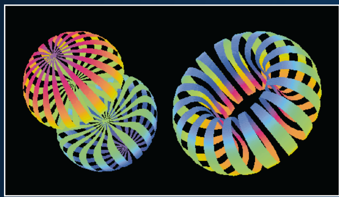

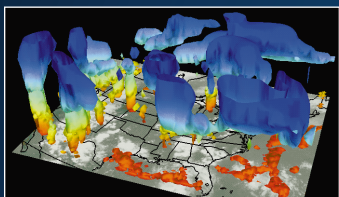

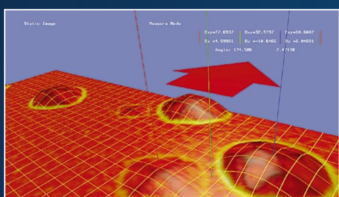

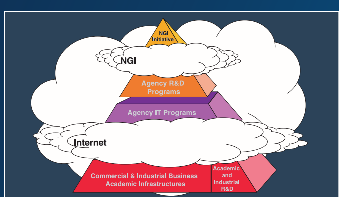

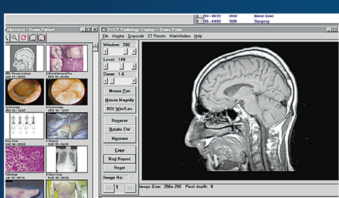

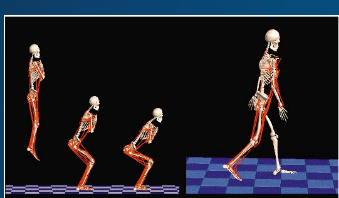

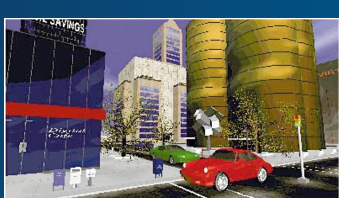

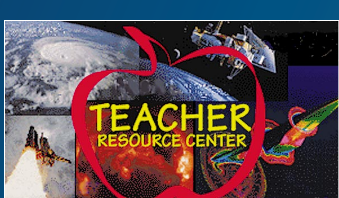

Computing, Information, and Communications

Technologies for the 21st Century

Supplement to the President's FY 1998 Budget

National Science and Technology Council
Committee on Computing, Information, and Communications

About the National Science and Technology Council:

President Clinton established the National Science and Technology Council (NSTC) 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.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research, to improving transportation systems and strengthening fundamental research. The Council prepares research and development strategies that are coordinated across Federal agencies to form an investment package that is aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, contact the NSTC Executive Secretariat at 202-456-6100.

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.

To obtain additional information regarding the OSTP, contact the OSTP Administrative Office at 202-395-7347.

Cover Images

From top to bottom:

1. Properties of light nuclei (up to 40 neutrons and protons) are computed employing realistic two- and three-nucleon interactions such as those illustrated here. *(Page 9)*

2. This image compares remotely sensed cloud data from the Geostationary Operational Environmental Satellite (GOES) seen as white clouds at the bottom of the image with 3-D cloud data predicted by NCAR's Mesoscale Meterological Model. *(Page 14)*

3. A close-up view of germanium pyramids and domes grown on silicon. Part of the nanoManipulator project. *(Page 41)*

4. Illustration depicting the collaborations involved in the Next Generation Internet initiative announced by President Clinton and Vice President Gore on October 10, 1996. (*Page 17*)

5. Example of a patient's record containing multidisciplinary images available over networks to authorized health care providers. *(Page 23)*

6. A three-dimensional simulation of the jumping figure, the first of its kind, consumes 800 CPU hours on an IBM SP2. *(Page 29)*

7. One view of a virtual city created using the Virtual Reality Modeling Language. Potential applications include treating acrophobia. *(Page 27)*

8. An abundance of free educational information is available to educators and students through the World Wide Web. *(Page 34)*

COMPUTING, INFORMATION, AND COMMUNICATIONS

TECHNOLOGIES FOR THE 21ST CENTURY

A Report by the Committee on Computing, Information, and Communications

National Science and Technology Council

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Computing, Information, and Communications R&D Subcommittee
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Education, Training, and Human Resources Working Group

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CIC R&D Highlights:

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Executive Summary

As the 21st century approaches, the rapid convergence of computing, communications, and information technology promises unprecedented opportunities for scientific discovery, industrial progress, and societal benefit. The development of ever more powerful high-performance computers and effective low-cost computers, advanced networking technologies, evolving software technologies, and the phenomenal growth of the World Wide Web are enabling unparalleled advances in science and engineering, as well as facilitating the integration of information technology into the mainstream of American life. Research in computing, communication, and information systems will be pivotal at this unique juncture of technological, historical, and societal forces.

To meet the challenges of a radically new and technologically demanding century, the Federal Computing, Information, and Communications (CIC) programs are investing in long-term research and development (R&D) to advance computing, information, and communications in the United States. CIC R&D programs help Federal departments and agencies to fulfill their evolving missions, assure the long-term national security, better understand and manage our physical environment, improve health care, help improve the teaching of our children, provide tools for lifelong training and distance learning to our workforce, and sustain critical U.S. economic competitiveness.

These programs are an outgrowth of the highly successful, Congressionally-chartered High Performance Computing and Communications (HPCC) initiative. That initiative was responsible for accelerating entry of the U.S. into the era of teraop computers, gigabyte networks, and computation-intensive science and engineering applications.

Program Component Areas

One of the nine committees of the National Science and Technology Council (NSTC), the Committee on Computing, Information, and Communications (CCIC) — through its CIC R&D Subcommittee — coordinates R&D programs conducted by twelve Federal departments and agencies in cooperation with U.S. academia and industry. These R&D programs are organized into five Program Component Areas:

HECC	High End Computing and Computation
LSN	Large Scale Networking, including the Next Generation Internet Initiative
HCS	High Confidence Systems
HuCS	Human Centered Systems
ETHR	Education, Training, and Human Resources

A brief synopsis of FY 1997 accomplishments and FY 1998 goals by PCA appears in this summary.

High End Computing and Computation

HECC R&D investments provide the foundation for 21st century U.S. leadership in high end computing. This R&D focuses on advances in hardware and software, and in algorithms for modeling and simulation needed for computation- and information-intensive science and engineering applications. HECC research also explores advanced concepts in quantum, biological, and optical computing.

HECC R&D targets system software technology with an emphasis on the usability and effectiveness of teraflops-scale systems, future generation computing focusing on petaflops-scale computation and exabyte-level mass storage, the incorporation of HECC technologies into Federal agency applications, and the maintenance of a state-of-the-art HECC R&D infrastructure.

HECC programs support outstanding, leading-edge science and foster innovative solutions to complex computational problems. Select FY 1997 HECC accomplishments highlighted in this report include advances in supercomputing technology, advances in design optimization techniques in such critical areas as aircraft wing design, improved system for visualizing output from computations such as atmospheric and ocean models with composite images from the Geostationary Operational Environmental Satellite (GOES), a more sophisticated understanding of the complex modeling of molecular and nuclear structures, and advances in biological modeling.

FY 1998 Federal investments in HECC will enable development of the distributed, computation-intensive applications necessary to support future U.S. science and engineering research, Government missions, economic competitiveness, and long-range national priorities.

Large Scale Networking

FY 1998 LSN R&D, including the new Next Generation Internet (NGI) initiative, focuses on developing the landmark networking technologies and applications that will keep the U.S. in the forefront of the information revolution. Key research areas include technologies and services that enable advances in wireless, optical, mobile, and wireline network communications; networking software that enables information to be disseminated to individuals, multicast to groups, or broadcast to an entire network; software for efficient development and execution of scalable distributed applications; software components for distributed applications; and research infrastructure support and testbeds.

FY 1997 LSN R&D accomplishments include improvements in the advanced Federal networks that connect U.S. researchers and educators to computing, information, and scientific resources and facilities such as remote telescopes, microscopes, and advanced light sources; and support for networking research in gigabit testbeds, optical fiber networks, adaptive networks, and packetized video and voice. These accomplishments are enabling researchers to use distributed database architectures to access, for example, molecular biology, biochemistry, and genetics data, such as GenBank, a key resource of the Human Genome Project.

Next Generation Internet

There is little historical precedent for the swift and dramatic growth of the Internet, which, just a few short years ago, was a limited scientific communication network developed by the Government to facilitate cooperation among Federal researchers and the university research community. With its rapid adoption by the private sector, the Internet, while remaining an important research tool, is now becoming a vital ingredient in maintaining and increasing the scientific and commercial leadership of the U. S.

In the 21st century, the Internet will provide a powerful and versatile environment for business, education, culture, and entertainment. Sight, sound, and even touch will be integrated through powerful computers, displays, and networks. People will use this environment to work, study, bank, shop, entertain, and visit with each other. Whether at the office, at home, or traveling, the environment and its interface will be largely the same. Security, reliability, and privacy will be built in. Customers will be able to choose among different levels of service at varying price points. Benefits of this dramatically different environment will include a more agile economy, improved health care - particularly in rural areas, less stress on the ecosystem, easy access to life-long and distance learning, a greater choice of places to live and work, and more opportunities to participate in the community, the Nation, and the world.

The Next Generation Internet (NGI) initiative will be a primary focus of LSN R&D beginning in FY 1998. Announced by President Clinton and Vice President Gore on October 10, 1996, the NGI initiative will create a foundation for the more powerful and versatile networks of the 21st century. Based upon strong R&D programs across CIC agencies, NGI will foster partnerships among academia, industry, and Government that will keep the U.S. at the cutting-edge of information and communications technologies. It will accelerate the introduction of new networking services for our businesses, schools, and homes. Agencies are already taking actions to accomplish the initiative's goals, which are

- ❏ Conducting experimental research in advanced network technologies
- ❏ Developing a Next Generation Internet testbed
- ❏ Creating revolutionary applications

The Federal NGI initiative is closely related to Internet2, a collaborative effort by more than 100 U.S. research universities to create and sustain a leading edge network capability enabling the creation of the broadband applications, engineering, and network management tools needed for advanced research and education. While the goals of the NGI and Internet2 are complementary and interdependent, they are clearly distinct. The NGI initiative is a Federal mission-driven R&D program, while Internet2 focuses on innovation in academic research and education applications. The NGI initiative will create an experimental, wide area, scalable testbed to develop mission-critical applications; Internet2 will meet end-to-end performance requirements by developing and deploying advanced network infrastructure. Much of the wide area testbed for Internet2 will be provided by the NGI initiative. Both the NGI initiative and the Internet2 project will develop and test advanced network technologies not supported by today's Internet, primarily through NGI-funded research at Internet2 universities. Continued strong coordination and communication between the Federal and academic communities will be crucial for the success of both programs.

High Confidence Systems

HCS R&D focuses on the technologies necessary to achieve high levels of security, protection, availability, reliability, and restorability of information services. Systems that employ these technologies will be resistant to component failure and malicious manipulation and will respond to damage or perceived threat by adaptation or reconfiguration.

High confidence technologies can be applied in the areas of system reliability, security and privacy, and testing and evaluation. With rapid advances in areas as disparate as Federal agency missions, health care, public safety, and manufacturing, HCS technologies are proving more important than ever to assure the reliable, secure transmission of critical data.

FY 1997 HCS accomplishments include advances in making images available over networks to authorized health care providers through the merging of computerized patient record systems and telemedicine systems in a way that assures integrity and confidentiality, and improvements in the reliability of information exchange among manufacturing applications.

FY 1998 HCS R&D will focus on applications requiring HCS technologies, including protocols and mechanisms that allow intrusion detection systems to share information, high assurance configurable security architectures, privacy protection methods for transmission of health data, and tools for assessing the vulnerability of source code.

Human Centered Systems

The goal of HuCS R&D is increased accessibility and usability of computing systems and communications networks. HuCS technologies are needed to assure that today's rapid advances in computing, information, and communications continue to be readily accessible to Federal agencies and to all U.S. citizens no matter where they might live and work.

Select FY 1997 HuCS accomplishments include improvements in advanced visualization techniques, such as the Climate Visualization System, an interactive tool designed for examining online data at the National Climatic Data Center; advances in the multiagency Digital Libraries Research

Initiative, which supports university-led research in the development of advanced methods for collecting, storing, and organizing information in digital form for network access; and advances in multi-agency supported basic research on multimodal interaction with computing systems, including speech, text, image, and multimedia advanced technology.

FY 1998 HuCS R&D areas include the continuing development of knowledge repositories and information agents that sort, analyze, and present massive amounts of multimedia and multi-source information; collaboratories that provide access to knowledge repositories and facilitate knowledge sharing, group authorship, and control of remote instruments; systems that enable multi-modal human-system interactions including speech, touch, and gesture recognition and synthesis; and virtual reality environments and their use in scientific research, health care, manufacturing, and training.

Education, Training, and Human Resources

ETHR R&D supports research to advance education and training technologies. The complex and technically challenging applications flowing from leading edge HECC and LSN R&D make it increasingly important for today's students and professionals to update their education and training on an ongoing basis in order to exploit the latest technological advances. ETHR technologies focus on the user and will improve the quality of today's science and engineering education, leading to more knowledgeable and productive citizens and Federal employees.

Basic research and education remain foundations of the CIC R&D programs. FY 1997 ETHR accomplishments include improved access to information on technologies and resources for classroom use, including the ability to select and copy teacher's guides and activities for use at elementary, middle, and high school levels; and programs such as Telescopes in Education and 4-Winds that allow K-12 educators to bring astronomy and weather prediction research into the classroom via the Internet.

FY 1998 ETHR research includes curriculum development, fellowships, and scholarships for computational, computer, and information scientists and engineers; the application of interdisciplinary research to learning technologies; and R&D in information-based learning tools, lifelong learning, and distance learning - especially critical in bringing the latest educational tools to isolated, rural, or underserved areas of the country.

Presidential Advisory Committee

Established on February 11, 1997 by Executive Order, the Presidential Advisory Committee on High Performance Computing and Communications, Information Technology, and the Next Generation Internet provides the NSTC, through the Director of the Office of Science and Technology Policy (OSTP), with an independent assessment of progress made in implementing high end computing and communications and information technology programs, advice on revising components of these programs, and an evaluation of their effectiveness in helping the U. S. maintain leadership in advanced computing and communications technologies and their applications. They will report on progress in designing and implementing the Next Generation Internet initiative. The distinguished researchers and industrial leaders on the Committee represent universities, the communications networking industry, the computing systems manufacturing industry, the entertainment industry, the software industry, the telecommunications industry, and applications communities including libraries and medicine.

Applications Council

The CCIC Applications Council promotes the early application of CCIC technologies throughout the Federal government, and especially in non-R&D organizations. Crisis Management, FedStats, Universal Access, and Next Generation Internet Applications Working Groups have been formed. Cross-disciplinary workshops including both creators and consumers of CCIC research products are planned for FY 1998.

Technology Policy Subcommittee

The Technology Policy Subcommittee of the CCIC succeeds the Technology Policy Working Group of the Committee on Applications and Technology of the Information Infrastructure Task Force. It supports the CCIC by identifying, studying, recommending, and, as appropriate, resolving relevant policy issues.

FY 1997 Accomplishments and FY 1998 Goals

With science and technology advancing at an almost dizzying speed, it seems at times that the 21st century has already arrived. Scientific breakthroughs that used to take decades to develop now take years or months. The CIC R&D programs are a driving force in information technologies, computing, and communications, and are a major component of America's investment in its future, helping to maintain and widen the competitive lead that will keep our citizens productive well into the next century. The estimated FY 1997 HPCC Program budget for the 12 participating Federal organizations was $1,008.5 million. For FY 1998, the President requested $1,103.7 million for these same 12 organizations.

This report highlights many of these vital, ongoing efforts, focusing on representative FY 1997 accomplishments, key FY 1998 research and development areas, and the budget crosscut. It also highlights areas of special interest that are even now changing the way we live.

This book and links to other Web sites can be found at *http://www.ccic.gov/*.

High End Computing and Computation

Key research and development (R&D) areas

HECC R&D investments provide the foundation for U.S. leadership in high end computing. HECC research explores the advanced concepts in quantum, biological, and optical computing that will keep the U.S. in the forefront of computing breakthroughs for years to come through its hardware and software innovations; algorithms for physical, chemical, and biological modeling and simulation of these processes in complex systems; and information-intensive science and engineering applications.

HECC R&D targets four areas:

- ❒ System software technology focuses on improving the usability and effectiveness of teraflops-scale systems across a wide range of government, industry, and academic applications.
- ❒ Leading-edge research for future generation computing focuses on creating the technology necessary to achieve petaflops-scale computation and exabyte-level mass storage.
- ❒ Incorporation of high end technology into real applications focuses on first use of HECC technologies in agency applications, the practice of high performance computational science, and the required underlying algorithms.
- ❒ Infrastructure for research in HECC focuses on computational facilities for research, large scale test systems, and high performance networks, with a goal of maintaining a state-of-the-art infrastructure for HECC R&D.

Federal investments in all four of these areas will enable development of the distributed, computation-intensive applications necessary to support future U.S. science and engineering research, economic competitiveness, and national security priorities.

HECC goals:

The medium range (three to five year) technology development goal for HECC R&D is the achievement of major improvements in usability and effectiveness in teraflops-scale systems across a wide range of applications. Longer range goals (more than five years) include a firmer understanding of the device technology, algorithms, and software that are required for petaflops-level computation and exabyte-level mass storage.

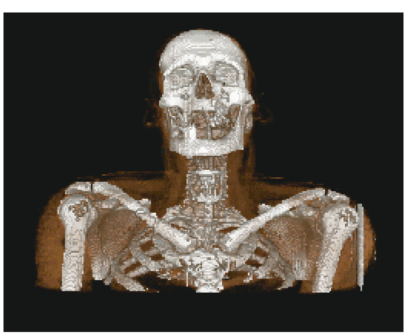
1. System software

HECC system software R&D will focus on developing parallel software tools, operating systems, program development environments, and performance monitoring for use in distributed, scalable systems. These tools and system software will improve scalability, throughput, speedup, portability, and programmability. HECC R&D will support parallel systems software such as innovative languages and their compilers, debuggers, performance monitors, scalable operating systems and I/O, program development environments, scientific visualization, data management, as well as frameworks to link software components. Large scale data management will also require the development and adoption of new storage technologies ranging from exabyte tape robots to large, fast, on-chip memory.

2. Future generations computing research

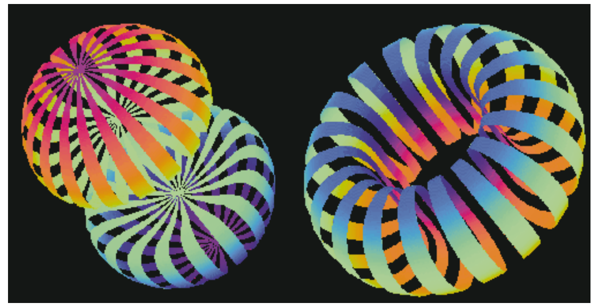
HECC will support research and technology necessary to achieve petaflops-level computation and exabyte-level mass storage by developing innovative technology for software, hardware, architecture, and components. Research based on the shared-memory programming model will create techniques to overcome memory latency through multithreading, better caching algorithms, or other means. R&D will also focus on software to support these techniques, applications design studies, architecture point design studies, and new approaches to component technology. Also included in this area is research on transportable software technologies that scale the symmetric multiprocessor systems currently available (with several to hundreds of processors) to systems with very large numbers (tens of thousands) of processors.

