding rate of 15 to 20 percent, and ensures about half of CCF funds are available each fiscal year for new awards. This flexibility is particularly crucial in the computing field where the pace of technological innovation is rapid.

CCF supports the Science and Technology Center for Embedded Networked Sensing (CENS). CENS is exploring embedded networked sensing systems, large-scale, distributed, systems, composed of smart sensors and actuators embedded in the physical world. These systems promise to form a critical infrastructure resource for society – they will monitor and collect information on such diverse subjects as plankton colonies, endangered species, soil and air contaminants, medical patients, and buildings, bridges and other man-made structures. Across this wide range of applications, embedded networked sensing systems promise to reveal previously unobservable phenomena.

CCF Priorities for FY 2006:

Ensuring Architectural Robustness for Hardware and Software:
Innovative computing architectures are needed that improve not just the raw performance of computing systems, but their reliability, predictability, and transformability. As an example, researchers at the

University of Maryland and at Mississippi State University are mining data on defects and changes in industrial software projects. This will lead to software architectures that can cope with change during software development. Introduction into the classroom will help train individuals who can produce robust, high-quality software. A new CCF focus on Architectural Robustness will seek to improve the quality of all aspects of computing and information systems. Architectural Robustness will guide the CISE-wide emphasis on High-End Computing research in FY 2006, which will focus on easing the integration of applications onto high-end architectures.

Fabricating Emerging Technologies:
New technologies for computation demand new fabrication methods. For example, lithographic techniques used in today's silicon chips may not extend to the nanometer scale, or may require additional constraints for such technologies as quantum logic. Research on fabricating emerging technologies will explore the algorithmic and computational implications of these new methods and constraints. Currently researchers at the California Institute of Technology are developing tiling techniques for building DNA nanostructures that assemble themselves automatically and correct for errors in self-assembly. This may result in a new understanding of biological processes, as well as miniaturizing devices that compute or communicate.

Strengthening the Foundations of Connectivity:
High-speed wireless and optical communications continue to change the ways we interconnect sensors, processors, and other devices. Massive numbers of devices may change positions and connections, leading to new protocols and algorithms as well as new inherent limits. For example, researchers at Brigham Young University and the University of Colorado are developing techniques for controlling multiple unmanned air vehicles that can sense and communicate. The Theoretical Foundations cluster will support research on Foundations of Connectivity to explore the control and use of these mobile changing networks, which will accelerate their use in applications such as environmental monitoring, precision agriculture, and homeland security.

Enabling Geometric Computation:
CCF will also focus on the scientific opportunities associated with Geometric Computation, to transform the use of information technology to improve modeling and understanding of the physical world. Researchers at Carnegie–Mellon University are developing new techniques for geometric modeling of soft tissue. Researchers at Johns Hopkins University are exploring haptic interfaces that provide tactile understanding of complex shapes or soft tissue. New techniques for rendering graphics images will improve our visual understanding of complex structures. These will come together to produce ideas such as biophysical models of tissues of individual patients that physicians can use for disease diagnosis and treatment.

Changes from FY 2005:

The FY 2006 Request for CCF includes an increase of $11.12 million, which will be directed toward the following activities:

Core Research and Education: +$11.12

Disciplinary and interdisciplinary research in the CCF core will increase by $10.77 million. This additional support will be allocated to activities like those described herein, and will help address the low proposal funding rate in CCF.

Support for Research Experiences for Undergraduate supplements will increase by $350,000.

COMPUTER AND NETWORK SYSTEMS $142,960,000

The FY 2006 Request for the Division of Computer and Network Systems (CNS) is $142.96 million, an increase of $10.57 million, or 8.0 percent, over the FY 2005 Current Plan of $132.39 million.

Computer and Network Systems Funding
(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Computer and Network Systems	**$115.39**	**$132.39**	**$142.96**	**$10.57**	**8.0%**
Major Components:					
Research & Education Grants	100.73	111.81	122.38	10.57	9.5%
Computing Research Resources	14.66	14.66	20.58	5.92	40.4%
Other Infrastructure Support	0.00	5.92	0.00	-5.92	-100.0%

About CNS:

The CNS Division is organized into four clusters: Computer Systems, Network Systems, Computing Research Infrastructure, and Education and Workforce. Organization into clusters minimizes stove-piping within the subdisciplines that CNS supports and allows changes in support patterns dependent on the scientific opportunities and needs of the subdisciplines represented in this Division. Within and across these clusters, CNS supports research and education activities that invent new computing and networking technologies and that explore new ways to make use of existing technologies. The Division seeks to develop a better understanding of the fundamental properties of computer and network systems through analysis, prototyping, and experimentation, and to create better abstractions and tools for designing, building, analyzing, and measuring future systems. The Division also supports the computing infrastructure that is required to enable state-of-the-art computer science research and education, and it coordinates cross-divisional activities that foster the integration of research, education, and workforce development to develop future generations of computer science and engineering professionals.

