Brief Review ■

The High-Performance Computing and Communications Program, the National Information Infrastructure, and Health Care

DONALD A. B. LINDBERG, MD, BETSY L. HUMPHREYS, MLS

Abstract The High-Performance Computing and Communications (HPCC) program is a multiagency federal effort to advance the state of computing and communications and to provide the technologic platform on which the National Information Infrastructure (NII) can be built. The HPCC program supports the development of high-speed computers, high-speed telecommunications, related software and algorithms, education and training, and information infrastructure technology and applications. The vision of the NII is to extend access to high-performance computing and communications to virtually every U.S. citizen so that the technology can be used to improve the civil infrastructure, lifelong learning, energy management, health care, etc. Development of the NII will require resolution of complex economic and social issues, including information privacy. Health-related applications supported under the HPCC program and NII initiatives include connection of health care institutions to the Internet; enhanced access to gene sequence data; the "Visible Human" Project; and test-bed projects in telemedicine, electronic patient records, shared informatics tool development, and image systems.

■ *J Am Med Informatics Assoc.* 1995;2:156-159.

The High-Performance Computing and Communications Program

The High-Performance Computing and Communications (HPCC) program¹ was established in 1991 by P.L. 102-194. The objectives of the HPCC program initiative are to advance the state of computing and communications; to maintain U.S. leadership in these fields; and to provide the platform on which the National Information Infrastructure (NII) can be built. The HPCC program supports the development of 1) high-speed computers, 2) high-speed telecommunications, 3) software and algorithms that make use of

the new computers and communications, 4) training and education in the use of these advanced tools, and, since 1993, 5) information infrastructure technology and applications. Initial HPCC program research and development were focused on "grand challenges" of computing. These are fundamental problems in science or engineering, with broad economic, scientific, and social impact, that require more advanced computing techniques and resources than are currently available. Examples include weather modeling and prediction, modeling a full manufacturing process, origin of galaxies, geologic models, rational drug design, and informatics for the human genome project.

The HPCC program is a multiagency effort that, by law, reports to the Office of Science and Technology Policy within the Executive Office of the President. The National Coordination Office is currently located in the National Library of Medicine (NLM). The Advanced Research Projects Agency (ARPA) of the Department of Defense, the National Science Founda-

Affiliation of the authors: National Library of Medicine, Bethesda, MD.

Correspondence and reprints: Donald A. B. Lindberg, MD, National Library of Medicine, 8600 Rockville Pike, Building 38, Room 2W04, Bethesda, MD 20894. e-mail: lindberg@nlm.nih.gov

Received for publication: 12/08/94; accepted for publication: 12/23/94.

tion (NSF), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA) did the early groundwork for the program and make the largest budgetary contributions to it. The 1991 authorizing legislation added the National Institutes of Health (NIH), the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Agency (NOAA), the National Institute of Science and Technology (NIST), and the Department of Education as HPCC participants. Several other agencies have visitor status on the HPCC program operating committees. The Department of Veterans Affairs and the Agency for Health Care Policy and Research (AHCPR) have recently joined the HPCC program as full members and are participating in the FY 1996 crosscut budget formulation. HPCC program activities are carried out through a combination of intramural research and development and contracts, grants, and partnerships with the commercial sector and universities. Individual participating agencies fund and direct all HPCC program work. They collaborate to develop complementary projects and budgets, review progress toward objectives, and adjust program priorities.

The HPCC program supports the development of advanced parallel computing designs that are scalable across a wide range of problems and computer systems. The idea of massive parallelism is to speed up the computational task by doing many things at once, rather than in sequence. Computing hardware designs that support parallelism include single instruction, multiple data (SIMD) machines that perform the same operation on massive numbers of pieces of data simultaneously; multiple instruction, multiple data (MIMD) machines that perform different operations throughout the parallelized sections of the machine; clustered professional workstations; and parallel assemblies of reduced instruction set computer (RISC) machines. As would be expected, developing the software and algorithms that operate efficiently on parallel machines is more difficult than developing the hardware design and packaging. The HPCC program also supports the development of new computer language specifications for parallel systems (for example, High Performance FORTRAN), as well as software tools to reduce the level of effort required to convert important "heritage" codes to new parallel forms.

The High Performance Computing Act (P.L. 102-194) authorized the creation of a National Research and Education Network (NREN), the federal high-speed "backbone" of the Internet. All HPCC program agencies participate as sponsors or users of the NREN; the NSF is the lead agency. The NSF offers encouragement and a small amount of federal assistance to

the development of regional and local networks that provide Internet access to institutions and individuals across the United States. As part of its HPCC program participation, the NSF has funded small "connections" grants that help institutions to defray the initial costs of gaining access to the network. The NLM has provided funds for hospitals to participate in the NSF program.² The last five years have seen a tremendous growth in the number of computers, institutions, and individuals connected to the Internet, with the majority of this growth financed outside the HPCC program. Even so, a 1993 survey of the member institutions of the National Network of Libraries of Medicine revealed that while 72% of the academic medical libraries already had Internet connections, only 24% of the hospital libraries had connections.³