Concepts in the research stage include logic circuits based on current semiconducting materials as well as novel materials, such as low and high temperature superconductors, and quantum mechanics-based devices, such as rapid single-flux quantum devices used for logic circuits and memories. Research will be conducted on the technological, algorithmic, and architectural foundations for amorphous computing with programmable materials. Other promising research concepts are on- and off-chip interconnections based on guided optics that employ wavelength division multiplexing, and massive holographic optical memory devices for mass storage. Basic research will be conducted on innovative logic devices based on nanotechnology and biological materials that may exploit the information contained in large molecules such as deoxyribonucleic acid (DNA).



Volume rendering includes several techniques for visualizing 3-D scalar fields. For example, "isocontouring" extracts constant valued surfaces from these fields. An alternative is to render directly the 3-D data using forward projection or backward projection methods. Forward projection methods project samples of the 3-D field to the screen, generally using traditional graphics techniques. Backward projection, commonly referred to as volume raycasting methods, determines the color of each pixel by finding the subset of the 3-D field that projects to the pixel being colored, and then combining them. NSF-supported research in volume rendering is being conducted at Purdue University.

The properties of light nuclei (up to 40 neutrons and protons) are computed employing realistic two- and three-nucleon interactions (such as those illustrated here). Many-body methods are used to compute the properties of a nucleus for complicated forces that are strongly dependent on the spins and charge states (isospin) of the nucleons. Unlike the Coulomb force used in atomic or condensed-matter calculations, there is no useful fundamental theory that defines this force. One can partially constrain the two-body force by fitting nucleon-nucleon scattering data, but many-body calculations are required to test other properties of this force as well as the three-body interaction. DOE-supported researchers are refining their knowledge of the forces and using that knowledge to make predictions about the behavior of nuclei.



3. Agency applications

R&D will focus on incorporating HECC technologies into agency applications, as well as on developing high performance computational science and its underlying algorithms to ensure that key applications will run at their full potential. Many Computing, Information, and Communications (CIC) agencies support scientific mission-driven applications projects requiring large scale computation-intensive or data-intensive operations. These projects span the spectrum of scientific problems from cosmology to global climate modeling to short range weather prediction to protein folding to quantum chromodynamics. R&D is required to support advances in fast, efficient algorithms for computational sciences addressing emerging computational challenges, including very large sparse matrix-based problems, searching, sorting, and pattern matching. Research on algorithms with large amounts of concurrency, fault tolerance, and latency hiding is also crucial to the use of the high end computational systems of the future.

4. Infrastructure for research

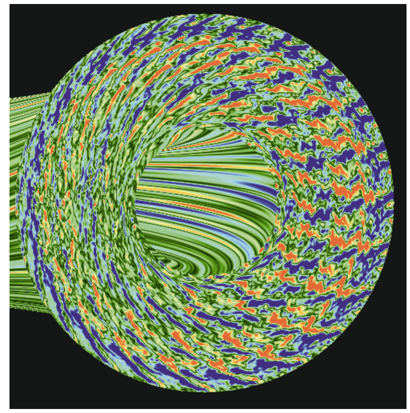
By planning and coordinating the design, implementation, and maintenance of a state-of-the-art computational infrastructure, HECC R&D will ensure that the full potential of computational research facilities, large scale test systems, and high performance networks is realized. Information exchange and coordination will ensure the continued development of a balanced infrastructure with the maximum computational strength and network bandwidth such as that available through the CIC-supported centers. This infrastructure is critical in order to continue ongoing research in large scale computation-intensive problems.

Examples of HECC R&D are described in the rest of this section.

ACTS

The Department of Energy's (DOE) Grand Challenge and Accelerated Strategic Computing Initiative (ASCI) applications are the focus of the agency's DOE 2000 Program. A primary thrust is the Advanced Computational Testing and Simulation (ACTS) Toolkit, which will provide an integrated set of software tools, algorithms, and environments to accelerate the adoption and use of advanced computing by DOE programs for mission-critical problems. An example is the Scientific Template Library project, which involves numerous DOE laboratory and university developers who are creating software toolkits written in a data-structure-neutral manner to enable easy reuse and flexibility. DOE supports user access to new high performance computing architectures at the National Energy Research

A major theme of the DOE-supported Numerical Tokamak Turbulence Project's (NTTP) gyrofluid research in the past year has been the study of plasma turbulence suppression methods discovered recently in the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory, the DIII-D in Georgia, and the Japanese JT-60 tokamaks. If these methods scale to larger devices, they could lead to more attractive and economical fusion reactor designs. There have been several NTTP studies focusing on the importance of shear in the background flow in stretching and tearing turbulent eddies, resulting in a suppression of the turbulence and a reduction in the concomitant transport. The stabilizing effects of velocity shear have been seen in numerous tokamak experiments. Shaping the magnetic field in the tokamak experiments introduces physics that is related to the sheared-flow stabilization method seen in simulations, and has led to improved confinement in recent experiments. The goal of this multidisciplinary effort is the realistic simulation of the tokamak plasma turbulence needed to optimize performance of fusion devices.



Scientific Computing Center (NERSC) and four High Performance Computing Resource Providers at DOE's Argonne, Lawrence Berkeley, Los Alamos, and Oak Ridge National Laboratories.

The National Science Foundation (NSF) Supercomputer Centers program has been instrumental in advancing science and engineering research and in enabling the U.S. to lead the world in computational science and engineering. The program is now evolving into the new Partnerships for Advanced Computational Infrastructure (PACI) program.

PACI

The PACI program is based on partnerships that will operate two leading-edge sites equipped with high-end computing systems one to two orders of magnitude more capable than those typically available at a major research university. Systems accessible by the Nation's academic research community will scale to teraflop computing capability within the next two to three years. Partners not directly involved in high end R&D will contribute to education, outreach, and training, and will develop software that will facilitate and enhance both the overall infrastructure and access to that infrastructure. After an intense competition and extensive review cycle, two sites were selected:

- ❏ The National Partnership for Advanced Computational Infrastructure (NPACI), led by the University of California at San Diego (UCSD)
- ❏ The National Computational Science Alliance (NCSA) led by the University of Illinois at Urbana-Champaign (UIUC).

At NPACI, high performance compute servers will be located at four major partner sites: University of California-Berkeley, Caltech, University of Michigan, and University of Texas. Several partners will focus on data intensive computing, as computational science and engineering evolve to enable the analysis of massive data sets from remote-sensing sources, numerical simulation output, and discipline-specific databases.

Additional NCSA computational resources will be provided by major partners Boston University and DOE's Argonne National Laboratory. The alliance will provide visual supercomputing capabilities in collaboration with several partners and with one of its strategic vendors, Silicon Graphics, Inc. The current supercomputing center at UIUC has pioneered the use of visualization for comprehending the mass of data produced by simulations or experiments and will continue this thrust in the new alliance.

ASCI's Academic Strategic Alliance Centers

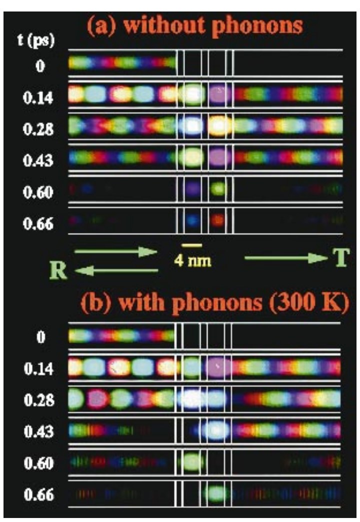
DOE's ASCI program focuses on creating leading-edge computational modeling and simulation capabilities to maintain the safety, reliability, and performance of the U.S. nuclear stockpile. The goal of the ASCI Academic Strategic Alliance Centers is to validate the scientific methodologies of large scale modeling, simulation, and computation. They will form Centers of Excellence to foster research in scientific, computational, and computer science areas that support ASCI and Science Based Stockpile Stewardship (SBSS) objectives. The Centers will have collaborative relationships with ASCI laboratories and will facilitate technical partnerships with ASCI researchers.

High Performance C++

The Defense Advanced Research Projects Agency-supported (DARPA) High Performance C++ project is defining a standard model for parallel programming using the C++ programming language. The model will support both data parallel and distributed object task parallelism, enable the construction of portable parallel applications, and provide a target for vendors to support with compiler optimization. The end product will be used on multiple platforms such as symmetric, shared memory multiprocessors as well as massively parallel systems with complex memory hierarchy. DARPA's goal is the seamless integration of science, engineering, and commercial applications that require the resources of new generation supercomputers with software that runs on conventional hardware platforms.

The M-Machine

The M-Machine is a fine grained concurrent computer being designed and built by the Massachusetts Institute of Technology (MIT) Concurrent Very Large Scale Integration (VLSI) Architecture group under the DARPA "Mechanisms for Teraflops" project. The aim of this project is to exploit increased circuit density more efficiently by building multi-ALU (arithmetic



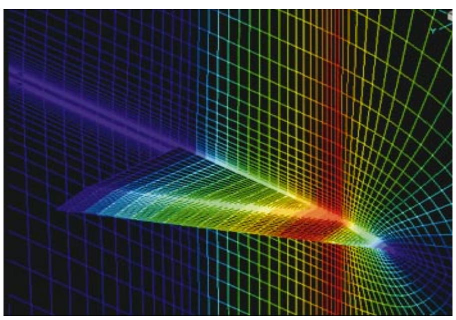
NSF-supported researchers have developed a new quantum dynamics simulation scheme to study highly nonlinear, far-from-equilibrium electron dynamics in nanodevices. The scheme incorporates the electron-phonon interaction in the mean-field approximation and dissipation through the Langevin equation. This approach has been used to study nonlinear electron transport in numerous areas, including electron mobility in amorphous Silicon.

The figure to the left represents electron wave functions in a double quantum dot: (a) no coupling; (b) electron coupled to phonons at 300 K. Brightness represents the intensity of the electron wave function, and color represents the phase. The incident electron energy is at the resonant transmission peak corresponding to the antisymmetric quasi-bound level. Without the electron-phonon interaction, the probabilities build up and decay equally in the two dots. With the electron-phonon interaction, the probability density first localizes in one dot and then starts to oscillate between the two.

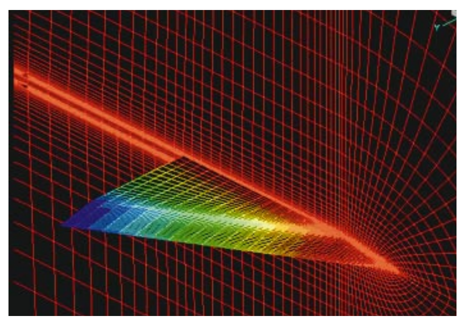
logic unit) processing nodes. While building arithmetic units, register files, and memories and replicating them on an integrated circuit is straightforward, new architecture technology is required to organize and control many arithmetic units on a single chip. The M-Machine is designed to execute programs efficiently with any or all granularities of parallelism by means of parallel instruction sequences called H (horizontal)-Threads, as well as by exploiting thread-level parallelism, and masking variable pipeline, memory, and communication delays through V (vertical)-threads. The M-Machine will employ silicon fabrication technology that will deliver 1200 MIPS (millions of instructions per second) and 800 Mflops (millions of floating point operations per second) per node.

National Compiler Infrastructure project

The goal of the National Compiler Infrastructure project is to develop a common platform for compiler development that will support open academic collaboration on compilers and facilitate the transfer of technology to industry. The project combines technology developed under the Stanford University Intermediate Format (SUIF) project and the Zephyr project located at the University of Virginia. The SUIF project, co-funded by DARPA and NSF and based on the Stanford University Intermediate Format parallelizing compiler developed at Stanford University, involves collaboration with researchers at Harvard University, Rice University, and the University of California at Santa Barbara. The infrastructure project is intended from the outset to involve one or more industrial partners, and its objective is to develop a system that is modular, easy to extend and maintain, supports current research, and supports software reuse.



Sensitivity of volume X with respect to sweep angle

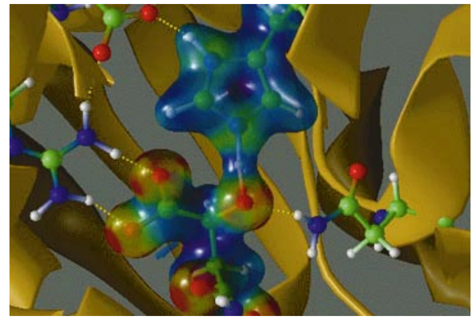


Sensitivity of volume Y with respect to sweep angle

Sensitivity analysis is used in design optimization, such as the design of an aircraft wing that involves integration of several different programs. Optimized designs can be found automatically by computing sensitivities of each code with respect to design parameters and applying a gradient-based optimization technique.

The Automatic Differentiation Tool for ANSI-C (ADIC) developed by researchers in the Mathematics and Computer Science Division at Argonne National Laboratory has been applied to the Coordinate and Sensitivity Calculator for Multidisciplinary Design Optimization (CSCMDO) code developed at NASA's Langley Research Center in southern Virginia. CSCMDO fits into the design optimization environment as a means for automatically modifying structured volume grids used in computational fluid dynamics. The ADIC-enhanced version of CSCMDO automatically produces the required volume grid sensitivity. CSCMDO provides a rapid and highly automated 3-D volume grid generation capability that produces changes in the surface and volumetric grids to reflect the perturbations of the baseline system. Algebraic techniques are used to generate and modify block face and volume grids to reflect geometric changes resulting from design optimization. These figures, obtained from an Automatically Differentiated (AD) version of CSCMDO, represent volume grid sensitivity derivatives with respect to different design parameters.

DOE-supported researchers have conducted a computational simulation and analysis of the reaction mechanism of the enzyme malate dehydrogenase (MDH). Encouraged by preliminary results, researchers calculated the minimum energy surface and reaction pathway for the interconversion of malate and oxaloacetate catalyzed by MDH. Analysis of the energy profile shows that solvent effects due to the protein matrix dramatically alter the intrinsic reactivity of the functional groups involved in the MDH reactions. The enzyme effectively changes the reaction from an exothermic reaction in the gas phase to a nearly isoenergetic one in the protein-solvent environment of MDH. Energy decomposition analysis indicates that specific MDH residues in the vicinity of the substrate make significant energy contributions to the stabilization of proton transfer and destabilization of hydride transfer. This data suggests that amino acids play an important role in the catalytic properties of MDH, consistent with site-directed mutagenesis experiments.



The Zephyr project, supported by DARPA and NSF, is a collaboration between Princeton University and University of Virginia. Zephyr's organizational structure separates the form of its intermediate languages from their content. Zephyr intermediate representations have tree-like forms describable by abstract syntax specifications. The language- or machine-specific content of a Zephyr intermediate representation is described by other compact specifications. Decoupling form from content permits researchers to choose the intermediate language most appropriate for their needs, to extend an existing intermediate language, or to develop a new high level intermediate language, while still using the Zephyr infrastructure.

Parallelization of commercial engineering software

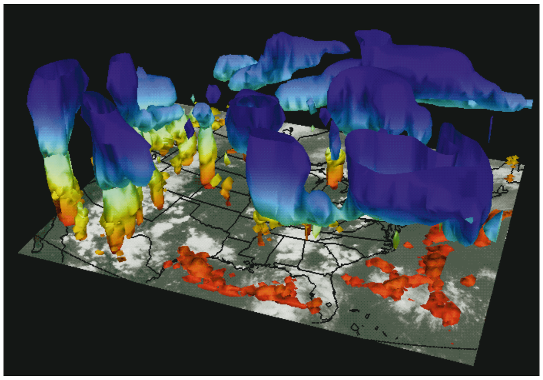
The DARPA-supported Parallelization of Commercial Engineering Software project is a cooperative program between the Federal government and industry. Its objective is to spur the introduction of scalable parallel applications software to U.S. industrial markets by directly providing leading-edge independent software vendors (ISVs) with small parallel development platforms in order to minimize their investment risk. The immediate goal of the program is to produce first-generation parallel implementations of existing commercial engineering software using system software and enablers — software tools that allow programmers to implement applications effectively — that are currently emerging as industry standards.

Parallel system software tools

Each of the ISVs involved in the program will gain access to scalable parallel computing hardware, state-of-the-art systems software and enablers, and techniques that will ensure compatibility with MPI (message passing interface) software, a standard programming interface. Although the proprietary nature of the individual application development projects will be protected, IBM's common platform support will ensure that the resulting parallel applications are portable and consistent with industry standards.

Computational Aerosciences Project

The National Aeronautics and Space Administration's (NASA) HECC R&D centers on development of parallel system software tools as well as development of mission-driven applications. NASA's high performance computing research facilities were established to accelerate the transition to new generations of high performance computing technology and include access to the NASA Research and Education Network (NREN), early systems or prototype storage subsystems, and state-of-the-art visualization



Cooperation between the EPA Scientific Visualization Center and the Space Science and Engineering Center (SSEC) of the University of Wisconsin at Madison has given EPA scientists 3-D visualization capability using desktop workstations. This capability joins SSEC's Vis5D system for visualizing the output of atmospheric and ocean models with composite images from the Geostationary Operational Environmental Satellite (GOES). This image compares remotely sensed cloud data from GOES seen as white clouds at the bottom of the image with 3-D cloud data predicted by the National Center for Atmospheric Research's (NCAR) Mesoscale Meteorological model. Cloud water is seen in blue, rain water in white, and temperature of the clouds ranges from cold blue to warmer red. Vis5D makes this interactive exploration possible by compressing data sets so they fit in workstation memories.

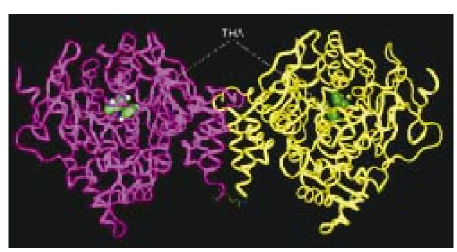
applications. NASA plans to install a 100-250 gigaflops sustained, scalable teraflops testbed in FY 1998 to support its mission-critical efforts.

NASA's Computational Aerosciences Project (CAS) focuses on using the high performance computing environment to solve a range of problems in aerospace engineering at a cost that reflects the value, flexibility, and short cycle time required by the aerospace community. Aerospace design problems include high speed technology, advanced subsonics technology, and rotorcraft. Research products are made available to system vendors as quickly as possible.

