The National Research and Education Network Program

A Report to Congress

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Submitted by the Director
Office of Science and Technology Policy

in response to a requirement of
The High Performance Computing Act of 1991
(P.L. 102-194)

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Executive Summary

This is a report on the National Research and Education Network (NREN) Program required by the High Performance Computing Act of 1991 (P.L. 102-194). Six specific issues are to be addressed:

- effective mechanisms for providing operating funds for the maintenance and use of the Network, including user fees, industry support, and continued Federal investment;

- the future operation and evolution of the Network;

- how commercial information service providers could be charged for access to the Network, and how Network users could be charged for such commercial information services;

- the technological feasibility of allowing commercial information service providers to use the Network and other federally funded research networks;

- how to protect copyrights of material distributed over the Network; and

- appropriate policies to ensure the security of resources available on the Network and to protect the privacy of users of networks.

It is useful to group these questions according to three themes: funding, transition and protection, and the report is organized along these lines. However, before these questions can be addressed, the purpose and nature of NREN need to be explained with clarity.

Purpose of the NREN Program

The NREN Program is one of the four principal components of the interagency program on High Performance Computing and Communications (HPCC). The primary purpose of the NREN Program is to establish a gigabit communications infrastructure that will dramatically enhance the ability to collaborate among members of the research and education community. In order to establish such an infrastructure, networking technologies have to be developed and services from common carriers and other communications service providers must be made available in this development effort. Furthermore, the process of establishing the NREN Program will provide an unprecedented opportunity to catalyze the development of a general purpose high speed communications infrastructure for the nation. Ultimately, the NREN Program cannot be cost effective or realize its full potential without such a development. Thus, the NREN Program has a series of synergistic goals:

- establishing a gigabit network for the research and education community and fostering its use;

- developing advanced networking technologies and accelerating their deployment;

- stimulating the availability, at a reasonable cost, of the required services from the private sector; and

- catalyzing the rapid deployment of a high speed general purpose digital communications infrastructure for the nation.

To achieve these goals, the NREN Program is divided into two parts:

- the Gigabit Research and Development component; and

- the Interagency Interim NREN component.

As its name implies, the former is an R&D program designed to develop needed technologies. The latter is a coordinated program to support an operational network that will, in stages, realize the primary goal of the NREN Program, viz., to establish a gigabit network for the research and education community. Since the questions that we are to address all pertain to the operational network, we shall henceforth in this document use the term NREN, when not followed by the word "program," as an abbreviation for the Interagency Interim NREN.

Nature of NREN

To address the issues required of this report, it is necessary to understand two important characteristics of NREN. First, it is a logical, not physical, entity. It is best understood as a collection of interlinked nodes operating under specific rules for moving information along the links. The logical network is realized by purchasing transport services from network service vendors. How the vendors implement the services through hardware using cable and switches or bulk purchase of transport services from other vendors, should be transparent to the users and the administrators of NREN. Thus, for example, whether non-NREN traffic uses the same physical medium as NREN traffic is not an NREN issue, unless such traffic affects the operational characteristics of NREN as a logical entity.

A second important characteristic of NREN is that it is a hierarchy of networks. At the top of the hierarchy, NREN's components are **backbone** networks, each of which is itself a network of networks (called midlevels and regionals) connected to a common communications trunk (backbone). The major components of NREN are national agency backbone networks: NSFnet of NSF; ESnet of DOE; NSI of NASA; and TWBnet of DOD. The agencies' NREN backbones are high speed networks that will eventually attain gigabit speed. The backbones in NREN will be interconnected through a set of nodes known as the **network access points** (NAPs). Any backbone, whether or not serving research and education purposes, can be connected to the NAPs. The backbone networks have a high degree of autonomy and each can impose its own local rules and restrictions. It is the policy of NREN, however, that restrictions should be based on traffic characteristics and not on the source or destination of such traffic. With this formulation, we can define "NREN proper" as composed of a collection of agency backbone networks plus a set of associated NAPs. NREN-in-the-large will also include any backbone network connected to one of the NAPs.

