COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING $584,260,000

The FY 2004 Request for the Computer and Information Science and Engineering Activity is $584.26 million, an increase of $57.32 million, or 10.9 percent, above the FY 2003 Request of $526.94 million.

CISE Funding
(Dollars in Millions)

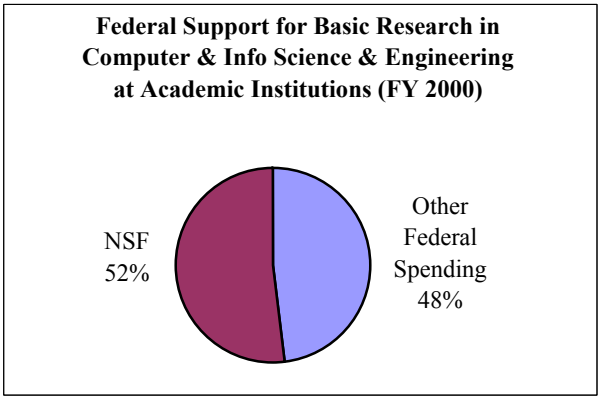
	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Computer-Communications Research	69.69	70.17	75.87	5.70	8.1%
Information and Intelligent Systems	51.65	50.61	52.40	1.79	3.5%
Experimental and Integrative Activities	63.15	62.16	57.67	-4.49	-7.2%
Advanced Computational Infrastructure and Research	86.76	85.42	92.56	7.14	8.4%
Advanced Networking Infrastructure and Research	69.77	67.91	67.65	-0.26	-0.4%
Information Technology Research	174.01	190.67	218.11	27.44	14.4%
Cyberinfrastructure	0.00	0.00	20.00	20.00	N/A
Total, CISE	$515.02	$526.94	$584.26	$57.32	10.9%

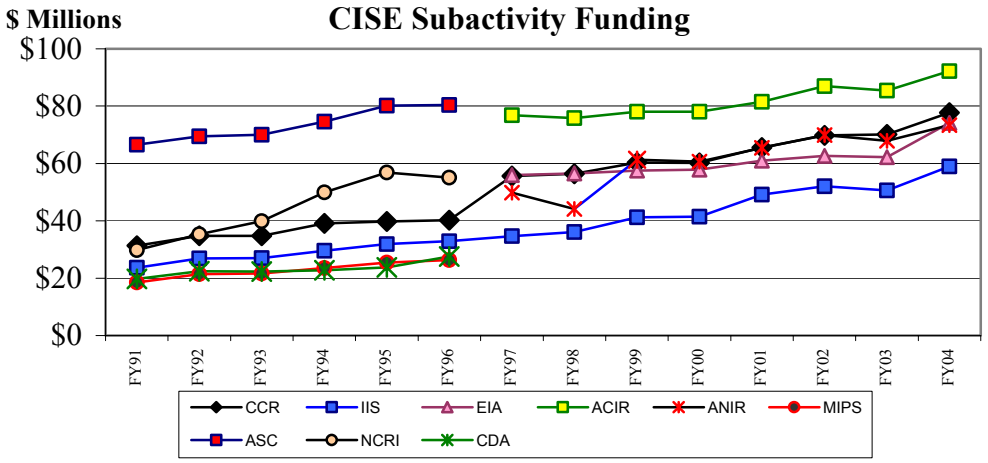
Totals may not add due to rounding.

The Computer and Information Science and Engineering (CISE) Activity supports research, infrastructure, and education in the computer science, computer engineering, information science, networking and computational science disciplines.

RELEVANCE

CISE is the principal source of federal funding for university-based basic research in the computer science, computer engineering, information science, networking, and computational science disciplines, providing over half of the total federal support in this area. The directorate exerts a lead role in the multi-agency Networked Information Technology Research and Development program by providing 28% of total funding and chairing many of the working groups. CISE is one of the leading supporters of research in many fundamental areas of computing such as computer security, human-computer interaction, computer networking, and other areas. Building on past accomplishments, such as developing the Internet and fundamental advances in computer languages and systems, CISE is positioning its activities for the future with new efforts to address growing concerns about the vulnerability and trustworthiness of computers and networks, to develop cyberinfrastructure to address the data demands of science and engineering research across the frontier, and continuing needs for a US workforce to maintain leadership in the information technology arena.





ITR Funding FY2000-2004: $90.4, $155.4, $173.5, $190.7, $218.1 million
FY 1991-1996: MIPS, Microelectronic Information processing Systems;
ASC, Advanced Scientific Computation; NCRI, Networking & Communication Research & Infrastructure;
CDA, Cross-Directorate Activities

The CISE Activity, working in close cooperation among its divisions and with other directorates, supports programs across the leading edge of information technology. Computer-Communications Research focuses on computer systems and the foundations of computing including algorithms, geometric methods, computer security research, and hardware systems. Information and Intelligent Systems focuses on information systems, robotics, cognitive science, digital libraries research and the social implications of computing technologies. Experimental and Integrative Activities supports a range of programs to expand the IT workforce and increase its diversity, to provide mid-scale infrastructure for computer science research, and a research focus on areas where IT and the life sciences intersect. Advanced Computational Infrastructure and Research supports the needs of computational scientists across the range of NSF disciplines through infrastructure for high-performance computing and with a research program creating innovative methods for computational science. Advanced Networking Infrastructure and Research supports networking to advance uses of the existing Internet and high performance networks such as Internet2/Abilene, and to foster invention for new network technologies. ITR, begun in FY 2000, supports IT research that is larger in scale, fosters interdisciplinary studies, and requires larger, longer duration awards. Cyberinfrastructure is a new effort, building on advanced computing infrastructure and advanced networking infrastructure and capitalizing on growing data from networked sensors and instruments and advance capabilities to share, interpret and understand fundamental science and engineering phenomena.

STRATEGIC GOALS

Three aims guide CISE's activities:

- PEOPLE: Improvement in the quality of education, training and diversity in the fields of computer science, computer engineering, information science, and computational science. CISE advances education and training for current computer scientists and engineers, increases the diversity of these communities, facilitates education of future generations of computer scientists and engineers, and enhances the public's knowledge of IT related disciplines.

- IDEAS: Advancement of knowledge across the computer science and engineering spectrum including both maintaining adequate base support across all IT fields and identifying opportunities where more focused support can play a catalytic role in advancing scientific progress.

- TOOLS: Enhancement of the infrastructure for the conduct of computational science research supporting computational methods such as data mining, simulation, and modeling used in all areas of NSF sponsored research and education. CISE will identify and make investments in instrumentation and facilities, including Partnerships for Advanced Computational Infrastructure, Terascale computing, high-performance networking, and a new effort on cyberinfrastructure that will enable a new generation of data and information based research in all science and engineering disciplines.

CISE's support for ongoing core and new activities contributes to NSF's efforts to achieve its strategic goals, and to the administration and management activities necessary to realize these goals.

Summary of CISE Funding by Strategic Goal
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
People	44.84	53.33	56.94	3.61	6.8%
Ideas	321.36	328.58	354.12	25.54	7.8%
Tools	141.70	139.29	166.09	26.80	19.2%
Administration & Management	7.11	5.74	7.11	1.37	23.9%
Total, CISE	$515.02	$526.94	$584.26	$57.32	10.9%

Totals may not add due to rounding.

