Interagency Working Group on Information Technology Research & Development

National Science and Technology Council

Networking and Information Technology Research and Development

Supplement to the President's Budget for FY 2002

About the National Science and Technology Council

The National Science and Technology Council (NSTC) was established by Executive Order on November 23, 1993. This Cabinet-level council is the principal means for the President to coordinate science, space, and technology policies across the Federal government. NSTC acts as a "virtual agency" for science and technology to coordinate the diverse parts of the Federal research and development enterprise. The NSTC is chaired by the President. Membership consists of the Vice President, Assistant to the President for Science and Technology, Cabinet Secretaries, agency heads with significant science and technology responsibilities, and other White House officials.

To obtain additional information regarding the NSTC, please contact the NSTC Executive Secretariat at (202) 456-6100. The NSTC Web site is: www.nstc.gov.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on all questions in which science and technology are important elements; articulating the President's science and technology policies and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academe. The Assistant to the President for Science and Technology serves as the Director of the OSTP and directs the NSTC on behalf of the President.

For additional information about OSTP, please call (202) 456-7116. The OSTP Web site is: www.ostp.gov.

Cover Design

This year's cover, depicting the broad scope of Federal networking and information technology research and development activities, was designed by National Science Foundation (NSF) designer-illustrator James J. Caras.

The circular graph inset on the front cover is a computer-generated macroscopic snapshot of global Internet connectivity; it was created from real-time data collected in October 2000. This graph, reflecting more than 600,000 IP addresses and more than one million links, shows that North America has by far the world's greatest number of direct connections (shown as criss-crossing lines) between autonomous systems, or Internet service providers. The data for the graph were generated by Skitter, an Internet measurement tool developed by the Cooperative Association for Internet Data Analysis (CAIDA) with support from DARPA and NSF. Image courtesy of CAIDA.

The graphic on the back cover depicts NSF's very high performance Backbone Network Service (vBNS), which provides advanced connectivity enabling research universities to link to the Nation's high-speed networks and academic supercomputing facilities. The image is a screen shot of a 3-D graphic generated by Cichlid, interactive software for 3-D visualization of distributed data developed by Jeff Brown of the network measurement and analysis group at the National Laboratory for Applied Network Research (NLANR) with NSF funding. Cichlid users can view, explore, and interact with high-quality data sets in distributed locations as the information changes in real time and can specify various visualization formats.

NETWORKING
AND INFORMATION TECHNOLOGY
RESEARCH AND DEVELOPMENT

SUPPLEMENT
TO THE PRESIDENT'S BUDGET
FOR FY 2002

A Report by the Interagency Working Group
on Information Technology Research and Development

National Science and Technology Council

JULY 2001

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

July 5, 2001

MEMBERS OF CONGRESS:

I am pleased to forward with this letter *Networking and Information Technology Research and Development*, an annual report prepared by the Interagency Working Group on Information Technology Research and Development of the National Science and Technology Council. This report supplements the President's FY 2002 Budget for Information Technology Research and Development (IT R&D). It also highlights IT R&D activities and the future challenges that face the Federal agencies that collaborate in the Administration's Networking and Information Technology Research and Development (NITRD) multiagency program.

Today more than ever, information technology provides the infrastructure and advanced capabilities needed to strengthen the Nation's economic competitiveness and to meet vital national objectives. These objectives include such critical areas as maintaining a strong national defense; enabling bold new advances in science and engineering, biomedical research, and aerospace design; identifying new paradigms for computing and networking devices; and responding to societal challenges in transportation, crisis response and management, and workforce education and training. As a society, we have come to expect and rely upon secure, failure-resistant and high-performance digital infrastructure in our personal lives, in our businesses, and in our efforts to develop new opportunities for the future. A main component of this accelerated development and rapid diffusion of information technology throughout the fabric of the American endeavor is the ongoing Federal investment in fundamental IT R&D conducted in universities, in Federal research facilities, and in diverse partnerships with private firms and nonprofit organizations.

The Administration looks forward to working with Congress in support of this Federal program in advanced networking and computing research and development that forms the foundation for a critical 21st century American resource.

Sincerely,

Rosina Bierbaum
Acting Director

Table of Contents

INTRODUCTION

The New American Infrastructure

Overview

Today, at the beginning of a new millennium, networking and information technologies are transforming our world, generating unprecedented American prosperity, and building revolutionary new infrastructures for commerce, communication, human development, national security, and scientific research. In this remarkable period of transformation, the United States stands preeminent as the world's information technology pioneer, research leader, and foremost developer and deployer of cutting-edge computing, high-speed telecommunications, and information technology (IT) systems.

Like the road, railway, electrical, and telephone systems fostered by Federal investment in earlier eras, networking and IT form the new infrastructure for national development – an infrastructure more powerful, complex, multidimensional, and far-reaching than any of its predecessors. In the national defense and national security arenas alone, computing and networking technologies underpin every advanced U.S. capability.

"When historians look back a decade or so hence," Federal Reserve Board Chairman Alan Greenspan said in a March 6, 2000, address on the New Economy, "I suspect they will conclude we are now living through a pivotal period in American economic history. ... It is the growing use of information technology throughout the economy that makes the current period unique."

National goals of networking and information technology R&D

The New Economy arose from the Nation's immense industrial and entrepreneurial enterprise. But it was Federal investment in fundamental, long-term networking and IT research and development (R&D) that launched the digital revolution, and that investment continues to play a critical role in generating the technological breakthroughs the country needs to meet vital national objectives and achieve the full promise of information technology in such public benefits as:

- Immediate on-site medical care, in the home and at remote locations
- Reliable, failure-resistant systems for such mission-critical applications as air-traffic control, defense, financial transactions, life support, and power supply
- Reduction of battlefield risk for military personnel

- Industrial process and product modeling, visualization, and analytical capabilities, such as in aircraft design and production, automotive efficiency and safety, and molecular synthesis of new drugs
- Expanded e-commerce with assured security and privacy of information
- On-demand universal access to education and knowledge resources
- Advanced computing capabilities that underpin the Nation's leadership in science and technology, including the biotechnology revolution, and the success of critical civilian and national security missions of the Federal government
- More accurate weather forecasting and improved environmental analysis and decision making
- High-performance networking and information systems for emergency and disaster management
- Access to information anytime, anywhere, with any device

Returns on Federal IT investment

As the President's Information Technology Advisory Committee (PITAC) noted in its 1999 report on the status of U.S. information technology research, bipartisan support of Federal investment in fundamental networking and information technology R&D over the last several decades has produced "spectacular" returns for the economy and for society generally.

Catalyst for economic growth

The U.S. House of Representatives reached a similar conclusion in its findings on the Networking and Information Technology Research and Development Act (H.R. 2086), which the House passed in 2000, saying: "Information technology is recognized as a catalyst for economic growth and prosperity. ... Fundamental research in information technology has enabled the information revolution."

Technical innovation for improved living standards

Senate findings on the Federal Research Investment Act (S. 2046), passed by the Senate in 2000, concluded that "technical innovation is the principal driving force behind the long-term economic growth and increased standards of living of the world's modern industrial societies. ... Research and development across all Federal agencies have been effective in creating technology that enhances the American quality of life."

Skilled researchers and technical workers

Both pieces of legislation also noted the unique role of Federal research investment in training the bulk of the Nation's scientists, engineers, educators, and technical workers, with the Senate bill noting that Federal research support creates "more than simply world-class research – it creates world-class researchers." "Fundamental research in information technology has contributed to the creation of new industries and new, high-paying jobs," said the House bill. "Scientific and engineering research and the availability of a skilled workforce are critical to continued economic growth driven by information technology."

Global stakes in IT R&D

The global stakes for the U.S. in maintaining preeminence in IT R&D are high. In the past, the benefits of any single area of scientific research might be limited in scope – enabling, for example, development of one weapon or treatment for one disease. But information technology is by its nature pervasive, providing tools, systems, and capabilities that daily touch hundreds of millions of citizens as well as operate the Nation's most critical defense and civilian infrastructures. The balanced, diversified portfolio of Networking and Information Technology R&D (NITRD) activities not only advances vital Federal missions but helps the Government sustain economic growth and competitiveness and support overarching public goals in education, environmental management, health care, law enforcement, productivity, scientific research, transportation safety, and other national priority areas.

About the multiagency research program

NITRD is the collaborative research framework of the government agencies whose critical missions require advanced information technology R&D. The multiagency research effort is the successor of the High Performance Computing and Communications Program established by Congress in 1991.The NITRD agencies have built a 10-year record of highly successful coordinated and collaborative accomplishments in multiagency projects and in partnerships with industrial and academic researchers. The multiagency approach leverages the expertise and perspectives of scientists and technology users from agencies, Federal laboratories, universities, and corporations who are working on a broad range of IT research questions across the spectrum of human uses of information technology.

Participating agencies

The NITRD agencies are: Agency for Healthcare Research and Quality (AHRQ), Defense Advanced Research Projects Agency (DARPA), Department of Energy (DOE) National Nuclear Security Administration (NNSA), DOE Office of Science, Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH), National Institute of Standards and Technology (NIST), National Oceanographic and Atmospheric Administration (NOAA), National Security Agency (NSA), National Science Foundation (NSF), and Office of the Deputy Under Secretary of Defense for Science and Technology (ODUSD [S&T]).

Program Component Areas (PCAs)

The major research emphases of the NITRD effort are reflected in Program Component Areas (PCAs), which are led by Coordinating Groups of program managers from participating agencies. These groups confer regularly to coordinate the objectives and activities of the multiagency projects in their specialized research areas.The PCAs are:

- High End Computing (HEC), which includes both HEC R&D and HEC Infrastructure & Applications (I&A)
- Human Computer Interaction & Information Management (HCI&IM)

- Large Scale Networking (LSN)
- Software Design and Productivity (SDP)
- High Confidence Software and Systems (HCSS)
- Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW)

In addition to the PCAs, the Federal Information Services and Applications Council (FISAC) is chartered to facilitate partnerships between the Federal IT R&D and non-R&D communities to promote early application of advanced computing, information, and communications technologies within the Federal government.

Interagency Working Group on IT R&D

NITRD activities are coordinated by the Interagency Working Group (IWG) on IT R&D, made up of representatives from the participating agencies.The work of the IWG and its PCA Coordinating Groups is supported by the National Coordination Office (NCO) for IT R&D.

Program funding

Funding for agency NITRD activities is implemented through standard budgeting and appropriations processes that involve the participating agencies and departments, the Office of Management and Budget, and the Congress. Some activities are funded and managed by individual agencies. Others involve multiagency collaboration, with mutual planning and mutual defense of budgets. For some highly complex, mission-critical R&D efforts, such as the HEC R&D program, agencies create integrated programs and budgets and detailed management plans.

About this Supplement to the President's FY 2002 Budget

"Networking and Information Technology Research and Development" is a Supplement to the President's FY 2002 Budget that describes the Federal NITRD activities. As required under the High-Performance Computing Act of 1991, the Supplement covers current work and planned directions for FY 2002. FY 2001 budget estimates and FY 2002 requests for the multiagency program, by PCA and by agency, are shown on pages 34-35.

This year's Supplement is organized around key research challenges that must be overcome to ensure continuing U.S. leadership in advanced computing and networking and in all the defense and non-defense sectors that increasingly rely on these capabilities. The Supplement also describes some of the significant national applications of IT that can have a transforming impact on critical infrastructures nationwide, to the benefit of all citizens. The Nation's ability to deploy these powerful emerging applications will depend, however, on many successful results of the fundamental research in component technologies outlined in this report.

Information on the Web

Copies of NCO publications, including this report, and links to participating agency and related Web sites can be found at:

http://www.itrd.gov/

THE RESEARCH AGENDA

Why the Nation Needs Fundamental Networking and IT R&D

Information technology's promise

No longer just a provider of tools for the sciences and engineering, information technology today is the uniquely interdisciplinary field at the core of American innovation in every sector, from national defense to industrial production.

IT begins with fundamental research in science and engineering and stretches across the applied scientific and engineering knowledge it takes to design, construct, and maintain computing and telecommunications equipment. IT encompasses the mathematics and computer science expertise that goes into writing the complex sets of instructions – the software – that enable digital devices to do what people want them to do. IT also engages the thinking and imagination of scholars, students, government and business officials, and other computer users in virtually every field who help figure out how to harness computing and communications capabilities to human needs, interests, and aspirations. All these scientific and technical skills and knowledge bases working together produce the complex digital systems that we have come to depend on in our day-to-day lives.

Whether we are aware of it or not, we are surrounded by the results of this multidisciplinary R&D activity, in such applications as precision instrumentation and visualization capabilities for medical diagnosis and treatment; inventory-management systems for agile, just-in-time manufacturing; the Mars rover and astronomical images from the far reaches of the universe; monitoring and management of large-scale financial systems; standardized transmission protocols for electronic mail and audio, video, and sound files; international air-traffic communication and control systems; and weather forecasts based on collection and analysis of data from real-time observations of wind, water, and other environmental systems.

Federal role in the IT revolution

Many of the most visible and influential of today's computing and networking capabilities originated in Federally funded research conducted to support key missions of Federal agencies. For a sampling of the Federally sponsored R&D that has fueled the Information Age and dynamic business opportunities throughout the private sector, see pages 6-7.

Long-range research, interdisciplinary scope

These Federal research projects explored core technical problems that had to be solved to advance the capabilities of computing systems, networks, and information systems generally. The projects were not designed to result in commercial products within six months. They achieved results over years of experimentation and revisions that spread across the research community, enabling many scientists to join in the problem solving. It is this ongoing foundational research process that has generated scientific, technical, and engineering breakthroughs that benefit us all.

Technology transfer

Because the coordination of Federal IT research investments across many agencies and private-sector partnerships leverages the mission-related research, producing general-purpose, broadly useful, and interoperable technologies, tools, and applications, NITRD has been a powerful engine of technology transfer. This is a direct result of its focus on widely applicable solutions to basic IT problems and its mechanisms of supporting R&D in universities, research institutions, and collaborative partnerships with industry. The large number of Federally funded breakthroughs subsequently commercialized in the private sector – often by graduates of U.S. research universities whose education was supported by NITRD funding – leverage the Federal investments even further.

