COMPUTER AND INFORMATION SCIENCE AND ENGINEERING $638,760,000

The FY 2009 Budget Request for the Computer and Information Science and Engineering (CISE) Directorate is $638.76 million, an increase of $104.23 million, or 19.5 percent, over the FY 2008 Estimate of $534.53 million.

Computer and Information Science and Engineering Funding

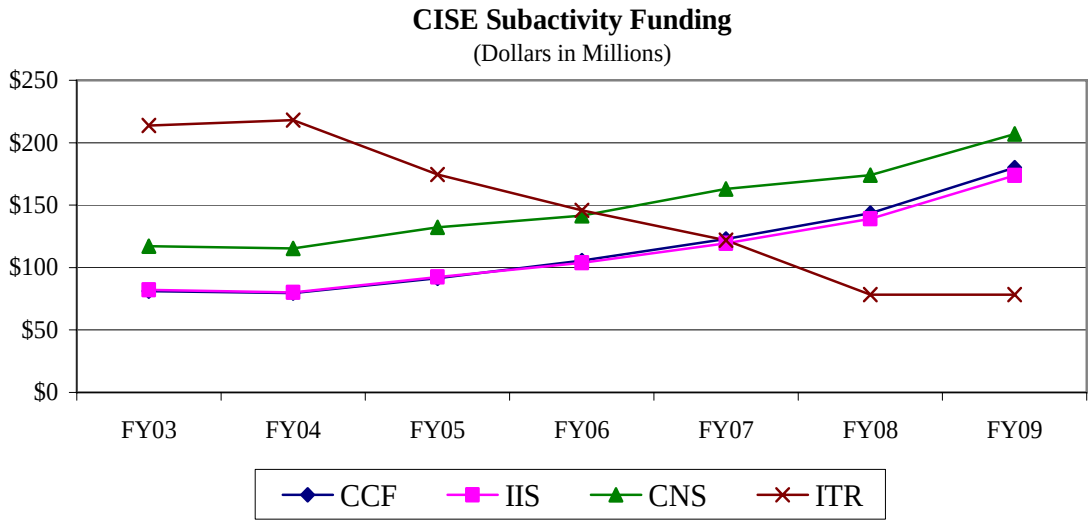
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Change over FY 2008 Estimate Percent
Computing and Communication Foundations (CCF)	$122.76	$143.45	$180.01	$36.56	25.5%
Computer and Network Systems (CNS)	162.77	173.91	206.91	33.00	19.0%
Information and Intelligent Systems (IIS)	119.26	138.93	173.60	34.67	25.0%
Information Technology Research (ITR)	121.89	78.24	78.24	-	-
Total, CISE	$526.68	$534.53	$638.76	$104.23	19.5%

Totals may not add due to rounding.

CISE's mission is to enable the U.S. to uphold a position of world leadership in computer and information science and engineering; to promote understanding of the principles and uses of advanced computer, communications, and information systems in service to society; and to contribute to universal, transparent, and affordable participation in an information-based society. CISE supports ambitious, long-term research projects within and across the many sub-fields of computing, contributes to the education and training of computing professionals and, more broadly, informs the preparation of a U.S. workforce with computing competencies essential to success in an increasingly competitive, global market. CISE-supported fundamental research outcomes in computing and information technology inform the development and deployment of cyberinfrastructure supported by the agency in service to all fields of science and engineering.

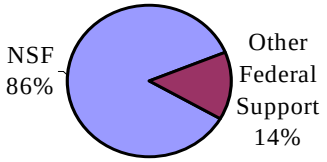
The CISE Directorate is in a unique position to help realize the goals and objectives outlined in the President's American Competitiveness Initiative (ACI). CISE research and education outcomes are vital to the Nation's economic future in two important ways: they catalyze innovations in the information technology (IT) industry itself; and they stimulate innovation across a much wider range of economic sectors, including finance, healthcare, manufacturing, natural resources, transportation, and many others.



RELEVANCE

NSF is the principal source of federal funding for university-based basic research in computer science, providing the vast majority – 86 percent – of total federal support in this area. In recent years, basic research investments in computing have provided unsurpassed value-added to the U.S. economy. As the President's Council of Advisors in Science and Technology (PCAST) recently referenced in their 2007 report, Leadership Under Challenge: IT R&D in a Competitive World, "*since 1995, networking and information technology industries have accounted for 25 percent of the Nation's economic growth, although they represent only 3 percent of the gross domestic product.*"

Federal Support for Basic Research in Computer Science at Academic Institutions



Essentially all practical applications of IT are based on ideas and concepts that emerged from basic research investments. These fundamental ideas and concepts have enabled innovative product and application developments that now permeate all areas of modern life. IT not only forms a sizeable portion of the economy in its own right, but drives discovery and innovation in many other areas, including advanced scientific research, healthcare, national and homeland security, organizational effectiveness, and governmental efficiency. Innovation in IT will remain an essential and vital force in productivity gains and economic growth in both the manufacturing and service sectors for many years to come, positioning NSF and CISE as central and essential actors in realizing the goals of the ACI.