The FY 2004 Request level for the Computer and Information Science and Engineering (CISE) activity is $584.26 million, an increase of $57.32 million, or 10.9 percent, over the FY 2003 Request of $526.94 million.

In FY 2004, CISE will emphasize new and increased activity in three areas:

Information Technology Research (ITR), begun in FY 2000, has diversified modes of funding for CISE researchers and established a new Terascale Computing facility. With ITR funding, CISE has been able to fund larger and longer duration projects with multiple investigators, cross-disciplinary teams, and more realistic project scales. This funding continues to transform research in information technology areas and is effectively building bridges between CISE disciplines and other fields. Terascale Computing is exploring new models for teraflop computing to provide the most advanced computing facility available to civilian researchers in the nation. In FY 2004, CISE will emphasize growth in ITR to continue improving the modes of funding. Additional Terascale investments are addressing the needs to link the three terascale computing facilities with other computational and data resources enabling modeling and simulation at unprecedented scale and resolution.

Cybersecurity research has recently benefited from increased coordination and funding. There are presently programs in three CISE Subactivites addressing computer system security, computer network security, and secure data resources. ITR also addresses security in larger projects. In FY 2004, CISE will increase funding and cooperation for all of these efforts.

A cyberinfrastructure focus will begin in FY 2004 with requested funding of $20 million. Cyberinfrastructure will link computational and data resources (building on experience being gained with Terascale efforts) with sensors and instruments, advanced software and middleware to enable distributed systems and analysis, and visualization resources and facilities to promote understanding of science and engineering applications. The promise and demand for cyberinfrastructure has been articulated in a draft NSB report on "Science and Engineering Infrastructure for the 21st Century: the Role of the National Science Foundation." (NSB-02-190) and in an upcoming report from CISE's Advisory Committee on Cyberinfrastructure. Both reports concur that the needs and opportunities are great at this time, due to rapidly increasing volumes of data generated by scientific instruments and sensors, the increasing capability (with decreasing costs) of computing, networking and sensors, and the demonstration in all fields of the potential for revolutionizing science and engineering.

People (+$3.61 million for a total of $56.94 million)

CISE places high priority on programs to develop the advanced IT workforce. This workforce, including researchers, educators, and technology leaders for industry, is key to the health of the computing and communications sectors. The strong demand for a workforce with advanced information technology knowledge continues even while unemployment in other sectors has risen.

The principal strategies to develop this workforce include increasing graduate training and improving the attractiveness of university careers for computer scientists and engineers; increasing participation of under-represented groups in the workforce; and enhancing the ability of all citizens to benefit from the expanded use of computing and communications technologies. The following table shows investments in training programs, but does not include the extensive support for graduate training supported under research grants (see Ideas, below), the support enabled by advanced computational and network infrastructure, or the programs supported in centers.

CISE People Investments
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
K-12	-	-	-	-
Undergraduate	9.32	10.27	0.95	10.2%
Graduate & Professional	44.01	46.67	2.66	6.0%
Total, People	$53.33	$56.94	3.61	6.8%

Enhancement of multidisciplinary education, teaching, and training activities include:

- **Curriculum Development** (+$800,000 to $3.60 million): In cooperation with ENG, CISE sponsors projects that draw on research advances to create university curriculum materials that prepare students for the research and development opportunities of the future. In response to strong proposal pressure, this increase will allow 2 to 3 additional projects to be funded.
- **CAREER** (+$2.20 million to $29.55 million): Increasing CISE CAREER award size will encourage young scientists and engineers to continue in academic career paths and develop strong professional programs that integrate research and education.
- **Graduate Stipends** (+$1.01 million to $5.63 million): CISE will increase stipends to $30,000 for graduate research fellowships for women, IGERT, and GK-12 to meet the need to provide adequate support for advanced training. Above the increased stipends, this will also support an increase in the number of graduate students.
- **Postdoctoral Support** (-$550,000): CISE will phase out its targeted postdoctoral program in FY 2004, though postdoctoral fellows will continue to be supported through individual and group awards. The need for a dedicated program in computer fields is small, and the field is well served through the other awards.

Ideas (+$25.54 million for a total of $354.12 million)

CISE supports research across the full range of disciplines that increase understanding of information, communication, and computing – from the basic principles and technologies to new applications. Support for discovery across the frontier of science and engineering connected to learning, innovation and the service of society underlies all the research areas in the CISE activity; it accounts for about 60 percent of the funding in the CISE activity. Projects that support research as well as the university training environment are the highest priority across CISE. As part of this support for discovery, funding for ITR will increase to $218.11 million, with approximately two-thirds of this support going to individual and small group projects and one-third to large, interdisciplinary, multi-investigator projects designated as centers.

Enhancement of multidisciplinary research activities, inter-agency partnerships, and international activities through:

- **Cybersecurity** (+$20.0 million to approximately $35.0 million): Increasing support of research addressing security needs for IT systems, involving computers, networks, and databases, and adding a network security component. This will build a foundation of knowledge to build a next generation of secure systems that will benefit all sectors of society.
- **Vulnerabilities Analysis, Consequence Management, and Threat Reduction** ($2.0 million): Initiating support of research that creates and manages integrated multidisciplinary and multi-sector resources for response to extreme events, such as: data repositories, tools for planning and decision-making, communications infrastructures, sensor infrastructures, and real-time data-driven simulations.
- **Language Technologies** (+$2.0 million to $7.0 million): Initiating support for new opportunities in language technologies include natural language processing, speech recognition by computer, and applications such as use of language for human-computer interaction in ubiquitous computing environments. Enables the start of a 'new core' program that will provide a comprehensive approach to technologies for human languages. This supports national security and homeland defense by sponsoring the basic research that enables automated understanding of natural language resources, automatic translations, and other services.

- **Biologically Inspired Computing** (+$1.0 million to $4.0 million): Supports improvements on fundamental capabilities of computer and information systems by incorporating insights from deeper understanding of the information mechanisms of biological systems at all levels ranging from the atomic to systems of organisms.

Funding for CISE Centers
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Percent Change
Information Technology Centers	70.00	74.00	5.7%
Science and Technology Centers[1]	-	4.00	N/A
Total, Centers Support	$70.00	$78.00	11.4%

[1]The increase in STC funding reflects new awards made in September 2002. These funds are shown in Integrative Activities in the FY 2003 Request, and are transferred to the appropriate managing R&RA Activity in the FY 2004 Request.

Information Technology Centers are large projects funded in the Information Technology Research program that are typically multi-disciplinary and multi-investigator projects. Many involve more than one university. These projects support IT researchers to address problems of larger scale and complexity than CISE was previously able to support - projects that are more representative of actual practice in the IT focused sector. Such projects give students a more realistic experience than was previously possible.

The Center for Embedded Networked Sensing (CENS) at UCLA is the Science and Technology Center supported by CISE. CENS is developing Embedded Networked Sensing Systems and applying this revolutionary technology to critical scientific and social applications. Like the Internet, these large-scale, distributed systems, composed of smart sensors and actuators embedded in the physical world, will eventually infuse the entire world, but at a physical level instead of virtual.