In FY 2004, the CNS Division received over 2,000 proposals, including many more quality proposals than could be funded. In fact, the CNS funding rate was only 18 percent, six percent below the NSF average. Within the FY 2005 Current Plan, approximately 50 percent of CNS funding is already committed toward previous awards. A portfolio that includes a "mortgage" of approximately 50 percent for ongoing grants allows CNS to maintain a funding rate of 15 to 20 percent and ensures about half of CNS funds are available each fiscal year for new awards. This flexibility is particularly crucial in the computing field where the pace of technological innovation is rapid.

CNS Priorities for FY 2006:

Strengthening Systems Software:
Computer systems are ubiquitous in today's world; hence society's increasing dependence on them. However, computer systems often tend to perform poorly, become compromised, or fail. Moreover, as they become increasingly large and complex, these problems are compounded, threatening the infrastructure on which society depends. CNS will increase support for projects aimed at making significant breakthroughs in the design and implementation of systems software. This software must be

smarter in order to adaptively support applications working in dynamic environments, and simpler not only for reliability improvement but for cost reduction of application development.

Building Cyber Trust:
The Cyber Trust program promotes a vision of a society in which networked computer systems are: more predictable, more accountable, and less vulnerable to attack and abuse; developed, configured, operated and evaluated by a well-trained and diverse workforce; and used by a public educated in their secure and ethical operation. As such, the program covers a wide range of research areas. The FY 2006 foci will be both in foundation establishment and security-measure development. The former is important since we will only be able to develop predictably trustworthy computer systems if we can model and analyze cyber-trust-related phenomena. Given security threats faced today, we also need to accelerate developing technologies that can immediately address these threats.

Examining Networked Systems:
Computer and communication networks are among society's most important infrastructures. However, today's network systems are based on models developed in the 1970s and 1980s. To develop an architecture that takes into account current and future technology advances and the requirements of modern applications, CNS will support projects that study the systematic redesign of current network systems. This will lead to a new understanding of digital (wired, wireless, sensor) networks and lay a solid foundation for their long-term development.

Changes from FY 2005:

The FY 2006 Request for CNS includes an increase of $10.57 million that will be directed toward the following areas:

Core Research and Education: +$10.57

Disciplinary and interdisciplinary research in the CNS core will increase by $10.20 million. This additional support will be allocated to research and education priorities as described above and will help address the low funding rate in CNS.

Support for Research Experiences for Undergraduates increases by $370,000.

Computing Research Resources:

Funding for Computing Research Infrastructure is $20.58 million in FY 2006. This reflects a recategorization of computing infrastructure funds previously reported as other support.

INFORMATION AND INTELLIGENT SYSTEMS $104,670,000

The FY 2006 Request for the Division of Information and Intelligent Systems (IIS) is $104.67 million, an increase of $12.13 million, or 13.1 percent, over the FY 2005 Current Plan of $92.54 million.

Information and Intelligent Systems Funding
(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Information and Intelligent Systems	**$80.02**	**$92.54**	**$104.67**	**$12.13**	**13.1%**
Major Component:					
Research & Education Grants	80.02	92.54	104.67	12.13	13.1%

About IIS:

The IIS Division at NSF is organized into three clusters: Data, Inference, and Understanding; Systems in Context; and Science and Engineering Informatics. Organization into clusters minimizes stove-piping within the subdisciplines that IIS supports and allows changes in support patterns dependent on emerging scientific opportunities and needs. Within and across these clusters, IIS supports research and education that increases the capabilities of human beings and machines to create, discover, and reason by advancing the ability to represent, collect, store, organize, locate, visualize, and communicate information. The IIS Division contributes to interdisciplinary research on how observational data leads to discovery in the sciences and engineering. IIS activities also integrate research and education activities to prepare future generations of computer science and engineering professionals.