Addressing challenges in the national interest

NITRD agencies address the most significant scientific and technical challenges standing between today's networking and computing capabilities and the affordable advanced technologies and tools that both the Federal

These Results of Federally Funded IT Research ...

Computing systems

- The first operational, electronic stored-program computer, the Standards Eastern Automatic Computer (SEAC), was developed for the U.S. Air Force by the predecessor of NIST; a similar machine, the Standards Western Automatic Computer (SWAC), built by the agency the same year for the U.S. Navy, was the fastest in the world at the time.
- Reduced instruction set computing (RISC) technology, the basis for many of today's fastest microprocessors, was advanced by DARPA-funded research in the 1970s and early 1980s.
- Parallel computing concepts explored by Federally supported researchers for two decades laid the groundwork for the development of commercial high-end computing platforms in the late 1980s and 1990s.

Networking

- The Internet grew out of ARPANET, the network invented by DARPA-funded researchers in the 1960s.
- High-speed optical networks. Federal networking research has produced the world's first prototype optical networks with end-to-end transmission speeds and carrying capacities a thousand times those of the current Internet. With $276 million in funding over three years, this research has stimulated development of new private-sector companies with a combined value in the tens of billions of dollars.

Human-computer interaction

- The mouse and the graphical user interface (GUI), now standard to desktop computers, government and the Nation need to sustain U.S. world leadership in such vital areas as:

- National defense and national security
- Science and engineering
- Biomedical research
- Health care
- High-speed networking (wireless as well as wired)
- Industrial modeling and pharmaceutical design
- Aerospace engineering and air-traffic control
- Reliable, secure, failure-resistant computing and networking systems for national security as well as for communications, finance, health care, industrial development, and e-commerce
- Standards, measures, and testing to assure worldwide IT interoperability across multiple frames and applications

The sections that begin on page 8 describe 10 major research challenges that the Federal NITRD agencies plan to work on in FY 2002.

... Fueled the Information Technology Revolution

stem from DARPA-funded research in the late 1960s.

- The first graphical Web "browser" was developed by university-based researchers supported by NSF; Web search engines grew out of initial research investments by DARPA and NSF.
- Java, the programming language that supports interoperability across networks, is based on concepts first explored by Federally funded researchers.
- Speech and spoken dialogue technologies funded over decades by DARPA have led to new customer call center concepts and more efficient service for industry worldwide.

Information management

- The world's first and largest public medical database, integrating research findings and medical-journal citations, was developed and is managed by NIH's National Library of Medicine.
- Relational databases – the industrial-strength software systems needed to store and manage large quantities of information, such as financial records, census data, and business inventories – were pioneered by university researchers funded by NSF in the 1970s.
- Machine learning research, sponsored by DOE and NSF, was employed in decoding the human genome and also spawned the data-mining industry.
- Numerical linear algebra libraries research sponsored by DOE, DARPA, NIST, and a number of other Federal agencies has produced high-performance libraries of numerical linear algebra software that are used by thousands of researchers worldwide. These libraries have become a critical part of the world's scientific computing infrastructure.

CHALLENGE #1

Next-Generation Computing and Data Storage Technologies

Graphic by Janet Ward of NOAA's High Performance Computing and Communications Program

Representative FY 2002 agency activities

NSF: Support for acquisition and development of equipment, instrumentation, and distributed systems for advanced research in engineering and the sciences, including the terascale computing platform at the Pittsburgh Supercomputing Center; new device and system architectures, technologies, and tools to assemble nano-size components into functional IT structures

DARPA: Prototype data-intensive systems and software; processor in memory for rapid data access; morphable computing micro-architectures

NASA: Extend base of Beowulf clusters of sovereign workstations to achieve high- performance computing; research to extend the capability of single-image supercomputing systems

Critical Federal missions and industry needs both call for new scientific and technical paradigms that significantly raise high-end computational speeds, provide adaptable and reconfigurable computing environments, and reduce the size, cost, and power requirements of high-performance computing and data storage equipment.

For example, the world's fastest computing platform today is DOE/NNSA's "Option White" system at the Lawrence Livermore National Laboratory. A massively parallel system made up of 512 IBM multiprocessor nodes, it requires 13,000 square feet of floor space and more than 3.2 megawatts of electricity for power, cooling, and mechanical equipment. Option White is capable of 12.3 teraops (trillions of operations per second) in processing speed. But even such a system is not adequate for the massive computational requirements of the most complex scientific problems, whose solutions are critical to the missions of many Federal agencies as well as to the Nation.

At the same time, the Nation's high-end computing sector – the companies that produce computing platforms much faster than the standard desktop computer – is a shrinking fraction of the U.S. marketplace. Business purchasers of high-end machines prefer mid-range machines that are less costly and physically demanding. As a result, the technical challenges of developing technologies that break through today's upper-end barriers in computing speed, storage capacity, and equipment are left orphaned. Federal R&D bridges the gap between the products available commercially and the requirements of critical government missions, to sustain U.S. capabilities at the highest levels of computational performance.

Currently, the Government supports several dozen high-end computing platforms at academic computing centers and national laboratories, along with a number of mid-range machines, that are used by both academic and Federal researchers. But these are not nearly enough to support the high-end research and applications needs of university-based and government scientists. Nor do they offer a viable model for scaling up to the processing speeds and storage capacity that future advanced applications will demand. Today's Option White platform, for example, has 160 terabytes of storage space spread over 7,000 disk drives. This amount of storage space can hold about six times the contents of the entire Library of Congress, but it is only

NIH: Planning for evolution to new architectures and algorithms for advanced biomedical computation

DOE Office of Science: Extend MVICH system of high-performance communications for cluster computing at the National Energy Research Supercomputer Center; develop enabling technology centers for libraries of high-performance software components for science applications and critical computer science and software issues in terascale computing systems

NSA: Discovery and application of methods to achieve orders of magnitude improvement in the computational capability needed to derive intelligence from mathematical and signal-processing problems. Exploration includes advanced microscopy, micro spray cooling, optoelectronic circuits, and optical tape

NIST: Prototype software library of mathematical functions based on client-server transactions for computational problems such as solving linear systems and eigenvalue problems

NOAA: Innovative technologies and tools for advanced scalable computation on highly parallel computing systems to provide greater computing power at substantially lower cost

ODUSD (S&T): Support for universities' acquisition of equipment for defense-related research in high-end hardware, software, and applications

a small fraction of the scientific data that future research will call for.

Finding cost-effective solutions requires fundamental cross-disciplinary research in disciplines such as physics, chemistry, materials science, and electrical engineering, as well as innovations in computer science and applied mathematics. Next-generation supercomputing architectures, systems software, and middleware must also address interoperability needs of both Federal agencies and the private sector. These technological breakthroughs will also aid U.S. competitiveness.

In FY 2002, the NITRD agencies will proceed with research to increase the delivered performance of computing systems. The goal is to produce, by the end of this decade, systems that are capable of 1,000 times or more the speeds of today's fastest systems, while reducing cost, energy consumption, and footprint, and to develop interoperable systems software and tools that will:

- Improve sustained application performance, ease of use, manageability, and high-speed network connectivity of teraops-scale systems
- Be scalable (expandable) to petaops-scale systems (petaops systems perform a thousand trillion calculations per second)
- Provide a unifying environment for high-end scientific computing

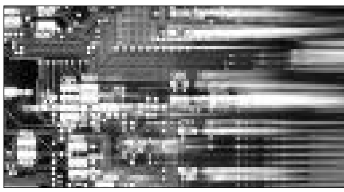
The demand for substantial increases in computing capability, to a level many thousands of times beyond today's systems, will continue to grow in the years ahead. These increases cannot be attained solely by isolated enhancements in hardware or software, no matter how dramatic such individual improvements may be. The architecture of future supercomputers must consist of components carefully developed, assembled, and tuned, and must be matched by an application development process that allows close integration with the system architecture. This ubiquitous close integration will require substantial breakthroughs in every area of high-end computing research.

Long-Term Research Needs

- Advanced computing concepts (including nonconventional architectures, components, and algorithms)
- Systems software technologies (including operating systems, programming languages, compilers, memory hierarchies, input/output, and performance tools)
- Systems architectures that integrate device and component technologies, systems software, and programming environments (including device technologies, node functionalities, configuration, software for managing highly parallel computations, and hierarchical programming), and network connectivity
- Software component technologies for high performance computing

CHALLENGE #2

Surmounting the Silicon CMOS Barrier



The complementary metal oxide semiconductor (CMOS) chip, the two-dimensional miniature electronic map on a silicon wafer that is the standard building block of computing systems, is fast approaching its physical limits. That is, the electronic signals that can be routed through its pathways are finite in quantity and speed. Even the complex technical amassing of chips that produced Option White demonstrates these limitations in the machine's enormous size and power requirements. The NITRD agencies are examining new materials and methods to create wholly new designs for processors in computing devices. Federal missions and private-sector IT innovation alike require both mid-term incremental improvements in computational speeds and long-term breakthroughs to radically new processor architectures capable of teraops and petaops speeds.

Representative FY 2002 agency activities

NSF: Continue exploring quantum phase data storage and retrieval; shared-memory multiprocessor design;nanoscale device and system architectures

DARPA/NSF: Investigate the use of DNA-like molecules to store and compute terabyte-scale problems

DARPA: Investigate very large-scale integration of photonics for intra- and inter-chip communication,including processor-in-memory arrays

In FY 2002, the agencies will support research at the theoretical and empirical intersection of biology, information science, and micro-electromechanical systems [Bio:Info:Micro]. Advances in photonics, nanotechnologies, sensors, actuators, optoelectronics, digital, analog, and mixed signal processing, and new fabrication technologies make it possible, for example, to conceive of integrated designs in 3-D on a chip with billions of transistors.This work focuses on designing new, modular hybrid architectures that include fault-tolerance, programmability (including novel approaches such as amorphous computing methods), and security features needed in embedded systems for defense.

A related research area is biological substrate computing, the potential in organic molecules – such as deoxyribonucleic acid (DNA), ribonucleic acid (RNA), and proteins – to provide vast storage and processing capacities. For example, one gram of DNA contains 10^{21} DNA bases, which is equal to 10^{8} terabytes of information storage. Breakthroughs in this area could result in:

- High-volume, content-addressable storage
- Solutions to computationally hard problems that are not now solvable
- Self-assembly of nanostructures using DNA/RNA tiling. The

nanostructures in turn could be used for nanoscience such as molectronics (described below)

Because the timing of revolutionary breakthroughs in all these fundamental investigations cannot be predicted, the NITRD agencies also continue to explore superconducting materials and related technologies that offer the potential to produce the substantial incremental improvements in processing speeds that will be needed in the near- and mid-term.

NSA: Continue research to demonstrate the feasibility of quantum computing devices and other high-performance, superconducting alternatives to current silicon and gallium arsenide technologies; architecture, configuration, and programming of "smart memory" chips

NIST: Research in quantum computing,secure quantum communication,photonics, nanotechnologies,optoelectronics, and new chip designs and fabrication techniques

ODUSD (S&T): University-based research in quantum communications and quantum memory

Long-Term Research Needs

Agencies will support long-range research to explore the potential of atomic phenomena – such as quanta of light or molecular nuclei – to serve as high-speed processing mechanisms. This area holds great promise as a future means of providing:

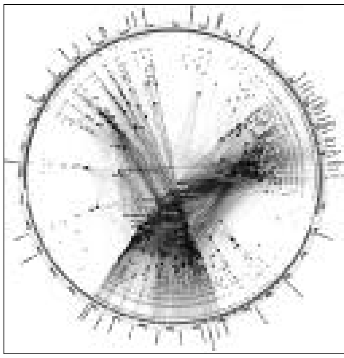
- Ultrasecure communications over optical backbone networks
- Orders of magnitude increases in the speed of algorithms such as for searching unsorted databases or factoring large numbers
- Quantum computers that can give detailed and faithful simulations of molecular processes and phenomena in physics

In addition, agencies will support research to attain long-term breakthroughs in computer design and fabrication.The potential results of these efforts include:

- Innovative computational structures, 3-D architectures, hybrid technologies
- Reconfigurable systems on a chip, adaptive and polymorphous computing
- Processor in memory (PIM) and other efforts to provide memory performance commensurate with processor performance
- New computational substrates:
    - Quantum computing
    - Biological substrate computing
    - "Smart fabric." Using technology for interweaving battery, fiberoptic cable, and metal connectors, scientists can produce fabric that can be embossed with enough processors to provide on-person processing on the order of tens of teraops (the size of today's larger supercomputers)
    - Molectronics: computation at the molecular scale, which holds the potential of providing extremely fast, high-density processing power for the next generation of strategic computing for the military

CHALLENGE #3

Versatile, Secure, Scalable Networks for the 21st Century



Graph of global Internet connectivity (see inside front cover for details). Image courtesy of CAIDA.

Representative FY 2002 agency activities

NSF: Network-centric middleware, high-performance connections,and strategic Internet technologies such as network monitoring, problem detection and resolution, automated advanced tools for active and intelligent networks, and innovative access methods such as wireless

DARPA: Active networks, adaptive, reflective middleware, and composable high-assurance trusted systems for highly secure distributed defense applications; network modeling and simulation

The Internet is at the heart of the IT revolution, and Federally sponsored networking research plays a pivotal role in generating the technological advances critical to the Net's growth and evolution. Though the focus of Federal work is exploration of technologies and tools to support critical agency missions, the Federal research emphases on long-range needs – including such vital emerging areas as smart, active networking, automated resource discovery, and online resource access – not surprisingly turn out to be the core research problems that must be solved to transition the Internet into a secure, reliable, expandable, very-high-speed knowledge and communications infrastructure for the Nation in the new century.

Smart, active networks, for example, will be aware of changing demands for network resources and able to adjust to meet those demands. Automated resource discovery technologies will enable such networks to "see" where network-intensive applications are running and supply the necessary bandwidth; likewise, large-scale applications will seek out the network resources they need. Active networks will also be able to adjust when wireless devices move from place to place.