The CISE Directorate continues to play a leadership role in the multi-agency subcommittee on Networking and Information Technology Research and Development (NITRD), which is co-chaired by the CISE Assistant Director. All projects supported by CISE investments, including all research, education, and cyberinfrastructure (computing research infrastructure), enrich the agency's NITRD portfolio. Consistent with the Administration's NITRD priority, in FY 2009 CISE will continue to explore the computing frontier, stimulating research advances in new algorithms, architectures, languages, and systems and in emerging models of computing – all enabling applications yet to be

imagined. As computing systems provide richer functionalities and faster performance, as they become more ubiquitous and pervasive, and as user expectations of and demands on them increase, CISE investments in the fundamental research essential to systems design for properties such as privacy, security, reliability, and usability become increasingly important. The directorate's programs in cybersecurity, information security and privacy, distributed systems, and networking will produce research results that allow society to more fully exploit the potential benefits of an increasingly networked world. As we seek to better understand human intelligence and to use computing to enhance our quality of life, CISE will continue to invest in artificial intelligence, computer vision, graphics, machine learning, natural language processing, robotics, speech, search, information retrieval, and technologies for collaboration. CISE also will continue to strengthen the intellectual foundations of computing, supporting research in algorithms and theoretical computer science, cryptography, network and communication theory, and information theory. CISE contributions to the National Nanotechnology Initiative will permit exploratory and interdisciplinary work on novel quantum and bio-inspired device and systems technologies, as well as related programming models, languages and tools that promise to form the basis of the revolutionary new computing systems of the future.

As a result of the increasingly important role of computing in society, the number of new scientific opportunities and challenges presented by the field far exceeds the directorate's ability to fund them. While CISE has always received many more quality proposals than can be funded, proposal funding rates have declined dramatically since FY 2000 as a consequence of growth in the field. CISE was able to fund 32 percent of the proposals received in FY 2000; in FY 2009, it is projected that 22 percent will be supported.

NSF is the principal source of federal support for strengthening science, technology, engineering and mathematics (STEM) education across all levels and is uniquely positioned to lead the Nation in STEM education due to its focus on STEM education research. Two programs in particular, CISE Pathways to Revitalized Undergraduate Computing Education (CPATH) and Broadening Participation in Computing (BPC), increase American competitiveness in the global economy and support NSF's underlying strategy of integration of research and education. Further, they respond directly to PCAST 2007 recommendations that a nationwide effort be undertaken "*to strengthen networking and information technology education and training programs*," with special attention "*paid to programs that educate future generations of workers involved in research and development, whose innovations and leadership will be critical to America's competitiveness in networking and information technology industries*."

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

FY 2008 Estimate, CISE..……...…….....…$534.53

Computing and Communication Foundations (CCF) +$36.56

Increased funding will be used to further support Cyber-enabled Discovery and Innovation (CDI) research, emphasizing the application of computational thinking and algorithmic insights across all areas of science and engineering supported by NSF. In addition, CCF CDI investments will support research aimed at the engineering of software for complex systems along two complementary lines: establishing the scientific and engineering principles (e.g., inspired by complexity sciences) for developing software for tomorrow's complex cyber-based systems; and exploiting computational models underlying software systems to understand natural and physical systems. Through investments in Science and Engineering beyond Moore's Law (SEBML), CCF will explore revolutionary new computing paradigms, including bio-inspired and quantum computing. Finally, through increases in the CCF core programs, the

division will call upon the academic research community to identify emerging transformative research opportunities that promise to revolutionize the field of computing.

Computer and Network Systems (CNS) +$33.00

Increased funding will be used to support CDI, with a focus on gaining better understanding of complex computer systems and networks and their emergent behavior. CNS will support research on new frameworks and models to understand and control emergent behavior in complex systems and networks, and on innovative ways to design and implement large-scale systems that exhibit robust and predictable behavior, particularly when operating under stress. Within CDI, CNS will also support transformative research which seeks to establish new scientific foundations and technologies for cyber-physical systems, an emerging class of physical and engineered systems whose operations are integrated, monitored and controlled by a computational core. In addition, CNS will support new CDI research directions in data-intensive applications, emphasizing powerful data-driven architectures and programming models that lead to natural, machine-independent, large-scale parallelism. Finally, CNS will increase support for the core areas of network science and engineering, computer systems, cybersecurity, education and workforce development, and research infrastructure.

Information and Intelligent Systems (IIS) +$34.67

Increased funding will be used to support CDI research, emphasizing new multidisciplinary research and education efforts that explore advanced data technologies, computing platforms, and collaborative environments in demanding scientific and engineering domains. Through Adaptive Systems Technology (AST) investments, IIS will support new research directions in which the robustness and adaptive capability of biological organisms inform the problems and approaches taken within CISE research. In addition, IIS will emphasize research on human-computer systems that explicitly expands our knowledge of how people interact with information technology, and how information technology can be designed that is explicitly informed by such knowledge. Finally, through increases in the IIS core programs, the division will support the most creative ideas generated by the IIS community to expand or enhance the impact of computing innovations in society.

Subtotal, Changes +$104.23

FY 2009 Request, CISE……...…….....$638.76

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

FY 2008 Estimate, CISE……..……..…….…….…$534.53

The CISE budget contributes directly to the goals of the ACI as well as to other Administration priorities including advanced networking and high-end computing. In FY 2009, the agency will build on core themes developed for CDI, highlighting new activities that hold significant promise for economic competitiveness and societal impact. Through joint investments with other directorates and offices, CISE researchers will explore and expand the use of computational abstractions to extract knowledge from digital data and to yield new insights in and understanding of a wide range of complex systems, including natural, built, and social systems. The computational concepts, methodologies, and tools developed with CDI investments promise to transform the conduct of research across all fields of science and

engineering, and to result in a new wave of technological and societal innovations that will accelerate productivity growth and ensure American competitiveness for decades to come.