The architecture of NREN described above is designed to create a synergy between the twin purposes of NREN: to establish a high speed network for research and education while catalyzing and accelerating the development and deployment of a national communications infrastructure.

Funding

Establishing and maintaining a composite gigabit backbone made up of the Federal agency backbones, including NAPs, are currently the responsibility of the Federal Government. It does not mean, however, that the Federal Government should bear the "full freight" for either the initial backbone implementation or ongoing backbone maintenance and operation. It is expected that pricing of the initial establishment will reflect some shared investment with industry and the ongoing operation will require a charge for transport and connectivity services to the network providers, who may then pass charges to the end-users.

Federal funds will pay for the operations of the agency networks that make up NREN. These funds will also support users that serve Federal missions whether or not they access NREN through the agency networks.

Both common carriers and other service providers have provided direct support for the development of network technologies, and are expected to share the cost of the initial establishment of the high speed backbone by providing services at a rate lower than supporting NREN as the sole customer. Such cost-sharing would represent an early investment by the communications industry in the networking market.

Information service vendors will contribute to bearing the cost of operating NREN through connectivity and transport fees mainly through network providers, and in turn will charge the users directly for the information services provided. The architecture of NREN is intended to facilitate such funding arrangements.

End users of NREN must go through some network service provider, either under contract with an agency or as a commercial service. The network service vendor will charge a connectivity fee and a subscription fee and possibly traffic dependent fees which will then be used to pay connectivity (NAP and backbone) and transport charges.

Transition

The architecture of NREN is designed to foster flexible evolution. NREN is a federation of networks at different levels of a hierarchy. At the top level of this hierarchy are the backbone networks which will be interconnected through the NAPs. Adding new backbone networks to NREN is readily accommodated, subject only to the capacity of the NAPs and the cost of connecting to them. Each backbone network is a network of networks connected to a common backbone. A backbone network is semi-autonomous and can impose its own restrictions. However, such restrictions will be based on traffic characteristics, not source or destination of network traffic.

NREN can grow indefinitely by adding new backbone networks and additional NAPs. Furthermore, if the same architecture is adopted for a national general purpose network, then NREN can be readily integrated without change. What constitutes "NREN proper" will then be a small sub-collection of the backbone networks plus a subset of the NAPs which it shares with other backbone networks or other "federations" of networks.

NREN, being a federation of networks, will have segments that restrict use. Agency backbones are restricted to uses related to agency missions. The NSFnet backbone is restricted to uses related to research and education. Some regionals also have similar restrictions. NREN restrictions only require that the traffic support research and education. Commercial traffic, whether for profit or not, that meets this condition is unrestricted. Furthermore, even commercial traffic unrelated to research and education could use the NREN NAPs to access backbone networks of any variety that wish to connect to these NAPs. Thus, NREN in its largest sense can indeed carry commercial traffic, and the establishment of NREN will play a major role in fostering the development of general purpose high speed networks.

Protection

Most of the protection issues concerning NREN are not new. They exist for communications systems that are accessible to the public in general. It is important that protection policies and mechanisms developed for NREN be consistent with those that already exist. Wherever possible, it is useful to seek models that apply to NREN, or can be generalized to apply to NREN. For example, the "common carriage" model fits the role of network providers in many ways. The time tested rules and responsibilities applied to common carriers may well be appropriate to network providers.

With the exception of performance capabilities, high speed digital networks are not inherently different from telephone networks, or any other point-to-point switched communications system. It may be a sound principle to adhere to the rules applicable to such systems, unless it can be demonstrated that the change in speed renders a particular rule ineffective or inappropriate.