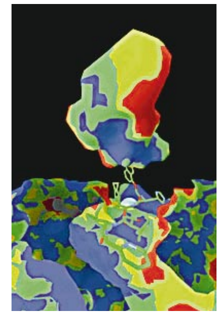
CAS researchers work with computational fluid dynamics simulations of aircraft and energy-efficient jet engines in order to save fuel and reduce design time. NASA has shown that using parallel computing-based simulations can reduce overall design and development time for high pressure compressors in turbofan engines from 18 months to 14 months, resulting in several millions of dollars in savings.

The aim of NASA's Flow Analysis of a Gas Turbine Low Pressure Subsystem project is to simulate the aerodynamic flow in the complete low pressure subsystem (LPS) of a gas turbine engine. The detailed LPS model will be integrated into the Numerical Propulsion System Simulator (NPSS) that will serve as a numerical "test cell." The goal of the LPS project and NPSS is to provide a tool that can significantly reduce risk, uncertainty, and the cost associated with designing advanced gas turbine engines.

Biomolecular computing using high performance computing involves extensive, often complex calculations. This study involves the computer simulation of the enzyme acetylcholinesterase (AChE),which is responsible for degrading the neurotransmitter acetylcholine in species from man on down to insects. Due to its ubiquitous presence in nature and key role in biological systems, AChE is a target for many commonly used drugs and toxins. Clinical studies supported by NIH and NSF suggest that acetylcholinesterase inhibitors such as tacrine (tetrahydro-9-aminoacridine) may be useful in enhancing memory in patients with Alzheimer's disease. The figure to the right illustrates an AChE-THA complex structure after 100 picoseconds of molecular dynamics simulation. The ribbon traces the amino acid chain forming the molecule. Two tacrine molecules are visible inside the protein.



Researchers at the UCSD Computational Center for Macromolecular Structure (CCMS) have developed filters and modules for the AVS software package to project the results from simulations onto molecular surfaces, here showing the hydrophilicity between the HIV enzyme protease (lower surface) and a bound inhibitor (floating "balloon"). CCMS develops software for analyzing those structural features of molecules that play key roles in drug design, such as docking, electrostatics, and hydrophilicity. CCMS is a joint project of UCSD, The Scripps Research Institute, and the San Diego Supercomputer Center, supported by NSF.



Earth and Space Sciences project

Earth and Space Sciences (ESS) research covers two areas:

- ❏ coupling advanced discipline models into scalable global simulations to better understand global change;
- ❏ integrating models and analysis algorithms for processing, analyzing, and understanding the enormous volumes of data expected from scientific missions.

ESS researchers are simulating the earth’s climate and are using large parallel computers to model dynamics within the sun, the solar wind, and the formation of galaxies.

Biomedical research

The mission of the National Center for Research Resources (NCRR) is to serve as a “catalyst for discovery” for National Institutes of Health-supported (NIH) research by developing resources to enable biomedical research advances. NCRR promotes collaborations within and across scientific disciplines and provides quick, flexible approaches to new and emerging research needs. Its greatest challenge is to keep abreast of rapidly evolving trends in basic and clinical research.

Biomolecular computing

HECC research in biomolecular computing with high performance computers involves extensive and often complex calculations to determine or predict protein structures and their structural and functional changes due to interactions with other molecules or drugs. NIH in partnership with NSF supports research that demonstrates the utility of novel protein functions for the biotechnology industry in areas such as synthesizing models of protein receptors for structure-based drug design.

Supercomputing Research Program

The National Security Agency's (NSA) Supercomputing Research Program focuses on research and applications that will gain order of magnitude improvement in computer support for intelligence processing. NSA's research activities range from the invention and prototyping of new concepts to improvements in the use of leading-edge commercial projects, with a current focus on parallelism. Current projects include support for flight testing MARQUISE (an embedded high performance computer) on Air Force aircraft; in partnership with DARPA, the 3-D Diamond MCM Cube computer project that will build a test vehicle to demonstrate a 3-D computer architecture with a nanosecond system clock; and funding of several fundamental studies to explore the feasibility of quantum computing.

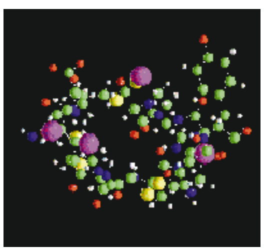
Scalable Systems and Software

DARPA's Scalable Systems and Software program is developing technologies for secure, scalable, distributed computing. The program focuses on creating the architecture and software components needed to reduce risks and accelerate commercial development of new generations of the scalable, high-performance computing systems required by DOD, with a goal of enabling procurement of very high-performance systems that run unique applications without requiring continual hardware, operating system, and applications redevelopment. Advanced technology for teraflop-class systems is an emerging development from DARPA investments in this area.

Quorum

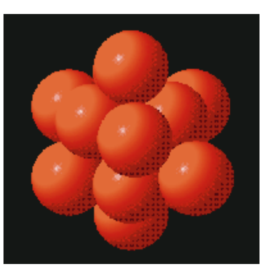
DARPA's Quorum research — part of its Information Sciences project — focuses on developing technologies that will allow end users to achieve predictable and controllable end-to-end quality of service for critical DOD computing needs in a global heterogeneous distributed computing environment. These technologies and architectures will be integrated into a global operating system in such a way that this resource pool appears to end users as a single computing platform. They will be demonstrated on key defense problems in shipboard computing and command and control, focusing on human-computer interaction and design methods and technology enabling more natural interaction between people and computers.

Molecular dynamics



Global optimization techniques are central solving macromolecular modeling and simulation problems, since many fundamental problems in these areas are formulated as global optimization problems. One aim of this R&D is to develop a high performance environment on the IBM SP at DOE's Argonne National Laboratory to support large scale global optimization algorithms and software for solving global optimization problems arising in the modeling and simulating of large molecular systems. This figure illustrates applications in protein conformation and modeling, ionic system configuration, and molecular cluster simulation.

Researchers are using optimization methods to find stable configurations of ionic systems. In this figure, the stable configuration for an ionic system has the lowest energy, and therefore can be found by minimizing the energy function for the system over the configuration space. Stable configurations for a set of small systems (fewer than 100 ions) have been obtained by using global continuation algorithms on the IBM SP. The optimal structure with 60 ions is shown here. A goal of this work is to find the stable configurations for very large systems, say, systems of 200,000 ions, from which a phase transition of the ionic system can be observed.

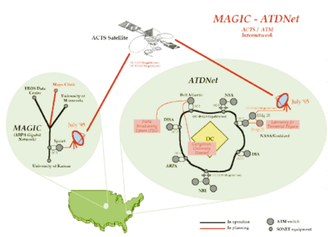


Researchers have applied global continuation algorithms to a set of Lennard-Jones-potential-based microcluster conformation problems. In this figure, the optimal structure is shown for small clusters (fewer than 75 atoms) as the global minimizers of the Lennard-Jones potential functions. This work is being extended to the general area of molecular cluster simulation, such as simulation of metal clusters with semi-empirical potentials.

Large Scale Networking

Goals and focus areas

LSN R&D will help assure U.S. technological leadership in high performance network communications through research that advances the leading edge of networking technologies, services, and performance. Key research areas include advanced network components and technologies for engineering and management of large scale networks. Areas of particular focus include:

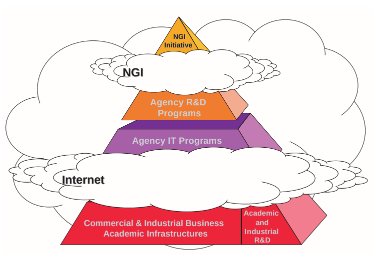


DARPA's 2.4 Gigabits per second (Gbps) metropolitan area network testbed, ATDnet, emphasizes early deployment of Asynchronous Transfer Mode (ATM) and Synchronous Optical Network (SONET) technologies.

- ❏ Technologies and services that enable advances in wireless, optical, mobile, and wireline network communications
- ❏ Networking software that enables information to be disseminated to individuals, multicast to select groups, or broadcast to an entire network
- ❏ Software for efficient development and execution of scalable distributed applications
- ❏ Software components for distributed applications, such as electronic commerce, digital libraries, and health care
- ❏ Research infrastructure support and testbeds

Advancing this agenda will lead to new and more capable networking technologies to support Federal agency missions. The Next Generation Internet (NGI) initiative will be the dominant focus of LSN R&D beginning in FY 1998. Some effects are already evident as agencies shift their focus to better accomplish the initiative's goals. This chapter highlights FY 1997 R&D accomplishments and FY 1998 R&D plans.

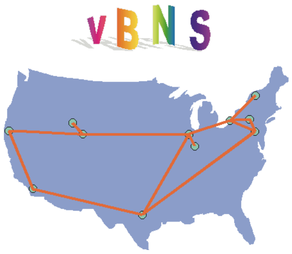
The NGI Initiative



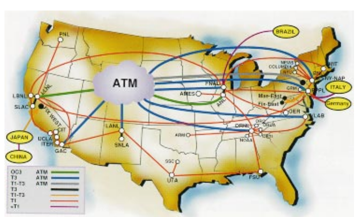
Announced by President Clinton and Vice President Gore on October 10, 1996, the NGI initiative will create a foundation for the more powerful and versatile networks of the 21st century. Based upon strong research and development programs across Federal agencies, NGI will foster partnerships among academia, industry, and Government that will keep the U.S. at the cutting-edge of information and communications technologies, and will accelerate the introduction of new networking services for our businesses, schools, and homes.

NGI Goals:

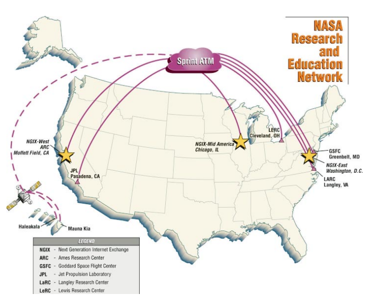
- ❑ Experimental research for advanced network technologies
- ❑ Next Generation Internet testbed
- ❑ Revolutionary applications



In partnership with MCI, NSF's Connections Program is developing technology for high performance networking through the Very high speed Backbone Network Services (vBNS) — technology that will help make the Internet faster and more efficient.



The Energy Sciences Network (ESNet) is the DOE Office of Energy Research nationwide network that supports open scientific research.



The NASA Research and Education Network (NREN) is an ATM wide area network (WAN) connecting five NASA sites in a fully meshed topology supporting advanced aerospace applications.

Today's Internet is the outgrowth of decades of Government investment in research networks such as the Defense Department's (DOD) ARPANET, DOE's ESnet, NASA's Science Internet, and NSF's NSFNET and NSF-initiated regional networks. The relatively small amount of Federal seed money invested in these evolutionary multi-agency programs stimulated much greater investment by industry and academia and helped create a large and rapidly growing market, resulting in one of the most spectacularly successful public-private technical collaborations in history. NGI is the next, but undoubtedly not the last, logical step in the cycle of evolving networking technologies and infrastructure needed to support U.S. research and industry.

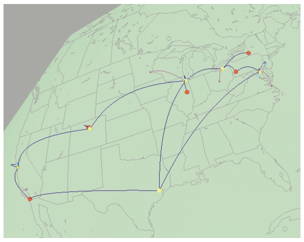
The NGI initiative, other Federal agency information technology and R&D programs, as well as R&D programs from academia and industry, will combine to create a foundation for the networks needed in the next century. Building on these networks, universities, Federal research institutions, and industry will conduct research and develop the advanced services, protocols, and functionality necessary to support next generation applications. These activities will create an open technology transfer environment, continuing a strategy that determined much of the success of the original Internet.

To achieve this vision, the NGI initiative has established the following three goals:

Experimental research for advanced network technologies. NGI activities will develop and demonstrate the advanced network services technologies required to support next generation applications. The main areas of network services and protocols that will be developed and demonstrated include security, robustness, Quality of Service (QoS), improved network management including the allocation and sharing of bandwidth, and enhanced collaborative and distributed application environments. The challenge is to ensure that NGI capabilities can be made predictably and reliably accessible to a broad spectrum of users sharing a common infrastructure.

Next Generation Internet testbed. The Federal organizations participating in the NGI initiative will build a prototype high-performance network testbed for system-scale testing of advanced services and technologies and for developing and testing advanced applications. The testbed will emphasize improved end-to-end network performance, connect at least 100 NGI sites—universities, Federal research institutions, and other research partners—at speeds 100 times faster than today's Internet, and connect on the order of 10 sites at speeds 1,000 times faster than the current Internet.

Revolutionary applications. Participating Federal agencies will develop and demonstrate a wide variety of nationally important applications that cannot be achieved over today's Internet. These applications will include Federal agency mission applications, university and public sector applications, and private sector applications with the potential to improve U.S. competitiveness in vital business areas. These revolutionary applications will also demonstrate the potential for opening entirely new business areas based on commercializing the technologies that are developed within the NGI initiative.



The MBone, which stands for the Internet Protocol (IP) Multicast Backbone on the Internet, uses an addressing scheme developed at the Xerox Palo Alto Research Center (PARC) and the University of Southern California (USC). Many of the tools that make the MBone valuable were developed at Lawrence Berkeley National Laboratory (LBNL), part of DOE's National Laboratory system.

Federal agencies will begin the NGI initiative by constructing high performance collaborative networks in partnership with the telecommunications industry, Internet service providers, universities, and major Federal research institutions. Such networks will be created on the foundation of existing Federal networks (illustrated on this and the previous page), and will allow universities, Federal research institutions, and industry to conduct research and develop the services, protocols, and functionality needed to support next generation applications. In order to facilitate the development of these leading-edge applications, NGI will seek substantial matching funds from private sector partners, as well as commitments from major applications developers.

The potential economic benefits of this Federal initiative are enormous. Because the Internet originated in the U.S., American companies have seized and maintained a substantial lead in a variety of communications and information markets. The explosion of the Internet has generated economic growth, high-wage jobs, and a dramatic increase in the number of high-tech start-up companies. The NGI initiative will strengthen America's technological leadership and create new jobs and market opportunities in the next century.

Today's advanced federal networks

Even as the NGI initiative commences, the research and education communities continue to need ready access to high performance data networks in order to advance current research projects and educate U.S. citizens. Federal networks such as NSF's vBNS, DOE's ESnet, NASA's NREN, DOD's DREN, and the DARPA-led Advanced Technology Demonstration network (ATDnet) serve as the foundation for the NGI and continue to connect researchers and educators to information and computational resources. These networks also support networking research in gigabit testbeds, optical fiber networks, adaptive networks, and packetized video and voice.

Global Grid

To meet demand for very high bandwidth networks, terabit optical fiber networks with global reach will be required. At present, fiber networks use at most one percent of this potential capacity due to electronic bandwidth limitations. DARPA's Global Grid program is developing the network technologies, architectures, and protocols necessary to access the 30 TeraHerz (THz — trillions of cycles per second) bandwidth using multiple channels and picosecond optical pulses.

Active Networks

The goal of DARPA's Active Networks program is to create a new networking platform that will prove flexible and extensible at runtime to accommodate the rapid evolution and deployment of networking technologies, as well as provide the increasingly sophisticated services demanded by Defense applications. The Active Networks architecture is based on a dynamic runtime environment that supports finely tuned control over network services. Flexible, efficient, and secure protocols are being prototyped.

Biomedical research

Many areas of biomedical research computing are too demanding to be pursued using conventional computers and networks. Of primary concern are structure determination by x-ray and magnetic resonance, structure prediction of nucleic acids and proteins, computational biochemistry, and problems that arise from modern molecular biology. Each of these research areas needs not only the latest in computational power, but faster networks than are currently commercially available. NIH supports research in providing biomedical researchers access to new network technologies.

Unified Medical Language System (UMLS)

With the large and rapidly growing number of computerized database resources and services offering bibliographic, full text, and factual data via the Internet, it is difficult for users to locate and process vital information. To facilitate complicated searches, the National Library of Medicine (NLM) is developing intelligent gateways among database services, using a Unified Medical Language System to account for the dissimilarity in the ways related information is classified in different automated systems. Intelligent-agent-mediated gateways will provide users with a single point of access to the information they need.

National Center for Biotechnology Information

The growth of the Internet and the availability of higher bandwidth connections will also lead to a significantly greater user load on services such as text retrieval, sequence analysis, and 3-D structure comparisons. The expansion of the scientific literature database and increased linkage between literature and experimental databases will create additional demands. To accommodate these increased computing requirements, NLM's National Center for Biotechnology Information (NCBI) has the legislative mandate to create automated systems for storing and analyzing this vast and growing amount of data using technologies developed with LSN R&D, such as low cost compute servers for parallelizing repetitive database searches.

Crisis management

Many Federal agencies support R&D in crisis management and disaster planning. Since most national emergencies are related to the weather, the National Oceanic and Atmospheric Administration (NOAA) has a strong need to provide data, model results, and crisis response tools, including networking technologies, that are viable under emergency conditions. NOAA and other agencies are planning ahead for future network services, with an aim toward expanding the accessibility and increasing use of the technology, services, and information available within the Federal government to improve significantly the management of the nation's forecasting, preparedness, and response to crisis situations.

The Radiology Consultation Workstation (RCWS) is a multimedia medical imaging workstation being developed for the electronic radiology environment. It uses a prototype ATM telemedicine network to support radiotherapy treatment planning. With RCWS, radiation oncologists and radiologists will be able to consult with each other prior to designing a treatment plan. They will use a shared cursor that allows them to interact fully while identifying and delineating the relevant physical structures. High quality displays are a key technology requirement.

High Confidence Systems

Overview

HCS R&D focuses on the critical technologies necessary to achieve high levels of security, protection, availability, reliability, and restorability of information services. Systems that employ these technologies will be resistant to component failure and malicious manipulation and will respond to damage or perceived threat by adaptation or reconfiguration.

High confidence technologies can be applied to any element of a system, including:

- system reliability — for example, management of networks under load, failure, or intrusion; emergency response; firewalls; secure enclaves; and formal methods
- security and privacy, including personal identification, access control, authentication, encryption and other privacy assurance techniques, public key infrastructures, and trusted agents for secure distributed computing
- testing and evaluation

Applications requiring HCS technologies include national security, law enforcement, life- and safety-critical systems, personal privacy, and the protection of critical elements of the National Information Infrastructure (NII). Systems for power generation and distribution, banking, telecommunications, medical implants, automated surgical assistants, and transportation also need reliable computing and telecommunication technologies.

Through their HCS R&D, Federal agencies collaborate in developing network and systems security and reliability and provide mechanisms for cooperation with the private sector. FY 1997 accomplishments and FY 1998 plans are presented in this section.

INFOSEC

The NSA information systems security (INFOSEC) mission provides leadership, products, and services to protect classified and unclassified national security systems against exploitation due to interception, unauthorized access, or related technical intelligence threats. All INFOSEC research activities of NSA and DARPA are reviewed and coordinated by the Joint Technology Office (JTO). The JTO leverages DARPA's work in cutting edge technologies, including network technologies, while allowing DARPA to use NSA security expertise in developing advanced information technologies.

Macrophage attacking a bacterium. Biological defense mechanisms detect external attack and respond to penetration. Using this metaphor, DARPA-funded researchers have developed GrIDS (Graph-based Intrusion Detection System) to detect attacks using "specification-based intrusion detection."