Discovery +$101.47

CISE will continue its investments in high-risk, high-return, fundamental research essential to innovation and economic competitiveness in IT. Just as research advances in IT have made unsurpassed contributions to the Nation's technological, economic, and security posture over the past decade, so future CISE research investments are designed to both deepen and broaden computing contributions to the Nation's competitive position.

- *Computing Fundamentals (+$78.35 million).* CISE will increase investment in core and emerging areas of computer and information science and engineering in research programs that emphasize transformative work. These areas include: the exploration of revolutionary computational models, languages, and tools, and hardware and software architectures that will serve as the primary catalysts for future innovations in information technology; transformative research on trustworthy software and networked systems that simultaneously explore the technological challenges as well as the equally important organizational, sociological, economic, legal, and psychological factors impeding progress in securing cyberspace; and exploration of human-centered computing and information and intelligent systems that promise value to a diverse range of individuals and to society at large. CISE will increasingly focus on programs and projects that identify plausible but high-risk opportunities with potential to result in significant, enduring impact in societal applications.

  As part of CISE's $113.50 million investment in cybersecurity research and education, the directorate will devote $30.0 million to research in usability (+$10.0 million); theoretical foundations (+$10.0 million); and privacy (+$10.0 million) to support the Comprehensive National Cybersecurity Initiative.

- *Cyber-enabled Discovery and Innovation (+$13.63 million).* To transform an abundance of digital data into new knowledge, CISE researchers will: explore new fundamental mathematical and computational abstractions to represent and manage data; participate in multidisciplinary projects that explore data mining, data federation, and extraction strategies in demanding science and engineering applications; and develop the underpinnings essential to the development of sophisticated data visualization and delivery tools. CISE will also invest in an emerging data-intensive computing paradigm where systems are designed, programmed, and operated to enable different forms of computation over massive data sets. To better understand complexity in built systems, CISE will emphasize investments in cyber-physical systems and software for complex systems. Finally, increased CISE investments will support the design, development, and assessment of IT-enabled, human-centered virtual organizations, advancing our ability to build and leverage the computational and organizational potential of virtual organizations as new modalities of scientific and engineering research and education and enterprise productivity enhancement.

- *Science and Engineering Beyond Moore's Law (+$6.0 million).* In SEBML, CISE researchers will explore radically new systems based on revolutionary technologies such as organic molecules, carbon nanotubes, optical switches, and superconductors, among others. New programming models will also be explored, along with the languages and compilers that support them. To optimize computing power, new algorithms that exploit highly parallel

hardware and architecture characteristics in contemporary silicon-based technologies, such as multi-cores and communication and memory latencies, will also be examined.

- *Adaptive Systems Technology (+$3.49 million).* CISE will contribute $3.49 million to the NSF-wide Adaptive Systems Technology investment. CISE researchers will apply neuroscience concepts and principles in the investigation of the promise of intelligent distributed knowledge networks. Biological organisms whose self-assembly draws on a massively parallel fabrication process comprising large numbers of cells will serve as inspiration for CISE and other researchers exploring revolutionary new computing system architectures. And investigators will explore biomimetic organs and limbs that promise to augment human capabilities.

Learning +$0.37

Research Experiences for Undergraduates (+$200,000).
CISE will provide an additional $200,000 in support for students through the Research Experiences for Undergraduates (REU) Sites program.

Integrative Graduate Education and Research Traineeship (+$170,000).
CISE will provide an additional $170,000 in support for students through the Integrative Graduate Education and Research Traineeship (IGERT) program.

Stewardship +$2.39

A number of activities are funded directly from NSF's programs to advance NSF's Stewardship goal. These include Intergovernmental Personnel Act appointments, NSF-wide studies and evaluations, and mission-related information technology investments. As is discussed further in the Stewardship chapter of this Request, in FY 2009 NSF has realigned IT investments to tie mission-related activities more directly to NSF's programs.

Subtotal, Changes +$104.23

FY 2009 Request, CISE……..……...…….…….....$638.76

NSF-WIDE INVESTMENTS

In FY 2009, CISE will support research and education efforts related to broad, Foundation-wide investments in a number of areas including the Administration's interagency R&D priorities.

CISE NSF-wide Investments

(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Percent
Adaptive Systems Technology	-	-	$3.49	$3.49	N/A
Cyber-Enabled Discovery and Innovation	-	20.00	33.63	13.63	68.2%
Cyberinfrastructure	71.00	87.00	87.00	-	-
Human and Social Dynamics	5.00	2.00	-	-2.00	-100.0%
National Nanotechnology Initiative	12.89	12.22	11.00	-1.22	-10.0%
Networking and Information Technology R&D	526.69	534.53	638.76	104.23	19.5%
Science & Engineering Beyond Moore's Law	-	-	6.00	6.00	N/A

Adaptive Systems Technology (AST): A level of $3.49 million will support CISE research on the application of neuroscience concepts and principles in the investigation of the promise of intelligent distributed knowledge networks.

Cyber-enabled Discovery and Innovation (CDI): A level of $33.63 million will support CISE research in a variety of areas including new fundamental mathematical and computational abstractions, data mining, data federation, and extraction, and data visualization and delivery tools.

Cyberinfrastructure (CI): A level of $87.0 million will support research on computing systems and capabilities likely to become essential components in the cyberinfrastructure of the future. The challenges of scalability, security, reliability, and extensibility will be met with research and education activities in architecture, software, networking, theory, and new underlying technologies. The prominent role that digital data now play across science and engineering leads to systemic thinking about technologies that can support broad access to and use of scientific and engineering data in both educational contexts and in diverse uses in science and engineering research.