In FY 2004, the IIS Division received over 2,300 proposals, including many more high quality proposals than could be funded. In fact, the IIS funding rate was only 13 percent, more than ten percent below the NSF average. Within the FY 2005 Current Plan, approximately 50 percent of funding is already committed toward previous awards. A portfolio that includes approximately 50 percent of continuing grants made in prior years allows IIS to maintain a funding rate of 10 to 15 percent and ensures almost half of IIS resources are available each fiscal year for new awards. This flexibility is particularly crucial in the computing field where the pace of technological innovation is rapid.

IIS Priorities for FY 2006:

Enabling Science and Engineering Informatics:
A recent article in The Washington Post notes that "There are so many genes for drug companies and researchers to target due to the slew of information netted by the Human Genome Project, that better technology is needed to help search and sort the genes…" (The Washington Post, TechNews, June 9, 2004). The technology underlying search engines that enable information on the World Wide Web to be indexed and searched has been supported by IIS grants. Analogous technology is needed to organize scientific data and knowledge.

In FY 2006, IIS will develop an emphasis on ecosystem informatics, modeling, and visualization. This work will build on workshops co-sponsored by NSF, the U.S. Environmental Protection Agency, the National Aeronautics and Space Administration and the U.S. Geological Survey that have identified information technology needs in this area. As an example of the challenges in this area, researchers at the University of Southern California have been working on automating the integration of databases across

state government agencies. They are addressing the challenging problem of merging different fields with the same information from different databases. The goal of this integration is to provide a complete picture of air quality and emissions, a phenomenon that does not conform to the regional, state, and country organizations charged with collecting this information.

Enhancing Information Security and Privacy:
The storing of digital records provides efficiencies through the sharing of information, but may also result in the compromise of individual privacy. The inability to transfer paper medical records, x-rays, and other test results across organizations increases the possibility of adverse medical outcomes and may result in unnecessarily repeating medical tests. Storing this information in databases permits rapid access to the information but unfortunately may permit unauthorized disclosure.

In FY 2006, IIS will support research to develop new technologies to ensure that privacy is not sacrificed while realizing the compelling advantages of sharing and aggregating data. For example, researchers at Purdue University have recently demonstrated an approach to analysis of medical data to find correlations between symptoms and diseases without revealing information about the individuals.

Creating Usable Information Technology:
IIS will also focus resource increases on research that makes information technology more usable. Advances will lead to computers that conform to people's needs rather than making people conform to the constraints of computers. Research on how people make decisions, collaborate, and organize information informs the design of interfaces and tools that present or summarize information at the appropriate time for a given task. For example, researchers at Oregon State University have developed an approach to organizing information (such as documents, e-mail, and World Wide Web activity) around tasks, such as preparing a budget, making travel arrangements, or teaching a class. Such an organization allows tasks to be suspended and resumed, freeing the user from remembering where documents were previously saved when returning to a task.

Changes from FY 2005:

The FY 2006 Request for IIS includes an increase of $12.13 million, which will be directed toward the following:

Core Research and Education: +$12.13

Disciplinary and interdisciplinary research in the IIS core will increase by $11.83 million focused in areas such as those highlighted herein. This funding increase will also help address the extremely low proposal funding rate in IIS.

Support for Research Experiences for Undergraduate supplements will increase by $300,000.

SHARED CYBERINFRASTRUCTURE $124,960,000

The FY 2006 Request for the Division of Shared Cyberinfrastructure (SCI) is $124.96 million, an increase of $1.36 million, or 1.1 percent, over the FY 2005 Current Plan of $123.60 million.

Shared-Cyberinfrastructure Funding

(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Shared Cyberinfrastructure	**$112.29**	**$123.60**	**$124.96**	**$1.36**	**1.1%**
Major Components:					
Cyberinfrastructure Tools	110.66	120.76	114.00	-6.76	-5.6%
Workforce Development	1.63	2.84	10.96	8.12	285.9%

About SCI:

The SCI Division supports acquisition, operation, and upgrade of national cyberinfrastructure in support of the nation's science and engineering research and education community. Cyberinfrastructure includes resources such as supercomputers; high-capacity mass-storage systems; system software suites and programming environments; productivity software libraries and tools; large-scale data repositories; and the experts and support staff that create and maintain these IT-based resources. Cyberinfrastructure also includes networks of various reach and granularity from dedicated, high-speed backbone networks that connect high-performance computational resources and high-end instrumentation sites, to wireless networks that connect embedded sensor nodes in remote scientific field sites. SCI also meets the community's needs with an array of software tools and services that hide cyberinfrastructure complexities and heterogeneity while offering clean logical interfaces to users. The tools and services supported by SCI include information management systems and data services, scalable interactive visualization tools, and middleware service building blocks for high-end computational resources.