Today a new generation of these and other enabling technologies is needed to "modernize" the Internet for rapidly growing traffic volumes, expanded e-commerce, and the advanced applications that will be possible only when next-generation networks are widely available. More than a third of a billion people worldwide – 6 percent of the global population – now use the Internet, including about 60 percent of all North Americans, according to recent Internet surveys. With the advent of connectivity for wireless devices and a predictable rise in users globally, the number of Internet nodes is expected to grow to a billion or more within a few years. An Internet of that scale will be vastly larger than architects of today's network protocols ever anticipated. Its operability presents many research unknowns since there is no way to prototype a network of that size.

With the goal of assuring the Internet's capacity for growth and improved capabilities, the NITRD agencies have developed an ambitious coordinated research program to:

NIH: Projects to develop telemedical applications using advanced network capabilities such as quality of service, data privacy and security, nomadic computing, and network management

NASA: Enable ubiquitous networking by developing interoperable heterogeneous access technologies including broadband wireless,mobile wireless, satellite, and landline

DOE Office of Science: Network technologies to enable high end-to-end performance for applications such as distributed visualization and petabyte-scale data transfers

NIST: Measurement technologies to support specification, standardization,and testing of protocols and software for agile networking infrastructures

NOAA: Early adoption of scalable network capabilities and applications in support of severe weather forecasting and warning,and hazardous materials response

- Understand how to extend, or scale up, the network infrastructure so that it is available anytime and anywhere, and so that it includes ubiquitous networking that extends the network to millions and potentially billions of new devices and chips embedded in larger devices such as appliances, automobiles, and transportation systems
- Provide needed network services, such as management, reliability, security, and high-speed transmission rates

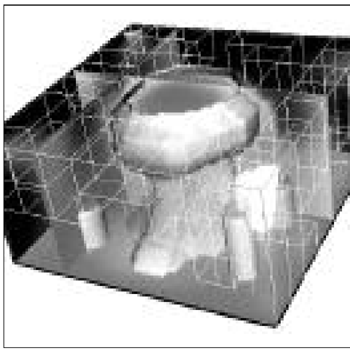
In FY 2002, research sponsored by the NITRD agencies will focus on middleware; access from the edges of the network (mobile wireless connectivity); environments with dense arrays of sensors (sensornets) and of embedded devices; trust, security, and privacy; and tools and infrastructure for collaboratories. The agencies are also developing an integrated plan that encompasses the long-range research it will take to realize the potential of 21st century networks.The following list suggests the R&D areas in which fundamental, not just incremental, advances are required before pervasive high speeds, security, flexible access, and reliability are standard features of the Nation's digital communications systems.

Long-Term Research Needs

- Fundamental network research, including:
  - Optical networking (flow, burst, and packet switching; access technologies; gigabit per second interfaces; protocol layering)
  - Network dynamics and simulation (automated management, automated resource recovery, network modeling)
  - Fault tolerance and autonomous management
  - Resource management (discovery and brokering, advance reservation, co-scheduling, policy-driven allocation mechanisms)
  - Wireless technologies (technical standards for discovery, co-existence, and configuration)
  - Increasing capability to support bandwidth requirements
  - Enhancing and scaling networks to improve robustness and handling of transient interactions among billions of devices and to maximize access from the edges of the network, such as methods for ubiquitous broadband access, tether-free networking, security and privacy, and network management
  - Understanding global-scale networks and information infrastructure (end-to-end performance, backbone structures, applications)
- Enabling new classes of applications (distributed data-intensive computing; collaboration; computational steering of scientific simulations; distance visualization; operation of remote instruments; large-scale, distributed systems)

CHALLENGE #4

Advanced IT To Sustain U.S. Strength in Science and Engineering



Large data-set visualization of combustion produced by volume-rendering software at DOE's Lawrence Berkeley National Laboratory

Representative FY 2002 agency activities

NSF: High-end applications promoting collaborative research and information sharing in astronomy, engineering, environmental and geosciences, and genomics; support the Partnerships for Advanced Computational Infrastructure headquartered at the National Center for Supercomputing Applications (University of Illinois at Urbana-Champaign) and the San Diego Supercomputer Center (University of California-San Diego)

NASA: Develop space-based data and analysis infrastructure, high-end science collaboratories, and interactive environments for engineering

The Federal investments described in this report include development and demonstration of leading-edge computational science and networked IT systems in engineering and the sciences. These high-performance IT capabilities, like all important innovations, drive new waves of exploration and discovery at the forefront of scientific and engineering knowledge, where the U.S. must remain in the years ahead.

High-end scientific computation and visualization technologies and tools enable researchers to "see," interact with, and analyze the structures and behaviors of organic and inorganic matter more precisely than previously possible – from the tiniest building blocks of the universe, to the tolerances of manufacturing designs, to the properties and interactions of the biosphere's large-scale phenomena. These exciting explorations leverage Federal NITRD investments to attract talented researchers into engineering and the sciences and strengthen the Nation's leadership in these fields.

In addition, these advanced capabilities both require and enable the increasingly interdisciplinary scientific environments that new generations of scientists need to master in order to solve the 21st century's most complex science problems. The work of designing, building, tuning, integrating, and using very complex high-end computing systems and applications is itself rigorously interdisciplinary and requires a high level of teamwork among specialists in many disciplines. These advanced systems in turn make possible one of the most promising new developments of our era in scientific research – electronic collaboratories in which scientists in any field and any location can work together in real time through distributed networked applications.

Integrating the science and engineering of advanced computing systems into large-scale, multilayered technological systems of systems to address significant societal needs expands the requirement for multidisciplinary collaboration to an even greater scale. (Descriptions of some of the integrated technological systems that fundamental NITRD research is aiming toward can be found in the National Grand Challenge Applications section on pages 27-31 of this report.)

NIH: Demonstrate network infrastructure technologies for scientific collaboration; develop tools for determining 3-D molecular structures and methods for displaying and analyzing images from microscopy, magnetic resonance, and positron emission tomography; develop high-end modeling and simulation capabilities; expand biomedical supercomputing programs

DOE Office of Science: Partnerships, under DOE's Scientific Discovery through Advanced Computing program, between computer scientists and application scientists in global climate research, high-energy and nuclear physics, chemistry, and fusion energy sciences to develop the next generation of scientific simulation and collaboration tools

NOAA: Research in advanced scalable, highly parallel computing systems and software to support data-intensive modeling and simulation of large-scale weather and environmental phenomena

NIST: Computational tools for modeling the micro-magnetic properties of materials; conformance tests for Virtual Reality Modeling Language (VRML) and standards for making VRML accessible to the disabled; integrate human ergonomic simulations with manufacturing simulations; virtual reality environment for evaluating machine processes

EPA: Component-based, cross-media (e.g., air, water, soil), multiscale modeling framework for environmental research and decision support

Examples of the advanced science and engineering activities that Federal research in high-performance IT systems seeks to enable include:

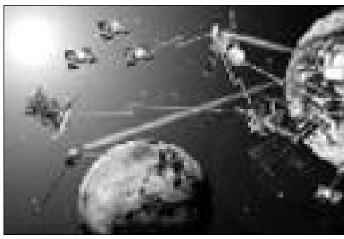
- Modeling and simulation in the biological, chemical, environmental, material, and physical sciences, such as:
  - Dynamic integrated models of the Earth's atmosphere, oceans, fresh water, soil, and biosphere at scales ranging from kilometers to meters
  - A model of the human body and its components at scales ranging from atoms to molecules, cells, and organs, to the whole body
  - Complete engine simulation, including combustion, chemical mixing, and multiphase flow
  - Simulation for controlled fusion to optimize the design of future nuclear reactors
  - Design of new chemical compounds for biological and manufacturing applications
  - Models of chemical, manufacturing, and assembly plants for optimization
  - Simulations of automobile crash tests for different spatial configurations that reliably substitute for real tests
- Data assimilation, fusion, visualization, and manipulation for modeling and simulation
- Modeling and simulation in IT, including:
  - High-end computing systems
  - Network dynamics
  - Large-scale IT systems such as embedded systems and distributed heterogeneous applications
- Collaboration technologies in clinical medicine, scientific research, and professional education and training

Long-Term Research Needs

- Increasingly capable and interoperable computing systems, storage systems, networks, software development capabilities (including languages and tools), and human/computer interaction technologies to enable faster, higher-resolution, more realistic 3-D simulations of phenomena of interest to scientists, engineers, and society
- Approaches for building, understanding, and evaluating complex interdisciplinary modeling systems
- Languages and tools that allow scientists and engineers to better access and utilize distributed and high-end computing resources
- IT for supporting distributed interdisciplinary teams

CHALLENGE #5

Ensuring Reliable, Secure Operation of Critical Systems



NASA image of future space-based communications architectures, now under development in the agency's High Rate Data Delivery research program

The 1999 report of the President's Information Technology Advisory Committee argued that fundamental software research must be "an absolute national priority" in Federal networking and IT research. The Committee highlighted a reality of the Information Age: The software running today's computing systems and networks is a vast patchwork of often idiosyncratically designed, insecure, and non-interoperable code whose fragility manifests itself daily in unreliability, security breaches, performance lapses, errors, and difficulties in upgrading.

Unlike the design of bridges and airplanes, for example, there exists today no framework of formal scientific and engineering principles governing software development. At the same time, the demand for software currently exceeds our capacity to produce it, and the software that is developed is very costly and increasingly complex, with many programs running to millions of lines of code.That is far too many to be effectively validated or made secure from attack with today's technology.

Representative FY 2002 agency activities

NSF: Scientific principles for construction of high-confidence systems; innovative research in trusted computing: safety, security, and privacy for Internet-enabled systems; foundations for real-time distributed and embedded systems; software and modeling technologies for hybrid discrete and continuous systems; innovative fault-tolerance approaches for critical infrastructure protection

If all that were at stake were the frustrations of home computer users, perhaps we could leave software development as a cottage craft rather than a formal scientific discipline. But with software already managing such large-scale and mission-critical systems as aircraft and air traffic, medical devices including life-support systems, electrical power grids, international financial networks, and advanced weaponry, funding for research in software development methods must be continued.

The Federal NITRD agencies are undertaking the research necessary to develop software governed by formal principles and methods and structured so that its security and reliability can be assured through automated testing and validation. Mission-critical systems must be able to withstand hacker, criminal, and enemy attacks as well as unanticipated system interactions; "self-healing" so they can continue to function after an attack or system failure; and designed to guarantee predictably high levels of data integrity and security.

In FY 2002, the agencies will fund research to develop and demonstrate revolutionary high-confidence software and systems development and assurance capabilities that balance risk, cost, and effort to achieve systems

DARPA: Research in high-confidence control systems; design for robust, coordinated hybrid control; applications of formal reasoning to system and software certification to reduce test effort; management of assurance evidence; robust management of authority; safe semi-autonomous cooperating systems; coherent and manageable control by human operators and decision makers

NASA: Develop methods and technologies to assure reliability and security in high-performance software and systems

NSA: Expand research in high-assurance computing platforms, security management infrastructures, cryptography, active network defense, and secure communications and network management

NIST: Promulgate advanced encryption standard selected by NIST to replace previous data encryption standard; develop reference data and guidelines for face-recognition technologies; with NSA, support the National Information Assurance Partnership to promote cost-effective international standards for software evaluation, testing, and certification

ODUSD (S&T): Support defense-related university research in assurance foundations and technologies, information security, survivability technologies, software control systems,and public key infrastructures

that behave in predictable and robust ways. The goals of this research effort are to:

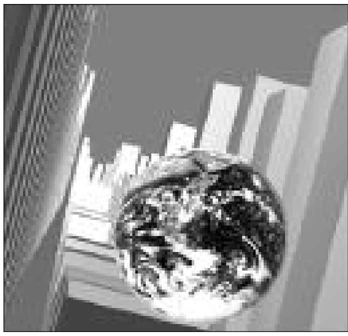
- Provide a sound theoretical, scientific, and technological basis for assured construction of safe, secure systems
- Develop hardware, software, and system engineering tools that incorporate ubiquitous, application-based, domain-based, and risk-based assurance
- Reduce the time, effort, and cost of assurance and certification processes
- Provide a technological base of public domain, advanced prototype implementations of high-confidence technologies to enable rapid adoption

Long-Term Research Needs

- Foundations of assurance and composition:
  - Rigorous modeling and reasoning about high-confidence properties
  - Interoperable methods and tools
  - System composition and decomposition
  - Specification
  - Safety and security foundations
- Scalable fault prevention, detection, analysis, and recovery:
  - Robust system architectures
  - Monitoring, detection, and adaptive response
- Correct-by-construction software technologies:
  - Programming languages, tools, and environments
  - Systems software, middleware, and networking, including reusable middleware services such as efficient, predictable, scalable, dependable protocols for timing, consensus, synchronization, and replication for large-scale distributed embedded applications and domain-specific services
- Evidence technologies for verification and validation
- Experimentation and reference implementations:
  - Assured reference implementations and assurance cases, such as Public Key Infrastructure (PKI) for advanced networks, software control of physical systems, and mobile networked devices
  - Domain-specific certification technologies, such as technologies for cost-effective verification and validation and verified hardware/software co-design technologies
- Forensic and diagnostic tools

CHALLENGE #6

Making Software for the Real World



Background of this illustration produced with Cichlid software for depicting network behavior, developed by the National Laboratory for Applied Network Research (NLANR) with NSF support

The well documented, widely experienced effects of inadequate software quality and productivity jeopardize U.S. security and economic viability. A conspicuous example of the enormous research challenges before us is embedded software – that is, software operating with and controlling the physical world. Embedded software is extremely hard to build because its design cannot be based on an idealized model of the real world. While the primary stakeholder is DoD (embedded software is the main reason for significant time and cost overruns in major weapon programs and presents a profound technical challenge for developers), embedded software has tremendous commercial significance. Examples of this may be found in automotive electronics (where it is predicted that the cost of the embedded computers and software will exceed that of the drive train and body by early 2003), consumer electronics such as personal digital assistants (PDAs), cell phones, television sets and other household devices, and industrial process control systems.