National Nanotechnology Initiative (NNI): A CISE investment of $11.0 million will support research in areas such as fundamental nanoscale phenomena and processes; nanoscale devices and systems; nanomanufacturing; and research facilities and instrumentation. Within CISE, these general categories encompass architecture, design, and fabrication of computer and information systems based on nanoelectronics, representation of quantum and classical information in nanostructures, and the national infrastructure needed to support such research.

Networking and Information Technology Research and Development (NITRD): CISE's entire request of $638.76 million is included in NITRD activities supporting fundamental research and related education in information technology and networking.

Science and Engineering beyond Moore's Law (SEBML): A level of $6.0 million will support CISE research on radically new systems based on revolutionary technologies, new programming models, and new algorithms that exploit highly parallel hardware and architecture characteristics in contemporary silicon-based technologies.

QUALITY

CISE identifies the highest quality research 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 95 percent in FY 2007, 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. COVs for all the CISE divisions are being planned for 2009.

CISE also receives advice from the Advisory Committee for Computer and Information Science and Engineering (CISEAC) on such issues as: mission, programs, and goals that best serve the scientific community; promotion of 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 and institutions.

PERFORMANCE

The FY 2009 Budget Request is aligned to reflect funding levels associated with the Foundation's four strategic outcome goals stated in the FY 2006-2011 Strategic Plan. These goals provide an overarching framework for progress in fundamental research and education and facilitate budget and performance integration.

Computer and Information Science and Engineering

By Strategic Outcome Goal

(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Percent
Discovery	$451.86	$463.23	$564.70	$101.47	21.9%
Learning	36.47	37.23	37.60	0.37	1.0%
Research Infrastructure	30.56	26.50	26.50	-	-
Stewardship	7.79	7.57	9.96	2.39	31.6%
Total, CISE	$526.68	$534.53	$638.76	$104.23	19.5%

Totals may not add due to rounding.

Recent Research Highlights

► **Digitizing a River in One Week:** In response to growing freshwater resource problems, scientists and engineers from the Center for Embedded Networked Sensing tested a sensor deployment campaign at the confluence of the Merced and San Joaquin Rivers. Their objective was to create a system for rapidly characterizing a complex river reach not only in terms of its bathymetry and floodplain, but also its flow and water quality parameters. Using a robotic sensing device, researchers scanned flow and water quality conditions across transects taken upstream, downstream, and within the confluence zone. Over a five-day period, nearly 300 cross-sectional distributions for flow velocity, temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen, nitrate, and chlorophyll a were collected. Their work resulted in a three-dimensional map of the confluence zone, which, together with the transect data, will be used to create a multi-dimensional river model that scientists can use to analyze and forecast river conditions, and plan future large-scale experiments aimed at understanding and improving water quality. (CCF)

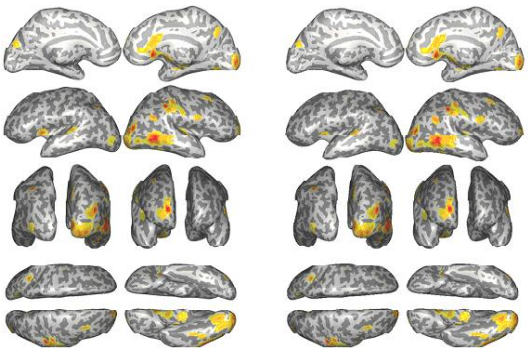
Scientists and engineers from the Center for Embedded Networked Sensing test a sensor deployment campaign approach at the confluence of the Merced and San Joaquin Rivers. *Credit: Jason Fisher, UC Merced.*

► **Light Fields and Computational Photography:** The explosive growth of digital photography, combined with the shrinking size of computers, has led to the birth of computational photography--techniques that extend the capabilities of digital photography. Light fields, a type of computational photography, means a collection of views of a scene, each taken from a slightly different position. Unlike conventional photography, light fields permit viewpoint and focus to be changed after the snapshot is taken. Researchers at the Stanford Computer Graphics Laboratory have built several devices for capturing light fields, including a "plenoptic camera," which is an ordinary camera with a microlens array inserted near the sensor. As computational photography moves into consumer products, it will change the face of photography forever. Since it is software-intensive, it may give the United States a competitive advantage in the photography marketplace. (CCF)

Photographs captured by Stanford Plenoptic Camera are digitally refocused after they are captured. The refocusing algorithm used in this camera was developed using NSF funding. Ren Ng (pictured above) won the 2007 ACM Doctoral Dissertation award for this research. *Credit: Ren Ng, Refocus Imaging.*

► **Improving Bridge Safety:** Researchers are working to improve bridge safety in Missouri as a model approach for the nation. The project involves equipping vulnerable bridges with sensors that monitor the bridge's structural condition and utilizing networks that can manage high-performance queries over wireless sensor networks. A particular research target is the Bill Emerson Memorial Bridge in Cape Girardeau, Missouri. It is a main crossing of the Mississippi River and lies within the New Madrid seismic zone. This bridge experiences a high volume of traffic and is a crucial component of the transportation network within the central US. With a sensor network embedded within the bridge's structural elements, the bridge can be continuously monitored for changes that may predict component failures. (CNS)

This picture shows the Bill Emerson Memorial Bridge in Cape Girardeau, Missouri, when it was under construction. It is the main crossing on the Mississippi River and lies in the New Madrid seismic zone. The real-time wireless sensor network system developed in this project is being deployed to insure the bridge's safety. *Credit: Missouri Department of Transportation.*