Priority Areas

In FY 2004, CISE will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Information Technology Research, Nanoscale Science and Engineering, Mathematical Sciences, and Human and Social Dynamics.

CISE Investments in Priority Areas
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Biocomplexity in the Environment	6.10	7.36	8.00	0.64	8.7%
Information Technology Research	173.51	190.67	218.11	27.44	14.4%
Nanoscale Science and Engineering	10.20	11.14	15.14	4.00	35.9%
Mathematical Sciences	N/A	2.29	2.29	0.00	0.0%
Human and Social Dynamics	N/A	N/A	3.00	3.00	N/A

- **Biocomplexity in the Environment**: Funding for BE in FY 2004 increases by $640,000 or 8.7 percent for a total of $8.00 million. These funds will contribute to NSF's coordinated central competition and will support focused environmental informatics activities such as multi-scale modeling and simulation, dynamic data analysis and interpretation, synthesis studies, and data mining and data management, as well as enabling increased award size for new projects in the Tree of Life emphasis area.

- **Information Technology Research**: Funding within CISE for the Foundation's ITR priority area will total $218.11 million in FY 2004, a $27.44 million increase or 14.4 percent over the FY 2003 Request of $190.67 million.

  Information technology (IT) was responsible for a third of the nation's economic expansion during the 1990s, primarily due to advances in fundamental understanding of computing, communications, and information systems. The Internet, personal computers, Web browsers, software for medical, scientific, educational, and business applications, as well as many other features of daily life are rooted in the basic IT research achievements of the past few decades. In the future, IT will have an even greater impact on the quality of our lives, the state of the economy, and national security.

  ITR continues the Foundation's effort to address computing, communications, and information research and related education and training and infrastructure efforts essential for maintaining the nation's preeminence in IT and its wider applications to all sectors of society. In response to the need for more long-range IT research, the ITR program will support research that often entails a higher risk than that prevailing in established areas. In managing the award process, CISE will ensure that at least 10 percent of funding is used for these high-quality, higher-risk proposals. ITR funds larger, more ambitious projects than CISE has been able to fund in the past.

  In FY 2004, CISE will focus on broad thematic, large-scale, long-term, basic computer science research challenges, such as the following:

  - Increased research will address the theory and technology for building safe and secure, complex, embedded, networked and autonomous systems. This will include methods to assess and measure risk and performance assurance, an essential step to improve confidence in information and communications systems. This is the principal priority for increased support.
  - Human Augmentation research will expand the capabilities of computers by exploring new interfaces, such as speech, touch/tactile sensing, and telepresence. This new focus will serve the increasing population of aging Americans. These advances will allow the disabled and elderly to more fully participate in the information age and will expand the abilities of all people to enjoy the power of computing and communications. Speech technology will be an area of particular emphasis.
  - Research at the interface of biology and information technology will be conducted in computational biology to understand biological and social systems, biological systems informatics to understand the "IT" mechanisms of biological systems, biomolecular computation to explore new biological and chemical mechanisms that may form the basis of a new generation of computing, and biologically inspired computing to understand how biological systems process information.
  - Interdisciplinary research funded in ITR will continue to prepare the foundation for cyberinfrastructure. This research is leading new efforts in grid computing, large databases for science and engineering along with new methods to gain understanding from data, and a new effort on sensors and sensor networks.

- **Nanoscale Science and Engineering**: CISE support for Nanoscale Science and Engineering Research will focus on quantum computing, self-assembly of biomolecular computer components, nano-robotics, and design automation to support a new approach to molecular architectures and totals $15.14 million for FY 2004, an increase of $4.0 million over the FY 2003 Request of $11.14 million.

- **Mathematical Sciences**: CISE will participate in this priority area at the level of $2.29 million for FY 2004, continuing the same level of support as in the FY 2003 Request. One emphasis area will be on research to improve comprehension and presentation of data focusing on research in massive data analysis, algorithms, storage, computer input/output issues, networking, digital libraries, etc. A second area will be on continuous computing, specifically at the interface of discrete and combinatorial systems research, which is the traditional preserve of computer science, with the continuous domain research, which is the traditional domain of mathematics.

- **Human and Social Dynamics**: CISE will provide $3.0 million in research funding in FY 2004 for this new priority area. Research support focused on improving use of IT systems including visualization, human-computer interaction, and language interfaces; modeling uncertainty, representing uncertainty of data objects, reasoning with uncertain objects, and semantics of distributed reasoning on uncertain objects; and mechanisms for how humans and groups interact with them. This will also support research on Vulnerabilities Analysis, Consequence Management, and Threat Reduction that will initiate research that creates and manages integrated multidisciplinary and multi-sector resources for response to extreme events, such as: data repositories, tools for planning and decision-making, communications infrastructures, sensor infrastructures, and real-time data-driven simulations. These areas have elements of compelling applications of IT and research areas that promise to improve the effectiveness of IT to serve citizens in roles as varied as learners, scientists, or users of technology in the home.

Tools (+$26.80 million for a total of $166.09 million)

Funding is concentrated in the followiong areas: the Advanced Computing Infrastructure in ACIR, the Advanced Networking Infrastructure in ANIR, additional CISE facilities supported in Experimental and Integrative Activities, and a new subactivity, Cyberinfrastructure. Tools also supports operations for the MREFC-funded Terascale Computing effort.

CISE Investments in Tools
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
PACI	71.49	76.49	5.00	7.0%
Terascale Computing Operations	7.00	7.00	0.00	0.0%
Advanced Networking Infrastructure	46.62	46.42	-0.20	-0.4%
Cyberinfrastructure	N/A	20.00	20.00	N/A
Additional CISE Facilities	14.18	16.18	2.00	14.1%
Total, Tools	$139.29	$166.09	26.80	19.2%

Enhancement of national and international facilities and laboratories includes:

- **Cyberinfrastructure:** (+$20.0 million): A new investment of $20.0 million in Cyberinfrastructure will begin to transform the existing S&E infrastructure of high-performance computers and networks and raise it to a new level by integrating these resources with sensors, data resources, and new analysis and visualization capabilities. These resources will enable new types and depths of research using massive data resources, supporting deeper detail for computational analysis and opening new frontiers for analysis and understanding. Funding will allow 3 to 5 large projects to be funded to introduce these new capabilities to support a greater range of science and engineering and will also allow additional components addressing edge connectivity (to the "lab") to these resources along with visualization or interpretation facilities.
- **PACI** (+$5.0 million to $76.49 million): Additional funds for PACI will support increased operations costs, small projects that often support outreach and training, and additional costs the PACI sites incur as part of working with the Pittsburgh-based Terascale Computing System.
- **Additional CISE Facilities** (+$2.0 million to $16.18 million)**:** Increased support for the CISE's Research Resources Program, supporting multi-investigator instrumentation needs and distributed resources; the CISE Research Infrastructure program, supporting large-scale research synergizing more complex projects; and the CISE Minority Institutions Infrastructure program, building the research capacity at minority institutions and facilitating CISE-related advanced degrees.

Administration and Management

Administration and Management provides for administrative activities necessary to enable NSF to achieve its strategic goals. Requested funding for FY 2004 is $7.11 million, an increase of $1.37 million over the FY 2003 Request of $5.74 million. This includes the cost of Intergovernmental Personnel Act appointments and contractors performing administrative functions.