Representative FY 2002 agency activities

NSF: Empirical software engineering research to address problems of software productivity and product quality

DARPA: Deeply networked systems research using model-based integration of distributed software for integrating information processing and physical process demands,and highly complex systems that may be composed of systems of sensors or systems of systems

Given the staggering impact of the software industry on both the private sector – where personnel costs have reached $400 billion a year – and the Federal government, the NITRD agencies are sponsoring fundamental research that will lead to more cost-efficient, productive software development methods. This will result in higher-quality software with predictable characteristics, as well as support the construction of advanced applications that stress and evaluate current and evolving best practices.

Tiny embedded processors lie at one end of the continuum of software research needs, but at the other lie the largest digital systems in existence. The National Research Council, in its Fall 2000 report "Making IT Better," argues that the single greatest challenge in IT research today is presented by large-scale systems, which now power society's most complex and critical infrastructures but which have not been the IT research community's primary focus. Citing the growing complexity, heterogeneity, distribution, and integration of these vast interconnected systems, the report urges that research to improve their design, development, and operation be made a national priority.

In large-scale systems, the validity of theoretical approaches is drastically challenged by scalability pressures and by the inherent heterogeneity of components. We cannot achieve improvements without evaluating the practical applicability of methods and techniques and actually testing them in large-scale application platforms.

The NITRD agencies' research program addresses the scientific foundations of software design and investigates the related engineering process, including substantial experimental evaluations. In FY 2002, agency-sponsored research will focus on developing mathematical, computer science, and engineering models to test fundamental new directions for cost-efficient development of very high-quality software in the emerging world of interconnectivity among heterogeneous devices, from embedded processors to massive systems of systems.

Long-Term Research Needs

- Science of software and system design:
  - Languages and compilers - e.g., domain-specific languages to make software specification and development easy for end users and languages that are easier to use and harder to abuse
  - Effective methods for composing software and systems – better techniques for composing, analyzing, and verifying complex systems, and making them interoperable on widely distributed heterogeneous systems
  - Foundations for advanced frameworks and middleware – adaptive and reflexive components, composition frameworks and middleware, theoretical basis for the construction of scalable distributed software systems
- Automating the engineering process:
  - Methods for putting together software "components" to reduce development time and increase reliability, including technologies for developing distributed, autonomous and/or embedded software; software development automation
  - Integrated software and systems development process, including methods for specifying, analyzing, testing, and verifying software and physical systems
  - Interoperability of network applications running concurrently
  - Integrated configurable tool environments that enable rapid composition and customization of integrated domain-specific development environments
- Pilot applications and empirical evaluation:
  - Technologies for embedded software applications and other complex applications
  - Empirical studies of software and systems development projects

NIH: The NCI Advanced Biomedical Computing Center continues to develop high-end computational methods to support cancer research

NASA: Establish and develop High Dependability Software Consortium with leading universities and industry for proving methods and techniques to achieve very high reliability in mission-critical software

NIST: Research in techniques for self-integration of manufacturing system components to enable full or partial interoperability in a world where standards are changing quickly; automated or partially automated creation of software using combinations of formal methods, machine learning, and knowledge-based techniques

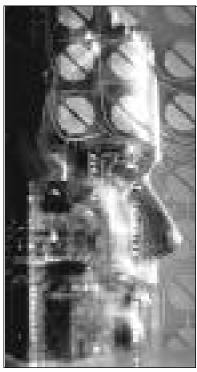
NOAA: Advanced scalable computation research to develop the Flexible Modeling System for climate and atmospheric scientists working on highly parallel scalable systems

ODUSD (S&T): University-based research in data fusion in large arrays of microsensors (SENSORWEB), learning technologies, solitonic information processing, and adaptive mobile wireless networks for highly dynamic environments

EPA: Research and development in component-based methods for environmental modeling

CHALLENGE #7

Supporting Human Capabilities and Universal Human Development



Information technology holds the potential to help all people enhance their individual capacities and skills.The research agenda of the Federal IT research agencies aggressively pursues technical innovations that bring us closer to universal access to and easy usability of computing and communications systems.

First, human-computer interaction research aims to expand the scope of what computing devices can contribute to human abilities, such as by augmenting human memory, attention span, sensory perception (such as in sight, hearing, and touch), and comprehension. A simple but powerful example of this augmented cognition is visualization technologies, which enable researchers to turn complex data into 2-D and 3-D graphics that can be manipulated and analyzed. Such visualization capabilities are revolutionizing not only scientific and engineering research but industrial production processes as well.

Representative FY 2002 agency activities

NSF: Innovative IT applications in education; collaboration technologies for research and work environments; assistive technologies to enable universal access to IT

DARPA: Dialogue-based spoken language systems; network-based capabilities to support "all source" and "all language" analysis of intelligence information

Federally sponsored human-computer interaction research also focuses on integrating advanced functionalities – that is, computing technologies that input and output speech, translate languages, are activated by sensory data or remote instruction, and the like – so that they best support people performing multiple tasks in varying configurations within complex work environments. For example, Federal research on "smart spaces" – work environments with embedded computers, information appliances, and multi-modal sensors – seeks to integrate these devices in ways that allow people to perform tasks efficiently by offering unprecedented levels of access to information and assistance from computing systems.

End user focused research seeks to re-invent such IT components as interfaces, search engines, and communications technologies from the standpoint of expanding the user's capabilities and ease of use. Investigations in language technologies – such as machine translation, speech-driven computer interactions, pattern recognition, and automated transcription – aim to enable, for example, hands-free communication between people and computing devices, computer-generated translations of materials in foreign languages, computer analysis of texts, and voice recognition and spoken-language transcription for meeting discussions. These capabilities not only have vital applications in military and national security settings but also have an enormous range of uses in other spheres.

NIH: Methods for generating, displaying, and analyzing images in electron and light microscopy and a number of medical imaging modalities including positron emission tomography and electron paramagnetic resonance imaging; tools for accessing molecular biology, biochemistry, and genetics data

NASA: New interfaces enabling users to visualize, manipulate, compare, and analyze large-scale, 3-D temporal data sets

DOE Office of Science:Integrated set of software tools to enable scientists to remotely access and control facilities and share large-scale data sets in real time

NIST: Usability studies resulting in new tests for evaluation of Web pages and other applications; testing and commercialization of new devices for the visually handicapped

ODUSD (S&T): University-based research in mobile augmented battlespace visualization and tutorial dialogue for artificial intelligence training systems

This research supports development of technologies, tools, and devices that help enable all individuals to live full and independent lives, whatever their ages or physical capacities. A key goal of universal access research is development of multimodal design strategies – such as incorporating speech-activated technologies – that will work across a range of technologies, devices, and user capabilities and preferences.

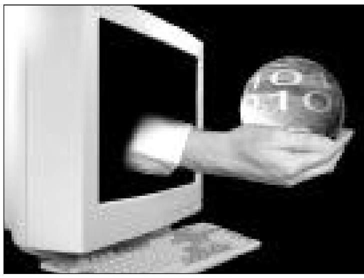
In FY 2002, the NITRD agencies will sponsor research to solve methodological and technical issues in integrating functionalities and to develop designs and tools for diverse distributed applications. Other projects will focus on understanding the needs of end users in work and learning environments and modeling multimodal interactions between users and computing devices in these environments.

Long-Term Research Needs

- Development of advanced functionalities:
    - Language-engineering technologies, including translation between languages and between spoken and written languages, and spoken-language query systems
    - Spoken, aural, and multimodal interfaces – for hands-free and untethered computing in military and advanced aerospace applications and for computer access for the blind
    - Technologies for use of sensors in such settings as health care, national defense, and emergency management, and for the severely physically disabled
    - Real-time interaction with databases to accelerate decision making
- Integration of advanced functionalities:
    - Intelligent systems, such as "smart spaces," for ubiquitous computing with multiple interactions; collaborative mobile agents
    - Remote collaboration, visualization, and virtual-reality environments
    - Computer-assisted prosthetics for motion, sight, and hearing; monitoring systems; and remote consultation technologies to increase the independence of the elderly and disabled
    - Methods and technologies for modeling and sharing expertise; models and metrics for collaborative performance of complex tasks

CHALLENGE #8

Managing and Enabling Worlds of Knowledge



Graphic by Janet Ward of NOAA's High Performance Computing and Communications Program

Representative FY 2002 agency activities

NSF: Development of digital library collections, including research in architectures, tools, and technologies for organizing, annotating, searching, and preserving distributed multimedia archives; expand online scientific data and large-scale data-mining research to accelerate use of existing data to supplement new observations

DARPA: Deploy scalable prototype analysis environment in defense application with cross-repository information analysis functionality (semantic retrieval, indexing, value filtering, user defined alerting, and categorizing)

Early Federal IT investments have pioneered development and implementation of digital repositories of information and such basic enabling technologies as search engines, record management systems, and linkages among distributed archives. Creating digital libraries across the range of human knowledge and developing the technologies and tools to make that knowledge universally available on demand is a core challenge in information technology whose advances benefit every profession, every academic discipline, every learner, and every citizen.

Digital libraries form the basis of the Nation's 21st century knowledge network. The Federally supported research to decode the human genome, for example, was accelerated by many years because researchers could create, store, and immediately share over the Internet massive databases of genetic information representing pieces of the enormous biological puzzle. Federal digital libraries funding not only established major digital collections in such areas as Earth and space sciences, the humanities, law, medicine, oral history, and science, mathematics, and engineering education, but also spun off search engine technologies that have become successful commercial enterprises.

Developmental issues in the digital libraries field are growing in tandem with today's knowledge explosion. Their scale is suggested by a recent University of California at Berkeley study estimating that the world now produces between one and two exabytes (an exabyte is a billion billion 8-bit bytes) of information annually; most of this vast output is images, sound, and numeric data already in digital formats; only 0.003 percent represents print documents. At the same time, barely 10 percent of all public information ever produced in print has been digitized and made available on the Internet. How to determine, collect, and preserve what is of value in the world's dizzying new digital output now joins older questions of how and what to digitize from humanity's pre-digital knowledge stores as issues for archivists.

Building archives is only one step in generating the technological framework that makes a digital library useable. It also takes advanced technologies for managing and working with digital information, from visualization, data fusion, and analysis capabilities to remote collaboration

NIH: Continue work on query by image content to produce a reliable method for computer-assisted x-ray image segmentation, indexing, and query; establish an information storage, curation, analysis, and retrieval (ISCAR) program for biological data

DOE Office of Science: Modular electronic notebook prototype, whiteboard, and related tools for collaboratory sharing of scientific data, instrumentation, and research results

NIST: Initial Internet-accessible repository of full structural crystallographic data for inorganic materials and a second repository of Internet-accessible molecular recognition knowledge; intelligent interfaces for using existing bioinformatics tools for protein databases

NOAA: Extend real-time collaborative access to chemical disaster information by surrounding this functionality with synchronous collaborative tools to enable experts nationwide to consult while maintaining a consistent view of the data

AHRQ: Develop Web-based applications to improve health data systems and quality of care; innovative strategies for data collection in clinical settings; approaches for integrating quality and outcomes data into the care process

and metadata notation schemes, to advanced interoperable systems. The NITRD effort is building on early Federal successes to develop the next-generation technologies that are needed to help realize the full potential of electronic information. Today's search engines, for example, are based on fundamental algorithms developed 20 years ago; current search tools cannot locate audio or image information by content description. Strategies to assure long-term preservation of digital records constitute another particularly pressing issue for research. As storage technologies evolve with increasing speed to cope with the growing demand for storage space, the obsolescence of older storage hardware and software threatens to cut us off from the electronically stored past.

Federal agencies' FY 2002 research efforts will include development of large-scale digital collections in engineering, sciences, and humanities; research to increase interoperability and integration of software in distributed systems; protocols and tools for data annotation and management; and research in technical issues in preservation.

Long-Term Research Needs

- Data storage and management technologies:
  - Tools for collection, indexing, synthesis, and archiving
  - Protocols for data compatibility, conversion, interoperability, interpretation
  - Technologies and tools for fusion of databases, such as molecules and macromolecular structures in biology or disparate real-time weather observations, with remote access and analysis capabilities
  - Component technologies and integration of dynamic, scalable, flexible information environments
  - Digital representation, preservation, and storage of multimedia collections
  - Protocols and tools to address legal issues such as copyright protection, privacy, and intellectual property management
- Usability of large-scale data sets:
  - Intelligent search agents, improved abstracting and summarizing techniques, and advanced interfaces
  - Digital classification frameworks and interoperable search architectures
  - Metadata technologies and tools for distributed multimedia archives
  - Ultra-scale data-mining technologies
  - Testbeds for prototyping and evaluating media integration, software functionality, and large-scale applications

CHALLENGE #9

Supporting Education and Development of a World-Class IT Workforce

Representative FY 2002 agency activities

NSF: IT tools and applications in education and training, including approaches to increasing IT literacy; research on barriers to IT careers for women and minorities; and multidisciplinary research opportunities for students

NIH: Expanded opportunities for IT training, especially in bioinformatics; individual and program grants for advanced IT R&D training for health professionals

NASA: Use Internet for training and development of engineers and scientists in IT security and collaborative engineering

DOE Office of Science: Computational Science Graduate Fellowship Program, a nationwide competitive program to train the next generation of leaders in computational science for DOE and the Nation

NIST: Summer undergraduate research fellowships, in cooperation with NSF; postdoctoral fellows and university guest researchers

Employers in every sector as well as a variety of studies identify the persistent shortage of skilled IT workers as the single greatest threat to U.S. competitiveness over the next 10 years. "Building a Workforce for the Information Economy," a new report by the Computer Science and Telecommunications Board of the National Research Council, concludes that the tight IT labor market will continue for the foreseeable future and that there is no single solution to the problem. "Coping with a tight labor market," the report states, "requires the best efforts of all stakeholders: employers, employees, educational institutions, and government at all levels."