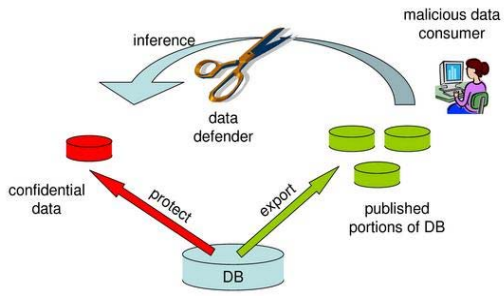
Reconstruction by a new method of the locations and extents of 70 simulated cortical electromagnetic source areas from only 1,000 simulated magnetic (MEG) time points at 273 scalp sensors (not shown). The left panel shows the mean activity levels of the simulated data on a human cortex. The right panel shows the mean activity levels of the estimated sources. Note the accuracy of the new method in capturing the locations and extents of the multiple cortical source areas. *Credit: Scott Makeig, UCSD.*

► **Brain Imaging in High Definition Mode:** The central problem of cognitive neuroscience is to identify, from non-invasive brain recordings, the patterns of distributed brain activity that support human cognition and behavior. Researchers at the University of California, San Diego, have made break-though progress in developing a new modeling method to identify the brain sources of signal patterns. The new method identifies not just the approximate points from which these signals emerge, but also the varying extents of the cortical areas whose electromagnetic field activities become locally synchronized, producing electrical and magnetic field changes that can be recorded from the scalp. The new method promises to make possible a new mode of high-definition dynamic brain imaging that, applied in particular to high-density EEG measurements, will be both much less expensive and much more flexible than existing dynamic brain imaging technologies, with unprecedented spatial and time/frequency resolution of complex patterns. (IIS)

An electronic-textile garment fabricated for context-awareness. The insets show sensors and processing elements, all of which are connected together by an on-fabric network. *Credit: Virginia Tech/Rick Griffiths/David Lehn/Joshua Edmison.*

► **E-Textile Garments:** Researchers at Virginia Tech are developing e-textile garments that can sense their own shapes and the wearer's activities. Continuously sensing the garment's shape makes it possible to determine the wearer's activity, whether the wearer is moving or perhaps falling. This enables the e-textile to adapt to the user's current situation. The software, sensors, and algorithms developed in this project permit the design of e-textiles that can adapt to a wide range of applications, without extensive tuning of the devices. In cooperation with the Intel Corporation, the researchers also have developed an e-textile rug that can track the position and motion of persons walking on the fabric. Applications for e-textile-based "wearable" computing include medicine, home health care, manufacturing and industrial processes, entertainment, and emergency response. One researcher, Dr. Thomas Martin, received the NSF Presidential Early Career Award for Scientists and Engineers (PECASE) for his leadership in the emerging area of e-textiles. (CNS)

► **Lower Energy Consumption for Data Centers:** Data centers like the ones built by Google, Microsoft, and Yahoo demand massive amounts of power. High power means higher costs, increased environmental impacts and limits on where the centers can be located. Research has been conducted on memory energy management, but few studies have focused on data servers where main memory is predominantly accessed by direct memory access (DMA) instead of processors. Researchers at the University of Illinois at Urbana-Champaign are pursuing memory energy management for these data servers by investigating DMA-aware multi-processor memory energy management for multi-threaded data servers. The project has explored the characteristics of these data centers to better understand how they use--and sometimes waste--energy. Using this information, the researchers have developed prototypes that use up to 38.6 percent less energy while providing similar performance. (CCF)



Privacy in Database Publishing. *Credit: Alin Deutsch.*

► **Hiding Confidential Data While Posting Public Data on the Web:** Information owners (governmental, academic, commercial entities, or private citizens) are subjected to two conflicting requirements: they must publish portions of data on the Web for the benefit of data consumers but, for legal, business, or personal reasons, they must preserve the privacy of the confidential information residing in their databases. In many instances, the published data can be used by malicious consumers to infer the confidential data. Researchers at the University of California, San Diego developed concepts and tools which assist database owners in identifying portions of data that can be safely published without compromising the privacy of confidential information. This research introduces novel privacy guarantees that balance strictness and practicality. The research also proves an optimal attack strategy that guarantees no other attack can expose more about the confidential data. Users only need to test for privacy guarantees against this optimal attack instead of against an infinite number of attacks. (IIS)

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 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate
Senior Researchers	6,361	6,361	7,645
Other Professionals	649	649	780
Postdoctorates	293	293	355
Graduate Students	5,732	5,732	6,900
Undergraduate Students	1,533	1,533	1,850
Total Number of People	14,568	14,568	17,530

CISE Funding Profile

	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate
Statistics for Competitive Awards:			
Number	1,635	1,635	1,950
Funding Rate	28%	22%	22%
Statistics for Research Grants:			
Number of Research Grants	1,310	1,310	1,550
Funding Rate	24%	19%	19%
Median Annualized Award Size	$115,300	$120,000	$145,000
Average Annualized Award Size	$139,000	$150,000	$180,000
Average Award Duration, in years	2.9	3.0	3.0

COMPUTING AND COMMUNICATION FOUNDATIONS $180,010,000

The FY 2009 Budget Request for the Division of Computing and Communication Foundations (CCF) is $180.01 million, an increase of $36.56 million, or 25.5 percent, over the FY 2008 Estimate of $143.45 million.

