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Steps Toward a National Research Telecommunications Network

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In response to provisions in Public Law 99-383, which was passed 21 June 1986 by the 99th Congress, an inter-agency group under the auspices of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) for Computer Research and Applications was formed to study the following issues: the networking needs of the nation's academic and federal research computer programs, including supercomputer programs, over the next 15 years, addressing requirements in terms of volume of data, reliability of transmission, software compatibility, graphics capabilities, and transmission security; the benefits and opportunities that an improved computer network would offer for electronic mail, file transfer, and remote access and communications; and the networking options available for linking academic and research computers, including supercomputers, with a particular emphasis on fiber optics. Bell reports on the process and recommendations associated with the committee's work, and suggests a means for accomplishing the network objectives addressed by its report.

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Introduction

Modern science depends on rapid communications and information exchange. Today, many major national and international networks exist using some form of packet switching to interconnect host computers. State and regional networks are proliferating. NSFNET, an "internet" designed initially to improve access to supercomputer centers, has in the space of two years, forged links among 17 state, regional, and federal agency networks.

In the early 1980s, the lack of access to supercomputing power by the research community caused the formation of the NSF Office of Advanced Scientific Computing, which funded five centers for supercomputers. Given the highly distributed location of users, the need for a national wide area network for computer access and for the interchange of associated scientific information (such as mail, files, databases) became clear.

Further, it immediately became obvious that existing agency networks both lacked the inherent capacity and were overloaded. In fact, the current federal wide area networks still operate at the speed (56 Kbits/sec) of the original ARPAnet (circa 1972), despite the fact that computers have both increased in number (by a factor of 100) and speed (by a factor of 30). Moreover, the very nature of what is communicated has changed with the power of computers. Computer simulations of physical processes yield output expressed as three-dimensional dynamic graphics. Computer-based research tools are becoming more interactive, and the problems under study often require the active collaboration of researchers who are distributed in various research

institutions.

Today's fiber optic communications links offer the ability for a factor of 1,000 to 100,000 increase in capacity and speed over traditional cable and satellite channels. The price of fiber optic links is based on equivalent voice grade circuits, and as such remains high, despite a vast amount of unused capacity. Switching equipment to exploit even DS3 (45 Mbits/sec) is unavailable. While several proposals for DS3 fast packet protocols and switches exist, no technology exists to switch packets at fiber optic speeds.

Most federal agencies support an average of two, independent wide area networks. One may be used to couple researchers to one another for mail, collaboration, and file transfer. The other connects researchers to large, central systems that support major research initiatives. Often these networks go to the same institution (an academic campus, federal facility, or industrial lab), but to a different building, wasting resources in the process. While a few years ago all wide area networks used different protocols and could not communicate with one another, today most networks are migrating toward DARPA's TCP/IP protocol with a commitment to use the ISO protocols when available.

Campuses are being wired to interconnect the array of Local Area Networks (LANs)--a wiring scheme for a single building or small cluster of buildings--to form Campus Area Networks (CANs). At present, these Campus Area Networks form networked islands.

Congressional Action and Executive Branch Response

Some in Congress have recognized the telecommunications problem and opportunity. In June 1986, Senator Gore introduced the Supercomputer Network Study Act of 1986. Public Law 99-383, passed 21 June 1986 by the 99th Congress, charged the Office of Science and Technology Policy (OSTP) with conducting "a study of critical problems and current and future options regarding communications networks for research computers, including supercomputers at universities and federal research facilities in the United States."

At OSTP's direction, an inter-agency group under the auspices of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) for Computer Research and Applications --the Computer Network Study Planning Group --was formed to carry out the study of the following issues:

- the networking needs of the nation's academic and federal research computer programs, including supercomputer programs, over the next 15 years, including requirements in terms of volume of data, reliability of transmission, software compatibility, graphics capabilities, and transmission security;
- the benefits and opportunities that an improved computer network would offer for electronic mail, file transfer, and remote access and communications; and
- the networking options available for linking academic and research computers, including supercomputers, with a particular emphasis on fiber optics.