Secure operating system development program

NSA's ongoing secure operating system development program is evaluating methods to assure authenticated network transactions, data integrity, and non-exploitation of transactions across the Defense Information Infrastructure. NSA is also conducting research to support an evolving suite of information security services to help customers implement security technology, and is conducting research in standards for secure interoperability of nonhomogeneous computer and telecommunications systems. Robust secure network management techniques that allow a network to be managed without fear of malicious denial-of-service attacks, such as flooding, corruption of data, or falsified identification of nodes or users, will be developed.

GRiDS: Intrusion Detection

DARPA supports research at the University of California at Davis to develop the Graph-based Intrusion Detection System (GrIDS) of instrumented network services. GrIDS consists of routers, network file servers, domain name systems, communications protocols, and host workstations that detect and trace intrusions. GrIDS first collects data on computers and the network traffic among them, then reports a possible anomaly when the graph-patterns exceed a user-specified threshold. By learning about the vulnerabilities, attacks, and countermeasures relevant to all-optical network technologies and architectures, GRiDS will provide both a foundation for designing network defenses and an understanding of the means available to attack an adversary's network.

SAW: Secure Access Wrapper

Databases are ubiquitous in distributed military and commercial network infrastructures, and many are subject to stringent security requirements. The objective of the DARPA-supported Secure Access Wrapper (SAW) project is to develop a SAW for securing access to commercial off-the-shelf (COTS) and legacy databases in very large-scale information systems. The SAW generates database wrappers for security consistent with the security policy of the underlying database. Moreover, databases wrapped by SAWs can be composed systematically to form secure systems. The SAW will consist of an automated tool kit addressing local and global issues in securing access.

TBA: Task-Based Authorization

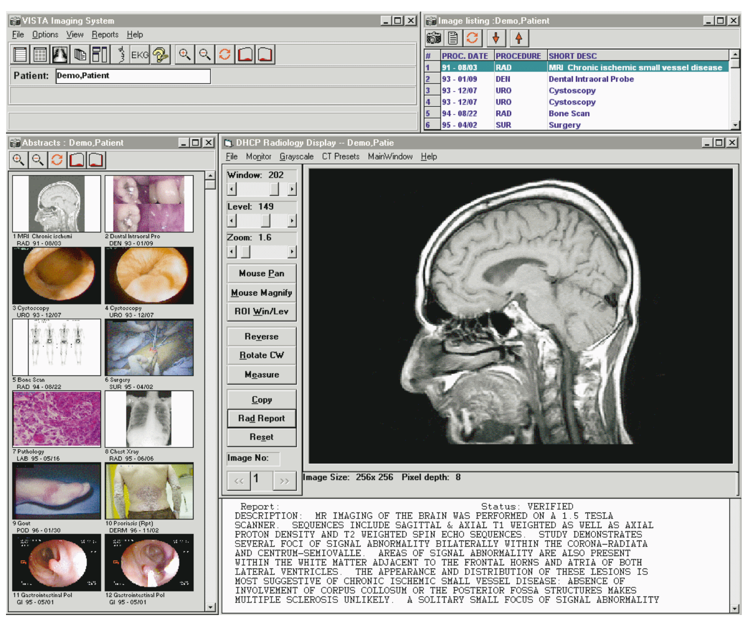
DARPA's Task-Based Authorization (TBA), a new paradigm for access control, is particularly suited for distributed computing and information processing with multiple points of access, control, and decision making. TBA articulates security issues at the application and enterprise level by taking a task-oriented or transaction-oriented perspective instead of a traditional subject-object view of access control. TBA applicability ranges from access control for client-server interactions in a distributed system, to distributed applications and workflows that cross departmental and organizational boundaries.

Secure All-Optical Networking

The DARPA-funded Secure All-Optical Networking project will investigate techniques to increase the security of all-optical networks against service denial, eavesdropping, traffic analysis, and unauthorized access at a level equal to or greater than the current generation of electro-optical networks. The program focus includes: (1) secure architectures for all-optical networks, (2) understanding and countering optical network component vulnerabilities, and (3) developing concepts for attack-resistant network control and management algorithms. Through understanding the vulnerabilities, attacks, and countermeasures relevant to all-optical network technologies and architectures, the project will provide both a foundation for designing network defenses and an understanding of the means available to attack an adversary's network.

Network infrastructure and security

HCS R&D supported by NSF and DARPA is developing access control mechanisms that can be layered over existing operating systems. These mechanisms are able to enforce a variety of security policies and can be customized for the varied needs of many sectors, such as financial, business, health care, and defense. Using a simple language, a system administrator can specify an organization's policy in terms of groups of users and objects. This policy is automatically translated into low-level permissions on files and other resources. Integrating these access control mechanisms into firewalls



Records containing multidisciplinary images will be available over networks to authorized health care providers through the merging of computerized patient record systems and telemedicine systems in a way that assures integrity and confidentiality. This image illustrates how this work is being done at some VA medical centers nationwide.

will enable more intelligent filtering of traffic exchanged between a local area network and the Internet. Security policies can be registered with a remote policy server, which can be queried by firewalls, to allow the firewalls to make more intelligent filtering decisions.

Protecting privacy for medical records

NLM and Veterans Administration (VA) support research in technologies for storing and transmitting patients' medical records while protecting the accuracy and privacy of those records. FY 1997 and 1998 projects will promote the application of HCS technologies to health care, telemedicine evaluation, and the testing of methods for protecting the privacy of electronic health data. R&D for computer-based patient records and public health applications of the NII will also be emphasized.

Reliable information

HCS R&D at the National Institute of Standards and Technology (NIST) focuses on two areas. Research in the NIST Manufacturing Engineering Laboratory (MEL) is concerned with reliable information exchange among manufacturing applications. This standards-based effort for computer integrated manufacturing examines product/process design, manufacturing engineering, and production system control within and across the enterprise. Reliable mechanisms for testing manufacturing application integration solutions will be developed. Current NIST efforts are described more fully in the CIC R&D Highlights section of this report.

Through the Computer Security Division of its Information Technology Laboratory, NIST is working with industry and government on standards and test methods for cryptographic modules, test methods for security products and systems, development of infrastructure for public key based security, and common architectures that promote use of strong authentication technologies.

Human Centered Systems

HuCS technologies

HuCS R&D leads to increased accessibility and usability of computing systems and communications networks. Scientists, engineers, educators, students, the workforce, and the general public are all potential beneficiaries of HuCS technologies, which include:

- "Knowledge repositories" and "information agents" for managing, analyzing, and presenting massive amounts of multimedia and multi-source information
- "Collaboratories" that provide access to knowledge repositories and facilitate knowledge sharing, group authorship, and control of remote instruments
- Systems that enable multi-modal human-system interactions including speech, touch, and gesture recognition and synthesis
- Virtual reality environments and their application to scientific research, health care, manufacturing, and training

HuCS activities for FY 1998 will focus on collaboration among Federal departments and agencies, the university community, and U.S. industry. Specific activities are detailed below.

Knowledge repositories

Knowledge repositories are huge electronic databases with multimedia content (text, voice, images, and video), residing on distributed heterogeneous computing systems that use different database management software. There is a critical need for applications that will make it easier for people to manage these complex databases, as well as for intelligent "information agents" that will help them analyze the data and present the results effectively.

DARPA's major areas of HuCS technical emphasis are intelligent systems, software development, manufacturing automation and design engineering (MADE), Text Video Speech (TVS) technology focusing on emerging language understanding technology, and resource organization to obtain logistical information on demand.

DARPA's intelligent systems and software project develops new information processing technology that will lead to innovative software and intelligent

Vice President Al Gore speaking to the DARPA-supported GALAXY conversational system during an April 26, 1996 visit to the MIT Laboratory for Computer Science. This research will lead to the development of conversational systems that can interact with users by employing speech recognition and language understanding to solve everyday problems.

systems capabilities. Advances in projects such as the high performance knowledge base library will enable information systems to accomplish decision-making tasks more effectively in stressful, time sensitive situations and will help create efficient software to support computer-intensive defense systems.

DARPA supports research in modular human-computer interaction technologies, that will provide easy, low-cost, rapid technology transfer and application development for document understanding, machine translation, and speech understanding. In the intelligent integration of information area, DARPA researchers will develop tools and techniques to enable the rapid construction of information fusion, aggregation, and summarization software to filter, access, and integrate information from hundreds of heterogeneous distributed data sources. In the TVS area, researchers will develop initial prototypes for multi-language text extraction and audio transcription using the performance of human operators as a baseline.

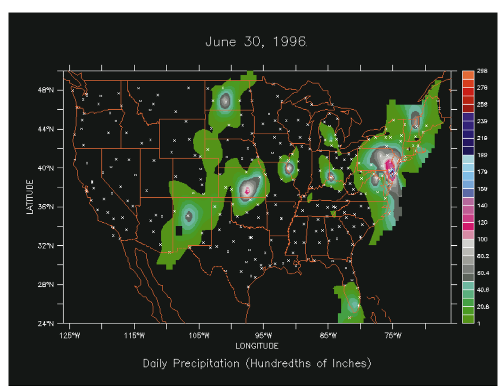
NSF's Knowledge Networking projects focus on a new generation of interconnected networks and associated database and collaborative technologies, with an emphasis on learning and intelligent systems and new approaches to computation.

Collaboratories

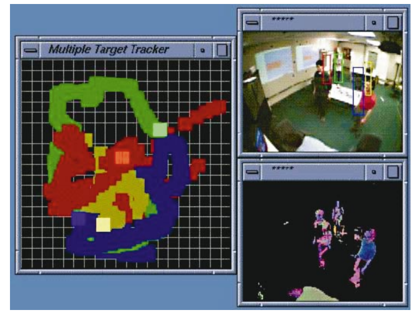
Collaboratories — virtual laboratories that permit geographically separated researchers to work together and to use identical remote resources — build upon breakthrough technologies employed in creating knowledge repositories and information agents. Collaboratories also require new technologies for creating multimedia information. Examples are DARPA's Intelligent Collaboration and Visualization effort and DOE's DOE2000 initiative, which include middleware for advanced collaboration across very large distributed systems, as well as software for controlling remote instruments, enabling geographically dispersed researchers to access expensive research resources from their desktops.

DOE is building a scalable, standards-based software infrastructure to support collaborative environments, employing advanced ATM capabilities to provide interagency collaborative environments and to support leading-edge applications. This software infrastructure is being tested in two national collaboratory pilot programs — the Diesel Combustion Collaboratory and the Materials MicroCharacterization Collaboratory.

The Climate Visualization system CLIMVIS is an interactive tool for browsing visual displays of numeric data available on-line at NOAA's National Climatic Data Center (NCDC) in Asheville, NC. The user steps through the data and graphing feature selection process to browse the displayed data, as illustrated to the right. Systems like CLIMVIS will make it easier for people to manage and use highly complex databases, and for intelligent "information agents" to analyze the data and present the results effectively.



An "Intelligent Room" allows people to move within its space, speaking and gesturing as they normally do. Outfitted with special eyeglasses, they can view personalized informational displays enabling them to command a vast array of computational and communication resources. The occupants will be able to concentrate on solving problems, such as planning distributed and collaborative activities. They will also be able to rehearse their actions in trauma care, crisis management, and rapid response deployment. Supported by DARPA, the Intelligent Room is a part of the Human-Computer Interaction project at the MIT Artificial Intelligence Lab, which explores advanced human-computer interaction and collaboration technologies.

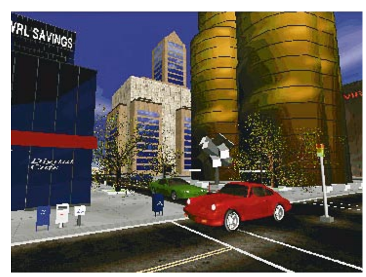


Regional Technology in Education Consortia

The Department of Education's (ED) Regional Technology in Education Consortia (RTEC) assist state and local education agencies with developing comprehensive educational technology plans, drawing upon existing resources, and anticipating future technological needs and innovations. In FY 1998, the RTECs will also focus on making the most valuable technology resources more easily accessible to educators through a variety of means, including the Internet and telecommunications technologies.

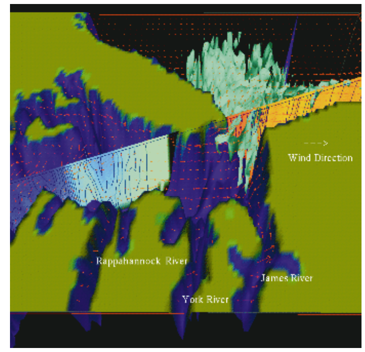
Enabling multi-modal human-system interactions

Today's graphical user interfaces are well-suited to trained, unimpaired users accessing desktop computers with a monitor, a keyboard, and a mouse. As inexpensive computing power becomes increasingly available to less technically-oriented users, tomorrow's sophisticated systems will require interfaces accessible both to experts and novice or infrequent users regardless of physical ability, education, or culture. Additionally, people who cannot see will require enhanced Braille interfaces, and people who are unable to type will require the latest eye-tracking technologies. HuCS R&D will explore speech recognition and synthesis technologies, as well as computers operated by facial expression, touch, and gesture. Such projects include a DARPA-funded NIST study to develop methods for evaluating and testing the image quality effects of optical character recognition (OCR). Funded as a joint project of NSF and ED's National Institute for Disability and Rehabilitation Research, the Web Accessibility Initiative will work to ensure that the evolution of the Web removes, rather than reinforces, accessibility barriers.



One view of a virtual city created using the Virtual Reality Modeling Language (VRML) by a team from UCSD and SDSC that is investigating the effects of visual cues in psychotherapy using the Internet and VRML. Potential applications include treating acrophobia (fear of heights) and other phobias. Patients might view this same street by looking down from the top floors of its skyscrapers.

Human-centered application development environments will allow users to tailor services and applications to meet individual needs. "More than Screen Deep," a wide-ranging 1996 study supported by NSF, suggests that such research also directly supports the general movement toward "nomadic" (access anytime, anywhere) computing. HuCS research includes interfaces to support computing systems embedded in wireless hand-held and wrist-mounted devices and in household appliances.



The NSF-funded Chesapeake Bay virtual environment is a a research tool combining the CAVE Automatic Virtual Environment (CAVE) software, the Vis5D scientific visualization package, and the Vanilla Sound Server in order to place modeled sonic data in an interactive navigable virtual environment. It will incorporate runtime computational steering, interactive visualization, data sonification, and wide area information dissemination to enable geographically distributed users to interact multi-modally in real time across a high speed network. A university-based research oceanographer running a numerical simulation on a remote supercomputer at one institution can be observed by researchers at other institutions. As the technology improves, all researchers should be able to steer the simulated environment, maximizing its effectiveness. The CAVE's three-wall and ceiling environment provides an optimal environment for this type of research.

The Speech, Text, Image, and MULtimedia Advanced Technology Effort (STIMULATE) will fund university researchers investigating human communication and seeking to improve our interaction with computers. NSF, NSA, and DARPA are involved in this interagency effort, whose projects will include a filter for TV, radio, and newspaper accounts that provides the user with a quick synopsis; a computerized translation program; and a "humanoid" computer that will understand human communication, including facial expressions, gestures, and speech intonation.

Virtual environments

FY 1998 virtual environments R&D will address immersion in simulated environments, advanced modeling technologies, and group collaborations in virtual spaces. Virtual environments are interactive, computer-generated multi-dimensional "worlds" designed to allow the user's view of the environment to change in real time in response to user control. Such control creates kinesthetic depth perception in which a user can interactively alter a virtual world by directly manipulating virtual objects in a virtual environment. Intelligent real-time response and multi-dimensional sensory information embodied in virtual environments can facilitate explorations involving complex science, medicine, and manufacturing tasks.

Expert systems that aid in designing virtual environments will be needed to construct and model complex environments for specialized tasks. Portable, wearable, augmented reality systems will enhance human performance in tasks such as maintaining military or civilian equipment in the field. These systems will demand extremely accurate tracking and methods to align virtual environments closely with the real world and will require high quality visual, force, and touch displays.

Supported by DARPA and NSF, the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago allows researchers to use the latest in computer graphics and interactive technology to explore data in highly immersive, interactive environments. EVL provides an infrastructure for computer scientists to collect, maintain, develop, distribute, and evaluate virtual environment tools and techniques for scientific computing. These include computer-based models, simulations, data libraries, programming libraries, and user interfaces. The libraries and user interfaces encompass visual, auditory, tactile, and motion-based information displays. The Multi Mega Book in the CAVE was designed to create an immersive experience of being in different centuries and in different worlds. Here, the viewer has arrived in a composite Renaissance Italian city.

HuCS virtual environment R&D is needed to develop new knowledge presentation and collaboratory technologies. For example, high-quality sensory information, derived from sight, sound, and touch, is generated by computing systems and delivered to users by special interface devices developed by DARPA, NSF, and DOE. These devices give users the sensation that they are interacting with the virtual environment just as they would interact with the real world. At the same time, these tools provide "intelligence amplification" to expand the user's decision-making capabilities.

Simulation of complex situations in planning and management

Battlefield management and planning, emergency management, multi-government interactions, and industrial competition and collaboration are other Federal applications that require HuCS technologies. In each of these areas, human centered systems can provide an information-rich overview of complex situations involving many participants. HuCS technologies can be used to simulate these applications for training and evaluation and to use real-time input to monitor actual situations for situation awareness and decision making. These applications also require special authoring tools for creating and maintaining simulations and the ability to partition a simulation into a hierarchy of detail. In product manufacturing, for example, these technologies can support the total life cycle of a manufactured product, resulting in improved design, development, testing, manufacturing, training and use, and maintenance and repair.

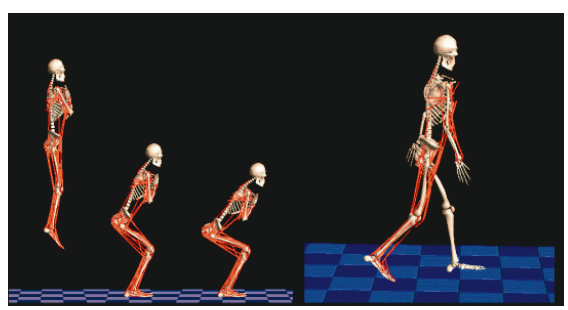
Telemedicine

Telemedicine allows patients and health care practitioners to be in different locations during consultation, diagnosis, and treatment. In these activities, images and data from diverse medical instruments (for example, MRI, CAT-scans, and sonograms) will be integrated and displayed in a 3-D environment. For example, such pioneering 3-D techniques are being used to diagnose emphysema and lung cancer at the Cornell Theory Center, as illustrated on page 30.

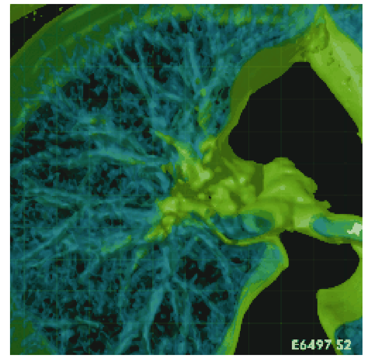
Transforming patient data into consistently useful and accessible information and knowledge is a challenge confronting health care providers today. The current clinical environment will need to converge with scientific research to achieve more precise diagnosis, better treatment plans, and more effective disease prevention.