A variety of research grants and contracts are funded by the HPCC program agencies, jointly or independently. More than 1,100 such awards were made last year by the NSF, including support for Grand Challenge teams, four Supercomputer Centers, and consortial arrangements with other HPCC program agencies, universities, and industrial companies. The popular Internet front end Mosaic⁴ was created by the National Center for Supercomputer Applications (NCSA) through just such support. The HPCC program uses a number of innovative mechanisms for collaborative research, including broad consortia of agencies, federal laboratories, schools, and companies that agree to focus on narrowly defined scientific and technical objectives. Frequently, collaborative projects are limited in duration and precompetitive in scope. The projects result in greatly improved understanding of implementation problems and often lead to new commercial products and services. An especially interesting mechanism for collaborative research is the Gigabit Testbed program. The five sites provide friendly test environments for precompetitive experiments to create, operate, and test communication networks that connect high-performance computers together and connect users performing real applications to the machines. Agencies supporting such sites include the NSF, the ARPA, the DOE, and, in one case, the NIH's National Center for Research Resources. This medical test site can display high-resolution color representations from radiologic studies of the brain and other body areas to assist radiation treatment planning.⁵

As the initial HPCC program participant from the Public Health Service (PHS), the NLM sponsored a range of health-related applications of advanced computing and telecommunication technologies. These included:

- Enhanced access to GenBank gene sequence data and to software tools that permit efficient remote searching and analysis of the data⁶
- Expanded Internet access to other NLM products and services and development of new multimedia information services that rely on Internet connectivity³
- The Visible Human Project⁷
- Use of high-speed communications to facilitate nationwide collaboration to construct and edit the Metathesaurus, access to the UMLS Knowledge Sources by software developers, and use of the UMLS Information Sources Map to select and connect to Internet-based information sources⁸
- Support for connections to the Internet for hospitals and health sciences libraries, through the National Network of Libraries of Medicine^{9,10} and the joint NLM/NSF grant program²
- Increased emphasis on HPCC program technology in NLM-supported informatics training programs.

The National Information Infrastructure

The concept of an NII based on HPCC program technology was embodied in bills approved during 1994 by both the House (HR 1757) and the Senate (S4) in slightly different forms. The vision of the NII includes millions of computers and other "information appliances" (including telephones and video displays) linked by a mixture of high-speed telecommunication media capable of transmitting billions of bits of information per second and operated by a nation of users trained to use this technology to access a huge array of information databases and services. This vision would extend access to HPCC program technology to every U.S. citizen. Uses would address major societal needs in such areas as the civil infrastructure, digital libraries, education and lifelong learning, energy management, the environment, health care, manufacturing processes and products, national security, and public access to government information. Implicit in the NII concept is the need to resolve complex economic and social issues, including those related to access, security, privacy, and intellectual property rights.

The whole point of establishing high-speed data lines between computers and users is to share computational resources and to facilitate both person-to-person and person-to-computer interactions. The net effect of reliable gigabit speed connectedness is to allow people to use many distant and near machines and

databases as if all were local. This "seamless" connectivity is apparent in the new Mosaic interface to World-Wide-Web-based network resources. Mosaic is one of a number of "stateless" clients. Each user query or command to a distant or local resource results in one, and only one, action (identical whether the information source is locally connected or reached at great distance on the Internet), but the connection between the user (client) and the resource (server) is immediately broken. This mode of communication is highly efficient for network resources, surprisingly useful when a fast connection is available, and yet sufficiently different from traditional information retrieval approaches to have stimulated a number of "pseudo-stateful" application programs for special purposes.

Interest in the NII concept led to the creation of the HPCC program's Information Infrastructure Technology and Applications component in 1993. Its purpose is to work with industry and academia to extend the technology base to support a universally accessible NII and to use this technology in national challenge applications, including health care applications. Although the federal agencies participating in the HPCC program will support underlying technologies and demonstration applications, it is expected that the NII will be built and operated primarily by the private sector.

The HPCC program focuses on underlying technology and applications in key areas. The administration has also created the Information Infrastructure Task Force to work toward resolution of public policy issues associated with the NII. This task force is chaired by the Secretary of Commerce. It emphasizes telecommunication laws and regulations, security and privacy, and copyright, as well as ways to foster applications.¹¹ A number of proposals have already been put forward to rewrite the Communications Act of 1994, reflecting in various ways the new balances between telephony, cable television, and wireless and satellite systems, along with implicit commercial and social goals.¹²

The NII and Health Care

All current bills related to the NII identify health care as a major potential beneficiary of enhanced nationwide computer and communication networks. In part, this reflects the view (shared by key players on all sides of the health care reform debate) that information technology is central to increasing access and quality while containing the costs of patient care. Despite serious concerns about protecting the privacy and confidentiality of health care data on the "infor-

mation superhighway," technology is seen as a way to reduce administrative costs, as a promising avenue for delivering prevention information to the American people, and as a method for providing better medical care in remote rural areas and the inner cities. Many in Congress and in industry also view telemedicine as the most compelling reason for installing high-speed communications throughout the U.S. In anticipation of increased funding for NII health care applications, the NLM issued a Broad Agency Announcement soliciting proposals for such applications in FY 1993. In FY 1993-94, the NLM made a total of twelve contract awards for health care applications such as test-bed networks to share system development tools, knowledge bases, computerized patient data, and medical images^{13,14}; telemedicine projects to provide consultation and medical care to patients in rural areas^{15,16}; and advanced computer simulations of human anatomy. The ARPA awarded complementary contracts to two of the institutions that received NLM awards.