In FY 2002, the NITRD agencies will sponsor research on issues in IT literacy and IT workforce development, including a focus on barriers and impediments to IT careers among women, minorities, and other underrepresented groups. The agencies also support efforts to develop innovative IT applications for work-related learning and broader access to IT by expanding the high-performance infrastructure to encompass underrepresented educational communities and students.

As researchers representing many different disciplines, NITRD participants know firsthand that the shortage of IT researchers is already jeopardizing their ability to carry out the research program that is crucial for the Nation's future. To address this problem, the Federal research community should strive to double the number of new IT researchers over the next five years and increase the support levels for existing faculty.

Current NITRD research also addresses fundamental questions about the efficacy of IT in education, examining theories and models of learning and developing high-quality IT applications for learning environments.

Long-Term Research Needs

- New knowledge about cognitive development and about group and individual learning in varied settings
- More substantial empirical data on the effects of IT systems in education and training environments
- Software for self-instruction and collaborative learning
- Integration of information technologies in learning environments

CHALLENGE #10

Understanding the Effects of IT To Maximize the Benefits

Representative FY 2002 agency activities

NSF: Support for research on effective uses of IT in education; social and economic implications of IT (such as e-commerce and the digital economy; community networking; computer-supported collaborative work; IT and transformations in work life; value systems in IT design, deployment,and consequences; information privacy and intellectual property; and the role of IT in facilitating scientific progress); issues related to attracting and retaining a strong workforce; technologies and tools enabling people to use IT regardless of age or physical limitation; and IT in the social and behavioral sciences

New modes of learning, research, communication, commerce, and human services are proliferating so rapidly that we as a society have hardly paused to contemplate the changes or analyze their effects on people and institutions. Most IT research investments to date understandably have centered on development of the new technologies themselves. A number of recent studies have brought into focus, however, the need for investment in research to identify, understand, anticipate, and address the unintended consequences of the increasing pace of technology transformation.

The NITRD agencies have begun a vigorous interdisciplinary research program to look much more closely at the nature and dynamics of the interactions between IT and social systems.This research will develop both empirical maps of the landscape of social change and new theories and models to describe the complex process of adaptation and interchange between humans and large-scale technical systems.

The research agenda will address a major initial challenge: Development of an intellectual architecture for this new multidisciplinary research area. Researchers currently working on IT-related studies are scattered across many different disciplines without either a single focus to draw them together or a multidisciplinary communications network oriented to their work. NITRD seeks to foster a national infrastructure for social, economic, and workforce-related research and to attract additional scholars to the work to be done. This capacity-building effort will provide policymakers, for the first time, with current, research-based findings about IT's societal effects.

Multidisciplinary research areas to be examined in FY 2002 include universal participation in the digital society; information privacy and intellectual property in the digital society; large-scale social technologies for science, education, and work collaboration and learning; ethical principles in socio-technical design; and technologies for independence throughout life. Projects focus on basic research, applications, and infrastructure topics to increase the value of IT to all sectors of society and the ability of individuals and social groups to participate in and contribute to advances in IT.

Long-Term Research Needs

- New knowledge about the interaction among people, groups, computing applications, communications networks, and information infrastructures across distances and in various social, cultural, legal, economic, and ethical contexts
- New knowledge about participation in a digital society, including such aspects as the digital economy, modes of work, Internet governance and Internet citizenship, barriers to universal access and participation, and cybercrime and law enforcement
- Fundamental theoretical and legal analyses and empirical studies of intellectual property and privacy issues in the digital age
- Research on integration and uses of large-scale social technologies for collaboration and learning in science, education, and the workplace
- Significant advances in our scientific understanding of what technologies, tools, and applications are effective for learning
- Research on technologies for successful aging
- Studies of ethical principles in IT socio-technical designs

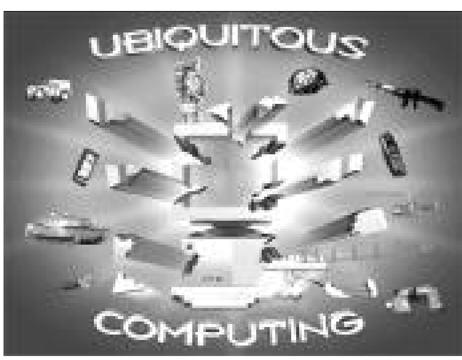
PUTTING FEDERAL RESEARCH INTO ACTION

National Grand Challenge Applications

Most of the IT enabling technologies that the Nation needs – and that constitute the core work of the Federal NITRD enterprise – are invisible to the public. It is the combination of these component technologies in far-reaching applications that marks the visible ultimate goal and crowning achievement of fundamental IT research. Many people think such applications are the main focus of IT research. But as this report explains, applications are effectively the final step in an R&D process that begins with methodical, multidisciplinary investigations across a variety of basic and applied sciences.

The bulk of the Federal investment in IT R&D supports this fundamental research in enabling technologies. But the NITRD agencies also propose to test and validate these technologies in prototypes and demonstrations of advanced IT applications in future multi-year efforts. Examples of such National Grand Challenge Applications are summarized in the following brief descriptions. Several descriptions are devoted to specific IT applications. Others point to broad areas of the national interest in which integration of many advanced applications is needed. Though these areas lie beyond the scope of NITRD activities, the NITRD agencies could play a key role in developing prototypes and testbed demonstrations in later fiscal years.

Next-Generation National Defense and National Security Systems



Graphic from DARPA's ubiquitous computing research program

The Federal NITRD investment provides the base technologies to ensure that the U.S. maintains its dominant position in the application of information technologies to critical national defense and national security needs. This Federal research provides the national defense and national security communities with the advanced information technologies needed to support weapons programs, military and intelligence operations, and effective information operations environments. Systems with these capabilities are needed to perform the computationally intensive fine grain simulation of new aircraft and smart weapons, and to permit full maintenance and reliability simulation of the Nation's nuclear weapons stockpile. NITRD will enable the efficient design and development of robust and reliable software with the high fault tolerance and high levels of security assurance and intrusion resistance that are vital to the Defense command, control, communications, and intelligence infrastructure. R&D in both microsensors and embedded and autonomous devices will enable the modeling and the management of huge battlespaces involving hundreds of thousands of objects in dynamic combat, support, and intelligence operations. As a result, it will be possible to link autonomous sensor, surveillance, and combat weapon systems to battle management and cyber warfare systems in order to support both defensive and offensive operations with minimum risk of casualties.

The NITRD agencies propose to develop and demonstrate new generations of highly secure, fault-tolerant computing, networking, and storage technologies, including high-end computing systems and distributed autonomous and embedded devices and systems, needed in weapons systems, battlespace, and national security applications.

Improved Health Care Systems for All Citizens

Secure high-speed networks and software that is reliable, interoperable, and safe from intrusion will enable basic improvements in the national health care infrastructure, such as high-confidence software for medical devices including life-support systems; management and usability of patient information; interactions between patients and health care providers; timely analysis of provider and institutional quality; and hospital systems, inventory, and procurement management.

More dramatic will be the extension of monitoring, diagnosis, care, emergency treatment, and even surgery to citizens in remote locations, or unable to reach the hospital, or housebound. Experimentation with telemedicine is showing the enormous promise in combining high-speed networking, two-way real-time video, embedded and robotic devices, and remote visualization and instrumentation to get needed care to citizens immediately wherever they are located.These capabilities will also make it possible to help maintain the independence of aging citizens and of citizens with physical limitations. In addition, this set of technologies will enable a whole new generation of techniques and practices in medical training and physician and health care professional continuing education.

The NITRD agencies propose to prototype and demonstrate high-confidence medical devices; multimodal systems for remote and emergency on-site patient care; advanced home devices and services for individuals with physical limitations; and advanced, distributed multimedia capabilities for medical education, biomedical research, and clinical practice.

Creating Scientifically Accurate, 3-D Functional Models of the Human Body

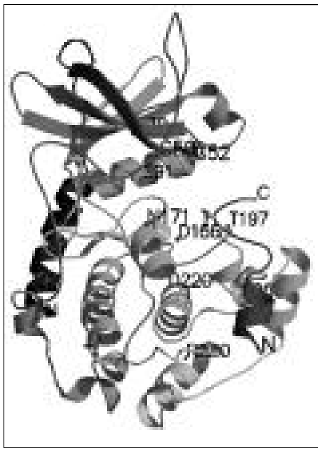


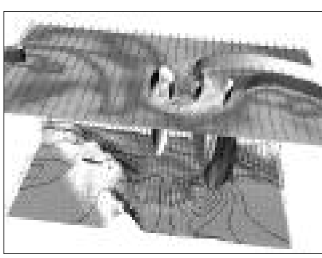
Image of the enzyme cAMP dependent protein kinase. The NSF-funded Molecular Interactive Collaborative Environment (MICE) developed at the San Diego Supercomputer Center enables researchers and students to see, manipulate, and annotate 3-D versions of complex molecules through the Web browsers on their own computers

Advances in computational speeds, visualization software, and data storage capacities are bringing us closer to being able to generate large-scale 3-D models and simulations of enormously complex phenomena such as the human body. To suggest how computationally challenging such models are: It is taking the world's fastest computing platforms in the Federal government's national research laboratories to begin to create quantitatively accurate visualizations of the Nation's nuclear weapons stockpile. It will take substantially more computational capacity to generate a precise 3-D visual model of the human body, starting from atoms, molecules, and cells, through organs and the circulatory and musculo-skeletal systems.

Federally funded researchers are working today on visualizing the neuronal structure of the brain. The scale of this problem alone is exemplified by the fact that one cubic millimeter of cerebral cortex may contain on the order of five billion interdigitated synapses of different shapes and sizes and a wide variety of subcellular chemical signaling pathways. Being able to visualize, manipulate, and test representations of structures and processes at this level of matter will mark an invaluable innovation for both scientific research and education.

The NITRD agencies propose to harness IT advances to create a complete, functional digital model of the human body.

IT Tools for Large-Scale Environmental Modeling and Monitoring



Visualization of energy transfer in the Blizzard of 1993 developed by NOAA's Geophysical Fluid Dynamics Laboratory

Advanced IT modeling, simulation, visualization, and analysis tools will also improve our ability to study and understand such complex phenomena as global warming, food shortages, energy depletion, drought, natural disasters, and human/environment interactions. More accurate measurement and analysis of such phenomena will provide better information for decision making in both the private and public sectors.

Developing a next-generation environmental monitoring, modeling, and prediction system will require real-time monitoring and observations above the Earth, on the Earth's surface, and below it. Because these real-time observations will be global in scale, the system will require high-speed digital connectivity and high-end computing platforms. The data must then be integrated with timely contextual knowledge in such disciplines as geophysics, biology, chemistry, and atmospheric and oceanic sciences. A key challenge in developing this application is the great complexity of assimilating observational data with models. Scientists will need new methods of visualization to understand the complexity and the spatial and time evolution of the underlying processes. Integration and synthesis of multidisciplinary data with advanced, high-resolution models will require coordination of component technologies, specialized languages for scientific software, storage strategies with very large capacities and good access characteristics, and metadata and search capabilities that include environmental semantics, data fusion, and data mining and/or automated pattern recognition.

The NITRD agencies propose to develop and demonstrate climate and environmental monitoring and modeling systems that improve environmental decision making, such as in forecasting of dangerous weather events, evolution of hazardous spills, ecosystem response to climate and environment change, and earthquake impacts.

Creating the World's Best Infrastructure for Lifelong Learning

Lifelong education, training, and development have become necessities of the Information Age. With human knowledge estimated to be doubling every two years and dynamic work environments calling for continuous skills development and adaptability to new information, the ability to keep learning is perhaps this era's core requirement for successful employment and career development. We currently have, or will soon, the enabling technologies in high-speed networks, software for information management, real-time collaboration, 3-D visualization, and the like to create multifaceted learning environments and experiences for learners of every age with every kind of academic, vocational, or personal learning focus. IT can provide ubiquitous access to structured knowledge (systematic course work, laboratory activities, and rich digital libraries) as well as immersive environments for experiencing scientific phenomena and different cultures and environments. IT interfaces and experiences can be tailored to individual learning styles, ages, physical and mental capacities and preferences, and interests, with automated feedback systems to guide progress.

The NITRD agencies propose to demonstrate prototypes of advanced learning systems for education, training, and development across age groups and needs.

Integrated IT Systems for Crises Management

Photo by John McColgan of the Alaska Fire Service, taken during August 2000 fire in Bitterroot Valley, Montana. Fires burned more than 7 million acres in the U.S. in 2000, more than double the 10-year average acreage.

In a major natural or human-caused disaster, there is a great need for an instantaneous common communication system and a common capability for real-time distribution of precise information, disaster guidance and directives, situational updates and analyses, and instructions for distributed disaster workers. To date, we have not put development of such a coordinated crises management system on the national agenda. It is time to bring the mobile wireless, nomadic, and satellite communications technologies now available together with scalable wireline networking capabilities, advanced microsensing technologies, data analysis and system-management software, and with our extensive multidisciplinary experience in crises management (for example, public health, emergency response, medical triage, fire, and policing). Combining these capabilities would make possible a state-of-the-art crises coordination and management system that could be deployed immediately and effectively in any kind of catastrophic situation.

NITRD agencies propose to support creation of a collaborative, interdisciplinary effort to develop and demonstrate this comprehensive IT framework. Federal agencies, with state and local government and private-sector partners, have the technologies, the personnel, and the broad experience in major environmental and other disasters to successfully build this much-needed grand challenge application.

Technologies and Systems for Advanced Aviation Management

Simulation of integrated IT controls and data-monitoring systems in an airplane cockpit. NASA's Aviation Safety Program, in partnership with the FAA and industry, is developing advanced technologies to increase the safety of air travel.

Few U.S. air travelers or business people who ship goods today avoid encountering significant difficulties in air transportation. Aviation safety and capacity have become national issues. The air transportation system is on the verge of gridlock, with delays and cancelled flights reaching all-time highs and passenger rage skyrocketing. As demand for air transportation continues to increase, fueled by a strong economy and the package-delivery needs of e-commerce, the capacity of the air traffic control system to accommodate the rapid growth is falling farther behind. It has become painfully clear that the present air traffic control system cannot continue to be scaled up to handle the increased capacity that will be required over the next 15 to 25 years. We need a fundamental change in the management of the aviation system, and information technology is the key.