The SCI Division staff collaborate closely with staff in all the NSF Directorates and Offices to ensure the advances in cyberinfrastructure supported by SCI will meet the demands of tomorrow's science and engineering communities.

In FY 2004, SCI received 220 proposals for funding consideration. In fact, the majority of SCI funds support ongoing longer-term projects such as the management and operations of the Extensible Terascale Facility, and the provision of network bandwidth for international research network connections. Within the FY 2005 Current Plan, approximately 65 percent of SCI funds are already committed to support for these longer-term cyberinfrastructure projects. An additional 10 percent of SCI funds are committed to other ongoing cyberinfrastructure projects such as those funded through the NSF Middleware Initiative.

SCI Priorities for FY 2006:

Providing Shared Cyberinfrastructure Tools:
SCI supports the management and operations of cyberinfrastructure resources to meet the computational needs of the national science and engineering community. This includes support for the management and operations of high-end computing assets resident in a number of organizations, including the National

Center for Supercomputing Applications, the Pittsburgh Supercomputing Center, the San Diego Supercomputer Center (SDSC), the Texas Advanced Computing Center and others. In FY 2006, SCI will continue to provide support for the vast majority of computing cycles made available to the open science community. Systems supported provide users with access to a broad range of supercomputer architectures and enable advances in all science and engineering disciplines. Consider, for example, the work done by researchers at the University of Oklahoma's Center for Analysis and Prediction of Storms (CAPS) using the SCI-funded LeMieux system at the Pittsburgh Supercomputing Center. Using 2048 processors on LeMieux, CAPS researchers successfully reproduced a 1977 storm and the high intensity tornado that it spawned. This simulation represents a watershed event in the drive towards more accurate warning systems for tornados and their precursor cyclones.

The addition of the Extensible Terascale Facility (also known as the Teragrid) to the SCI portfolio provides further value to the national community. Through the ETF Science Gateway effort, many new users from a range of scientific communities will be able to use sophisticated computational tools and applications developed specifically to meet the needs of their particular communities.

As an example of other essential contributions enabled by SCI funding, SDSC's Storage Resource Broker was recently endorsed and adopted as a cornerstone technology in the national strategy for the long-term (centuries in duration) preservation/archiving of digital data.

In FY 2006, approximately $19 million will provide for selective cyberinfrastructure enhancements identified through an ongoing process being developed within NSF to identify cyberinfrastructure priorities (see the Facilities chapter for more information).

Strengthening Network Infrastructure:
In FY 2006, SCI will also continue support for the development, deployment and sustained use of a set of reusable and expandable middleware functions that benefit many science and engineering applications in a networked environment. Robust middleware services are especially important for enhancing scientific productivity and for facilitating research and education collaborations through the sharing of data, instruments, and computing resources. SCI programs encourage open source software development and distribution approaches, as well as development of necessary middleware standards. As an example of the impact of middleware investments on scientific advances, SCI-supported investigators at the University of Wisconsin-Madison and their Condor software for grid computing have enabled a 100-fold increase in the performance of an important computational tool (Pedtool) used by geneticists worldwide to locate genes associated with complex diseases.

Preparing the Cyberinfrastructure Workforce:
Cyberinfrastructure is having a profound impact on the practice of science and engineering research and education. It is enabling individuals, groups, and organizations to advance science and engineering in ways that revolutionize *what they can do*, *how they do it*, and *who can participate*. To harness the full power of cyberinfrastructure and the promise it portends for discovery, learning, and innovation across and within all areas of science and engineering, SCI will make focused investments in the CI-TEAM program. CI-TEAM will contribute to the preparation of a science and engineering workforce with the knowledge and requisite skills needed to create, advance, and exploit cyberinfrastructure over the long-term. It builds on the outcomes created by prior investments in the Education, Outreach and Training (EOT) activities of the Partnerships for Advanced Computational Infrastructure (PACI).

Changes from FY 2005:

The FY 2006 Request for SCI includes an increase of $1.36 million, which will be directed toward the following:

Workforce Development

Funds allocated to the CI-TEAM program will increase to $10.0 million. Funds are reallocated from Cyberinfrastructure Tools[1]

[1] NSF's investments in the development and provision of shared cyberinfrastructure services and tools are made in partnership with a number of organizations around the nation, reflecting the pervasive impact of information technology and the growing capabilities and expertise now resident in a larger number of organizations. As such, the agency's investments in shared cyberinfrastructure tools are no longer best characterized as "facilities" investments. Consequently, in FY 2007 and beyond, NSF will report its investments in shared cyberinfrastructure tools as Infrastructure and Instrumentation. In the FY 2006 Request, further discussion of shared cyberinfrastructure tools can be found in the Facilities chapter.