More recently, the NLM and the AHCPR have awarded cooperative agreements for testing and demonstration sites for computer-based patient record systems. The NLM's principal interests are in testing relevant patient data standards as they emerge; using the UMLS components to link patient records to related information in practice guidelines, MEDLINE, expert systems, etc.; and developing strategies for extracting health services research and public health data from patient record systems.

In FY 1994, the NLM's and the AHCPR's HPCC-NII funding represented only a fraction of the federal resources available for health care research, development, and demonstrations related to high-performance computing and communication technologies. Additional funding sources included the ARPA, the NIST's Advanced Technology Program, and telemedicine initiatives sponsored by the PHS's Office of Rural Health Policy, the Health Care Financing Agency, and the Rural Electrification Agency (REA). Substantial funds have been allocated to the National Technical Information Agency (NTIA) to assist non-profit organizations, including libraries, schools, and some hospitals, in connecting to the Internet. The REA also supports Internet connections for rural institutions. Keeping up with NII funding opportunities has become a challenging task.

The HPCC program National Coordination Office's World-Wide-Web (www.hpcc.gov) and Gopher (gopher.hpcc.gov) servers are good sources of funding information.

References ■

1. Lindberg DAB. High Performance Libraries. The British Library Dainton Lecture. London: The British Library, 1994.
2. Corn MC, Johnson FE. Connecting the health sciences community to the Internet: the NLM/NSF grant program. *Bull Med Libr Assoc.* 1994;82(4):392-6.
3. Lacroix EM, Backus JEB, Lyon BJ. Service providers and users discover the Internet. *Bull Med Libr Assoc.* 1994;82(4):415-7.
4. Schatz BR, Hardin JB. NCSA Mosaic and the World Wide Web: global hypermedia protocols for the Internet. *Science.* 1994 Aug 12;265(5174):895-901.
5. Rosenman J. Future directions in 3-dimensional radiation treatment planning. *Oncology (Huntingt).* 1993;7(11):97-104, 107-8.
6. Benson D, Lipman DJ, Ostell J. GenBank. *Nucleic Acids Res.* 1993;21(13):2963-5.
7. Ackerman M. The Visible Human Project of the National Library of Medicine. In: Lun KC, Degoulet P, Piemme TE, eds. *MEDINFO 92: Proceedings of the Seventh World Congress on Medical Informatics.* Amsterdam: North-Holland, 1992.
8. Lindberg DAB, Humphreys BL, McCray AT. Unified Medical Language System. *Methods Inf Med.* 1993;32(4):281-91.
9. Rauch S, Holt MC, Horner M, Rambo N. Community hospitals and the Internet: lessons from pilot connections. *Bull Med Libr Assoc.* 1994;82(4):401-6.
10. Fuller SS. Internet connectivity for hospitals and hospital libraries: strategies. *Bull Med Libr Assoc.* 1995;83(1):32-5.
11. Putting the Information Infrastructure to Work: A Report of the Information Infrastructure Task Force Committee on Applications and Technology. Gaithersburg, MD: National Institute of Standards and Technology, 1994 May. (NIST Special Publication, no. 857.)
12. S. 1086 Telecommunications Infrastructure Act of 1993 sponsored by Senator Danforth and H.R. 1504 Communications Competitiveness and Infrastructure Modernization Act of 1993 sponsored by Representative Boucher. The text of the two bills is available on the [hpcc gopher -gopher.hpcc.gov/11/legislation.testimony/bills](http://hpcc.gopher-gopher.hpcc.gov/11/legislation.testimony/bills)
13. Overhage JM, Tierney WM, McDonald CJ. Design and implementation of the Indianapolis Network for Patient Care and Research. *Bull Med Libr Assoc.* 1995;83(1):48-56.
14. Lowe HJ, Buchanan BG, Cooper GF, Vries JF. Building a medical multimedia database system to integrate clinical information: an application of high-performance computing and communications technology. *Bull Med Libr Assoc.* 1995;83(1):57-64.
15. Kienzle M, Curry D, Franken E, et al. Iowa's National Laboratory for the Study of Rural Telemedicine: a description of work in progress. *Bull Med Libr Assoc.* 1995;83(1):37-41.
16. Perednia DA, Brown NA. Teledermatology: one application of telemedicine. *Bull Med Libr Assoc.* 1995;83(1):42-47.