High-performance computational and networking technologies, in combination with advanced applications in visualization, modeling, simulation, and distributed instrumentation make it possible now to design a fully integrated, large-scale aviation system encompassing both air and ground components. Such a next-generation IT infrastructure could help substantially increase the capacity of the air transport system to move people and cargo through integrated airspace operations. This integrated system would enable real-time sharing of information from distributed sources such as weather stations, air-traffic management systems, flight controllers, passenger managers, and other transport-related nodes. IT challenges include developing:

- The critical core component technologies to meet the requirements of the air transportation system
- A virtual airspace transportation environment for simulating the air traffic components at the system level with the requisite degree of fidelity
- Evaluation of candidate system-level concepts and architectures making use of the "virtual air transportation environment"

The expertise of the NITRD agencies could significantly contribute to a Federal initiative to transform the Nation's current air traffic control system into an advanced integrated system of systems for the 21st century.

NITRD Agencies and Their IT Research Interests

AHRQ - the Agency for Healthcare Research and Quality - focuses on research into state-of-the-art IT for use in health care applications such as computer-based patient records, clinical decision support systems, and standards for patient care data, information access, and telehealth.

DARPA - the Defense Advanced Research Projects Agency - is focused on future-generations computing, communications, and networking as well as embedded software and control technologies, and human use of information technologies in national defense applications such as battlefield awareness.

DOE/NNSA - the Department of Energy National Nuclear Security Administration - was established to develop new means of assessing the performance of nuclear weapon systems, predict their safety and reliability, and certify their functionality through high-fidelity computer models and simulations of weapon systems.

The DOE Office of Science is exploring, developing, and deploying computational and networking tools that enable researchers in the scientific disciplines to model, simulate, analyze, and predict complex physical, chemical, and biological phenomena important to DOE. The office also provides support for the geographically distributed research teams and remote users of experimental facilities that are critical to DOE missions. FY 2002 is the second year of the office's "Scientific Discovery through Advanced Computing" (SciDAC) initiative, which is focused on the next generation of scientific simulation and collaboration tools for the scientific areas that are the focus of DOE research.

EPA - the Environmental Protection Agency - has the IT research goal of facilitating multidisciplinary ecosystem modeling, risk assessment, and environmental decision making at the Federal, state, and local levels, and by other interested parties, through advanced use of computing and other information technologies.

NASA - the National Aeronautics and Space Administration - is extending U.S. technological leadership to benefit the U.S. aeronautics, Earth and space science, and spaceborne research communities.

NIH - the National Institutes of Health - is applying the power of computing, both to manage and analyze biomedical data and to model biological processes, in its goal to develop the basic knowledge for the understanding, diagnosis, treatment, and prevention of human disease.

NIST - the National Institute of Standards and Technology - is working with industry and with educational and government organizations to make IT systems more useable, secure, scalable, and interoperable; apply IT in specialized areas such as manufacturing and biotechnology; and encourage private-sector companies to accelerate development of IT innovations.

NOAA - the National Oceanic and Atmospheric Administration - is an early adopter of emerging computing technologies for improved climate modeling and weather forecasting, and of emerging communications technologies for disseminating weather forecasts, warnings, and environmental information to users such as policymakers, emergency managers, and the general public.

NSA - the National Security Agency - is addressing some of the most challenging problems in the country in computing, storage, communications, and information assurance in order to help ensure our national security.

NSF - the National Science Foundation - is the lead NITRD agency, with interest in developing new fundamental IT knowledge; applications in the biological, chemical, geophysical, mathematical, physical, social, and behavioral sciences and engineering; educating world-class scientists and engineers and a knowledgeable IT workforce; and research infrastructure.

ODUSD (S&T) - the Office of the Deputy Under Secretary of Defense for Science and Technology - manages the University Research Initiative, which focuses on IT R&D for Department of Defense applications, research infrastructure, and science and engineering education.

Other Federal agencies participate in networking and information technology research and development, and coordinate with NITRD activities, using funds that are not budgeted under the program.

Agency NITRD Budgets by Program Component Area

FY 2001 Budget Estimate (dollars in millions)

Agency	High End Computing Infrastructure and Applications (HEC I&A)	High End Computing Research and Development (HEC R&D)	Human Computer Interaction and Information Management (HCI & IM)	Large Scale Networking (LSN)	Software Design and Productivity (SDP)	High Confidence Software and Systems (HCSS)	Social, Economic, and Workforce (SEW)	Totals
NSF	240.3	71.4	108.5	97.8	39.7	46.2	37.3	641.2
DARPA	54.4	41.8	37.4	48.2	43.7	32.2		257.7
NIH	48.8	10.7	70.8	75.6	4.6	9.6	9.7	229.8
NASA	65.2	21.6	22.7	22.1	18.0	21.0	6.1	176.7
DOE Office of Science	98.8	31.5	16.4	25.9			3.5	176.1
NSA		32.9		1.9		45.6		80.4
NIST	3.5		6.2	3.2	2.0	7.5		22.4
NOAA	10.3	1.7	0.5	2.7	1.5			16.7
AHRQ			8.1	6.0				14.1
ODUSD (S&T)		2.0	2.0	4.0	1.0	1.0		10.0
EPA	3.5				0.6			4.1
Subtotals[a]	524.8	213.6	272.6	287.4	111.1	163.1	56.6	1,629.2
DOE/NNSA	131.8	36.5		35.0	40.2		55.7	299.2
Totals[a]	656.6	250.1	272.6	322.4	151.3	163.1	112.3	1,928.4

Notes:

[a] These totals include minor discrepancies from what appears in the President's FY 2002 Budget, due to a combination of rounding and small shifts in program estimates.

Agency NITRD Budgets by Program Component Area

FY 2002 Budget Request (dollars in millions)

Agency	High End Computing Infrastructure and Applications (HEC I&A)	High End Computing Research and Development (HEC R&D)	Human Computer Interaction and Information Management (HCI & IM)	Large Scale Networking (LSN)	Software Design and Productivity (SDP)	High Confidence Software and Systems (HCSS)	Social, Economic, and Workforce (SEW)	Totals
NSF	249.7	65.1	104.8	98.0	39.7	46.1	39.1	642.5
DARPA[b]	55.5	42.7	38.2	49.2	44.6	32.9		263.1
NIH	55.1	13.7	74.6	81.1	6.0	10.1	11.4	252.0
NASA	36.1	26.0	27.8	14.4	22.4	47.1	7.0	180.8
DOE Office of Science	98.3	31.5	16.4	25.9			4.0	176.1
NSA[b]		33.6		1.9		46.6		82.1
NIST	3.5		6.2	3.2	2.0	7.5		22.4
NOAA	13.3	1.8	0.5	2.7		1.5		19.8
AHRQ			9.2	6.7				15.9
ODUSD (S&T)[b]		2.0	2.0	4.2	1.0	1.0		10.2
EPA	1.8							1.8
Subtotals[a]	513.3	216.4	279.7	287.3	115.7	192.8	61.5	1,666.7
DOE/NNSA	133.8	37.0		35.5	41.1		56.5	303.9
Totals[a]	647.1	253.4	279.7	322.8	156.8	192.8	118.0	1,970.6

Notes:

[a] These totals include minor discrepancies from what appears in the President's FY 2002 Budget, due to a combination of rounding and small shifts in program estimates.

[b] The FY 2002 entry for DoD R&D represents a projection from enacted FY 2001 levels plus inflation. FY 2002 levels are subject to change as a result of the FY 2002 Defense Budget Amendment.

Participation in Federal NITRD Activities

The following are criteria developed by the multiagency IT research program that agencies considering participation can use to assess whether their research activities fit the NITRD profile.

NITRD Goals

Assure continued U.S. leadership in computing, information, and communications technologies to meet Federal goals and to support U.S. 21st century academic, industrial, and government interests

Accelerate deployment of advanced and experimental information technologies to maintain world leadership in science, engineering, and mathematics; improve the quality of life; promote long-term economic growth; increase lifelong learning; protect the environment; harness information technology; and enhance national security

Advance U.S. productivity and industrial competitiveness through long-term scientific and engineering research in computing, information, and communications technologies

Evaluation Criteria for Participation

Relevance/Contribution

The research must significantly contribute to the overall goals of Federal Networking and Information Technology Research and Development (NITRD), which includes the goals of the seven Program Component Areas – High End Computing Infrastructure and Applications (HEC I&A), High End Computing Research and Development (HEC R&D), Human Computer Interaction and Information Management (HCI & IM), Large Scale Networking (LSN), Software Design and Productivity (SDP), High Confidence Software and Systems (HCSS), and Social, Economic, and Workforce Implications of Information Technology and Information Technology Workforce Development (SEW) – to enable solution of Grand Challenge- and National Challenge-class applications problems.

Technical/Scientific Merit

The proposed agency program must be technically/scientifically sound and of high quality and must be the product of a documented technical/scientific planning and review process.

Readiness

A clear agency planning process must be evident, and the organization must have demonstrated capability to carry out the program.

Timeliness

The proposed work must be technically/scientifically timely for one or more of the multigagency research endeavor's Program Component Areas.

Linkages

The responsible organization must have established policies, programs, and activities promoting effective technical and scientific connections among government, industry, and academic sectors.

Costs

The identified resources must be adequate, represent an appropriate share of the total available R&D resources (e.g., a balance among Program Component Areas), promote prospects for coordinated or joint funding, and address long-term resource implications.

Agency Approval

The proposed program or activity must have policy-level approval by the submitting agency.

Agency Contacts

AHRQ

* J. Michael Fitzmaurice, Ph.D., FACMI
Senior Science Advisor for Information Technology, Immediate Office of the Director
Agency for Healthcare Research and Quality
2101 East Jefferson Street, Suite 600
Rockville, MD 20852
(301) 594-3938
FAX: (301) 594-2168

BLS

Cathryn S. Dippo, Ph.D.
Associate Commissioner, Office of Survey Methods Research
Bureau of Labor Statistics
2 Massachusetts Avenue N.E.,Room 4080
Washington, DC 20212
(202) 691-7372
FAX: (202) 691-7426

DARPA

Michael J. Foster
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 Fairfax Drive
Arlington, VA 22203
(703) 696-2245
FAX: (703) 696-4534

Robert Graybill
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-2220
FAX: (703) 696-4534

Gary M.Koob, Ph.D.
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-7463
FAX: (703) 696-4534

Mari W. Maeda, Ph.D.
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-2255
FAX:(703) 696-4534

Douglas C. Schmidt, Ph.D.
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-2239
FAX: (703) 696-4534

Jean Scholtz, Ph.D.
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-4469
FAX:(703) 696-4534

* Col. Mark Swinson
Acting Director, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-2247
FAX: (703) 696-4534

Janos Sztipanovits, Ph.D.
Program Manager, Information Technology Office
Defense Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714
(703) 696-2234
FAX: (703) 696-4534

DoD

* Charles J. Holland, Ph.D.
Director of Information Systems,ODUSD (S&T)
Department of Defense
1777 North Kent Street, Suite 9030
Rosslyn, VA 22209
(703) 588-7443
FAX: (703) 588-7560

Rodger Johnson
Program Manager, Defense Research and Engineering Network
DoD High Performance Computing Modernization Office
1010 North Glebe Road, Suite 510
Arlington, VA 22201
(703) 812-8205
FAX: (703) 812-9701

** Cliff G. Lau, Ph.D.
Associate Director for Corporate Programs
Office of Naval Research
4015 Wilson Boulevard, Suite 209
Arlington, VA 22203
(703) 696-0366
FAX: (703) 696-0569

* IWG Representative
** IWG Alternate

DOE

** Daniel A.Hitchcock, Ph.D.
Senior Technical Advisor for Advanced Scientific Computing Research, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-30, Room E-225
19901 Germantown Road
Germantown, MD 20874-1290
(301) 903-6767
FAX: (301) 903-4846

Frederick C. Johnson, Ph.D.
Program Manager, Mathematical, Information,and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown, MD 20874-1290
(301) 903-3601
FAX: (301) 903-7774

Norman H. Kreisman
Advisor, International Technology
Department of Energy, SC5
Mail Stop 3H049-FORS
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC 20585
(202) 586-9746
FAX: (202) 586-7719

Thomas Ndousse-Fetter, Ph.D.
Program Manager for Networking, Mathematical,Information, and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown, MD 20874-1290
(301) 903-9960
FAX: (301) 903-7774

* C. Edward Oliver, Ph.D.
Associate Director, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-30,
19901 Germantown Road
Germantown,MD 20874-1290
(301) 903-7486
FAX: (301) 903-4846

Walter M. Polansky, Ph.D.
Acting Director, Mathematical, Information,and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown,MD 20874-1290
(301) 903-5800
FAX: (301) 903-7774

Charles H. Romine, Ph.D.
Program Manager, Mathematical, Information,and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown,MD 20874-1290
(301) 903-5152
FAX: (301) 903-7774

Mary Anne Scott, Ph.D.
Program Manager, Mathematical, Information,and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown,MD 20874-1290
(301) 903-6368
FAX: (301) 903-7774

George R. Seweryniak
Program Manager, Mathematical, Information,and Computational Sciences (MICS) Division, Office of Advanced Scientific Computing Research (OASCR)
Department of Energy
OASCR/MICS, SC-31
19901 Germantown Road
Germantown,MD 20874-1290
(301) 903-0071
FAX: (301) 903-7774

DOE/NNSA

* José L. Muñoz, Ph.D.
Acting Director, Office of Simulation and Computer Science
Department of Energy, DP-14
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC 20585
(202) 586-5132
FAX: (202) 586-8005

EPA

** Robin L. Dennis, Ph.D.
Senior Science Program Manager, MD-80
Environmental Protection Agency
Research Triangle Park,NC 27711
(919) 541-2870
FAX:(919) 541-1379

* Steven Fine, Ph.D.
HPCC Program Manager, MD-80
Environmental Protection Agency
Research Triangle Park,NC 27711
(919) 541-0757
FAX:(919) 541-1379