QUALITY

CISE maximizes the quality of the R&D it supports through the use of a competitive, merit-based review process. The percent of basic and applied research funds that were allocated to projects that undergo merit review was 97 percent in FY 2002, 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, 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.

The CISE Activity also receives advice from the Advisory Committee for CISE (CISE-AC) 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 biological sciences; and priority investment areas in biological research. The CISE-AC meets twice a year and members represent a cross section of computer and information science and engineering with representatives from many different sub-disciplines within the field; a cross section of institutions including industry; broad geographic representation; and balanced representation of women and under-represented minorities.

PERFORMANCE

Recent Research Highlights

Examples of significant discoveries or advances resulting from CISE-supported research include:

- As part of the NPACI-supported eTEACH Learning on Demand project, University of Wisconsin researchers incorporated a multimedia format into their "Problem Solving with Computers." Students "attend" virtual lectures for this introductory course in computational science via streaming video on the Web. They do homework in active, faculty-facilitated team laboratories that focus on realistic problems. Students and faculty are giving high marks to the redesigned course.

After faculty lectures are recorded on video, they are delivered on demand to each student via streaming video on the Web. Making use of technology to automate time-consuming lectures allows instructors to spend more time interacting with the students. This increased contact takes place in a weekly lab, co-created by students who have already taken the course. Instead of being a solitary activity, homework now becomes an active environment for contact between faculty and students.

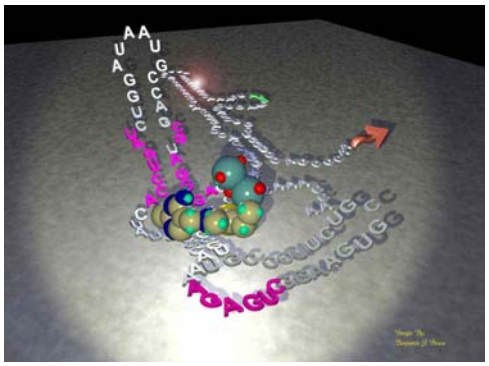
The first eTEACH offering is in a course focusing on NPACI's primary mission -- using computers to solve scientific problems. SDSC is providing technological support with the SDSC Storage Resource Broker software, which will be used to index and store lectures and other video materials.

For more information see: http://www.npaci.edu/envision/v17.3/eteach.html

- Richard Lipton at Georgia Institute of Technology received funding for *Improving Nash's Nobel Prize Result.* Nash received the Nobel Prize for defining and proving that any non-zero sum game between two or more players has a solution. This is known as the Nash Equilibrium Point (NEP), a major generalization to the classical result on zero-sum games. Since real life games are usually non-zero sum and often multiple player games, this is a superb result, but there are two problems with it:

  First, no one knows how to find the NEPs. Second, if the game has a huge number of strategies, then one must generally use all of them. Lipton showed that if a game has n strategies for a player, that player need only use a modest number of strategies (about $\log n$) to get approximately the same value from the game as if he or she used all the strategies, independent of what the other players do. Such strategies can be found much more efficiently then previously.

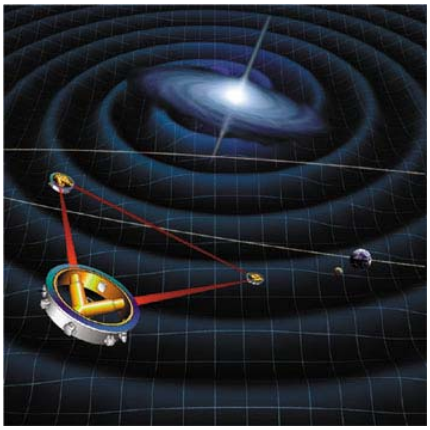
  Using fewer strategies is important since real life strategies cost money. Imagine a situation where we are deciding on what weapons to purchase for DoD. Clearly, we want to be at or near an optimal point, but cost issues favor strategies that use less choices. Lipton's result shows that this is always possible.



- Yale University researcher Ronald Breaker conducts research on Molecular Switches. Molecular engineering is being used to create new nucleic acid molecular switches analogous to electronic logic gates. In this project, the phenomenon of molecular "survival-of-the-fittest" is used to identify unique RNA switches that have AND gate and other logic functions. Researchers plan to assemble these into biocomputing devices.

- A collaborative effort among the Scripps Research Institute, the University of Utah, and the University of Washington aims to develop novel human-computer interfaces to convey concepts in structural molecular biology using auto-fabricated physical molecular models in an augmented reality environment. This is the first application to blend computer auto-fabrication technology and augmented reality into an educational tool for teaching concepts in molecular biology. The manipulation tools have already begun to show great value in teaching fundamental concepts of structure and assembly of biological molecules to students of all ages and backgrounds.

- NPACI-supported Rutgers University researchers are using supercomputers to model one of the most dramatic events in astronomy–the behavior of black holes when their host galaxies collide. From revealing strong and unexpected effects on surrounding stars to the potential to produce rogue black holes wandering the universe, these simulations–among the largest of their kind ever run–are shedding new light on the life cycle of gravitationally bound black holes in the nucleus of a pair of merging galaxies. Observations have yet to definitively detect black hole pairs, but simulation results of Merritt's team, published in the December 13, 2001, issue of *The Astrophysical Journal*, are helping astronomers find new evidence for the elusive objects.



A key question is whether the two black holes quickly coalesce into a single, larger black hole, or continue to orbit each other in the new galaxy. Simulations predict that black hole pairs could continue orbiting each other for one billion years or more–long enough to collide with a third galaxy. The researchers' simulations showed for the first time that the binary black hole efficiently scours away stars around it, hurling the stars outward and resulting in a new, emptier galaxy core with a uniform star density. Once the core is relatively devoid of stars, the black holes lose little additional energy and their orbits become stable. Eventually, the black hole binary will undergo a brief, final coalescence into a single black hole, during which energy radiates in the form of gravitational waves. Such gravitational waves, if detected, would not only provide a "signature" revealing the black holes, but also yield information about their orbits, masses, and spins–and furnish the first-ever test of Einstein's Theory of General Relativity under such extreme conditions.

The simulations are also useful to the designers of gravitational wave detectors, including the planned Laser Interferometer Space Antenna (LISA). For more information see: http://www.npaci.edu/envision/v18.2/blackhole.html

Other Performance Indicators

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

Number of People Supported in CISE Activities

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate
Senior Researchers	3,686	3,400	3,800
Other Professionals	974	890	990
Postdoctorates	407	510	450
Graduate Students	4,308	4,500	4,600
Undergraduate Students	780	860	860
K-12 Students	230	250	250
K-12 Teachers	130	140	140
Total Number of People	10,515	10,550	11,090

CISE Funding Profile

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate
Number of Requests for Funding	4,540	5,300	4,700
Dollars Requested (in millions)	$4,500	$4,800	$5,100
Total Number of Awards	2,355	2,150	2,400
Statistics for Competitive Awards:			
Number	1,093	980	1,150
Funding Rate	24%	26%	25%
Statistics for Research Grants:			
Number of Research Grants	949	870	1,000
Median Annualized Award Size	$93,311	$99,000	$99,000
Average Annualized Award Size	$140,084	$151,000	$143,000
Average Award Duration, in years	3.0	3.0	3.0

COMPUTER-COMMUNICATIONS RESEARCH $75,870,000

The FY 2003 Budget Request for the Computer-Communications Research (C-CR) Subactivity is $75.87 million, an increase of $5.7 million or 8.1 percent, over the FY 2003 Request of $70.17 million.