Clinical decision support systems

Partnering with VA and NIH, the Agency for Health Care Policy and Research's (AHCPR) HuCS research focuses on developing applications for computer-based patient record and clinical decision support systems for health care providers. Its objective is to evaluate the use of computers and



Scientists can estimate the forces of the body's muscles by simulating human movement on supercomputers. NASA-funded researchers at the University of Texas-Austin have combined control theory and mathematical modeling to determine musculoskeletal forces during different activities. These graphical models of jumping and walking incorporate joint angles from videotaped human subjects. Each muscle, with its connecting tendons, is represented by a three-element skeletal entity, appearing in series. A three-dimensional simulation of the jumping figure, the first of its kind, consumes 800 CPU hours on an IBM SP2.



HuCS technologies assist in diagnosing emphysema and lung cancer. Modern 3-D radiologic techniques, particularly computed tomography (CT) and magnetic resonance (MR) imaging, acquire more data than are routinely displayed in diagnostic images, such as in this 3-D image of a section of a lung from the Cornell University Medical College. A potentially cancerous nodule, highlighted in bright green, is easily distinguished from the adjacent vessels. Image analysis used in conjunction with representative patient databases will be an integral part of future clinical analysis, diagnosis, and decision support systems. NLM promotes the use of these technologies in health care.

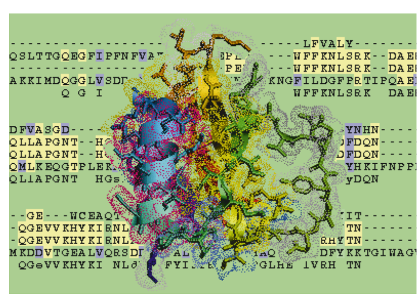
networks in order to improve health care outcomes, medical effectiveness, quality, and cost. Research topics will include object technology to facilitate transferring data from legacy systems, voice and speech recognition, remote monitoring of homebound chronically ill and disabled populations by health professionals, multimedia electronic mail for consultations among clinicians in local and regional networks, and intelligent dictionaries and networks to enable more effective communication among clinicians. Security, privacy, and integrity of health care data will be managed in regional repositories that will use key technology to register and certify users.

The Visible Human Project

In the Visible Human project, NLM continues to build and evaluate digital image libraries of anatomical structures of the human body. Using and understanding the biological structures depicted in such libraries will exploit the integration of advanced computer and communications technologies with medical imaging systems to render anatomic data into photorealistic images that are easily manipulated by students, researchers, and health care providers.

SIMA: Systems Integration for Manufacturing Applications

HuCS R&D is part of NIST's Systems Integration for Manufacturing Applications (SIMA) program that works with industry and academic researchers on projects such as the Manufacturing Collaboratory and Operator Interfaces for Distributed and Virtual Manufacturing. Research areas include information interfaces, collaborative technologies, remote operation, and virtual manufacturing. NIST collaborates with industry and standards bodies in supporting the development, specification, validation, and deployment of solutions for interoperability among advanced manufacturing systems applications.



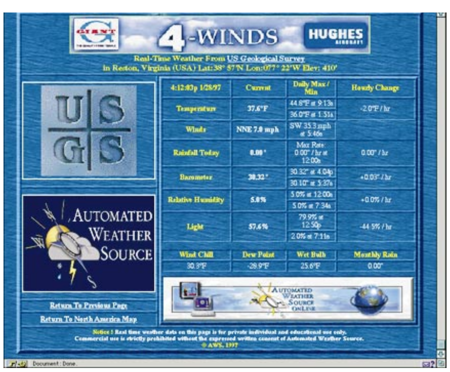
Developed by the Computational Biology Group at the NCSA (University of Illinois at Urbana-Champaign), the Biology Workbench is a collaborative software tool that allows researchers and physicians to access information needed to find cures for diseases like Alzheimer's, cancer, and AIDS. The Workbench enables a user with a browser to efficiently access, extract, and process data from remote databases. From the Biology Workbench home page (partially illustrated at the right), researchers can input a protein sequence into the Web-based software and locate the 3-D representation of the requested molecule. What once would have taken a molecular biologist weeks or months to find is now a simple task that takes only minutes.

Education, Training, and Human Resources

Overview

ETHR R&D supports research to advance education and training technologies. The complex and technically challenging applications flowing from leading edge R&D in HECC and LSN make it increasingly important for today's students and professionals to update their education and training on an ongoing basis in order to exploit the latest technological advances. ETHR technologies improve the quality of today's science and engineering education and lead to more knowledgeable and productive citizens. Major ETHR research areas include:

- ❏ Curriculum development, fellowships, and scholarships for computational, computer, and information scientists and engineers
- ❏ The application of interdisciplinary research to learning technologies
- ❏ R&D in information-based learning tools, lifelong learning, and distance learning.



Local weather reports from Reston, Virginia, are continuously updated as part of the 4-Winds project involving NASA, NOAA, and Washington, DC-area television station WRC-TV Channel 4.

Information technologies will have a profound impact on all forms and levels of education in the 21st century, ranging from the use of geographically dispersed learning centers to the extension of experiential learning (which is already transforming scientific and engineering research) through advanced visualization and simulation techniques. These new and enhanced information and computing technologies will enable students to obtain an education based on personal experience and simulation rather than abstract presentation.

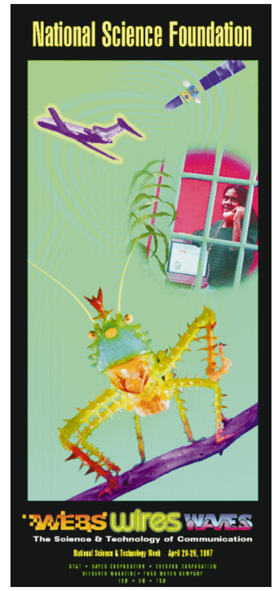
Research in learning technologies has direct implications for achieving the national goal of a technologically literate citizenry. Such research is required to enable use of the Nation's information infrastructure to provide the resources for efficient and effective education and training. Indeed, the training of the next generation of citizens skilled in developing and using information technologies is critical to the ongoing effort of maintaining U.S. competitiveness in today's highly aggressive international market environment.

Applications, tools, and collaborative research on learning technologies

ETHR R&D supports engineering applications in the classroom. For example, NSF funds new course and curriculum development in high performance computing and communications and information processing. NSF also supports research opportunities in high performance computing and communications for undergraduates.

ETHR R&D is creating collaborative tools for R&D in learning, creativity, and productivity. DOE's National Collaboratory Research, for example, will develop technologies and tools to enable scientists and engineers to collaborate easily across geographic boundaries and to interact cooperatively in solving problems and conducting experiments. This research also addresses the basic technologies and services that underlie such National Challenge applications as energy demand management and remote environmental monitoring.

NSF supports the Center for Collaborative Research on Learning Technologies, which is integrating technology with education at all levels. The Center will draw upon the efforts and expertise of participants from industry, research, and education to formulate responses to challenges and opportunities in science, mathematics, engineering, and technology education in order to reexamine the basic methods and practices of these fields, with a focus on the teaching potential of innovative learning technologies.



NSF's programs in education and training focus on increasing the number of individuals possessing the knowledge, skills, and insights to lead research in science and technology. This poster highlights NSF's 1997 National Science and Technology Week's school programs.

Research grants

ETHR supports graduate and postdoctoral CIC R&D with multiagency grants:

- ❑ NSF programs in education and training focus on increasing the number of individuals who possess the knowledge and skill to make high performance computing and information processing easier to use and to apply what they have learned to all science and engineering disciplines. The NSF Postdoctoral Research Associates program, for example, supports postdoctoral training in computational science and engineering and experimental computer science.
- ❑ NASA ETHR activities focus on educating the next generation of computer and computational scientists. NASA supports research institutes and centers of excellence engaged in computer science and computational science and funds university grants on CIC R&D topics at the individual principal investigator level.

❑ DOE's Computational Science Graduate Fellowship Program provides support for more than 50 doctoral students in computational science and engineering at select universities. Participating fellows spend at least one summer working on their dissertations at a DOE laboratory.

With digital camera technology, students now create permanent, storable records of their science projects for the school's database.

Innovative training

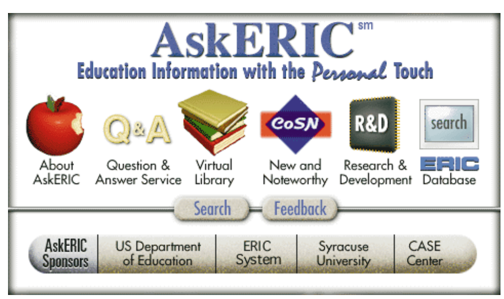
ETHR R&D supports innovative training such as NASA's annual summer school in High Performance Computational Physics and NSF's Metal-Oxide Semiconductor Implementation Service (MOSIS) program, which provides training for students who work within a research infrastructure for rapidly prototyping and manufacturing custom VLSI chips.

Grants for health professionals

The U.S. needs both biomedical professionals cross-trained in informatics and individuals from computer and information sciences and engineering with doctoral or post doctoral training in applying these technologies to health care. Medical centers that want to modernize and network their institution-wide information services find it increasingly difficult to identify and recruit senior professionals with this kind of education and training. The NLM awards training grants for health professionals and is expanding its pre-doctoral and postdoctoral grants program to provide career training in medical informatics, both for research and applications and for fellowship training support. NIH will implement a pilot training program at select NCRR-supported High Performance Computing Resource Centers to introduce biomedical scientists to high performance computing methods and tools.

K-12 Curriculum Products

ETHR R&D provides training and information services for grades K-12 students, teachers, and faculty in computing, networking, and computational science. The Department of Education's AskERIC (Educational Resources Information Center) is an online information service available free of charge to teachers, parents, and students. The AskERIC R&D team is expanding the AskERIC Virtual Library to provide image, sound, and video resources; providing free Internet access to the ERIC bibliographic database using friendly, high performance retrieval software; creating a full-text electronic collection of the documents in the



The Department of Education's AskERIC service (http://ericir.syr.edu/) provides users with customized information on educational topics delivered via the Internet and commercial services.

ERIC database; and experimenting with new Internet products to determine their value in education.

NIH education programs focus on engaging and training students, teachers, and faculty from middle school and high school through graduate school in computing, networking, and computational science, by leveraging the large DOE investment in these areas at universities and at its national laboratories. NASA is demonstrating education products from its K-14 Education Cooperative Agreement Notice.

Dramatic image of an erupting volcano on Russia's Kamchatka Peninsula — one of many images available through NSF's VizEarth Project.

Training for students, teachers, and faculty

Over the past two decades, technology has dramatically advanced the ability of scientists to use geographic visualizations to explore, learn, and communicate about the geosciences. These rich resources of data, images, and software tools can revolutionize Earth science education by enabling students to observe, explore, investigate, and visualize fundamental Earth science concepts. NSF's Visualizing Earth (VizEarth) Project aids these advances by promoting fundamental research in cognition and visualization, adapting existing technology and data sources for ease of use in schools, developing model curricula at the middle school level to support cognition and visualization research, and supporting implementation of national education standards in science, mathematics, and geography.

Information dissemination

CIC R&D will benefit U.S. citizens if they can access and make use of this information to improve their environment at work and at home. Recognizing this, GOALS 2000 legislation calls for increased emphasis on electronic networking and dissemination to support education reform, making this a critical part of ETHR R&D. In response to the GOALS 2000 legislation, the Department of Education's Information Network (INet) program, which manages the Internet and World Wide Web presence of the National Library of Education, will play a key role in the Department's efforts to make a high quality library of education information available online to assist the rapidly growing number of educators connecting to the Internet. The Department plans to provide increased access through the Internet to the Library's repository of information concerning Department programs, projects, publications, statistics, and network-based R&D materials for schools, educators, parents, and policy makers by developing a digital library.

Free educational information is available through the World Wide Web. Educators can access information on technologies and resources for classroom use; and select and copy teacher's guides and activities for use at elementary, middle, and high school levels.

NASA will develop and provide access to databases of remote sensing images and support software over the Internet. These databases can be used by both public and private institutions, promoting the dissemination of taxpayer-funded Federal information. The information contained within these databases can also be used by educational and library communities. The program goal is to provide broad public access to remote sensing data to isolated, under-served communities, in order to promote gains in education, quality of life, and economic growth.

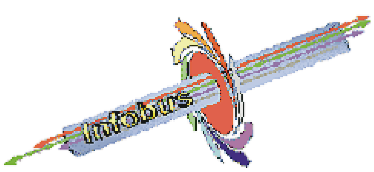
Digital Libraries Initiative

The Initiative

The Digital Libraries Initiative (DLI) is a joint four year NSF/DARPA/NASA program begun in FY 1995. Its broad goal is to advance the methods used to collect, store, organize, and use widely distributed knowledge resources that contain diverse types of information and content stored in a variety of electronic forms. Six university-led DLI projects are pursuing this goal in partnership with libraries, museums, publishers, schools, and computing and communications companies.

Digital Video Library Project

The Informedia Digital Video Library Project at Carnegie Mellon University uses intelligent, automatic mechanisms that provide users with full-content search and retrieval from online digital video that can scale to several thousand hours. The project is creating a multimedia library of more than 1,000 hours of digital video, audio, images, text, and related materials. New digital video library technology allows independent access to information for self-teaching and exploration, which can improve the ways in which both education and training are delivered. Tools that can automatically populate the library and support access via desktop computers on local, metropolitan, and wide area networks are being developed.



Stanford University's Digital Library project focuses on interoperability. At its heart is a testbed that runs the "InfoBus" protocol, providing uniform access to various services and information sources through "proxies" that act as interpreters. The Stanford Digital Library testbed is used to experiment with interoperability among these services. Distributed objects allow processes to be implemented in different languages on computing systems with differing architectures.

Interoperability and DLITE

The Digital Library Integrated Task Environment (DLITE) is an experimental, direct-manipulation interface to information objects and services. Information services are accessed via the InfoBus and are presented to the user as components in workcenters. DLITE is designed to make it easy for users to interact with many different services while focusing on a single task.

Intelligent Access

The University of California-Berkeley Digital Library project's goal is to develop technologies for intelligent access to massive, distributed multi-terabyte databases of photographs, satellite images, videos, maps, full text documents, as well as "multivalent" documents that presume a single document consists of multiple layers of different but closely related material. A major component of the project is to develop a large testbed of data and services that provides public access to environmental datasets.

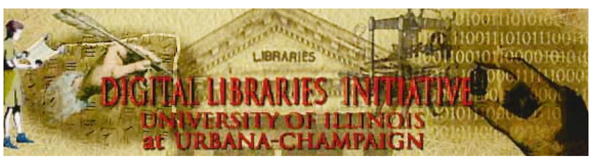
The Alexandria Project

The Alexandria Project at the University of California at Santa Barbara is building the Alexandria Digital Library (ADL) — a distributed digital library that will give users the ability to access and manipulate digital information in a variety of collection items, ranging from maps and images to text and multimedia. From the Internet, users and librarians will access various components of ADL, such as its catalog and collections, through powerful, graphical interfaces. In 1996, more than 2,000 registered users tested the ADL's Web Prototype (WP). In addition to providing valuable feedback on the appearance, usability, and content of the WP, the testing process helped researchers identify major problems such as system bottlenecks and speed and bandwidth issues.

In response to this testing program as well as additional research, the Alexandria Project will design and implement a new interface that will provide users with more functional options and greater ease of use.

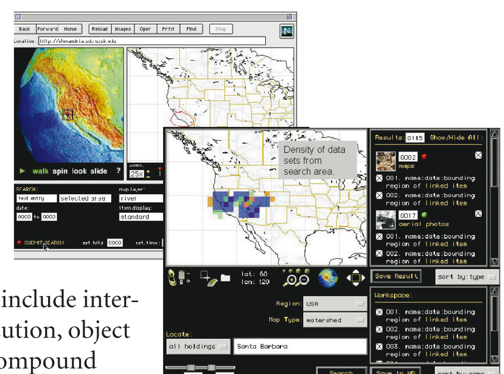
Scientific literature on the Internet

The Digital Libraries Initiative project at the University of Illinois at Urbana-Champaign is developing technology to handle digital libraries of scientific literature on the Internet effectively. The results will include digital library software and sociological evaluation of its use with hundreds of users searching tens of thousands of documents. Repositories of indexed multiple-source collections are being built and indexed by searching the material via multiple views of a single virtual collection. Both the testbed and production facilities as well as the Internet client are now operational. Concept spaces for 1,000 subfields of engineering have been computed on 10,000,000 abstracts using 10 days of supercomputer time — the largest computation ever in information science and a major step towards semantic interoperability.



Interspace

The Interspace research project at the University of Illinois at Urbana-Champaign seeks to unify disparate distributed information resources in one coherent model. The Interspace is a collection of interlinked information spaces where each component space encodes the knowledge of a community or a subject domain. Standard services include inter-object linking, remote execution, object caching, and support for compound objects (usually referred to as compound documents). Additionally, the Interspace system acknowledges the importance of legacy applications and supports their integration into the system in a relatively seamless manner. Ultimately, the Interspace system goal is to represent all types of data/objects in one flexible, cohesive, and scalable system.



Multimedia testbed of Earth and space science data

The University of Michigan Digital Library (UMDL) project is a multimedia testbed of Earth and space science data that supports "inquiry-based" approaches to science education in middle and high schools, as well as instruction and research at the university. For example, the project offers high school students links to scientific information about minerals such as the Smithsonian's Gem and Mineral Collection, NASA's Earth and Space Science Application Project, and NOAA's National Geophysical Data Center. The core of the project is an agent architecture that supports the teaming of agents to provide complex services by combining the limited capabilities of individual agents. R&D efforts aimed at deploying the UMDL in real-world settings focus on the need for advanced, friendlier interfaces that support simple or complex inquiries by students and teachers.

Workshops

The Digital Libraries Initiative sponsors numerous workshops. Recent workshops have included the following:

- ❒ Report of the Santa Fé Planning Workshop on Distributed Knowledge Work Environments: Digital Libraries, March 9-11, 1997
- ❒ Federation Across Heterogeneous Databases, A Report on the Spring 1997 Partners Workshop, April 3-4, 1997
- ❒ Libraries, People, and Change: A Research Forum on Digital Libraries, A Report on the October 27-29, 1996, Allerton Institute
- ❒ Workshop on Technology of Terms and Conditions, A Report on the September 24-26, 1996 Workshop at Columbia University
- ❒ DLI Spring Partner's Workshop, May 2-3, 1996, University of Illinois at Urbana-Champaign
- ❒ DLI SGML (Standard Generalized Markup Language) Mathematics Workshop, May 1, 1996, University of Illinois at Urbana-Champaign
- ❒ Social Aspects of Digital Libraries, A Report on the February 15-17, 1996, UCLA-NSF Social Aspects of Digital Libraries Workshop

Information on these workshops is available at

http://dli.grainger.uiuc.edu/workshops.htm.