The Computer Network Study Planning Group, composed of participants from the Department of Defense (DoD) (including DARPA), Department of Energy (DoE), Department of Health and Human Services (HHS), NASA, National Bureau of Standards (NBS), and the National Science Foundation (NSF), produced and delivered a three-volume report for OSTP in early August 1987, consisting of recommendations, results of a workshop, and background papers.

Summary of Recommendations to OSTP (for Congress) for the National Research Network

The Subcommittee on Networking, Infrastructure and Digital Communications (NIDC) recommended the following:

"The U.S. should undertake, as a national goal, the establishment of a National Research Network in a staged approach that supports the upgrade of current facilities, and development of needed new capabilities. Achievement of this goal would foster and enhance the U.S. position of world leadership in computer networking.

"As rapidly as feasible, the National Research Network should be designed, deployed and maintained as an advanced computer network. This network should interconnect substantially every academic, industrial, and government research establishment and unique scientific resource to encourage scientific collaboration unhindered by distance and to permit the sharing of unquiet research faculties and resources. Since security of the network is a vital concern, appropriate policies should be adopted to protect the information in the network from threats, vulnerabilities and risks, and to assure a uniform level of security.

"Until the National Research Network can replace the current system, existing networks should be maintained and modified as they join the national network. Since supercomputer systems comprise a special and valuable national research resource with very high performance requirements, the responsibility for network access to supercomputers

should be vested in the supercomputer centers themselves until the advanced computer network, capable of offering the requisite service level, is operational.

"Industry should be encouraged through special incentives to participate in research, development, and deployment of the National Research Network. Tariff schedules which have been set for voice transmission should be reexamined in light of the requirements for transmission of data through computer networking.

"To meet the goal for the National Research Network and to set an agenda for the future, the following actions are recommended:

- "The Subcommittee on Computer Networking, Infrastructure and Digital Communications which was established by the Office of Science and Technology Policy on 15 May 1987, should oversee the first stage in development and operation of the National Research Network--a coordinated internetwork that would include the Federal agencies that currently operate research supporting networking.
- "The FCCSET Subcommittee on Computer Networking, Infrastructure and Digital Communications should identify a lead agency which would be responsible for requesting funds for the National Research Network, and eventually for selecting a contractor to manage the network. The manager would be responsible for Stage 2 (45 Mbit/sec links) and Stage 3 (multi-Gigabit/sec links).
- "As a first stage in the development of the National Research Network, the current Internet system developed by DARPA and networks supported by agencies should be interconnected over the next two years. These facilities, if coordinated and centrally managed, have the capability to interconnect many computer networks into a single virtual computer network. The Federal government should encourage and assist research facilities and academic institutions to establish local and campus area networks to connect to the Internet systems. The estimated cost for this proposed upgraded service is $5 million per year, and should be implemented through the shared resources of NSF, DoE, DARPA, NASA, and HHS.
- "In the second stage, new funding for development should be requested at $5 million per year over the next five years to upgrade and expand the nation's computer networks, which support research programs, to achieve data communications at 1.5 Mbits/sec to 200-400 U.S. research institutions. It is estimated that these expanded and upgraded facilities will require an additional funding of approximately $50,000,000 to operate (GB: assumed the price of T1 line would decline by a factor of 2 over the next five years, whereas, in the six months since the report, line charges for many T1 lines have already dropped more than a factor of two due to over-supply.)
- "In the third stage, a vigorous focused program of research and development for the National Research Network should be immediately established. A total of $400 million is needed over ten years to advance the knowledge base and technology of computer network capabilities in order to achieve data communications and switching capabilities to support transmission of three billion bits per second within fifteen years. This will support a network 100,000 times more capable than currently available and will be essential to foster scientific collaboration and sharing of research resources. When fully deployed, the cost of operating this advanced network is estimated to be $400 million per year, given the current commercial tariffs for data communications.

"Support should be given to the development of standards and their harmonization in the international arena. Aggressive action is needed to increase user participation in the standards development process, to get requirement for standards expressed early in the development process, and to speed the implementation of standards in commercial off-the-shelf products. It is essential that standards development be carried out within the framework of overall systems requirements to achieve interoperability, common user interfaces to systems and enhanced security."