(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Change over FY 2008 Estimate Percent
Computing and Communication Foundations	**$122.76**	**$143.45**	**$180.01**	**$36.56**	**25.5%**
Major Components:					
Research & Education Grants	114.68	135.45	172.01	36.56	27.0%
Science and Technology Centers					
STC for Embedded Networked Sensing	4.04	4.00	4.00	-	-
STC for Ubiquitous Secure Technology	4.04	4.00	4.00	-	-

About CCF:
CCF addresses current and emerging areas of computing and communication foundations: theory and incubation of computing and communication; processes and artifacts for computing and communication; signals, communication and interaction; and foundations of systems in use. Within and across these areas, 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, foundations of computer languages and software, and investigations of revolutionary computing paradigms such as quantum and bio-inspired computing. CCF projects also integrate education with research to prepare future generations of computer science and engineering professionals.

In general, 58 percent of the CCF portfolio is available for new research grants. The remaining 42 percent is used primarily to fund continuing grants made in previous years.

Science and Technology Centers
CCF supports two Science and Technology Centers: 1) the Center for Embedded Networked Sensing (CENS) at the University of California at Los Angeles which is exploring embedded networked sensing systems, large-scale, distributed systems, composed of smart sensors and actuators embedded in the physical world; and 2) the Center for Ubiquitous Secure Technology at the University of California at Berkeley (TRUST). TRUST is addressing a parallel and accelerating trend of the past decade - the integration of secure, robust computing and communications capabilities across critical infrastructures, in areas such as telecommunications, finance, energy distribution, and transportation.

CCF Priorities for FY 2009
The longer-term context of the FY 2009 Request is focused on foundational ideas that will enhance American competitiveness.

Cyber-enabled Discovery and Innovation (CDI)
In support of the ACI, CCF will continue its emphasis on CDI with an investment of $13.0 million. By applying algorithmic insights broadly across science, engineering, and areas of societal importance, CDI

will spark a new revolution in our understanding of the world and in our productivity. Without algorithmic insights and computational thinking, complex objects and processes such as protein folding, telecommunication networks, or manufacturing processes can only be approximately understood. In FY 2009, CCF will continue to emphasize larger, multidisciplinary projects that apply foundational ideas across multiple disciplines.

Science and Engineering Beyond Moore's Law (SEBML)
CCF is participating in the NSF-wide investment in SEBML at a level of $4.0 million, with several avenues of research and education showing promise. CCF will support fundamental research to identify promising new technologies that continue scaling-based performance gains, including, for example, the use of molecules or biomolecules as basic logic elements, the use of nanowires for gates or interconnections, and the exploitation of quantum phenomena to perform computations in parallel. In addition, CCF will continue to support research aimed at optimizing performance of existing technology. For example, CCF will support research into the architecture of multicore chips, especially the interconnection networks, to find the best design alternatives over a range of chip sizes. In addition, research on new kinds of design tools will be needed that balance performance, size and power. Finally, and most importantly, new algorithms and software engineering tools and techniques will be needed that can take advantage of large-scale on-chip parallelism. While developing these techniques through research, CCF also plans to educate a new generation in their application.

Core CCF Activities
The foundational ideas of computing and communication have changed the world and society over the last few decades. CCF will continue and extend its foundational inquiries into the inherent limits of computation and communication, into the architecture of hardware and software systems, and into the use of new technologies to compute and communicate. These investigations will further transform all fields of human endeavor. For example, theoretical investigations of coding and information will increase the security of our data systems and the privacy of their users. As another example, new concepts in architecture will provide new ways of building reliable systems from unreliable components.

In FY 2009, one of the foci of CCF core activities will be massive data sets. The world is drowning in data. Networks of scientific instruments, earth-monitoring satellites, and security cameras, as examples are generating massive amounts of data. Yet the innovation and competitiveness of web-indexing services show that making such data available and searchable brings great rewards. CCF will emphasize research into techniques for computing and communicating essential properties of massive data sets. Communication can also benefit from a data-centric view. For example, if a receiver makes use of only certain properties of a stream of data, the whole data stream does not have to be communicated. It is possible that a small fraction of the data stream will suffice to compute the properties of interest, in which case only that small fraction need be communicated. For many data streams, it is possible to essentially reconstruct the entire stream from a compressed sample. Data-centric computing and communication has the potential to do for dynamic data what web indexing services have done for static data. By making these data streams available and usable, rather than just throwing them away, we may dramatically increase American innovation and competitiveness.

Changes from FY 2008:
The FY 2009 request for CCF reflects an increase of $36.56 million directed toward core research and education as well as CDI and SEBML investments. Research in the CCF core will be allocated to activities like those described above and will help maintain a consistent proposal funding rate.

COMPUTER AND NETWORK SYSTEMS $206,910,000

The FY 2009 Budget Request for the Division of Computer and Network Systems (CNS) is $206.91 million, an increase of $33.0 million, or 19.0 percent, over the FY 2008 Estimate of $173.91 million.

Computer and Network Systems Funding
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Percent
Computer and Network Systems	**$162.77**	**$173.91**	**$206.91**	**$33.00**	**19.0%**
Major Components:					
Research & Education Grants	132.21	147.91	180.91	33.00	22.3%
Computing Research Resources	30.56	26.00	26.00	-	-

About CNS:
CNS supports research and education activities that advance our understanding of the fundamental properties of computer systems and networks and their complexity, explore new ways to address the limitations of existing computer and networked systems to make better use of these technologies, and develop better paradigms, abstractions and tools for designing, analyzing and building next generation computer and networked systems that are robust, secure and trustworthy. To enable state-of-the-art computer science research and education, the division supports the development and use of computing research infrastructure. CNS also coordinates cross-divisional activities that foster the integration of research, education, and workforce development to prepare future generations of computer science and engineering professionals.