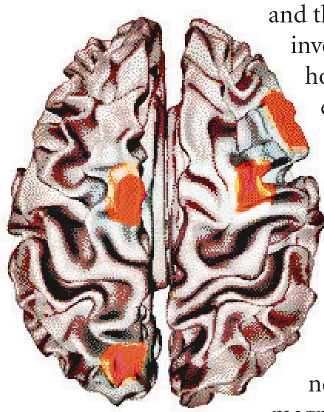
Human Brain Mapping through MEG

MEG

Magnetoencephalography (MEG) is the study of brain function using sensitive detection systems to measure the magnetic fields emanating from the head as a result of brain activity. In the image to the right, a magnetic field resulting from the brain's response to a visual stimulus is shown as a color contour map on a head surface reconstructed from MRI data. The disks represent sensor locations in a full-head MEG system.

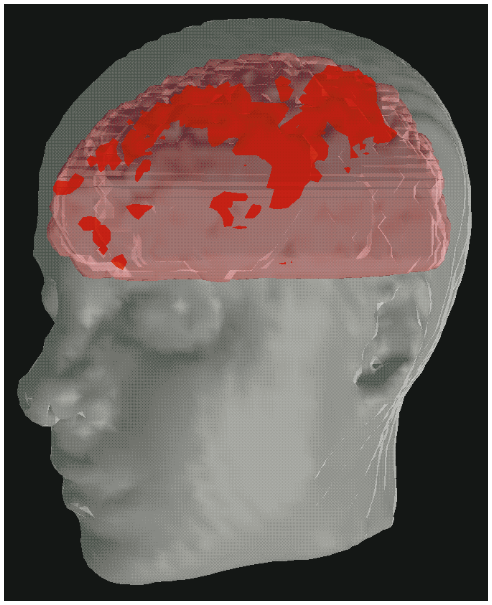
Dynamic brain visualization

Researchers at the University of California-San Diego's (UCSD) Cognitive Sciences Department are using MEG to investigate the flow of information in the brain and how it relates to mental functions and cognition. Visualization in 3-D enables one to "see" the dynamic characteristics of brain processes and the interplay of different functional areas involved and may lead to a new understanding of how the brain works. This image shows the electric current distribution in the visual, motor, and Broca's and Wernicke's areas involved in language processing. Bright red areas are the sites of present activity. The surrounding orange areas show the variability of activity over time. To produce an image of activity in these four primary areas that are normally not active at the same time, researchers simulate excitations of the neuronal cell groups using UCSD's neuro-magnetic simulation package.



Functional Magnetic Resonance Imaging

Functional MRI experiments have been used to investigate all aspects of brain function, including a concept known in cognitive psychology as working memory. Each subject's brain is scanned while he or she performs a working memory task (page 39, top left) and a control task. Results to date support the theory that the prefrontal cortex becomes engaged when recently presented information must be represented and actively maintained to perform a task. This type of study leads to improved understanding of

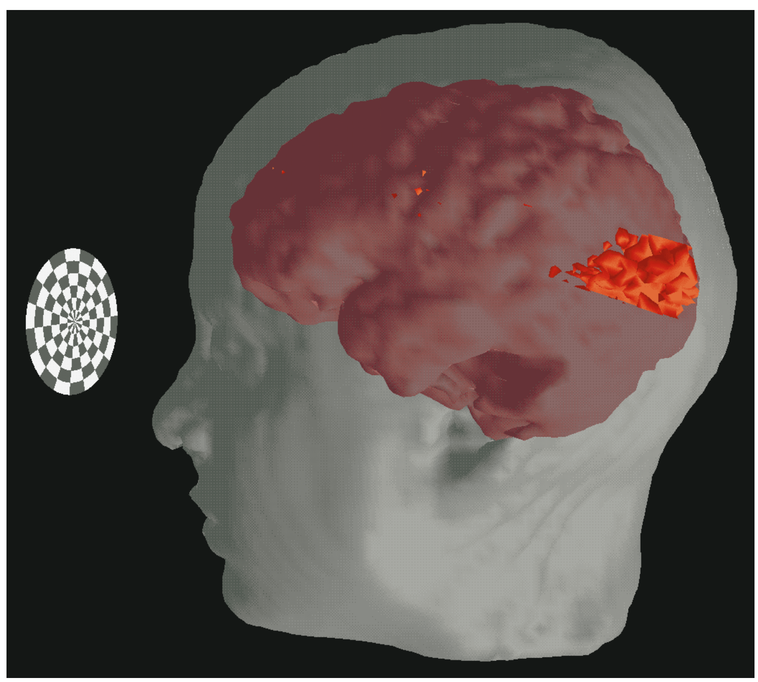


Brain activity during the memory task.

memory function, which impacts clinical treatment of major diseases such as schizophrenia and amnesias.

The primary visual cortex becomes active when a striking pattern is shown to the subject, visualized in the image at the bottom of this page. Both images were displayed in near real-time while the subject was being scanned. NIH-supported researchers at Carnegie Mellon University used Pittsburgh Supercomputing Center's Cray T3E to process the data acquired by the MRI scanner at the University of Pittsburgh Medical Center and visualized the results on a Silicon Graphics Onyx Reality Engine.

The processing included image reconstruction and motion correction to compensate for the movement of the subject's head. This real-time capability will make it possible to use brain-mapping as a routine clinical tool in diagnosing and treating brain pathology, as in neurosurgical planning for tumor removal. For example, neurosurgeons who use standard MRI to locate tumors will now be able to determine which cognitive and sensory-motor abilities (for example, language and motor-skills) are located close to the tumor site, allowing them to further refine their surgical plans.



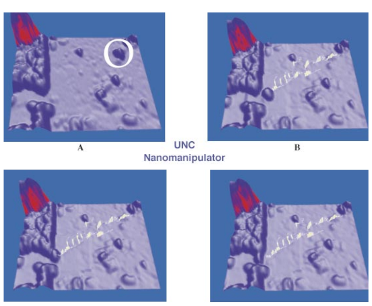
Brain activity that occurs when a pattern is shown to the subject of the experiment. The primary visual cortex becomes active.

nanoManipulator Surface Images

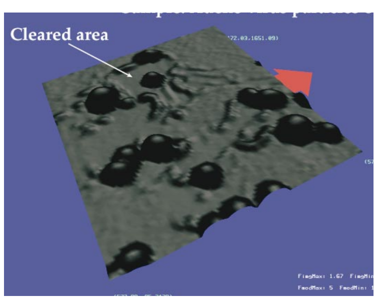
The nanoManipulator project

The nanoManipulator project is now under way at the University of North Carolina (UNC) at Chapel Hill. The project is developing an improved, natural interface to scanning probe microscopes, including Scanning Tunneling Microscopes (STM) and Atomic Force Microscopes (AFM). The purpose of a nanoManipulator is to scale the STM or AFM environments (on the nanometer scale) up to the human environment (on the meter scale) so that the researcher can use a virtual reality interface to interact with the environment at the atomic level. The required level of magnification is impossible for conventional optical microscopes that project magnified images. The STM provides its information as an elevation map that is then interpreted and rendered by the graphics portion of the system.

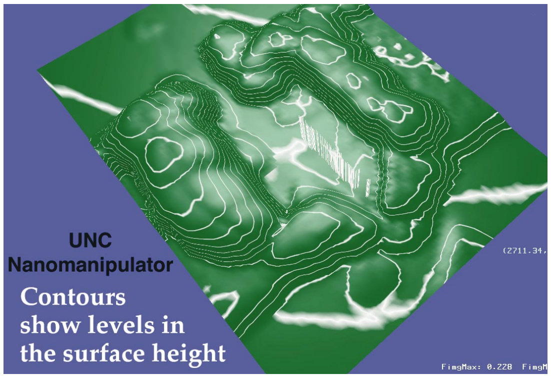
The nanoManipulator interface was conceived through a collaboration between UNC-Chapel Hill and the University of California at Los Angeles (UCLA). The effort commenced in 1991 with the development of a system to control an STM. Experiments conducted in 1993 led to the discovery of nanoWelding. The team works closely with users in biology, solid-state physics, and gene therapy to develop techniques and displays they could use to solve problems in their fields. The following examples illustrate the wide range of new capabilities that nanotechnologies are enabling:



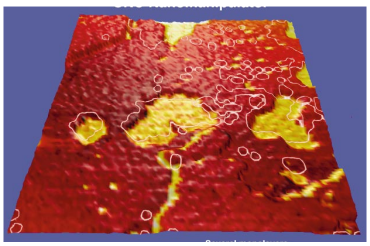
To the left, nanomanipulation of a 20 nM gold particle is shown as a sequence of pushes that move a colloidal gold particle across a micron-size field and into a gap etched in a gold wire. Force feedback during the pushes makes it possible to move the ball without destroying it and to avoid patches of surface contaminant. The ball starts in the circled position on the upper left image. Yellow lines trace the path of the ball, showing where high force was used to push it. The particle ends up in the gap as depicted in the lower-right image. Taking the two ends of the wire out to external contacts will allow measurement of the particle's energy states.



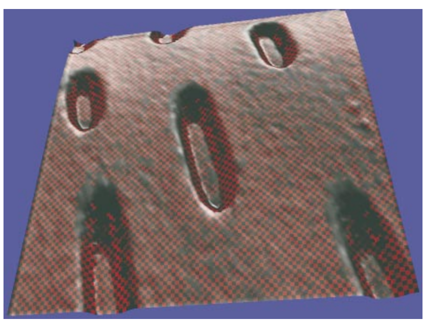
Collaborators at the UNC Gene Therapy Center have used the nanoManipulator to examine adenovirus particles. Since these particles are used as gene-delivering vectors in gene therapy, there is considerable scientific interest in learning how these particles stick to and move around on cell surfaces. A preliminary experiment, illustrated to the left, shows that particles have been moved around on a cleared area of mica substrate. The virus particles themselves were manipulated by pushing them together and pulling them apart.



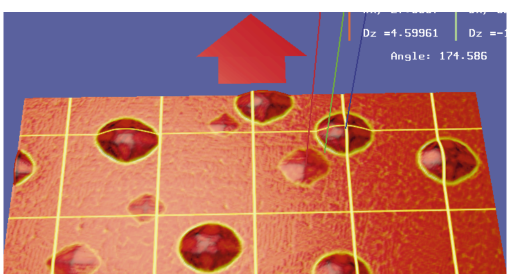
To perform an experiment in circuit tuning, the nanoManipulator was first used to cut a small gap in a 1-micron wire (shown to the left) while the impedance of the wire was measured. Once the impedance was infinite, the removed piece of wire was pushed back into the gap to tune the impedance from about 100 to about 1,000 Ohms. The wire in this image runs from the lower left to the upper right. The square in the center was machined first (leaving "snow piles" along the edges). Then the small gap in the upper left corner was formed, and finally the gap in the lower right corner. White contour lines indicate constant-height curves on the wire.



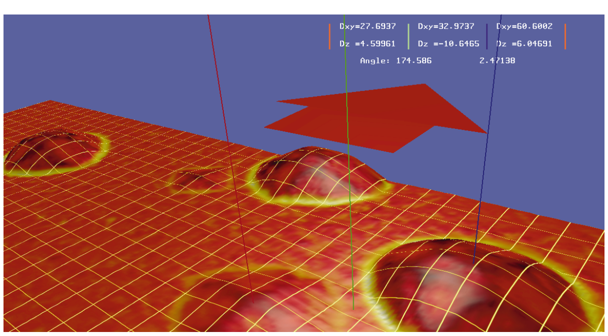
Three data sets of a mixed molecular monolayer of perfluorooctadecanoic acid and tetracosanoic acid deposited on mica are shown to the left. Color depicts the lateral friction of the sample with yellow areas indicating high friction and red low. The white lines are contours separating areas of high vertical adhesion from areas of low adhesion. The data sets on this one-square-micron sample were obtained by scanning with a Topometrix atomic-force microscope. The adhesion data set is misaligned and distorted because it was obtained on a separate, slower pass over the sample.



This image is a 5-micron area of the surface of a compact disc, with tracks running from the upper left to the lower right. The lateral force of the probe tip was measured along with the topography. A checkerboard pattern has been inlaid on the surface to indicate lateral force: areas of high force have a strong pattern, while areas with less force display no pattern. The researchers plan to use image and bump-map textures, together with color and contour lines, to indicate multiple data sets simultaneously. The PixelFlow graphics engine will enable them to do this rendering in real time.

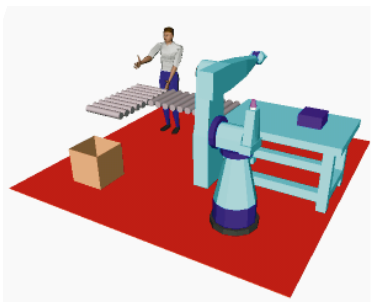


This image highlights germanium pyramids and domes grown on silicon. Color is from curvature information, using the black-body radiation spectrum. The gridlines are drawn on 100 nM boundaries.



To the left is a close-up view of the preceding image, magnified and viewed from a different angle. The numbers show the distance in the plane and are vertical to the plane, indicating relative heights of the two bumps. These visualizations were performed for Hewlett-Packard's science labs.

Information-driven Manufacturing



Human modeling applications, engineering analysis applications, and factory simulation applications are being integrated using VRML technology.

Technological innovations and advances are rapidly changing today's manufacturing infrastructure. U.S. manufacturers are being challenged daily to become more productive through shortened product development cycles, increased responsiveness, and flexibility. At the same time, they must continually raise quality and control costs. Information is the key issue in addressing these manufacturing challenges. Manufacturing firms not only must design and maintain comprehensive databases ranging from designs and processes to supplier performance and customer requirements. They must also have the tools to access the right information at the right time and in the proper format.

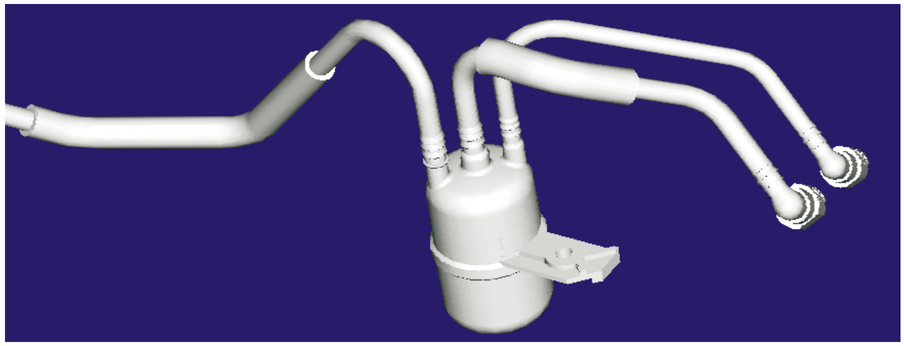
Continuing leading-edge R&D focused on setting standards and providing technology solutions to manufacturing systems integration challenges has been pioneered by NIST and other Federal agencies and promises to lead to the realization of virtual enterprises, seamless manufacturing information interchange, and distributed collaborative engineering. With the availability of interoperable systems and effective information management capabilities within and across enterprises, these information interface solutions will lead to innovative business models and reduced time-to-market.

Systems Integration for Manufacturing Applications

NIST's Systems Integration for Manufacturing Applications (SIMA) program is an ongoing effort whose goal is to apply state-of-the-art information technologies to the manufacturing systems integration challenges faced by industry. SIMA's primary focus is developing and testing of standards-based information interface solutions to these challenges. The program is also exploring techniques to provide easier access to the scientific data and analyses needed in the development of new products and processes, as well as improving technology for remote collaboration and interaction. The program's projects are organized into three major categories: the Manufacturing Systems Environment (MSE), the Standards Development Environment (SDE), and the Testbeds/Technology Transfer Environment (TTTE).

Manufacturing Systems Environment

MSE projects focus on developing integration technologies and standards that support a broad range of industrial manufacturing domains including mechanical products, electronics, construction, and chemical processing. Systems of interest within these domains include design (product, process, and enterprise), planning, scheduling, process modeling, shop control, simulation, inspection, assembly, and machining. Typical integration and



This complex fuel filter assembly model is being used to verify the efficacy of new product data exchange technology standards in the automotive supply chain.

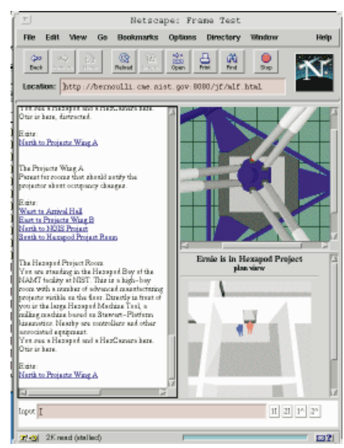
interface technology solutions include information protocols for product and process data, information repositories, and frameworks.

Standards Development Environment

SDE projects facilitate industry efforts to test evolving information exchange and interface specifications using the Internet and to accelerate industry deployment of consensus standards. One of the goals of SDE projects is to provide effective support environments for developing standards as well as harmonizing the broad spectrum of those standards required for enterprise integration.

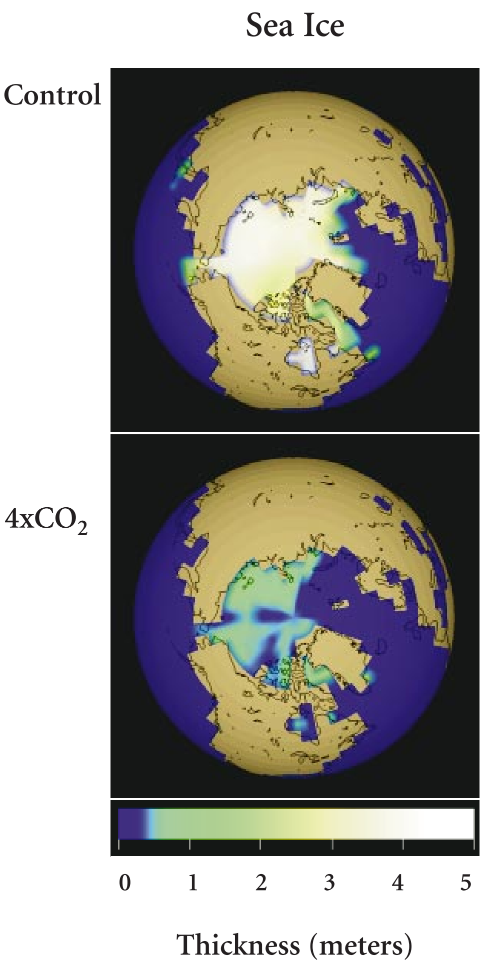
Testbeds/Technology Transfer Environment

TTTE projects develop technology infrastructure that provides access to government research results and test prototype collaboration technologies in partnership with industry and academia. Testbeds developed under TTTE auspices are intended to serve as collaborative testing and demonstration sites and as focal points for disseminating information.