The technical mechanism appropriate to protect copyright of material distributed over the Network is as yet unclear. Electronic information is much easier to copy and transmit than paper. Fewer identifying markings which show the source of the information exist or are retained in electronic copies. In addition, legal issues arise. For example, is the government, as a supporter of the Network, liable for the improper use of copyrighted material received via or transmitted over the Network? Current legal precedent for access to and protection of copyrights of material accessed via modems over telephone lines does not assign legal responsibility to enforce copyrights to the common carriers whose lines are used. The fair use of copyrighted materials, a feature of the Copyright Act and essential to scientific research, is an example of a concern that combines technical and legal issues. So too, technical means to ensure copyright protection on the NREN must provide for fair use, as must any legal arrangement.

Appropriate policies to ensure the security of resources and the privacy of users are addressed via four policy areas. First, the Federal Networking Council (FNC) has coordinated the development of a draft NREN security policy. A second aspect of security is the responsible and proper use of Network resources. Thus, the FNC also has been developing, in consultation with the non-Federal communities, an Appropriate Use Policy. In addition, P.L. 102-476 broadens the NSF's organic act and authorizes the NSF to foster and support access by the research and education communities to computer networks, which may be used substantially for purposes in addition to research and education in the sciences and engineering, if the additional uses will tend to increase the overall capabilities of the networks to support such research and education activities.

The Computer Security Act specifies a third policy requirement to ensure security of resources and protection of privacy. That Act requires each agency to create computer security plans for Federal computer and telecommunications systems which process or transmit sensitive, unclassified information. It also requires security and awareness training of Federal employees and contractors who use sensitive Federal computer and telecommunications systems. These activities, while not presented in this document, are separately reported by each agency through its Information Resources Management activity.

Finally, protection of users' privacy is provided for, to some extent, by the Privacy Act. That Act governs access to information about individuals maintained by Federal agencies that is contained in "systems of records," as defined by the Act. In addition, the Electronic Communications Privacy Act protects Network communications from unlawful interception. Encryption is an effective means for providing basic data security. As such, it is relevant to all the protection problems related to NREN.

Management and Status

The NREN Program is one of the four principal components of the interagency program on High Performance Computing and Communications (HPCC). All eight participating agencies of HPCC (DOC, DOD, DOE, ED, EPA, HHS, NASA, NSF) also participate in NREN. USDA and DOI are also participants in NREN. Management of NREN is distributed, with each agency implementing its own portion of the overall program. Coordination of HPCC is through the High Performance Computing, Communications, and Information Technology (HPCCIT) Subcommittee of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) and the recently established National Coordination Office (NCO) for the HPCC Program. Donald A. B. Lindberg, M.D., the Director of the National Library of Medicine, is currently the Director of the NCO and the Chairman of the HPCCIT subcommittee.

In addition to the coordination and management structure that exists for HPCC as a whole, the operational aspects of NREN have required special interagency coordination. This is done through the Federal Networking Council (FNC) which was established by NSF in its capacity as leader of the working group on networking within HPCCIT.

A detailed description of the management and coordination structure for NREN is given in Appendix A.

NREN is an evolving system that combines operational capabilities with technology development in a dynamic environment. A detailed description of its current operational status is given in Appendix B.

1. Introduction

This report responds to the High Performance Computing (HPC) Act of 1991 (P.L. 102-194) which, in Title I, Section 102, requires that the Director, Office of Science and Technology Policy (OSTP), within one year after enactment of the HPC Act of 1991, report to Congress on the National Research and Education Network (NREN, also referred to as the Network) regarding:

(1) effective mechanisms for providing operating funds for the maintenance and use of the Network, including user fees, industry support, and continued Federal investment;

(2) the future operation and evolution of the Network;

(3) how commercial information service providers could be charged for access to the Network, and how Network users could be charged for such commercial information services;

(4) the technological feasibility of allowing commercial information service providers to use the Network and other federally funded research networks;

(5) how to protect copyrights of material distributed over the Network; and

(6) appropriate policies to ensure the security of resources available on the Network and to protect the privacy of users of networks.