In general, 47 percent of the CNS portfolio is available for new research grants. The remaining 53 percent is used primarily to fund continuing grants made in previous years.

CNS Priorities for FY 2009
The FY 2009 Request for CNS focuses on NSF key investments in Cyber-enabled Discovery and Innovation; Science and Engineering beyond Moore's Law; and on strengthening existing programs such as computer systems research and revitalizing education in computing.

Cyber-enabled Discovery and Innovation (CDI)
In support of the ACI, CNS will participate in CDI at a level of $11.0 million, with emphasis in the following areas:
Understanding Complexity- Robust, secure and highly dependable networks are essential to support communication, coordination and collaboration in all sectors of society. New knowledge will lead to a better understanding of how complex computer systems and networks behave at scale, particularly when under stress, how they are designed and deployed, and how they evolve to support timely integration of technology innovation and meet the stringent timing and resource requirements of emerging social and scientific applications and services.
Cyber-physical Systems- Cyber-physical systems represent a class of physical and engineered systems at the core of human-scale structures, such as medical devices and systems, automobiles and intelligent highways, as well as large-scale applications, such as industrial process control, robotic manufacturing, aviation and airspace management and other areas. The operations of these systems are integrated, monitored, and controlled by a computational core, which is embedded, potentially distributed, and

requires real-time response. As such, the behavior of a cyber-physical system is a fully-integrated hybridization of computational (logical) and physical action. CNS research seeks new scientific foundations and technologies to enable the rapid and reliable integration of computer- and information-centric physical and engineered systems. The goal is to usher in a new generation of engineered systems that are highly dependable, efficiently produced, and capable of advanced performance in information, computation, communication, and control.

Software for Complex Systems- Within this area, CNS will support research on tools for analyzing, monitoring, debugging, and documenting software for complex systems, as well as other pertinent topics.

Science and Engineering Beyond Moore's Law (SEBML)

In support of the ACI, CNS will participate in SEBML at a level of $2.0 million, making research investments in innovative paradigms and design principles for distributed control of large-scale, parallel applications as well as new programming models and abstractions for massively parallel and data-intensive applications.

CNS Core Activities

Network Science and Engineering- The growing complexity of the Internet underscores the need to understand how future, large-scale networks can be engineered to have predictable behavior. It also raises a wide range of challenges in understanding the inter-play between the technical, economic and social drivers of our current networks and identifying their broad implications for network design. CNS will support fundamental research, emphasizing insights into the dynamics of complex networks, and transformational research leading to the architectures of future-generation networks and services. Further, a comprehensive, multidisciplinary agenda for network science and engineering research is being developed in FY 2009.

Computer Systems- CNS investments in computer systems research will focus on: distributed, mobile, and embedded systems; sensing and control systems; dynamically configured, multiple-component systems; and parallel systems. The FY 2009 Request will enable a focus on emerging areas, including data-intensive applications, self-managing and access-anywhere storage, data sharing for agile organizations, virtualization at scale, and cross-systems integration for configuration and management.

Cybersecurity- Research investments in cybersecurity, including those made through Cyber Trust, will continue, supporting a vision of a society in which networked computer systems are more predictable, more accountable, and less vulnerable to attack and abuse; are developed, configured, operated and evaluated by a well-trained and diverse workforce; and are used by a public educated in their secure and ethical operation.

Education and Workforce Development- The directorate will continue CISE Pathways to Revitalized Undergraduate Computing Education (CPATH), a program designed to equip future generations of the U.S. workforce with the computing competencies and skills necessary to insure the Nation's health, security and prosperity in the 21st century. CNS will lead the infusion of computational thinking into education at all levels and in all areas of science and engineering, and will continue its investments in Broadening Participation in Computing (BPC) to significantly increase the number of U.S. citizens and permanent residents receiving post secondary degrees in the computing disciplines.

Research Infrastructure- CNS will provide support for the acquisition, enhancement, and operation of experimental facilities that enable high-quality computing research and education. Support is also provided to enhance the computing research infrastructure in under-served institutions and to support the equipment needs of collaborative, distributed research projects.

Changes from FY 2008

Disciplinary and interdisciplinary research in CNS will increase by $33.0 million. This additional support will be allocated to research and education priorities such as those described above and will help maintain a consistent proposal funding rate in CNS.

INFORMATION AND INTELLIGENT SYSTEMS $173,600,000

The FY 2009 Budget Request for the Division of Information and Intelligent Systems (IIS) is $173.60 million, an increase of $34.67 million, or 25.0 percent, over the FY 2008 Estimate of $138.93 million.

Information and Intelligent Systems Funding
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Percent
Information and Intelligent Systems	**$119.26**	**$138.93**	**$173.60**	**$34.67**	**25.0%**
Major Component: Research & Education Grants	119.26	138.93	173.60	34.67	25.0%

About IIS:
The Division of Information and Intelligent Systems supports research and education that: develops new knowledge about the role of people in the design and use of information technology; increases the capabilities of human beings and machines to create, discover and reason with knowledge by advancing the ability to represent, collect, store, organize, visualize and communicate about data and information; and advances knowledge about how computational systems can perform tasks autonomously, robustly, and flexibly.

In general, 54 percent of IIS funding is available for new research grants. The remaining 46 percent is used primarily to fund continuing grants made in previous years.

IIS Priorities for FY 2009
The FY 2009 Request for IIS focuses on NSF-wide investments in Cyber-enabled Discovery and Innovation and Adaptive Systems Technology and on new and emerging research areas in human computer systems.