A prototype Web-based environment enabling remote collaborative experimentation with the hexapod machine tool in NIST's National Advanced Manufacturing Testbed is under development.

Environmental Modeling: Climate Change



The international climate community has focused considerable research on detecting and projecting climate change over the next century. Typical modeling experiments simulate the transient global warming response of the coupled atmosphere-ocean system to an expected doubling of the atmosphere's CO_2 content over the next century. However, recent analyses of future emission scenarios in international climate change assessments suggest that, on a multi-century time scale, CO_2 levels are likely to rise well beyond a doubling unless substantial emission reductions occur. To address this potential long-term scenario, NOAA's scientists at the Geophysical Fluid Dynamics Laboratory (GFDL) have performed a series of multi-century integrations of a global coupled ocean-atmosphere model in which CO_2 increases by one percent each year to a level four times that of the present climate and then remains constant thereafter.

Results from these quadrupled CO_2 experiments ($4xCO_2$) are compared to a control run with current-day concentrations. The experiments project a substantial increase in surface air temperature, with the summer warming predicted to increase markedly over much of the mid-latitude continental regions, including North America and Asia. The experiments' temperature changes are nearly as large as the difference between the present climate and that of the Late Cretaceous Period that occurred approximately 65-90 million years ago when dinosaurs still inhabited the Earth. While model resolutions are quite low compared to those used for daily weather forecasts, the five-century duration of each model run requires many hundred processor-hours to complete on a high performance computing system.

Along with surface warming, sea ice coverage over the Arctic Ocean is projected to decrease substantially. Mean sea ice thickness (in meters) in the model during late winter is shown in the illustration. The view is from above the North Pole; brown areas indicate the model's land regions. During late summer (not shown), sea ice is virtually absent in the $4xCO_2$ experiment.

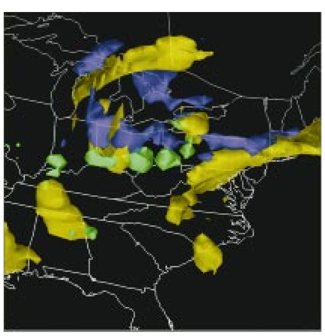
Environmental Modeling: Air Quality

Fine particles and health

Scientific studies have linked fine particles (less than 2.5 microns) produced by wood stoves, agricultural burning, and conversion of gases from fuel combustion to health problems such as aggravated asthma, chronic bronchitis, and severe chest pain. The elderly suffering from lung or heart disease and active children are most at risk from inhaling these fine particles. Asthmatic children and even healthy adults face an additional health risk from exposure to ground level ozone, a major ingredient of urban smog.

Community Multi-scale Air Quality model

To protect against these health risks, the Environmental Protection Agency (EPA) has proposed revisions to the Particulate Matter and Ozone National Ambient Air Quality Standards (NAAQS). States found in violation of these standards are required to prepare individual state implementation plans and perform air quality modeling studies to demonstrate how they will meet the NAAQS. Advanced computational techniques have enabled the development of a Community Multi-scale Air Quality (CMAQ) model to compute hourly ozone and fine-particle concentrations simultaneously as part of a "one atmosphere" approach to exposure and risk assessment. Models-3, an environmental problem-solving framework built upon information management and distributed computing technology, enables state and local/regional air pollution control managers as well as local industry to use these comprehensive multipollutant models to assist in environmental decision-making that affects the health, economic well-being, and quality of life in their communities.



Although ozone chemistry and sulfate particle formation are linked, changes in source emissions can influence ozone and sulfate concentrations differently. For this reason, knowledge of concurrent production of ozone and fine particles is critical. In the illustration, predicted ozone levels that meet the existing National Ambient Air Quality Standards but exceed the proposed revised standards are shown in blue. The green areas show high sulfur dioxide concentrations directly over large industrial sources, and the yellow plumes depict sulfate that was transformed from ground sources of sulfur dioxide and transported long distances by prevailing winds.

The Presidential Advisory Committee On High Performance Computing And Communications, Information Technology, And The Next Generation Internet

On February 11, 1997, President Clinton signed an Executive Order establishing the Advisory Committee on High Performance Computing and Communications, Information Technology, and the Next Generation Internet. The Committee is asked to assist the Administration's efforts to accelerate development and adoption of information technologies that will be vital for American prosperity in the 21st century.

The twenty-one industry and academic leaders who are members of the Committee represent the research, education, and library communities, network providers, and representatives from critical industries. President Clinton designated Ken Kennedy of Rice University and Bill Joy of Sun Microsystems as co-chairmen.

As part of the Executive Order creating the Committee, President Clinton has asked them for an independent assessment of:

- Progress made in implementing the High Performance Computing and Communications (HPCC) Program
- Progress in designing and implementing the Next Generation Internet initiative
- The need to revise the HPCC Program
- Balance among components of the HPCC Program
- Whether the research and development undertaken pursuant to the HPCC Program is helping to maintain U.S. leadership in advanced computing and communications technologies and their applications
- Other issues as specified by the Director of the Office of Science and Technology Policy (OSTP)

At the first meeting of the Advisory Committee on February 26 and 27, 1997, Dr. John H. Gibbons, the President's Science Advisor and Director of OSTP, said, as he welcomed the members, "The technology of information lies at the core of many of our hopes for America's future-in industry and commerce, in education, in medicine, in the way we talk with each other, in the way we organize knowledge.... We need your guidance to design programs that serve both public needs and the needs of the companies that we must rely on to convert ideas into products, income, and jobs." At this meeting, the Committee organized itself into the Broadbased, Highend, and NGI Subcommittees. The full Committee also convened June 24-25, 1997, and plans to meet December 9-10, 1997 and in March 1998.

The Committee conducted a review of the NGI initiative and submitted its assessment to OSTP as a letter report in May 1997. The Committee enthusiastically supported the motivation, goals, and proposed investments embodied in the NGI program. They strongly encourage even closer coordination between the Federal NGI initiative, the academic community's complementary program known as Internet 2, and related federal and industrial efforts. Four recommendations were made:

- ❑ Make key investments now since today's Internet is already showing signs of frailty and high bandwidth architectures and multimedia applications are stressing it for the future
- ❑ Encourage stronger cooperation since the NGI vision is beyond the scope of any one institution, company, or industry sector and the Federal government can stimulate progress
- ❑ Encourage all sectors to invest to realize benefits by creating an environment in which breakthrough research results are possible
- ❑ Restate program goals to better match intended research objectives

These recommendations have been incorporated into the NGI initiative. Committee members testified about the NGI initiative before the Senate Committee on Commerce, Science, and Transportation; the House Committee on Science; and the Congressional Internet Caucus.

Committee Members

Ken Kennedy is Director of the Center for Research on Parallel Computation at Rice University, and Ann and John Doerr Professor of Computer Science.

Bill Joy is co-founder and Vice President of Research at Sun Microsystems.

Eric A. Benhamou is President, Chairman, and CEO of 3Com Corporation.

Vinton Cerf is Senior Vice President of Internet Architecture and Engineering at MCI Communications.

Ching-chih Chen is a Professor in the Graduate School of Library and Information Science at Simmons College.

David Cooper is Associate Director of Computation at the Lawrence Livermore National Laboratory.

Steven D. Dorfman is Executive Vice President of Hughes Electronics Corporation and Chairman of Hughes Telecommunications and Space Company.

Robert Ewald is Executive Vice President for Computer Systems at Silicon Graphics, Inc.

David J. Farber is Alfred Fitler Moore Professor of Telecommunications at the University of Pennsylvania.

Sherrilynne S. Fuller is Director of the Health Sciences Libraries and Information Center, Acting Director, Informatics, School of Medicine, and Director of the National Network of Libraries of Medicine, Pacific Northwest Region at the University of Washington.

Hector Garcia-Molina is Leonard Bosack and Sandra Lerner Professor in the Departments of Computer Science and Electrical Engineering at Stanford University.

Susan Graham is Chancellor's Professor of Computer Science in the Department of Electrical Engineering and Computer Science at the University of California, Berkeley.

James N. Gray is a senior researcher in Microsoft's Scalable Servers Research Group and manager of Microsoft's Bay Area Research Center.

W. Daniel Hillis is a Vice President and Disney Fellow at Walt Disney Imagineering, Research and Development, Inc.

David C. Nagel is President of AT&T Labs.

Raj Reddy is Dean of the School of Computer Science and Herbert A. Simon University Professor of Computer Science and Robotics at Carnegie Mellon University.

Edward H. Shortliffe is Associate Dean for Information Resources and Technology, Professor of Medicine, and Professor of Computer Science at Stanford University School of Medicine.

Larry Smarr is Director of the National Computational Science Alliance and Professor of Physics and Astrophysics at the University of Illinois at Urbana-Champaign.

Leslie Vadasz is Senior Vice President and Director of Corporate Business Development at Intel Corporation.

Andrew J. Viterbi is a co-founder of QUALCOMM Incorporated and Vice Chairman of its Board of Directors.

Steven J. Wallach is Advisor to CenterPoint Ventures.

Computing, Information, and Communications Research Facilities

To foster technical research and demonstrate future directions of CIC R&D, Federal agencies operate numerous CIC research facilities across the country. These facilities provide capabilities to (1) evaluate early prototype systems and provide valuable feedback to developers, (2) integrate visualization and virtual reality systems into existing high performance systems, (3) run full scale applications on systems not otherwise available, and (4) develop parallel software using scaled down systems. These facilities provide access to innovations in network connectivity that allow large scale applications to run over remote connections.

The success of these research centers is attributed to many enabling technologies, such as high speed networks, supercomputers, parallel architectures, massive data stores, and virtual reality display devices, and to the dedication of researchers, facility staff, hardware and software vendors, and industrial affiliates. All facilities provide extensive K-12 and undergraduate educational opportunities, as well as training for researchers, graduate students, and faculty, and are ideal benchmarking sites for both systems and applications.

Funding for these facilities, primarily provided by CIC R&D agencies, is leveraged heavily through equipment and personnel from hardware and software vendors, discipline-specific agency funds, as well as state and local funds, and industrial affiliate contributions, offering a low risk, collaborative environment for exploring and ultimately exploiting CIC R&D technology. Below is a list of CIC R&D research facilities categorized by the primary funding agency.

NSF

Supercomputing Centers (through FY 1998)

Cornell Theory Center (CTC), Ithaca, NY

National Center for Supercomputing Applications (NCSA), Urbana-Champaign, IL

Pittsburgh Supercomputing Center (PSC), Pittsburgh, PA

San Diego Supercomputing Center (SDSC), San Diego, CA

National Center for Atmospheric Research (NCAR), Boulder, CO

PACI Centers

The NSF Partnerships for Advanced Computational Infrastructure Program (beginning in FY 1998) builds on and replaces the current NSF Supercomputer Centers Program established in 1985 and focuses on taking advantage of newly emerging opportunities in high performance computing and communications.

National Computational Science Alliance (NCSA), Urbana-Champaign, IL

National Partnership for Advanced Computational Infrastructure (NPACI), San Diego, CA

Science & Technology Centers

Center for Cognitive Science, University of Pennsylvania

Center for Computer Graphics and Scientific Visualization, University of Utah

Center for Research in Parallel Computation (CRPC), Rice University

NASA

Testbeds

Ames Research Center, Moffett Field, CA

Goddard Space Flight Center, Greenbelt, MD

Jet Propulsion Laboratory, Pasadena, CA

Langley Research Center, Langley, VA

Lewis Research Center, Cleveland, OH

DOE

Laboratories

Argonne National Laboratory, Chicago, IL

Los Alamos National Laboratory, Los Alamos, NM

National Energy Research Supercomputer Center at Lawrence Berkeley National Laboratory, Berkeley, CA

Oak Ridge National Laboratory, Oak Ridge, TN

NIH

Systems

Frederick Biomedical Supercomputing Center at the National Cancer Institute

Supercomputing Resources at the Division of Computer Research and Technology

National Center for Research Resources' High Performance Computing Resource Centers

Biomedical Computation Resource, University of California, San Diego

Parallel Computing Resource for Structural Biology, University of North Carolina, Chapel Hill

Parallel Processing Resource for Biomedical Scientists, Cornell Theory Center, Cornell University

Resource for Concurrent Biological Computing, Beckman Institute, University of Illinois

Supercomputing for Biomedical Research, Pittsburgh Supercomputing Center

Theoretical Simulation of Biological Systems, Columbia University

National Center for Research Resources' Scientific Visualization Resource Centers

Interactive Graphics for Molecular Studies, University of North Carolina, Chapel Hill

Special Research Resource for Biomolecular Graphics, University of California, San Francisco

NOAA

Laboratories

Forecast Systems Laboratory, Boulder, CO

Geophysical Fluid Dynamics Laboratory, Princeton, NJ

National Centers for Environmental Prediction, Camp Springs, MD

EPA

Systems

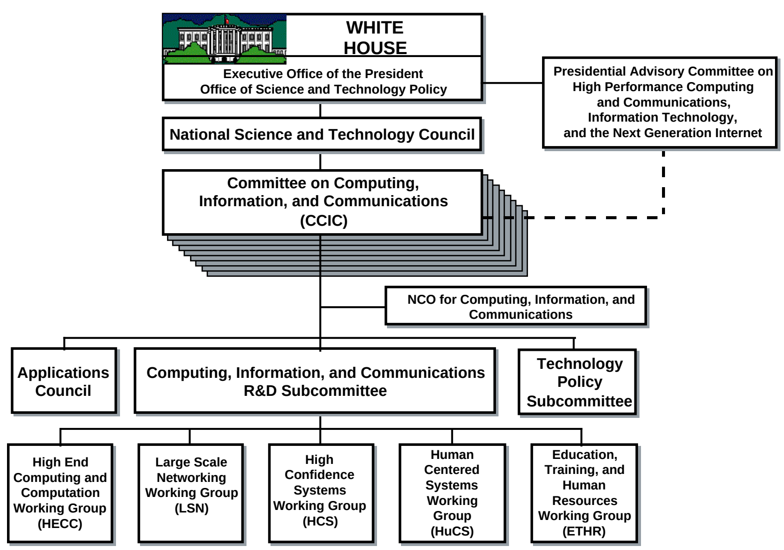
National Environmental Supercomputing Center, Bay City, MI

CIC R&D Programs

The National Science and Technology Council's FY 1998 Committee on Computing, Information, and Communications (CCIC) encompasses the Computing, Information, and Communications (CIC) R&D Subcommittee and its five Program Component Areas (PCAs), the Applications Council, and the Technology Policy Subcommittee. The twelve agencies participating in the CIC R&D programs develop computing, information, and communications technologies in close cooperation with academia and industry. The Presidential Advisory Committee on High Performance Computing and Communications, Information Technology, and the Next Generation Internet advises the Administration on the CIC efforts of these agencies and on the future of our Nation's CIC R&D programs.

National Coordination Office (NCO) for CIC

The NCO facilitates multi-agency CIC R&D activities, such as the preparation of planning, budget, and assessment documents and the development of inter-agency CIC programs, and supports the activities of the Presidential Advisory Committee. The NCO Director, who reports jointly to the Director of the Office of Science and Technology Policy (OSTP), Executive Office of the President, and to the Chair of the CCIC, serves as the chair of the CIC R&D Subcommittee.



The CIC R&D Subcommittee and the NCO meet frequently with representatives from Congress, Federal, state and local organizations, industry, academia, professional societies, foreign organizations, and others to exchange technical and programmatic information about CIC needs, issues, and trends. During past years, the NCO, the CIC R&D Subcommittee, and the Applications Council have sponsored several workshops to promote government-industry interaction and to address technical approaches to meet future architecture and software needs, including the:

- ❑ Workshop on Software Tools for High Performance Computing Systems, October 1996
- ❑ PetaFLOPS Software Framework Model Workshop, January 1997
- ❑ Algorithms for PetaFLOPS, April 1997
- ❑ Workshop on Research Directions for the Next Generation Internet, May 1997
- ❑ Workshop on Research and Development Opportunities in Federal Information Services, May 1997

Presidential Advisory Committee

Established February 11, 1997 by Executive Order 13035, the Presidential Advisory Committee on High Performance Computing and Communications (HPCC), Information Technology, and the Next Generation Internet (NGI) provides the National Science and Technology Council (NSTC), through the Director of OSTP, with an independent assessment of progress made in Federal computing, communications, and information technology R&D and with advice on initiatives such as the NGI.

CIC R&D Subcommittee

Twenty-one industry and academic leaders comprise the Presidential Advisory Committee, which is organized into the Broadbased, High-End, and NGI Subcommittees. The full Committee convened February 27-28, 1997, and June 24-25, 1997. Committee members testified before the Senate Committee on Commerce, Science, and Transportation; the House Committee on Science; and the Congressional Internet Caucus. The Committee conducted a review of the NGI initiative and submitted its assessment to OSTP as a letter report.

Applications Council

Chaired by the NCO Director, the CIC R&D Subcommittee consists of representatives from each participating agency and reports to the CCIC. The Subcommittee and its Executive Committee work with the agencies to plan, budget, implement, and review the multi-agency CIC programs, helping to shape the Nation's information infrastructure. The Subcommittee's five PCA Working Groups meet regularly to coordinate activities and discuss new initiatives.

Established in 1997, the CCIC Applications Council facilitates partnerships between Federal R&D and non-R&D agencies, to promote early application of CCIC-developed technologies within the Federal arena, in particular efforts that involve multiple agencies and disciplines. The Council's Working Groups address crisis management, Federal statistical information, the NGI, and universal access; working groups in geographical information systems and Federal-State-local government interaction are planned for FY 1998. In FY 1997, the Applications Council conducted a Workshop on Research and Development Opportunities in Federal Information Services. The workshop organizers issued a report outlining a digital government agenda focused on advanced information technology pilot projects in Federal agencies. Interaction with the Government Information Technology Services (GITS) Board include a digital government task force.

Technology Policy Subcommittee

The Technology Policy Subcommittee (TPS), formerly the Technology Policy Working Group of the Information Infrastructure Task Force (IITF) Committee on Applications and Technology, assists the CCIC in identifying, addressing, and resolving relevant technology policy issues. The TPS interacts with key industry groups, encouraging technology policy that promotes open architecture, interconnections, interoperability, and standards. The TPS participates in industry conferences, produces white papers on strategic policy issues, initiates projects through its member organizations, provides support and recommendations for legal and regulatory bodies, creates and chairs panels on technology policy issues, and makes recommendations to the CCIC.

Federal Networking Council

To achieve greater efficiencies within the CCIC, the R&D activities of the Federal Networking Council (FNC) have been transferred to the LSN Working Group. The FNC's Engineering and Operations Working Group has been succeeded by the Joint Engineering Team for the purpose of integrating the Federal networks that will be part of the NGI. The LSN's Privacy and Security Working Group, formerly part of the FNC, works closely with the Applications Council in piloting security and privacy technologies in Federal applications. Non-R&D activities are being transferred to other Federal organizations (for example, management of the *.gov* domain space is being transferred to the General Services Administration (GSA)).