It is useful to group these questions according to three themes: funding, transition and protection, and our report will be organized along these lines. However, before these questions can be addressed, the purpose and nature of NREN need to be explained with clarity. Therefore, we begin with a statement on the purpose of the NREN and an explanation of its conceptual architecture.

1.1. Purpose of the NREN Program

The NREN Program is one of the four principal components of the interagency program on High Performance Computing and Communications (HPCC). The primary purpose of the NREN Program is to establish a gigabit communications infrastructure that will dramatically enhance the ability to collaborate among members of the research and education community.[1] In order to establish such an infrastructure, networking technologies have to be developed and services from common carriers and other communications service providers must be made available in this development effort. Furthermore, the process of establishing the NREN Program will provide an unprecedented opportunity to catalyze the development of a general purpose high speed communications infrastructure for the nation.[2] Ultimately, the NREN Program cannot be cost effective or realize its full potential without being a part of a national infrastructure. Thus, the NREN Program has a series of synergistic goals:

- establishing a gigabit network for the research and education community and fostering its use;

- developing advanced networking technologies and accelerating their deployment;

- stimulating the availability, at a reasonable cost, of the required services from the private sector; and

- catalyzing the rapid deployment of a high speed general purpose digital communications infrastructure for the nation.

To achieve these goals, the NREN project is divided into two parts:

- the Gigabit Research and Development component, and

- the Interagency Interim NREN component.

As its name implies, the former is a research and development program designed to develop needed technologies. Examples of broad research problems that may be addressed in gigabit networking include network stability (i.e. the behavior of message traffic flow), network response, and network management.[3] The latter goal is a coordinated program to support an operational network that will, in stages, realize the primary goal of the NREN Program, viz., to establish a gigabit network for the research and education community. Since the questions that we are to address all pertain to the operational network, we shall henceforth in this document use the term NREN, when not followed by the word "program," as an abbreviation for the Interagency Interim NREN.

1.2. Conceptual Architecture of NREN

To address the issues required of this report, it is necessary to understand two important characteristics of NREN. First, it is a **logical**, not physical, entity. It is best understood as a collection of interlinked nodes operating under specific rules for moving information along the links. The logical network is realized by purchasing transport services from network service vendors. How the vendors implement the services through hardware using cable and switches or bulk purchase of transport services from other vendors, should be transparent to the users and the administrators of NREN. Thus, for example, whether non-NREN traffic uses the same physical medium as NREN traffic is not an NREN issue, unless such traffic affects the operational characteristics of NREN as a logical entity.

A second important characteristic of NREN is that it is a hierarchy of networks. At the top of the hierarchy, NREN's components are **backbone** networks, each of which is itself a network of networks (called midlevels and regionals) connected to a common communications trunk (backbone). The major components of NREN are national agency backbone networks: NSFnet of the National Science Foundation (NSF); ESnet of the Department of Energy (DOE); NSI of the National Aeronautics and Space Administration (NASA); and TWBnet of the Department of Defense (DOD). The agency backbones are high speed networks that will eventually attain gigabit speed. The backbones in NREN will be interconnected through a set of nodes known as the network access points (NAPs). Any backbone, whether or not serving research and education purposes, can be connected to the NAPs. The backbone networks have a high degree of autonomy and each can impose its own local rules and restrictions. It is the policy of NREN, however, that restrictions should be based on particular traffic characteristics and not on the source or destination of such traffic.

In contrast, subnets that connect strategically secure sites and/or provide classified, agency mandated services will not be connected to NAPs. Rather they will be connected only via a Federal information interchange node.

1.3. Management

The NREN Program is one of the four principal components of the interagency program on High Performance Computing and Communications (HPCC). All eight participating agencies of HPCC (Department of Commerce, DOD, DOE, Department of Education, Environmental Protection Agency, Health and Human Services, NASA, and NSF) also participate in NREN as agreed upon within the High Performance Computing, Communications, and Information Technology (HPCCIT) Subcommittee of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committee on Physical, Mathematical, and Engineering Sciences (PMES). In addition to these agencies, the Department of Agriculture and the Department of the Interior are also participants in NREN. Coordination of the HPCC Program is provided through the chairman of the HPCCIT Subcommittee and the staff of the recently established National Coordination Office (NCO). Management of NREN is distributed, with each agency implementing its own portion of the overall program.