INFORMATION TECHNOLOGY RESEARCH $145,440,000

The FY 2006 Request for the Information Technology Research (ITR) Subactivity is $145.44 million, a decrease of $28.34 million, or 16.3 percent, below the FY 2005 Current Plan of $173.78 million.

Information Technology Research Funding

(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Information Technology Research	**$218.06**	**$173.78**	**$145.44**	**-$28.34**	**-16.3%**
Major Component:					
Research & Education Grants	218.06	173.78	145.44	-28.34	-16.3%

About ITR:

During FYs 2000 through 2004, the ITR Subactivity provided for CISE investments in the agency-wide ITR priority area. It provided support for state-of-the-art IT research and related education activities; enhanced support for more focused research in areas of national importance such as cyber security, homeland security, and cyberinfrastructure; and permitted the funding of a larger number of complex, often interdisciplinary, projects.

In FY 2005, approximately 68 percent of ITR funds are committed to projects established in prior fiscal years. The remaining 32 percent of funds are available to make new awards.

The table above indicates that, with the completion of the ITR priority area, CISE is redirecting approximately $28 million to important IT research challenges and opportunities in core CCF, CNS and IIS activities. Funds available in the ITR Subactivity will be used to target prominent CISE-wide IT research and education priorities as described below.

ITR Priorities for FY 2006:

High-End Computing and Computational Science:
As a result of the ever-growing complexity of scientific and engineering problems, the computational needs of the national research community continue to grow. Some classes of scientific challenges and the optimal design of large and complex artifacts impose enormous demands on computing resources. Unfortunately, most of the currently available hardware, software, systems, and algorithms are primarily focused on business applications and are only suitable for smaller scale scientific and engineering problems; these hardware and software systems do not meet the high-end computing (HEC) needs of the science and engineering community.

Consequently, in FY 2006 ITR will emphasize fundamental research on high-end software and hardware systems that are designed specifically to address important computation- and data-intensive science and engineering opportunities and challenges. Research activities will focus on building complex software and tools for high-end computing architectures; developing multi-scale analysis methods in computational science; and developing more sophisticated information management and data analysis tools and technologies to support the analysis of scientific data and information.

Science of Design:
Complex interdependencies strain our ability to create, maintain, comprehend, and control software-intensive IT systems. The Science of Design emphasis seeks to build a body of knowledge that will provide a stronger scientific basis for the design of IT systems, leading to more effective development, evolution and understanding of IT systems of large scale, scope, and complexity. Research outcomes will include new theoretical and empirical knowledge on design, computational methods and tools for design, and new curricula for the next generation of IT designers.

Trustworthy Computing:
Targeted CISE investments in cyber security research and education will lead to the development of trustworthy IT systems. Research will be supported in a wide range of areas, addressing trustworthiness at all levels of IT system design, implementation, and use. Better abstractions are needed for reasoning about system behavior and attributing responsibility for system actions. Better means are needed for benchmarking, measurement, and data collection to build the empirical underpinnings of the field. Innovative approaches are also needed in cyber security education, so that capable students participate in relevant research and research results are quickly integrated into the educational process. System trustworthiness considerations must be included throughout the computer and information science and engineering curriculum, not just in courses for specialists. The concepts of proper system operation and ethical use of technology must have even broader reach, to touch individuals throughout the academic enterprise and beyond.

Broadening Participation in Computing:
The Broadening Participation in Computing (BPC) emphasis area aims to significantly increase the number of domestic students receiving post secondary degrees in the computing disciplines. Three types of BPC projects will be supported:

- Broad alliance projects will design and carry out comprehensive programs addressing under-representation in the computing disciplines;
- Demonstration projects will focus on a specific underrepresented community, a specific point in the academic pipeline, or a specific impediment to full participation in computing; and
- Supplemental grants to existing NSF projects will be made in order to engage more members of the computing research community in significant BPC efforts.

Changes from FY 2005:

In FY 2006, CISE will redirect $28.34 million from the broad category of IT Research to IT priorities in the core CISE Subactivities of CCF, CNS, and IIS. With funds available in the ITR Subactivity, CISE will fund the research and education and workforce preparation priorities described above.