CIC Program Evaluation

Critical analysis of the CIC programs is provided through the Presidential Advisory Committee, Federal and Federally-chartered organizations, industrial and academic organizations, professional societies, conferences, workshops, and reports. For example, recent National Research Council/Computer Science and Telecommunications Board analyses include:

- ❏ "More than Screen Deep: Toward Every Citizen Interfaces to the Nation's Information Infrastructure," August 1997
- ❏ "For the Record: Protecting Electronic Health Information," March 1997
- ❏ "The Unpredictable Certainty: Information Infrastructure through 2000," 1996
- ❏ "Computing and Communications in the Extreme: Research for Crisis Management and Other Applications," 1996

Buy American Report

Congress requires information concerning non-U.S. high performance computing and communications funding activities.

In FY 1997, DARPA was the only CIC R&D agency that entered into grants, contracts, cooperative agreements, or cooperative research and development agreements for CIC 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 has funded an award to the Department of Computer Science, University of Warwick, England, for methods and tools for performance modeling, measurement, analysis, evaluation and prediction.

In FY 1997, no CIC R&D 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.

Reports about CIC R&D Programs

The NCO responds to thousands of information requests from Congressional offices, industry, academia, and the public each year. To fulfill these requests, the NCO provides print and video materials and maintains Web servers that include all NCO publications since 1994; information on the CCIC and the organizations that report to it; the Presidential Advisory Committee; the Next Generation Internet initiative; Congressional testimonies; links to the servers of participating agencies; and other related information. Last year, individuals from approximately 100 countries accessed the NCO Web site.

For the most up-to-date information on CIC programs, the reader is invited to visit *http://www.ccic.gov/*.

CIC R&D Summary

CIC R&D Goals

Assure continued U.S. leadership in computing, information, and communications technologies to meet Federal goals and to support U.S. 21st century industrial, academic, and defense 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 of citizens; 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

CIC R&D Agencies

AHCPR – Agency for Health Care Policy and Research, Department of Health and Human Services

DARPA – Defense Advanced Research Projects Agency, Department of Defense

DOE – Department of Energy

ED – Department of Education

EPA – Environmental Protection Agency

NASA – National Aeronautics and Space Administration

NIH – National Institutes of Health, Department of Health and Human Services

NIST – National Institute of Standards and Technology, Department of Commerce

NOAA – National Oceanic and Atmospheric Administration, Department of Commerce

NSA – National Security Agency, Department of Defense

NSF – National Science Foundation

VA – Department of Veterans Affairs

Evaluation Criteria for CIC R&D Programs

Relevance/Contribution

The research must significantly contribute to the overall goals of the Federal Computing, Information, and Communications (CIC) R&D programs, which include the goals of the five Program Component Areas – High End Computing and Computation (HECC), Large Scale Networking (LSN), High Confidence Systems (HCS), Human Centered Systems (HuCS), and Education, Training, and Human Resources (ETHR) – 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 CIC R&D 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 CIC R&D resources (e.g., a balance among Program Component Areas), promote prospects for 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 HPCC Budgets by Program Component Area

FY 1997 Budget (Dollars in Millions)

Agency	HECC	LSN	HCS	HuCS	ETHR	TOTAL
DARPA	72.7	106.4	10.0	103.7		**292.8**
NSF	129.2	72.3	1.2	57.8	19.1	**279.6**
DOE	86.0	14.8		14.9	3.5	**119.2**
NASA	88.0	14.6	1.6	4.5	5.7	**114.4**
NIH	23.4	26.5	4.2	27.3	5.9	**87.3**
NSA	30.4	3.5	7.3			**41.2**
NIST	4.0	2.4	3.4	13.7		**23.5**
VA	1.0	9.5	2.3	1.8		**14.6**
ED				11.4	6.6	**18.0**
NOAA	4.3	2.7		0.5		**7.5**
EPA	5.6			0.6		**6.2**
AHCPR				4.2		**4.2**
TOTAL	**445.6**	**252.8**	**30.0**	**240.4**	**40.8**	**1,008.5**

FY 1998 Budget Request (Dollars in Millions)

Agency	HECC	LSN	HCS	HuCS	ETHR	TOTAL
DARPA	84.8	89.2	9.4	137.9		**321.3**
NSF	132.9	79.2	0.9	60.2	21.0	**294.2**
DOE	90.8	48.8		9.9	3.0	**152.5**
NASA	90.1	25.0	2.8	2.2	8.3	**128.4**
NIH	23.7	28.2	4.1	29.3	6.4	**91.7**
NSA	26.4	2.2	7.2			**35.8**
NIST	4.0	5.5	3.4	13.6		**26.5**
VA		7.5	5.4	9.2		**22.1**
ED				12.0		**12.0**
NOAA	4.3	2.7		0.5		**7.5**
EPA	6.2					**6.2**
AHCPR				5.5		**5.5**
TOTAL	**462.4**	**288.3***	**33.2**	**281.2**	**38.7**	**1,103.7‡**

* The requested FY 1998 LSN budget includes funds for the Next Generation Internet (NGI) Initiative. It also reflects the transition of DARPA's mature technology research from networking development to networking applications. For example, DARPA's FY 1998 allocation for HuCS includes $21 million transferred from its FY 1997 networking research budget.

‡ These totals vary slightly from the President's HPCC Budget. For example, funding for the Department of Transportation, one of the candidate agencies for participation in CIC R&D activities, is not included.

Glossary

AChE
Acetylcholinesterase, an enzyme.

ACTS
Advanced Computational Testing and Simulation.

AD
Automatically Differentiated.

ADIC
Automatic Differentiation Tool.

ADL
Alexandria Digital Library.

AFM
Atomic Force Microscope.

AHCPR
Agency for Health Care Policy and Research, part of the Public Health Service of the HHS.

Algorithm
A procedure designed to solve a problem. Scientific computing programs implement algorithms.

ALU
Arithmetic Logic Unit.

ARPANet
Advanced Research Projects Agency Network.

ASCI
DOE's Accelerated Strategic Computing Initiative.

AskERIC
Department of Education's Educational Resources Information Center.

ATDNet
Advanced Technology Demonstration Network.

ATM
Asynchronous Transfer Mode, a telecommunications technology, also known as cell switching, which is based on 53-byte cells.

AVS
Software package used to project the results from simulations onto molecular surfaces.

Backbone Network
A high capacity electronic trunk — for example the NSFNET backbone — connecting lower capacity networks.

Bandwidth
A measure of the capacity of a communications channel to transmit information; for example, millions of bits per second or Mb/s.

Benchmark
A point of reference (artifact) to compare an aspect of systems performance (for example, a well known set of programs). Also, to conduct and assess the computation (or transmission) capabilities of a system using a well known artifact.

BIT
DARPA's Broadband Information Technology.

Bit
An acronym for binary digit.

Bps, or B/s
An acronym for bytes per second.

bps, or b/s
An acronym for bits per second.

Byte
A group of adjacent binary digits operated upon as a unit (usually connotes a group of eight bits).

C
C programming language.

C++
C++ programming language, an object-oriented descendant of the C language.

CAD
Computer-aided design.

CAS
NASA's Computational Aerosciences Project.

CAVE
CAVE Automatic Virtual Environment. A surround screen, surround sound, projection-based virtual reality (VR) system.

CCIC
Committee on Computing, Information, and Communications (formerly the Committee on Information and Communications) of the NSTC.

CCMS
Computational Center for Macromolecular Structure.

CIC
Computing, Information, and Communications.

CIC R&D Subcommittee
Computing, Information, and Communications R&D Subcommittee (formerly HPCCIT), part of CCIC.

CIM
Computer Integrated Manufacturing.

CLIMVIS
Acronym for the Climate Visualization System at the National Climatic Data Center.

CMAQ
Community Multi-scale Air Quality.

COTS
Commercial off-the-shelf. Describes hardware and software that are readily available commercially.

CPU
Central processing unit.

CRPC
Center for Research in Parallel Computation.

CSCMDO
The Coordinate and Sensitivity Calculator for Multidisciplinary Design Optimization code — a 3-D volume grid generator.

CT
Computed tomography.

CTC
Cornell Theory Center.

DARPA
Defense Advanced Research Projects Agency, part of DOD. Formerly ARPA.

Digital Libraries Initiative (DLI)
Program that is developing an interoperability protocol for interconnecting diverse libraries and services.

DII
Defense Information Infrastructure.

Distributed Visualization Project
Develops data compression algorithms that provide fast data browsing and interactive visualization capabilities.

DLITE
Digital Library Integrated Task Environment.

DNA
Deoxyribonucleic Acid, a biomolecule from which genes are composed.

DOD
Department of Defense.

DOE
Department of Energy.

DOE 2000
Department of Energy program focusing on discovering solutions to the Department's increasingly complex scientific problems.

ED
Department of Education.

EMC
Enhanced Machine Controller.

EPA
Environmental Protection Agency.

ESNet
Energy Sciences Network.

ESS
Earth and Space Sciences.

ETHR
Education, Training, and Human Resources. One of the five Program Component Areas.

EVL
Electronic Visualization Laboratory.

Exa-
A prefix denoting 10^{18}, or a million trillion. (For example, exabytes).

Flops
Acronym for floating point operations per second. The term "floating point" refers to that format of numbers that is most commonly used for scientific calculation. Flops is used as a measure of a computing system's speed of performing basic arithmetic operations such as adding, subtracting, multiplying, or dividing two numbers.

FNC
Federal Networking Council.

G, or Giga-
A prefix denoting 10^9, or a billion. (For example, Gflops or gigaflops; gigabytes, gigabits).

Gateway
A system that interconnects networks (or applications) that communicate using different protocols, and bridges their differences by transforming one protocol (message) into another.

GB
An acronym for Gigabyte.

Gb
An acronym for Gigabit.

Gb/s
Gigabits per second.

GFDL
NOAA's Geophysical Fluid Dynamics Laboratory.

Gflops
Gigaflops, billions of floating point operations per second.

GOES
Geostationary Operational Environmental Satellite.

Grand Challenge
A fundamental problem in science and engineering, with broad economic and scientific impact, whose solution can be advanced by applying high performance computing and/or communications techniques and resources.

GrIDS
Graph-based Intrusion Detection System.

GSA
General Services Administration.

HCI
Human-Computer Interaction. A project at the MIT Artificial Intelligence Lab that explores advanced human-computer interaction and collaboration technologies.

HCS
High Confidence Systems. One of the five Program Component Areas.

HECC
High End Computing and Computation. One of the five Program Component Areas.

Heterogeneous system
A distributed system that contains more than one kind of computer.

HPCC
High Performance Computing and Communications.

HuCS
Human Centered Systems. One of the five Program Component Areas.

H-threads
Horizontal threads. Parallel instruction sequences.

IITF
Information Infrastructure Task Force.

INet
Information Network. A program of the Department of Education that manages the Internet and World Wide Web presence of the National Library of Education.

INFOSEC
Information Systems Security.

Internet
The global collection of interconnected, multiprotocol computer networks including Federal, private, and international networks.

I/O
Input/Output.

IP
Internet Protocol.

ISV
Independent Software Vendor.

JTO
Joint Technology Office.

K, or Kilo-
A prefix denoting 10^3, or a thousand. (For example, kilobits/second).

Kb/s
Kilobits per second or thousands of bits per second.

LANL
Los Alamos National Laboratory.

LBNL
Lawrence Berkeley National Laboratory.

LLNL
Lawrence Livermore National Laboratory.

LPS
Low pressure subsystem.

LSN
Large Scale Networking. One of the five Program Component Areas.

M, or Mega-
A prefix denoting 10^6, or a million. (For example, Mbps, or megabits per second; Mflops).

MADE
Manufacturing Automation and Design Engineering.

Math and Science Gateway
Internet link that connects students and educators to educational resources.

MB
An acronym for Megabyte.

Mb
An acronym for Megabit.

MBONE
Multicast backbone.

Mb/s
Megabits per second or millions of bits per second.

MCM
3-D Diamond MCM Cube Computer, a project that will build a test vehicle to demonstrate a 3-D computer architecture with a nanosecond system clock.

MDH
The enzyme malate dehydrogenase.

MEDLARS
Medical Literature Analysis and Retrieval System. Provides rapid access to the National Library of Medicine's biomedical and health information.

MEG
Magnetoencephalography.

MEL
NIST's Manufacturing Engineering Laboratory.

Mflops
Megaflops, millions of floating point operations per second.

MIPS
Millions of instructions per second.

MIT
Massachusetts Institute of Technology.

MM5
Mesoscale Meteorological model.

MOSIS
Metal-Oxide Semiconductor Implementation System.

MPI
Message Passing Interface.

MR
Magnetic Resonance.

MRA
Metacenter Regional Alliance.

MRI
Magnetic Resonance Imaging.

MSE
Manufacturing System Environment.

NAAQS
National Ambient Air Quality Standards.

NAS
National Academy of Sciences.

NASA
National Aeronautics and Space Administration.

National Challenge
A fundamental application that has broad and direct impact on the Nation's competitiveness and the well-being of its citizens and that can benefit from the application of CIC technology and resources.

National Information Infrastructure (NII)
The integration of hardware, software, and skills that will make it easy and affordable to connect people with each other, with computers, and with a vast array of services and information resources.

NCAR
National Center for Atmospheric Research.

NCBI
National Center for Biotechnology Information.

NCDC
NOAA's National Climatic Data Center.

NCI
National Cancer Institute, part of NIH.

NCO
National Coordination Office for Computing, Information, and Communications.

NCRR
National Center for Research Resources, part of NIH.

NCSA
National Computational Science Alliance, Urbana-Champaign, IL, successor to the National Center for Supercomputing Applications.

NERSC
National Energy Research Supercomputer Center.

Network
Computer communications technologies that link multiple computers to share information and resources across geographically dispersed locations.

NGI
Next Generation Internet.

NIH
National Institutes of Health, part of HHS.

NII
National Information Infrastructure.

NIST
National Institute of Standards and Technology, part of DOC.

NLM
National Library of Medicine, part of NIH.

nM
nanoManipulator.

NOAA
National Oceanic and Atmospheric Administration, part of DOC.

NPACI
National Partnership for Advanced Computational Infrastructure.

NPSS
Numerical Propulsion System Simulator.

NREN
NASA's Research and Education Network.

NSA
National Security Agency, part of DOD.

NSF
National Science Foundation.

NSFNET
National Science Foundation computer network program.

NSTC
National Science and Technology Council.

NTTP
Numerical Tokamak Turbulence Project.

OCR
Optical character recognition.

OMB
Office of Management and Budget.

ORNL
Oak Ridge National Laboratory.

OS
Operating system.

OSTP
White House Office of Science and Technology Policy.

PACI
Partnerships for Advanced Computational Infrastructure.

Parallel processing
Simultaneous processing by more than one processing unit on a single application.

PARC
Palo Alto Research Center.

PCA
Program Component Area. Structure of the Computing, Information, and Communications R&D programs. Each PCA spans an area in which multiple agencies have activities. The five PCAs are High End Computing and Computation (HECC); Large Scale Networking (LSN); High Confidence Systems (HCS); Human Centered Systems (HuCS); and Education, Training, and Human Resources (ETHR).

Peta-
A prefix denoting 10^{15}, or a thousand trillion. (For example, petabits).

PSC
Pittsburgh Supercomputer Center.

QD
Quantum dynamics.

QMM/MM
Quantum and classical mathematics.

QoS
Quality of Service.

R&D
Research and development.

RCWS
Radiology Consultation Workstation.

RSFQ
Rapid single-flux quantum devices.

RTEC
Regional Technology in Education Consortium.

SAW
Secure Access Wrapper.

SBSS
Science Based Stockpile Stewardship.

Scalable
A system is scalable if it can be made to have more (or less) computational power by configuring it with a larger (or smaller) number of processors, amount of memory, interconnection bandwidth, input/output bandwidth, and amount of mass storage.

SDE
Standards Development Environment.

SDSC
San Diego Supercomputer Center.

SGML
Standard Generalized Markup Language.

SIMA
Systems Integration for Manufacturing Applications.

SIMD
Single Instruction Multiple Data.

SONET
Synchronous Optical Network.

SSEC
Space Science and Engineering Center of the University of Wisconsin at Madison

STIMULATE
Speech, Text, Image, and Multimedia Advanced Technology.

STM
Scanning Tunneling Microscope.

SUIF
Stanford University Intermediate Format.

T, or Tera-
A prefix denoting 10^{12} or a trillion. (For example, terabits, teraflops).

TBA
Task Based Authorization.

TCP/IP
Transmission Control Protocol/Internet Protocol.

TFTR
Tokamak Fusion Test Reactor.

THz
Trillions of cycles per second

TPS
The Technology Policy Subcommittee.

TTTE
Testbeds and Technology Transfer Environment.

TVS
Text Video Speech.

UCLA
University of California-Los Angeles.

UCSD
University of California-San Diego.

UIUC
University of Illinois at Urbana-Champaign.

UMDL
University of Michigan Digital Library Project.

UMLS
Unified Medical Language System.

UNC
University of North Carolina.

USC
University of Southern California.

VA
Department of Veterans Affairs.

vBNS
Very high speed Backbone Network Services.

Vis5D
System for visualizing the output of atmospheric and ocean models with composite images from the Geostationary Operational Environmental Satellite (GOES)

VLSI
Very Large Scale Integration. A type of computer chip.

VRML
Virtual Reality Modeling Language.

V-threads
Vertical threads. Exploit thread-level parallelism, and mask variable pipeline, memory, and communication delays.

WAN
Wide area network.

Web
A reference to the World Wide Web, which is a subset of the Internet supported by a related set of protocols, services, and software tools including browsers.

Wireless technologies
Communications technologies that use radio, microwave, or satellite communications channels versus wire, coaxial, or optical fiber.

WP
Web Prototype.

WWW
World Wide Web.

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President Clinton established the National Science and Technology Council (NSTC) 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.

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Cover Images

From top to bottom:

1. Properties of light nuclei (up to 40 neutrons and protons) are computed employing realistic two- and three-nucleon interactions such as those illustrated here. *(Page 9)*

2. This image compares remotely sensed cloud data from the Geostationary Operational Environmental Satellite (GOES) seen as white clouds at the bottom of the image with 3-D cloud data predicted by NCAR's Mesoscale Meterological Model. *(Page 14)*

3. A close-up view of germanium pyramids and domes grown on silicon. Part of the nanoManipulator project. *(Page 41)*

4. Illustration depicting the collaborations involved in the Next Generation Internet initiative announced by President Clinton and Vice President Gore on October 10, 1996. (*Page 17*)

5. Example of a patient's record containing multidisciplinary images available over networks to authorized health care providers. *(Page 23)*

6. A three-dimensional simulation of the jumping figure, the first of its kind, consumes 800 CPU hours on an IBM SP2. *(Page 29)*

7. One view of a virtual city created using the Virtual Reality Modeling Language. Potential applications include treating acrophobia. *(Page 27)*

8. An abundance of free educational information is available to educators and students through the World Wide Web. *(Page 34)*

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