Computer-Communications Research Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Computer-Communications Research	69.69	70.17	75.87	$5.70	8.1%
Total, C-CR	$69.69	$70.17	$75.87	$5.70	8.1%

C-CR supports research underlying the design, construction, and utilization of information and communications systems of all kinds. It covers theory and implementation for both hardware and software research. The design of algorithms and architectures as well as the tools and technologies for exploiting them are in the scope of this subactivity. The goal is to promote fundamental understanding of computing and communication and to enable development of the advanced, highly reliable systems needed for critical applications in science, engineering, transportation, environment, industrial control, commerce, national defense, education, and health care. Because of the breadth of research it supports, C-CR has 8 standing programs and also takes part in other wide-ranging priority efforts. C-CR activities address two broad areas:

- Funding of approximately $45.0 million supports research on basic issues in the science and technology of computing and information that includes the trusted systems, embedded and hybrid systems, theory of computing, algorithms for scientific computation, computer graphics, operating systems, compilers, software design and productivity, computer architecture, and programming languages. This research provides the bridge from computing and communication systems to application systems with ideas used to design new types of computers and build operating systems and other software systems. Improvements in software quality and productivity are also important benefits of this research.
- Funding of approximately $30.0 million supports research in the design and engineering of computer hardware and communications and signal processing systems and addresses coding and compression techniques, design automation, and computer architecture. This research develops the ideas embodied in new computer and communications systems. Computing and communication improvements come from this research and continue to provide rapid improvements in technology.

Some examples of the research promoted by C-CR are:

- NSF-supported researcher, Andre Scedrov at the University of Pennsylvania is analyzing the widely used Kerberos protocol for secure, authenticated transactions. Scedrov and coworkers have found three anomalies that may occur when the protocol is used. Research on security is finding flaws and identifying needed repairs for the security of deployed systems; it also creates a knowledge base to improve future system designs.
- Eric Torng and Richard Enbody of Michigan State University are examining skew caches and other new cache designs that address the critical bottleneck for computer processor performance. They have developed new algorithms to efficiently manage these new cache methods. Research such as this is needed before these new designs can be incorporated into faster processor chips.
- Game theory, traditionally an economic sciences field, is being applied to the Internet by Vijay Vazirani at Georgia Tech. Understanding the evolving use of the Internet in terms of complex

interactions of many economic agents working with different degrees of collaboration, cooperation and competition, and using new concepts of algorithmic game theory is leading to new approaches to problems such as fair cost allocation and computing market equilibrium prices.

- David Koppelman at Louisiana State University has developed a visualization tool to help researchers visualize data sets from computer processor simulations. Tools such as this help researchers examine detailed data from processor simulations and to develop new techniques to reduce latency or branch costs for new processor designs. Successes from this research lead to improved computer processor performance.

In FY 2004, C-CR will emphasize increases for three research areas:

- Trusted Computing. C-CR will increase support for research in theory and technologies to increase the trustworthiness of computing and communications systems. Protection of computing and communication systems is critical to the privacy of citizens, the safety of transportation systems, the financial health of business organizations, stability of the global economy, and assurance of national security. Trusted Computing will focus on critical hardware and software technologies that are necessary to achieve high levels of system safety, security and privacy, and survivability. The research directions will include sound theoretical bases for assured construction of safe, secure systems; principles and methodology for secure and dependable hardware, software, and network design; and techniques to verify and validate high confidence systems against security breaches and hardware/software faults.

- Embedded and Hybrid Systems. These are typically small, stand-alone devices that are hybrids of digital and analog designs or devices that have embedded small digital systems along with other functions, such as cell-phones, personal digital assistants (PDAs), or medical devices. Research challenges in hybrid systems range from developing a fundamental, mathematical understanding of how discrete (digital) and analog systems interact to developing techniques for design and optimization of systems. Research on embedded devices includes new techniques for low power computing and design methods for small systems in which neither processing nor memory is ample.

- Molecular Architectures. Computer science has developed a very successful tradition for analyzing and synthesizing complex systems by imposing on them a conceptual "architecture." The architecture utilizes multiple layers of abstraction to represent component interactions within these layers as well as to provide clear interfaces between layers. The goal of this emphasis area is to develop new architectural notions for this emerging area of nanotechnology, with the goal of systematizing the design of nanoscale artifacts. The research will be coordinated through the NSF-wide Nanoscale Science and Engineering priority area.

CCR will manage a new Science and Technology Center, the Center for Embedded and Networked Sensing, headed by Dr. Deborah Estrin at UCLA. Funded at $4.0 million per year, the center will conduct basic research on sensors for use as varied as environmental sensing, airflows over airplane wings, and medicine. They will also study networking of sensors to improve signal quality, data management, power management and other research objectives.

INFORMATION AND INTELLIGENT SYSTEMS $52,400,000

The FY 2004 Request for the Information and Intelligent Systems (IIS) Subactivity is $52.40 million, an increase of $1.79 million, or 3.5 percent, above the FY 2003 Request of $50.61 million.

Information and Intelligent Systems Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Information and Intelligent Systems	51.65	50.61	52.40	$1.79	3.5%
Total, IIS	$51.65	$50.61	$52.40	$1.79	3.5%

The IIS Subactivity is the major source of support for research in the important and rapidly growing areas of human-computer interaction, databases, digital libraries, robotics, computers and society, and knowledge and cognitive systems.

Research in the IIS Subactivity is oriented broadly around two thematic areas: human-computer systems and information systems. Approximately 44 percent of this subactivity's funds, or about $23 million, support human-computer systems activities in human-computer interaction, universal access, and robotics and human augmentation. This research addresses areas such as graphics and language to enable new ways to communicate between computers and humans; new techniques to support access for those with limited vision, hearing or dexterity; and robotic devices to assist people or to complement the abilities of humans.

Approximately $29 million of this subactivity's funds support research in information systems and includes programs in information and data management, knowledge and cognitive systems, computers and social systems, and digital libraries. This research addresses topics such as visualization of data; data mining in scientific databases; analysis of imagery from medical and other sources; artificial intelligence and case-based reasoning, learning systems; understanding human learning and its relationship to machine learning; and the economic, ethical, and social impacts of IT.

The following are examples of major research efforts supported by IIS.

- Universal access projects exploit interface technology to assist the disabled, the elderly, and those with limited experience with computer systems. Research in these areas is leading to new methods for voice synthesis and recognition, multi-media information interfaces, haptic (force-feedback) interfaces, and the synthesis of systems to ease interaction with computers. Expanding the choices for interacting with electronic systems will have wide benefits.
- The Digital Libraries program (DLI), which combines resources from NSF, the Defense Advanced Research Projects Agency (DARPA), the National Endowment for the Humanities (NEH), and the National Library of Medicine (NLM), is also supported in the "Information Management" theme of the ITR program. It has expanded its international activities, supporting joint research programs with the United Kingdom, Germany, the European Union, and several Asian countries. Digital Library research now includes new applications of computer techniques to resources in education, for example in the use of digital libraries by children; these are further developed in the National STEM Digital Library program (NSDL) in the Education and Human Resources Activity (aimed at improving science, engineering, mathematics, and technology education).