EPA FedEx address:
79 T.W. Alexander Drive
Building 4201
Research Triangle Park, NC 27709

* IWG Representative
** IWG Alternate

GSA

Keith Thurston
Assistant to Deputy Associate Administrator, Office of Governmentwide Policy
General Services Administration
1800 F Street, N.W. (MK) Room 2239
Washington, DC 20405
(202) 501-3175
FAX: (202) 501-2482

Susan B. Turnbull
Director, Center for IT Accommodation
General Services Administration
1800 F Street,N.W. (MKC) Room 2236
Washington, DC 20405
(202) 501-6214
FAX: (202) 219-1533

G. Martin Wagner
Associate Administrator for Governmentwide Policy
General Services Administration
1800 F Street,N.W. (M) Room 5240
Washington, DC 20405
(202) 501-8880
FAX: (202) 501-8898

NASA

Ricky W. Butler
Senior Research Engineer, Airborne Systems Competency Division,NASA Langley Research Center
National Aeronautics and Space Administration
Mail Stop 130
Hampton, VA 23681-2199
(757) 864-6198
FAX: (757) 864-4234

Betsy Edwards
Telecommunications Program Manager for the Office of Space Flight
National Aeronautics and Space Administration
Code M
300 E Street, S.W.
Washington, DC 20546
(202) 358-4639
FAX: (202) 358-3550

William J. Feiereisen, Ph.D.
Division Chief, NASA Advanced Supercomputing (NAS) Division, NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 258-5
Moffett Field, CA 94035-1000
(650) 604-4225
FAX: (650) 604-7324

James R. Fischer
Project Manager, Earth and Space Sciences Project,NASA Goddard Space Flight Center
National Aeronautics and Space Administration
Code 930 – NASA/GSFC
Greenbelt,MD 20771
(301) 286-3465
FAX:(301) 286-1634

Kenneth Freeman
HPCC/NREN Project Manager, NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 233-21
Moffett Field, CA 94035
(650) 604-1263

* Lee B. Holcomb
Chief Information Officer
National Aeronautics and Space Administration
Code AO
300 E Street, S.W.
Washington, DC 20546
(202) 358-1824
FAX:(202) 358-3063

Anngienetta R. Johnson
Director, Program Planning and Development Division, Office of Earth Science
National Aeronautics and Space Administration
Code YF
300 E Street, S.W.
Washington, DC 20546
(202) 358-4717
FAX: (202) 358-2769

Nand Lal, Ph.D.
Computer Scientist,Digital Library Technologies,NASA Goddard Space Flight Center
National Aeronautics and Space Administration
Code 933 – NASA/GSFC
Greenbelt, MD 20771
(301) 286-7350
FAX: (301) 286-1775

Michael R. Lowry
Senior Research Scientist and Area Chief, Automated Software Engineering, NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 269-2
Moffett Field, CA 94035-1000
(650) 604-3369
FAX: (650) 604-3594

** David B. Nelson, Ph.D.
Deputy Chief Information Officer
National Aeronautics and Space Administration
Code AO
300 E Street, S.W.
Washington, DC 20546
(202) 358-1817
FAX: (202) 358-3063

Stephen Scott Santiago
Chief Information Officer, NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 233-7
Moffett Field, CA 94035-1000
(650) 604-5015
FAX: (650) 604-6999

Michael G. Shafto, Ph.D.
Program Manager, Human-Centered Computing,NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 269-4
Moffett Field, CA 94035-1000
(650) 604-6170
FAX: (650) 604-6009

John P. Ziebarth, Ph.D.
Deputy Division Chief, NAS Systems Division, NASA Ames Research Center
National Aeronautics and Space Administration
Mail Stop 258-5
Moffett Field, CA 94035-1000
(650) 604-2761
FAX: (650) 604-2824

NIH

NIH IT R&D Coordinator

Vacant

CIT Program:

Alan S. Graeff
Chief Information Officer, NIH, and Director, Center for Information Technology
National Institutes of Health
12 South Drive, MSC 5654
Building 12A, Room 3033
Bethesda, MD 20892-5654
(301) 496-5703
FAX: (301) 402-1754

** Robert L. Martino, Ph.D.
Director, Division of Computational Bioscience and Chief, Computational Bioscience and Engineering Laboratory, Center for Information Technology (CIT)
National Institutes of Health
12 South Drive, MSC 5654
Building 12A, Room 2033
Bethesda, MD 20892-5654
(301) 496-1112
FAX: (301) 402-2867

NCI program:

Carol A. Dahl, Ph.D.
Director, Office of Technology and Industrial Relations
National Cancer Institute
National Institutes of Health
31 Center Drive, MSC 2590
Building 31, Room 11A03
Bethesda, MD 20892-2590
(301) 435-3863
FAX: (301) 496-7807

Jacob V. Maizel, Ph.D.
Biomedical Supercomputer Center, National Cancer Institute, Frederick Cancer Research and Development Center
National Institutes of Health
P.O. Box B, Building 469, Room 151
Frederick, MD 21702-1201
(301) 846-5532
FAX: (301) 846-5598

NCRR program:

Michael Marron, Ph.D.
Director, Biomedical Technology
National Center for Research Resources
National Institutes of Health
One Rockledge Center
6705 Rockledge Drive, Room 6160
Bethesda, MD 20892-7965
(301) 435-0755
FAX: (301) 480-3659

** Judith L. Vaitukaitis, M.D.
Director, National Center for Research Resources
National Institutes of Health
31B Center Drive
Building 31, Room 3B11
Bethesda, MD 20892-2128
(301) 496-5793
FAX: (301) 402-0006

NIAID program:

Richard Morris, Ph.D.
Special Expert for Bioengineering, Bioinformatics and Emerging Technology, Division of Allergy, Immunology and Transplantation, National Institute of Allergy and Infectious Diseases,
National Institutes of Health
Room 5126
6700 B Rockledge Drive, MSC 7640
Bethesda, MD 20892-7640
(301) 594-7634
FAX: (301) 402-2571

* IWG Representative
** IWG Alternate

NIBIB program:

Donna J. Dean, Ph.D.
Acting Director, National Institute of Biomedical Imaging and Bioengineering
National Institutes of Health
Building 1, Room 257
1 Center Drive, MSC 0170
Bethesda, MD 20892-0170
(301) 435-6138
FAX: (301) 435-7268

NIGMS program:

James C. Cassatt, Ph.D.
Director, Division of Cell Biology and Biophysics, National Institute of General Medical Sciences
National Institutes of Health
4500 Center Drive, MSC 4500
Bethesda, MD 20892
(301) 594-0828
FAX: (301) 480-2004

NLM program:

** Michael J. Ackerman, Ph.D.
Assistant Director for High Performance Computing and Communications, National Library of Medicine
National Institutes of Health
Building 38A, Room B1N30
8600 Rockville Pike
Bethesda, MD 20894
(301) 402-4100
FAX: (301) 402-4080

Milton Corn, M.D.
Associate Director, National Library of Medicine, and Director, Division of Extramural Programs
National Institutes of Health
Rockledge One Building, Suite 301
6705 Rockledge Drive
Bethesda, MD 20892
(301) 496-4621
FAX: (301) 402-2952

Donald A.B. Lindberg, M.D.
Director, National Library of Medicine
National Institutes of Health
Building 38,Room 2E17B
8600 Rockville Pike
Bethesda, MD 20894
(301) 496-6221
FAX: (301) 496-4450

David J. Lipman, M.D.
Director, National Center for Biotechnology Information, National Library ofMedicine
National Institutes of Health
Building 38A,Room 8N803
8600 Rockville Pike
Bethesda, MD 20894
(301) 496-2475
FAX: (301) 480-9241

NIST

Ronald F. Boisvert, Ph.D.
Chief, Mathematical and Computational Sciences Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8910
Gaithersburg, MD 20899-8910
(301) 975-3812
FAX: (301) 990-4127

James E. Fowler
Manager, Systems Integration for Manufacturing Applications Program (SIMA),Manufacturing Engineering Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8260
Gaithersburg, MD 20899-8260
(301) 975-3180
FAX: (301) 258-9749

Martin Herman, Ph.D.
Chief, Information Access and User Interfaces Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8940
Gaithersburg, MD 20899-8940
(301) 975-4495
FAX:(301) 670-0939

D. Richard Kuhn
Computer Scientist,Computer Security Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8930
Gaithersburg, MD 20899-8930
(301) 975-3337
FAX: (301) 948-0279

* William Mehuron, Ph.D.
Director, Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8900
Gaithersburg, MD 20899-8900
(301) 975-2900

Kevin L.Mills, Ph.D.
Chief, Advanced Network Technologies Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8920
Gaithersburg, MD 20899-8920
(301) 975-3618
FAX: (301) 590-0932

Doug Montgomery
Manager, Internetworking Technologies Group, Advanced Network Technologies Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8920
Gaithersburg, MD 20899-8920
(301) 975-3630
FAX: (301) 590-0932

Steven R. Ray, Ph.D.
Chief, Manufacturing Systems Integration Division, Manufacturing Engineering Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8260
Gaithersburg, MD 20899-8260
(301) 975-3524
FAX: (301) 258-9749

** Larry H.Reeker, Ph.D.
Senior Computer Scientist,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8970
Gaithersburg, MD 20899-8970
(301) 975-5147
FAX: (301) 948-1784

Robert Rosenthal
Computer Security Division,Information Technology Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8930
Gaithersburg, MD 20899-8930
(301) 975-3603
FAX: (301) 948-1233

NOAA

Ants Leetmaa, Ph.D.
Director, Geophysical Fluid Dynamics Laboratory
National Oceanic and Atmospheric Administration
Forrestal Campus, U.S. Route 1
P.O. Box 308
Princeton,NJ 08542-0308
(609) 452-6502
FAX: (609) 987-5070

Alexander E.MacDonald, Ph.D.
Director, Forecast Systems Laboratory
National Oceanic and Atmospheric Administration
325 Broadway
Boulder, CO 80303
(303) 497-6378
FAX: (303) 497-6821

* Thomas N. Pyke, Jr.
Director for HPCC
National Oceanic and Atmospheric Administration
Room 15300
1315 East-West Highway
Silver Spring, MD 20910
(301) 713-3573
FAX:(301) 713-4040

Bruce B. Ross, Ph.D.
Deputy Director, Geophysical Fluid Dynamics Laboratory
National Oceanic and Atmospheric Administration
Forrestal Campus, U.S. Route 1
P.O. Box 308
Princeton, NJ 08542-0308
(609) 452-6504
FAX: (609) 987-5070

** William T. Turnbull
Deputy Director for HPCC
National Oceanic and Atmospheric Administration
Room 15300
1315 East-West Highway
Silver Spring, MD 20910
(301) 713-3573
FAX: (301) 713-4040

Louis Uccellini
Director, National Centers for Environmental Prediction
National Oceanic and Atmospheric Administration
5200 Auth Road, Room 101
Camp Springs,MD 20746
(301) 763-8000
FAX: (301) 763-8434

NSA

Curt Boylls, Ph.D.
Deputy Director, Advanced Research and Development Activity in Information Technology
National Security Agency
9800 Savage Road, Suite 6644
Fort George G. Meade, MD 20755-6644
(301) 688-7092
FAX:(301) 688-7410

Dean R. Collins, Ph.D.
Director, Advanced Research and Development Activity in Information Technology
National Security Agency
9800 Savage Road, Suite 6530
Fort George G. Meade, MD 20750-6530
(301) 688-7092
FAX:(301) 688-7410

* George R. Cotter
Office of Corporate Assessments
National Security Agency
9800 Savage Road, Suite 6217
Fort George G. Meade, MD 20755-6217
(301) 688-6434
FAX:(301) 688-4980

Howard Gordon
Senior Computer Scientist
National Security Agency
9800 Savage Road, Suite 6648
Fort George G. Meade, MD 20755-6648
(301) 688-9513
FAX: (301) 688-9454

William Bradley Martin
Senior Computer Scientist
National Security Agency
9800 Savage Road, Suite 6511
Fort George G. Meade, MD 20750-6511
(301) 688-1057
FAX:(301) 688-0056

Robert V. Meushaw
Technical Director, INFOSEC Research and Technology
National Security Agency
9800 Savage Road, Suite 6529
Fort George G. Meade, MD 20755-6529
(301) 688-0840
FAX: (301) 688-0255

William J. Semancik
Director, Laboratory for Telecommunications Sciences
National Security Agency
c/o U. S. Army Research Laboratory
Adelphi Laboratory Center
2800 Powder Mill Road, Building 601, Room 131
Adelphi, MD 20783-1197
(301) 688-1709
FAX: (301) 291-2591

NSF

S. Kamal Abdali, Ph.D.
Acting Division Director, Computer-Communications Research Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1145
Arlington, VA 22230
(703) 292-8910
FAX: (703) 292-9059

William Richards Adrion, Ph.D.
Division Director, Experimental and Integrative Activities Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1160
Arlington, VA 22230
(703) 292-8980
FAX: (703) 292-9030

Frank D. Anger, Ph.D.
Acting Deputy Division Director and Program Director, Software Engineering and Languages,Computer-Communications Research Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1145
Arlington, VA 22230
(703) 292-8911
FAX:(703) 292-9059

* IWG Representative
** IWG Alternate

William S. Bainbridge, Ph.D.
Staff Associate for Management and Planning,Social and Economic Sciences Division,Directorate for Social, Behavioral,and Economic Sciences
National Science Foundation
4201 Wilson Boulevard, Suite 905
Arlington, VA 22230
(703) 292-7470
FAX: (703) 292-9068

* Ruzena Bajcsy, Ph.D.
Assistant Director, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1105
Arlington, VA 22230
(703) 292-8900
FAX: (703) 292-9074

** Robert R. Borchers, Ph.D.
Division Director, Advanced Computational Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1122
Arlington, VA 22230
(703) 292-8970
FAX:(703) 292-9060

Lawrence E. Brandt
Program Manager, Experimental and Integrative Activities Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1160
Arlington, VA 22230
(703) 292-8980
FAX: (703) 292-9030