As cited in "A Report to Congress on Computer Networks to Support Research in the United States," the various government networking activities touch a significant segment of the U.S. academic research community.[4] In addition to the coordination and management structure that exists for HPCC as a whole, the operational aspects of NREN have required special interagency attention. This is done through the Federal Networking Council (FNC) which was established by NSF in its capacity as leader of the working group on networking within HPCCIT. These elements, along with industry, are members of an Advisory Committee to the FNC.

A detailed description of the management and coordination structure for NREN is given in Appendix A.

1.4. Current Status

NREN is an evolving system that combines operational capabilities with technology development in a dynamic environment. A detailed description of its current operational status is given in Appendix B.

2. Funding

2.1. Federal Role

As cited in the proceedings of the EDUCOM Workshop on the NREN by the EDUCOM Networking and Telecommunications Task Force, "a continued high level of Federal investment in the development and pre-commercial use of advanced network facilities and services is absolutely essential to a national strategy for competitiveness."[5] Establishing and maintaining a composite gigabit backbone, including NAPs, are currently the responsibility of the Federal Government. It does not mean, however, that the Federal Government should bear the "full freight" for either the initial backbone implementation or ongoing backbone maintenance and operation. It is expected that pricing of the initial establishment will reflect some shared investment with industry and the ongoing operation will require a charge for transport and connectivity services to the network providers, who may then pass charges on to the end-users.

Federal funds will pay for the operations of the agency networks that make up "NREN-proper." Federal funds will also support users that serve federal missions whether or not they directly access NREN through the agency networks.

2.2. Communications Service Vendors

Both common carriers and service providers have provided direct support for the development of network technologies, and are expected to share the cost of the initial establishment of the high speed backbone by providing services at a rate lower than that which would be required if NREN were the sole customer. Such cost-sharing would represent an early investment by the communications industry in the networking market.

2.3. Information Service Vendors

Information service vendors will contribute to bearing the cost of operating NREN through connectivity and transport fees charged network providers, and in turn will charge the users directly for the information services provided. The architecture of NREN is intended to facilitate such funding arrangements.

2.4. Network Service Providers

End users of NREN must go through some network service provider, either under contract with an agency or as a commercial service. The network service vendor will charge a connectivity fee and a subscription fee and possibly traffic-dependent fees which will then be used to pay connectivity (NAP and backbone) and transport charges.

2.5. Summary

Funding sources for the operation of NREN can be summarized as follows:

Interagency:	fund advanced network research fund collaborative and shared NREN operational activities
Individual Agencies:	fund agency backbone networks and their evolution to gigabit speeds fund NREN user serving agency missions
Communications Industry:	invest in underlying physical plant develop transport services support technology development invest in initial deployment
Information Service Vendors:	develop information service pay fee for connectivity and transport
Users:	pay network subscription pay connectivity charge pay user charge for information service

3. Transition

3.1. A Model for Evolution

The architecture of NREN is designed to foster its flexible evolution. NREN is a federation of networks at different levels of a hierarchy. At the top level of this hierarchy are the backbone networks which will be interconnected through the NAPs. Adding new backbone networks to NREN is readily accommodated, subject only to the capacity of the NAPs and the cost of connecting to them. Each backbone network is a network of networks connected to a common backbone. A backbone network is semi-autonomous and can impose its own restrictions. However, such restrictions will be based on traffic characteristics and not the source or destination of such traffic.

NREN can grow indefinitely by adding new backbone networks and additional NAPs. Furthermore, if the same architecture is adopted for a national general purpose network, then NREN can be readily integrated without change. What constitutes NREN will then be a sub-collection of the backbone networks plus a subset of the NAPs which it shares with other backbone networks or other clusters of networks.