- Data mining and data handling in general are rapidly expanding, with new work on long-term preservation of data, on understanding the provenance of data so that its reliability can be judged, and on extracting data from research to be used in many applications. For example, research on data mining in medical patient records not only assists doctors trying to treat a patient but also can help with epidemiological studies. This research has also proven useful for national intelligence efforts to enable analysis of foreign data sources. IIS has supported innovations leading to search engines such as Google.

The following are successes from recent IIS supported research.

- Tom Furness of the University of Washington is exploring uses of computer and visualization technology for partially sighted people. Some people with limited vision have at least part of their retina usable, but cataracts or other problems prevent them from seeing much. This project is exploring the use of a display that projects an image directly on an area of the retina, bypassing the lens in the eye and thus compensating in part for some visual defects. Recently this project has discovered and measured user preferences for display techniques; in particular, blue seems to be the easiest color to read with this technique. This will improve our ability to use such devices to help the partially sighted.
- Fred Jelinek of Johns Hopkins University, for several years has organized a summer workshop on language technologies; the workshop has been a training ground for graduate students and young faculty. The most recent topic was summarization techniques that automatically read and summarize documents. The workshop has been very influential in training, promoting this research area and disseminating state of the art knowledge to U.S. researchers.
- Shree Nayar of Columbia University is conducting research on using polarized light to compensate for the low contrast and bad light scattering in bad weather that degrade vision. His techniques work in haze, mist, fog, and other conditions; and they apply to grey-scale, color, or even IR imagery. This work can be applied to areas such as vehicle navigation and video surveillance and may improve road and airplane safety.

IIS plans to reallocate resources to support increased research on natural language processing including translation, summarization, and spoken language recognition. These research areas are timely and reach across the range of uses of information technologies; the recent emphasis on combating terrorism has also demonstrated the growing need for a strong research presence in these areas to serve long term needs in national and homeland security.

IIS is also increasing efforts on new generation data management systems that manage large amounts of structured and unstructured data, extract information from the data, as well as manage complex relationships between the data. These data management systems are being used in numerous applications and are vulnerable to malicious attacks. Data and applications security will provide new models for developing secure information applications.

EXPERIMENTAL AND INTEGRATIVE ACTIVITIES $57,670,000

The FY 2004 Request for the Experimental and Integrative Activities (EIA) Subactivity is $57.67 million, a decrease of $4.49 million, or 7.2 percent, below the FY 2003 Request of $62.16 million.

Experimental and Integrative Activities Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Experimental and Integrative Activities	63.15	62.16	57.67	-$4.49	-7.2%
Total, EIA	$63.15	$62.16	$57.67	-$4.49	-7.2%

The EIA Subactivity facilitates new ventures and the evolution of CISE-related disciplines, and encourages activities that cross traditional boundaries. Specifically, EIA promotes new and typically multidisciplinary research initiatives; builds capacity in terms of people and facilities; and assesses the impact of IT research, education, and technology on society.

EIA has a balanced portfolio across NSF's three strategic goals. Multidisciplinary research supports NSF's Ideas strategic goal; instrumentation and infrastructure supports Tools for CISE research; education, human resources, and workforce activities support the People goal; and EIA provides approximately $2.0 million to support workshops, symposia, studies, travel, and international activities. Approximately $28.0 million in multidisciplinary research funding supports projects that cross the disciplinary boundaries within CISE as well as projects that have a core of CISE research and application outside of CISE areas. Approximately $21.0 million for instrumentation and infrastructure efforts provides funding for groups of investigators for equipment (such as high-performance computers, robots, or visualization devices) and operations that enable multi-investigator research. Education, human resources, and workforce efforts provide approximately $11.0 million to support research on uses of technology to improve learning, to transfer research into college and graduate level curriculum, and to increase the participation of under-represented groups in educational and career paths in IT.

The following are areas of emphasis for FY 2004.

- EIA plans to continue to emphasize biomolecular computing, biologically-inspired information technology, and bioinformatics as well as coordinate CISE participation in the NSF-wide Biocomplexity and the Environment priority area. EIA will also continue its investment in the Digital Government.
- The portfolio of instrumentation and infrastructure programs will provide research equipment generally unavailable on individual research awards, ranging from specialized instrumentation for small research groups, to large-scale infrastructure, to nationally and internationally shared facilities, which are closely tied to research. Participation by regionally disadvantaged and underrepresented groups will be ensured through partnerships and special programs.

- Activities in education, human resources, and workforce will focus on the underlying issues, needs, and components of teaching and learning, workforce needs, pipeline problems, and under-representation in information technology. Demonstration projects to follow research on reasons for underrepresentation of women and minorities in the IT workforce are planned. The Information Technology Workforce Program is the primary program in this area, and EIA will continue to participate in many cross-directorate activities, including the Combined Research Curriculum Development (CRCD) program, the Graduate Teaching

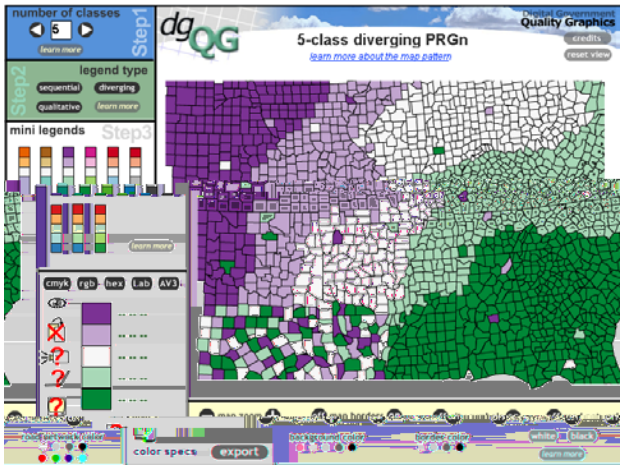
Fellowships in K-12 Education (GK-12) program, and in the Interagency Education Research Initiative (IERI).

Priority activities for reallocated funding are as follows.

- An increase in support for curriculum development projects will respond to strong interest from universities and use this strategy to improve curriculum and attract students to IT programs in colleges and universities.
- CISE support for the ADVANCE program to promote opportunities for women to develop careers in computer science and engineering research will be funded at $2.39 million. Increases in stipends for IGERT, and other graduate fellowships will attract more US students to graduate study.