Cyber-enabled Discovery and Innovation (CDI)
To address CDI's thrust on gaining knowledge from data, IIS will invest $9.63 million in research targeting new data technologies that can scale as technologies continue to increase the quantities, speed, and dimensionality of data, as well as in research attempting to cope with data heterogeneity due to the varying data resolutions, scales, modalities, sources, and inherent representational complexities confronted in scientific and engineering data. These challenges also require the development of new, suitable computational platforms, especially in the emerging data-intensive computing paradigm, which represents a rethinking of how computation is done when computing must reside where the data are, rather than the reverse. To address CDI's thrust on virtual organizations IIS will support research developing novel computing and communication infrastructure serving the needs of demanding scientific and engineering domains.

Adaptive Systems Technology (AST)
The robustness and adaptability of biological organisms have been a rich source of metaphors and models in computer and information science and engineering. IIS anticipates providing $3.49 million to support new research directions in which adaptive systems technology informs the problems and approaches taken within CISE research. Efforts to replicate the physical behaviors exhibited by living organisms can

provide ways to build systems that exhibit greater robustness than today's robots, thereby opening up new environmental niches in which we can contemplate novel pursuits in robotics research and providing a tool for "synthetic biology" by implementing and testing hypothesized mechanisms that might underlie behaviors exhibited by biological organisms. Brain-machine interfaces can provide new ways for computers and humans to interact based on better understanding of the human nervous system and how electronic technology can interface with it, paving the way for tools that behave as if they are a part of the nervous system, neural prosthetics that restore and supplement various functions lost during disease or injury, and more direct modes of interaction between man and machine. CISE research in adaptive systems technology can help with computational modeling and understanding the representations and computations that underlie biological organisms, including, importantly, understanding intelligence as a computational process.

Human-Computer Systems

Although computing is now pervasive in all aspects of human endeavor, the design of computing and communications systems is still largely *ad hoc*, developed by their designers via informal and poorly articulated intuitions about the human use of computing, whether at the level of individuals, groups, organizations, or societies. In 2009 IIS will target the development of efforts that explicitly build up our knowledge of how people interact with information technology, and how information technology design can be explicitly informed by such knowledge. IIS plans to support work that tackles such questions as: How does the human cognitive system constrain the ways we can most effectively use computing systems? How can computing systems bring together people to achieve results that are beyond the capabilities of either computers or people when acting in isolation? How does the structure and nature of our computing and information networks enable or constrain our ability to harness the combined strengths of computers and people working together? Although we have models of computability for a computer acting in isolation, can models be developed that provide insight and guide future development of systems in which humans and computers work together?

IIS Core Activities

IIS will increase its investments in the core areas of Information and Intelligent Systems, reflecting the continuing and growing importance of such topics as: accessing and understanding digital content in a broad range of heterogeneous forms; physics-based modeling for computational vision, robotics, computer graphics, and other areas that require accurate interaction with and representation or depiction of the physical world; building systems that exhibit the broad competencies and robust behaviors exhibited by humans and other biological organisms; and understanding the role of people – whether singly, in teams, or in society at large – in the context of computing technologies ranging from mobile platforms to virtual worlds to ubiquitous computing environments.

Changes from FY 2008

The FY 2009 Request for IIS includes an increase of $34.67 million that will be directed to core disciplinary and interdisciplinary research. This additional support will be allocated to research priorities as described above and will help maintain a consistent funding rate in IIS.

INFORMATION TECHNOLOGY RESEARCH $78,240,000

The FY 2009 Budget Request for the Information Technology Research (ITR) subactivity is $78.24 million, equal to the FY 2008 Estimate.

Information Technology Research Funding
(Dollars in Millions)

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Request	Change over FY 2008 Estimate Amount	Percent
Information Technology Research	**$121.89**	**$78.24**	**$78.24**	**-**	**-**
Major Component:					
Research & Education Grants	121.89	78.24	78.24	-	-

About ITR:

The ITR subactivity provides support for transformative explorations in computer information science and engineering research and related education activities, emphasizing the funding of multi-investigator, often multidisciplinary, projects.

In general, 70 percent of the ITR portfolio is available to make new research awards. The remaining 30 percent is used primarily to fund continuing grants made in previous years.

ITR Priorities for FY 2009
Funds from the ITR subactivity will be used to target prominent CISE-wide IT research and education priorities as described below.

Explorations
At a level of $50.0 million, CISE will support larger-scale, often multidisciplinary, research and education projects that promise fundamental new knowledge in computing, and IT systems that are more reliable and robust, have better and more predictable performance, provide useful new services, and exploit the potential of emerging technologies. Funded projects will permit full development and exploration of fundamental new concepts and ideas in the computing domain, and promise significant contributions to the ACI.

Established in 2008, the Expeditions in Computing program is a key component of the Explorations portfolio. The program provides CISE PIs with the opportunity to pursue ambitious, fundamental research agendas that promise to define the future of computing and information. In planning and implementing *Expeditions*, investigators are encouraged to come together within or across departments or institutions in the identification of compelling, transformative research agendas that promise disruptive innovations in computing and information for many years to come. Funded at levels up to $2.0 million per year, *Expeditions* represent some of the largest single investments currently made by the directorate. Together with the Science and Technology Centers CISE supports, *Expeditions* form the centerpiece of the directorate's award portfolio. With awards funded at levels that promote the formation of research teams, CISE recognizes that concurrent research advances in multiple fields or sub-fields are often necessary to stimulate deep and enduring outcomes.