Motivation for the National Research Network

If we use the original ARPAnet as a predictor of the future, it is safe to assume that the National Research Network is likely to have both more direct impact on the research and education community, and more indirect impact through the construction of a modern communications network than almost any other single program that can be identified.

ARPAnet was initially justified on the basis of being able to share facilities including particular programs, databases, and files, and being able to promote the use of idle computer capacity. What happened was that a completely different style of interaction developed based on being able to send mail and large documents. Extensive public forums and conferences evolved through bulletin board and computer conferencing. Remote terminal access is negligible, and file interchange was relatively smaller than expected.

With supercomputing, remote access is critical. Few institutions can support supercomputers and, given the limited amount of time available on them, it becomes necessary to send large programs and databases throughout the network in and from smaller computers including workstations. A recent NSF report on Visualization pointed out the need for research that would enable users to deal with the prodigious amount of data that comes from modern computers and applications. Also, we would expect a new form of video and computer conferencing to be possible utilizing high speed networks. Already researchers are considering how libraries might share information. Thus, it is fairly easy to predict that the future use of the research network will be a different, and vastly expanded, version of the past.

The inter-connection among government laboratories, universities, and industrial research organizations provided by the Network should facilitate technology transfer unlike almost any other facility. It will enable the instantaneous transfer of much of our knowledge, which we are increasingly embedding in databases and programs. Unlike earlier networks, the National Research Network is aimed at connections with many more institutions.

In addition to the direct benefit resulting in the use of the Network, we believe the Network is vital for maintaining a competitive telecommunications industry. By interacting with the academic community to build and develop the Network, we expect to create the same vitality and synergy that the computer industry enjoys.

Other countries are actively building high speed (fiber optic) computer networks aimed at Gigabit data transmission. For example, the European programs of ESPRIT and Eureka have significant research underway at all levels including fiber optics, switching, standards, and applications.

Onward Toward Our National Research Network

OSTP asked Congress for a time extension until November 1987 in order to incorporate the proposal for a National Research Network into a much larger report encompassing the support of high performance computing, computer science, and revamped infrastructure for computer applications in science and engineering. This new report from the FCCSET Committee on Computer Research and Applications was based on an integration of reports from its subcommittees: Science and Engineering Computing; Computer Research and Development; and Computer Networking, Infrastructure, and Digital Communications. The resulting report is entitled "A National R&D Strategy for High Performance Computing."

Given the clouded record of very large programs (e.g., Space Station, Star Wars, Superconducting Super-Collider, Superconductors, Human Genome Mapping) in either achieving funding or meaningful results, one can hardly be optimistic about the outcome of large scale recommendations encompassing virtually every facet of computer science, technology, use, and networking.

The community of research and educational computing users and network providers must understand the ramifications of the National Research Network initiative so that work on it can proceed as rapidly as possible, independent of the success or failure of a much larger set of goals for higher performance computing. It is imperative that the network be built as soon as possible, and that we not lose precious time in its development due to inaction or coupling of the project with other objectives in a much larger program.

Unlike the super-highway system, any one or any combination of existing telecommunications suppliers could preempt the National Research Network activity by simply building the network and offering the service for sale. A highly aggressive, imaginative industry could view the Network as the major, large scale, social experiment of this century--an experiment that could strategically position that industry for dynamic growth in the twenty-first century. An effort to achieve Phase II (45 Mbits/sec) in three years would cost a small fraction of this industry's current research, development, and operations budget. Government should encourage efforts on the part of private industry to build this system, but, based on history, we certainly can't depend on industry. Government must take the initiative to oversee development of the Network, an initial step being the development of NSF's backbone network.

The National Research Network can and must proceed using the current inter-agency coordinating committee. Even without the impetus of a major government initiative and outlay, funds can and must be made available on a shared basis utilizing existing agency, industrial, and academic resources in a much more propitious fashion. It is highly possible that coordination of the development and use of one major network would save money for all agencies, which would not have to operate duplicate networks. Agencies and other affected organizations could build the Network from their own coordinated resources and related savings in telecommunications costs. Hence, it is extremely important that these organizations commit themselves to the coordinated development and use of the Network. And our federal government should take a leadership step in committing itself to the development of a Network that will provide positive benefits and savings for its constituents (the taxpayers).