To better align programs with the focus of divisions, CISE has transferred a research program, Next Generation Software, with annual funding of $7.50 million to the ACIR division. The program funds research on improving high performance computing, and this management transfer will improve its overall effectiveness and coordination. Only some of the successes resulting from prior EIA funding include:

- Mark Kimmel of Rice University with NSF support is developing an innovative new curriculum in computational biology. His project will develop and disseminate curriculum for a new course based on recent multi-disciplinary research. Graduates will be prepared to work on leading research problems and able to apply bio-informatics to a wide range of problems.
- Supporting NSF's Tools goal, Christopher Kitts and Garrett Okamoto of Santa Clara University have developed a comprehensive mission control architecture enabling globally distributed researchers to monitor/control tele-robotic science missions and to verify/validate advanced command and control technology. Users can remotely monitor and control satellites or robots. This project is oriented to developing a shared resource and has already engaged 20 collaborators; demonstration projects to control satellites and undersea robots have been successful.
- The Digital Government program supports Alan MacEachren and Cynthia Brewer at the Pennsylvania State University in developing a new approach to exploratory data analysis. Working with the National Cancer Institute and the National Center for Health Statistics they have developed the ColorBrewer tool and demonstrated applications visualizing disease incidence. An outreach project to K-12 students is encouraging students to deepen understanding of maps and statistical information.



Tools – ColorBrewer is an online tool designed to help people select good color schemes for maps and other graphics.

ADVANCED COMPUTATIONAL INFRASTRUCTURE AND RESEARCH $92,560,000

The FY 2004 Request for the Advanced Computational Infrastructure and Research (ACIR) Subactivity is $92.56 million, an increase of $7.14 million, or 8.4 percent, over the FY 2003 Request of $85.42 million.

Advanced Computational Infrastructure and Research Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Advanced Computational Infrastructure	80.14	78.49	78.19	-0.30	-0.4%
Advanced Computational Research	6.61	6.93	14.37	7.44	107.4%
Total, ACIR	$86.76	$85.42	$92.56	$7.14	8.4%

Totals may not add due to rounding.

The ACIR Subactivity provides access to, and support for, high-end computing for the national scientific community, and research on the development, use, and applications of these computing systems.

Within the Advanced Computational Infrastructure (ACI) line item, the Partnerships for Advanced Computational Infrastructure (PACI) program in FY 2004 will be supported at $76.49 million, an increase of $5.0 million over the FY 2003 Request of $71.49 million. The Advisory Committee for Cyberinfrastructure is currently evaluating the PACI program and will make recommendations for its future in the context of broader cyberinfrastructure planning. ACI also provides operations support for the recently established Terascale Computing Facilities funded in the MREFC Account.

PACI consists of two partnerships, each consisting of a leading edge site and a number of partners. More than 60 geographically distributed partner institutions from 27 states and the District of Columbia are associated with PACI. The leading edge sites maintain a variety of high-end computer systems and together with their partners, develop, apply, and test software, tools, and algorithms to further the growth of a set of interconnected resources. These resources consist of advanced visualization and data handling capabilities linked with high-end computing capabilities.

PACI activities include the following.

- Access - making available a diverse set of advanced and mid-range compute engines, data storage systems, and experimental machine architectures.
- Enabling Technologies - developing parallel software and computation tools to enable effective exploitation of the partnerships' widely distributed, architecturally diverse, machines and data sources.
- Application Technologies - developing and optimizing discipline-specific codes and software infrastructures, making these broadly available to researchers.
- Education, Outreach, and Training - ensuring awareness and understanding of how to use high-end computing and communications resources, and broadening participation in advanced computational science and engineering.

Advanced Computational Research (ACR) complements PACI activities through single-investigator or small-group research grants to advance the state of the art in high-performance computation. It has three

principal technical thrusts: visualization, data handling, and parallel numerical algorithms. In FY 2004, funding support totals $14.37 million, an increase of $7.44 million over the FY 2003 Request of $6.93 million.

ACIR-funded advances include Globus and Legion, two middleware components that play an increasing role in building computational, information, and access grids. Grids are connected resources that enable researchers to access the best resources over networks without complex human brokering for those resources or requiring users to adapt data or software to unfamiliar computing environments. Researchers working with these grids are developing methods for security and privacy, distributed storage, grid measurement, and other techniques to enable seamless and efficient access to resources.

An example of what the PACI program enables is illustrated by the computational support it provides for research funded across NSF's other programs. The National Virtual Observatory (NVO), whose research is funded by the Information Technology Research program, is headed by astronomer Alex Szalay of Johns Hopkins University and computer scientist Paul Messina of Caltech. They plan to unite the astronomical databases of many earthbound and orbital observatories, taking advantage of the latest computer technology and data storage and analysis techniques. The goal is to maximize the potential for new scientific insights from the data by making them available in an accessible, seamlessly unified form to professional researchers, amateur astronomers, and students.

ADVANCED NETWORKING INFRASTRUCTURE AND RESEARCH $67,650,000

The FY 2004 Request for the Advanced Networking Infrastructure and Research (ANIR) Subactivity is $67.65 million, a decrease of $260,000, or 0.4 percent, below the FY 2003 Request of $67.91 million.

Advanced Networking Infrastructure and Research Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Advanced Networking Infrastructure	47.97	46.62	46.42	-0.20	-0.4%
Advanced Networking Research	21.80	21.29	21.23	-0.06	-0.3%
Total, ANIR	$69.77	$67.91	$67.65	-$0.26	-0.4%

Totals may not add due to rounding.

The ANIR Subactivity supports the research and development of high performance networking for the nation's science and engineering community, as well as fundamental research on networking and network interoperability and scaling in distributed information systems. ANIR also supports extensive collaborative development of national and international networks with other agencies and other countries. This is essential to the development of future generations of networks that will enable new applications such as nationwide and worldwide scientific collaboration, distributed high performance computation, and large scale distributed multimedia networked knowledge repositories. Distance education, digital libraries, and e-commerce activities are a few of the rapidly expanding applications enabled by the underlying network research and development that this Subactivity supports.

The FY 2004 Request for Advanced Network Infrastructure (ANI) is $46.42 million, a decrease of $200,000 from the FY 2003 Request of $46.62 million. ANI investments have changed the way that research is conducted in many areas of science and engineering by enabling almost instantaneous communications among researchers and educators worldwide. The very High-Speed Network Service (vBNS), together with the high performance connections program, has led to the development of a new level of networking for the nation's research universities. This work has gained additional momentum through important developments in the university-led Internet2 community. A critical mass of connected sites and research activities is now in position to exploit these important resources.

In FY 2004, ANI will emphasize testbeds for networking research and near term deployment. The research testbeds will provide realistic scale settings to for researchers to explore transformative new ideas in networking. Near term activities will work closely with applications to support knowledge transfer of promising technologies into the working high performance networks. ANI will also continue the High Performance Network Connectivity (HPNC) program begun in 2001 that extends connectivity to additional members of the research and education community; develop middleware used to build high performance network applications under a new program in Middleware (MWIR) begun in 2001; and continue research in new directions in access network technology through its Strategic Technology for the Internet (STI) program to extend the reach of high performance network environments.

FY 2004 funding for Advanced Networking Research (ANR) is $21.23 million, a decrease of $60,000 from the FY 2003 Request. The focus will be to continue the fundamental research necessary to enable the continued expansion of the capabilities of communications networks. Underlying goals of network research are handling greater volumes of information and increased numbers of users, more complex protocols, greater diversity of service types, and greater flexibility of use in mobile and fixed

environments. Areas for increased support are network security, wireless network access with improved data rates and improved interoperability with fixed networks; very high performance access networks including optical networks; and improved network architectures, protocols, monitoring, and management tools. Multidisciplinary small group projects bridging traditional disciplinary boundaries will continue to receive greater emphasis. Experimental aspects will be emphasized in small projects.