Aubrey M. Bush, Ph.D.
Division Director, Advanced Networking Infrastructure and Research Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1175
Arlington, VA 22230
(703) 292-8950
FAX:(703) 292-9010

John C.Cherniavsky, Ph.D.
Senior EHR Advisor for Research, Research,Evaluation and Communication Division,Directorate for Education and Human Resources
National Science Foundation
4201 Wilson Boulevard, Suite 855
Arlington, VA 22230
(703) 292-5136
FAX:(703) 292-9046

Frederica Darema, Ph.D.
Program Director, Experimental and Integrative Activities Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1160
Arlington, VA 22230
(703) 292-8980
FAX:(703) 292-9030

* Robert A.Eisenstein, Ph.D.
Assistant Director, Directorate for Mathematical and Physical Sciences
National Science Foundation
4201 Wilson Boulevard, Suite 1005
Arlington, VA 22230
(703) 292-8801
FAX: (703) 292-9151

Helen Gill, Ph.D.
Program Director, Computer-Communications Research Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1145
Arlington, VA 22230
(703) 292-8910
FAX:(703) 292-9059

Thomas J. Greene, Ph.D.
Senior Program Director, Advanced Networking Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1175
Arlington, VA 22230
(703) 292-8948
FAX: (703) 292-9010

Stephen M. Griffin
Program Manager, Digital Libraries Initiative, Information and Intelligent Systems Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1115
Arlington, VA 22230
(703) 292-8930
FAX: (703) 292-9073

Richard Hilderbrandt, Ph.D.
Program Director, Advanced Computational Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1122
Arlington, VA 22230
(703) 292-8963
FAX:(703) 292-9060

Richard S. Hirsh
Deputy Division Director, Advanced Computational Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1122
Arlington, Va 22230
(703) 292-8970
FAX:(703) 292-9060

C. Suzanne Iacono, Ph.D.
Program Director, Computation and Social Systems,Information and Intelligent Systems Division, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1115
Arlington, VA 22230
(703) 292-8930
FAX: (703) 292-9073

Clifford A. Jacobs, Ph.D.
Section Head, UCAR and Lower Atmospheric Facilities Oversight Section, Atmospheric Sciences Division, Directorate for Geosciences
National Science Foundation
4201 Wilson Boulevard, Suite 775
Arlington, VA 22230
(703) 292-8521
FAX: (703) 292-9022

** Bradley D. Keister, Ph.D.
Program Director, Nuclear Physics, Physics Division,Directorate for Mathematical and Physical Sciences
National Science Foundation
4201 Wilson Boulevard, Suite 1015
Arlington, VA 22230
(703) 306-1891
FAX: (703) 306-0566

Charles H.Koelbel, Ph.D.
Program Director, Advanced Computational Research,Advanced Computational Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1122
Arlington, VA 22230
(703) 292-8962
FAX:(703) 292-9060

Michael E. Lesk, Ph.D.
Division Director, Information and Intelligent Systems Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1115
Arlington, VA 22230
(703) 292-8930
FAX: (703) 292-9073

Stephen R. Mahaney
Senior Advisor for Budget, Policy, and Planning,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1160
Arlington, VA 22230
(703) 292-8900
FAX:(703) 292-9074

** George O. Strawn, Ph.D.
Executive Officer, Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1105
Arlington, VA 22230
(703) 292-8900
FAX: (703) 292-9074

Gary W. Strong, Ph.D.
Program Director, Experimental and Integrative Activities Division and Information and Intelligent Systems Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1160
Arlington, VA 22230
(703) 292-8980
FAX:(703) 292-9030

Taieb F. Znati, Ph.D.
Senior Program Director, Advanced Networking Infrastructure and Research Division,Directorate for Computer and Information Science and Engineering
National Science Foundation
4201 Wilson Boulevard, Suite 1175
Arlington, VA 22230
(703) 292-8949
FAX: (703) 292-9010

Executive Office of the President

NEC

John M. Ackerly
Special Assistant to the Director
National Economic Council
Room 235
Eisenhower Executive Office Building
17th Street and Pennsylvania Avenue, N.W.
Washington, DC 20502
(202) 456-2884
FAX: (202) 456-2223

OMB

David S. Trinkle
Program Examiner
Office of Management and Budget
Room 8225
New Executive Office Building
725 17th Street,N.W.
Washington, DC 20503
(202) 395-4706
FAX: (202) 395-4652

OSTP

Richard Russell
Chief of Staff
Office of Science and Technology Policy
Room 423
Eisenhower Executive Office Building
17th Street and Pennsylvania Avenue, N.W.
Washington, DC 20502
(202) 456-6140
FAX: (202) 456-6049

Paul D. Domich, Ph.D.
Senior Policy Analyst
Office ofScience and Technology Policy
Room 423
Eisenhower Executive Office Building
17th Street and Pennsylvania Avenue, N.W.
Washington, DC 20502
(202) 456-6037
FAX: (202) 456-6023

* IWG Representative
** IWG Alternate

Interagency Working Group on IT R&D

Chair
Ruzena Bajcsy, NSF

NSF/CISE
Representative
Ruzena Bajcsy
Alternates
George O. Strawn
Robert R. Borchers

NSF/MPS
Representative
Robert A. Eisenstein
Alternate
Bradley D. Keister

DARPA
Representative
Mark Swinson

NIH
Representative
Vacant
Alternates
Michael J. Ackerman
Robert L. Martino
Judith L. Vaitukaitis

NASA
Representative
Lee B. Holcomb
Alternate
David B. Nelson

DOE Office of Science
Representative
C.Edward Oliver
Alternate
Daniel A.Hitchcock

NSA
Representative
George R. Cotter

NIST
Representative
William Mehuron
Alternate
Larry H.Reeker

NOAA
Representative
Thomas N. Pyke, Jr.
Alternate
William T. Turnbull

AHRQ
Representative
J. Michael Fitzmaurice

ODUSD (S&T)
Representative
Charles J. Holland
Alternate
Cliff G. Lau

EPA
Representative
Steven Fine
Alternate
Robin L. Dennis

DOE/NNSA
Representative
José L. Muñoz

OMB
Representative
David S. Trinkle

OSTP
Representative
Paul D. Domich

NCO
Representative
Cita M. Furlani
Alternate
Sally E.Howe

PCA Coordinating Groups and Team Chairs

High End Computing and Computation (HECC) Coordinating Group
Co-Chairs
Robert R. Borchers,NSF
José L. Muñoz, DOE/NNSA

Human Computer Interaction and Information Management (HCI & IM) Coordinating Group
Co-Chairs
Gary W. Strong, NSF
Jean Scholtz, DARPA

Large Scale Networking (LSN) Coordinating Group
Co-Chairs
George O. Strawn,NSF
Daniel A.Hitchcock, DOE

High Performance Networking Applications Team (HPNAT)
Chair
William T. Turnbull,NOAA

Joint Engineering Team (JET)
Co-Chairs
Paul E. Love, Internet2
Vacant

Networking Research Team (NRT)
Co-Chairs
Mari W. Maeda, DARPA
Vacant

Software Design and Productivity (SDP) Coordinating Group
Co-Chairs
Frank Anger, NSF
Douglas C. Schmidt, DARPA

High Confidence Software and Systems (HCSS) Coordinating Group
Co-Chairs
Helen Gill,NSF
Gary Koob, DARPA

Social,Economic,and Workforce Implications of IT and IT Workforce Development (SEW) Coordinating Group
Co-Chairs
C. Suzanne Iacono, NSF
William S. Bainbridge, NSF

Federal Information Services and Applications Council (FISAC)
Co-Chairs
G.Martin Wagner, GSA
Lawrence E.Brandt,NSF

Digital Government Liaison
Lawrence E.Brandt,NSF

Federal Statistics Team
Chair
Cathryn S. Dippo, BLS

Information Technology for Crises Management Team
Chair
Anngienetta R. Johnson, NASA

Next Generation Internet Team
Chair
William T. Turnbull,NOAA

Universal Access Team
Chair
Susan B. Turnbull,GSA

National Coordination Office (NCO) for Information Technology Research and Development

Cita M. Furlani
Director

Sally E. Howe, Ph.D.
Associate Director

Suite II-405
4201 Wilson Boulevard
Arlington, VA 22230
(703) 292-4873
FAX: (703) 292-9097
nco@itrd.gov

Internet Web Site

http://www.itrd.gov/

FY 2002 Blue Book

Sally E.Howe
Executive Editor

Martha K. Matzke
Editor

Acknowledgments

This Supplement to the President's FY 2002 Budget reflects not only the scope and diversity of Federal Networking and Information Technology Research and Development activities but the editorial contributions of many individuals, to whom we extend sincerest thanks.

The editors thank the agency program managers who developed the research goals and program plans highlighted in this report and the NCO colleagues who provided ready and able support in all aspects of the production process, especially proofreading, preparation of the Web version, and distribution. Special thanks to Norman S. Glick, recently retired from NSA, for his continued contribution of unrivalled copyediting and proofreading skills.

Contributors

William S. Bainbridge, NSF
David Bernholz, NCO
George R. Cotter, NSA
Frank D. Anger, NSF
Betsy Edwards, NASA
Steven Fine, EPA
J. Michael Fitzmaurice, ARHQ
Helen M. Gigley, NCO
Helen Gill, NSF
Norman S. Glick (formerly NSA)
Stephen M. Griffin, NSF
Vicki L. Harris, NCO
Daniel A. Hitchcock, DOE
Charles J. Holland, DoD
Lee B. Holcomb, NASA
C. Suzanne Iacono, NSF
Norman H. Kreisman, DOE
Gary M. Koob, DARPA
Clifford G. Lau, ODUSD (S&T)
Stephen R. Mahaney, NSF
Michael Marron, NIH
Betty McDonough, NCO
Grant Miller, NCO
Virginia Moore, NCO
José L. Muñoz, DOE/NNSA
Larry H. Reeker, NIST
Shankar Sastry (formerly DARPA)
Frank Sledge, NCO
Gary W. Strong, NSF
Maj. James Sweeney, ODUSD (S&T)
Col. Mark Swinson, DARPA
Janos Sztipanovits, DARPA
William T. Turnbull, NOAA
Diane R. Vellines, NCO

Abstract

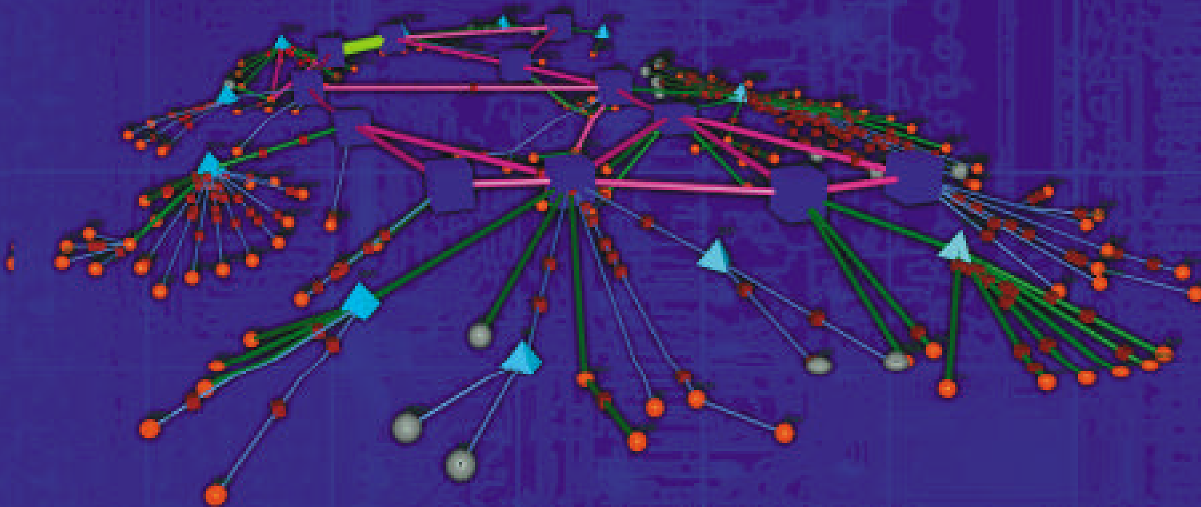
The Federal agencies that participate in the Networking and Information Technology Research and Development (NITRD) effort work collaboratively in fundamental, long-term research and development activities to assure continuing U.S. leadership in advanced computing, networking, communications, and information technologies. The NITRD agenda focuses on enabling Federal departments and agencies to fulfill their missions successfully in the 21st century. This Supplement to the President's FY 2002 Budget summarizes the major IT research areas that the NITRD agencies will address in FY 2002 and outlines long-term research needs in each area. The report also describes Grand Challenge National Applications of networking and information technology that will integrate in large-scale systems the enabling component technologies developed by the NITRD agencies.

Buy American Report

Congress requires information concerning non-U.S. high-performance computing and communications funding activities. In FY 2001, DARPA was the only NITRD agency that entered into grants, contracts, cooperative agreements, or cooperative research and development agreements for IT R&D with either 1) a company other than a company that is either incorporated or located in the U.S. and that has majority ownership by individuals who are citizens of the U.S.,or 2) an educational institution or nonprofit institution located outside the U.S. DARPA funded IT research-related awards of $94,900 to University College, London (UK). In FY 2001, no NITRD procurement exceeds $1 million for unmanufactured articles, materials, or supplies mined or produced outside the U.S., or for manufactured articles, materials, or supplies other than those manufactured in the U.S. substantially all from articles, materials, or supplies mined, produced, or manufactured in the U.S.

Ordering Additional Copies

To order additional copies of this Supplement to the President's FY 2002 Budget or other publications of the National Coordination Office for Information Technology Research and Development, please contact: National Coordination Office for IT R&D, Suite II-405, 4201 Wilson Boulevard, Arlington, Virginia 22230; (703) 292-4873; fax: (703) 292-9097; e-mail: nco@itrd.gov.



Interagency Working Group on
Information Technology Research and Development

National Science and Technology Council

Suite II - 405
4201 Wilson Blvd.
Arlington, VA 22230
(703) 292-4873

nco@itrd.gov
http://www.itrd.gov