Examples of outcomes from ANIR support include:

- Panos Crysanthis and Vicenzo Loberatore, of the University of Pittsburgh and Case Western Reserve University, are developing open source middleware and grid services software that will be enablers for distributed science and engineering applications that rely on networking and high performance computation. Users include NSF's Grid Physics Network, the International Virtual Data Grid Laboratory, the Particle Physics Grid, the Network for Earthquake Engineering Simulation and many others. The software was downloaded over 3,900 times in the first 9 months after becoming available.
- Jeffrey Cole of the UCLA Center for Communication Policy is supported for research on the effects of the Internet. Recent findings show that the Digital Divide is closing – the most rapid growth in users of the Internet is among people of lower income and education levels; that people who are active online are more social than average and feel more empowered politically; and that children are the age group most likely to make new friends online and to reveal details about themselves. These findings help us understand the changes underway and inform policy.

INFORMATION TECHNOLOGY RESEARCH $218,110,000

The FY 2004 Request for the Information Technology Research (ITR) Subactivity is $218.11 million, an increase of $27.44 million, or 14.4 percent, over the FY 2003 Request of $190.67 million.

Information Technology Research Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Information Technology Research	174.01	190.67	218.11	27.44	14.4%
Total, ITR	$174.01	$190.67	$218.11	$27.44	14.4%

Advances in computing and communications theory and practice and their implementation have made information technologies a transcendent agent of change. A cyber future is emerging, whose details are amorphous and unpredictable, but it is certain to impact individuals through its effects on such diverse areas as science and engineering research, education, commerce, health, and national security. Fundamental research in computer science and engineering is critical to laying the basis for advances and to utilizing the increasing power of computing and communications technologies.

As part of the Foundation's ITR priority area, $218.11 million is requested for FY 2004.

- Funding for large-scale networking will total $24.79 million for efforts that include ubiquitous connectivity, wireless networks, and advanced networked applications.
- High end computing at $19.94 million will support projects that include scaling systems to hundreds of thousands of processors and software to fully utilize the computing power, in addition to new architectures such as those based on bio-molecules or quantum principles.
- Support for high end computation and infrastructure efforts will total $30.39 million and provide research in integrated computing, storage systems, connections to high-data volume instruments, and visualization facilities.
- High confidence software and systems, funded at $27.90 million, reflecting an increase for cybersecurity of $10.0 million over the FY 2003 Request, will address the theory and technology of building safe and secure, complex embedded and autonomous systems and measurement of risk and performance assurance.
- Human-computer interaction and information management, funded at $48.12 million, will support technology for successful aging; universal access to expand the sensory and manipulation capabilities of all people; and new uses of computing and communications technology in the social sciences, humanities, and the arts.
- Software design and productivity, funded at $29.04 million, will focus on the creation of a new generation of information systems to support research and education.
- The social, economic and workforce implications of IT and IT workforce development efforts, funded at $37.93 million, will support research on technologies for assisting teaching, learning, collaboration, and creating educational environments to expand the pipeline for students and professionals in IT careers.

Research to enable cyberinfrastructure. This area will support research for creating a new generation of information systems to support research and education. The next transformations of the information revolution will integrate content sources, storage, and new modes for humans to access information with computing and communications. Scientific research is moving to large, shared instruments; to wide-area sensing and observing; and to shared data resources. These changes are creating massive amounts of data

that will require new methods for storage, search, and access; new techniques for distribution and sharing in the scientific community; and new tools for analyzing and presenting data and analysis. CyberInfrastructure research will build on many CISE research efforts to catalyze the next transformation of information systems including Grid Computing, Digital Libraries, Virtual Reality / Telepresence, and High Performance Networking and Middleware Applications.

The Terascale Computing Systems, formerly requested through the Major Research Equipment and Facilities Construction Account, will provide advanced computing capabilities for the most demanding scientific and engineering applications. This facility, in cooperation with the PACI centers and Advanced Networking Infrastructure, will provide computing and communications facilities for many of the application and research needs. Research awards will support novel databases and networking tools that enable broader communities of users to build state-of-the-art, distributed collaboratories, and other needs. CISE funding for operations totals $7.0 million in FY 2004, equal to the FY 2003 Request.

Within ITR, IT education and workforce activities will also be supported. IT has emerged as a delivery vehicle for education at all levels – from traditional school settings to workforce education – helping to maintain and improve skills. Education in IT itself addresses the shortage of skilled workers and the rapidly changing needs in this area. This effort will reach broader segments through programs collaborating with K-12 and improvement in curriculum for IT at the college level. Underrepresentation of minorities and women in the IT education and career paths will be addressed by research on the underlying causes of this phenomenon.

ITR also supports research on the social impacts of information technology. This is deepening our understanding of how computing and the Internet are changing society, as well as developing new knowledge about the factors that determine the acceptance and success of IT innovations.

Representative outcomes of ITR include:

- William Seales and colleagues at the University of Kentucky are conducting research to create high resolution displays at low cost. Combining multiple low resolution projectors and cameras to observe the project images, they can compute overlap and light levels. An observer 2 meters from the screen sees perfect registration of high resolution images. These techniques will enable low cost data displays that could be deployed widely in research and education.
- Nancy Leveson at MIT directs a center level activity on Safety-Critical Embedded Software. The project supports theoretical and experimental research as well as application to practical methodologies; a safety driven, human-centered specification together with modeling and formal analysis is being experimentally applied to air-traffic collision detection and conflict detection.

CYBERINFRASTRUCTURE $20,000,000

The FY 2004 Request for the Cyberinfrastructure Subactivity is $20.0 million.

Cyberinfrastructure Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Cyberinfrastructure	-	-	20.00	N/A	N/A
Total, Cyberinfrastructure	$0.00	$0.00	$20.00	N/A	NA

Focus on cyberinfrastructure will begin in FY 2004 with requested funding of $20.0 million. This new investment enhances base funding related to cyberinfrastructure of about $124.0 million. Cyberinfrastructure will link computational and data resources (building on experience being gained with Terascale efforts) with sensors and instruments, advanced software and middleware to enable distributed systems and analysis, and visualization resources and facilities to promote understanding of science and engineering applications. The promise and demand for cyberinfrastructure has been articulated in a draft NSB report on "*Science and Engineering Infrastructure for the 21st Century: the Role of the National Science Foundation*." (NSB-02-190). CISE's Advisory Committee on Cyberinfrastructure will also release a report. Both reports will concur that the needs and opportunities are great at this time, due to rapidly increasing volumes of data generated by scientific instruments and sensors, the increasing capability (with decreasing costs) of computing, networking and sensors, and the demonstration in all fields of the potential for revolutionizing science and engineering.

Cyberinfrastructure will transform the existing S&E infrastructure of high-performance computers and networks by integrating these resources with sensors, data resources, and new analysis and visualization capabilities. These resources will enable new types and depths of research using massive data resources, supporting deeper detail for computational analysis and opening new frontiers for analysis and understanding. Funding will allow for 3 to 5 large projects to introduce these new capabilities to support a greater range of science and engineering and will also allow additional components addressing connectivity to campus research laboratories along with visualization facilities.