NREN, being a federation of networks, will have segments that restrict use. Agency backbones are restricted to uses related to agency missions. The NSFnet backbone is restricted to uses related to research and education. Some regionals also have similar restrictions. NREN restrictions only require that the traffic support research and education. Commercial traffic, whether for profit or not, that meets this condition is unrestricted. Furthermore, even commercial traffic unrelated to research and education could use the NAPs to traverse those networks that are unrestricted. Thus, NREN in its largest sense can indeed carry commercial traffic, and the establishment of NREN will play a major role in fostering the development of general purpose high speed networks.

3.2. Implementation of NREN

The CSPP Report, "Expanding the Vision of High Performance Computing and Communications: Linking America for the Future," underscores the importance that government policies and programs have on the protocols used in future networks, and that these efforts must be coordinated to meet the goal of network interoperability.[6] The Interagency Interim NREN Program is an integrated program that combines the separate Federal agency networks and related technology developments into a consolidated multi-faceted national network system that builds on each agency's strengths. The Interagency Interim NREN provides interoperability between the agencies' separate networking services in a seamless manner (e.g., via Federal Internet eXchanges - "FIXes") in order to achieve end-to-end connectivity for the Nation's researchers and educators. A joint DOE/NASA project is aimed at accelerating the commercial availability of high performance "cornerstone" technologies and services for more focused applications, while a related NSF effort emphasizes the scope of applicability of such services and infrastructure. It is the coordinated integration of these two complementary endeavors that will best serve the research and education communities as a holistic program. Indeed these efforts were endorsed by the President's Council of Advisors on Science and Technology[7]. As such, major Interagency Interim NREN activities and plans - the NSF's and the joint DOE/NASA's projects - are outlined below.

3.2.1. NSF's Interagency Interim NREN implementation plans

The NSF implementation approach separates (1) the provision of Network Access Points (NAPs); (2) the operation of the Routing Arbiter (RA); and (3) organizations to provide very high speed Backbone Network Services (vBNS). The NSF has made public a draft version of its proposed solicitation and has requested and received numerous comments on this document.[8] The NSF architecture also takes into account major existing network components such as regional networks and network service providers for which NSF solicitations are not required. The two NSF solicitations are due to be awarded in mid-1993.

The NSF has explicitly designed the next generation Interagency Interim NREN architecture to allow increased access, greater interoperability, and adherence to standards for all subscribers to the NREN--requirements established by the HPCC Program and recommended by the CSPP.[9] Service providers will have the ability and experience to provide value-added services for both the original TCP/IP protocol and the CLNP protocol as described in the Government Open Systems Interconnection Profile (GOSIP), which the National Institute of Standards and Technology (NIST) has specified for government acquisitions in a Federal Information Processing Standard (FIPS).

Network Access Point and Routing Arbiter

The "Network Access Point" (NAP) is a key feature of NSF's Interagency Interim NREN architecture. The NAP allows other agencies and commercial service providers to interconnect and interoperate with networks of their choice, as well as the NSFNET, ESNet and NSI. This enables commercial service providers to offer competitively priced services to both commercial and R&E customers and will engender a larger set of capable and competitive service providers than could be developed under Federal funding alone. The NAPs will also provide the capability for interconnecting networks of dissimilar services (e.g. SMDS, ATM, DS3, DS1), and dissimilar speeds (1.5 Mb/s, 45 Mb/s, 155 Mb/s, 622 Mb/s, etc.). This feature is crucial for addressing the needs of scalable and evolutionary network architectures and for providing the mechanism for smooth transition to a national research and education gigabit network by 1996. These are timely concerns as gigabit class technology will begin to be deployed in prototype lower speed versions in 1993, with continuing escalation of performance and qualitative services as it moves towards production status. The NAPs, in conjunction with network customers, will incorporate a minimal set of standard routing protocols and use a standardized methodology for routing and transit of packets in the NREN.

The stability of the network is ensured by the prudent and careful maintenance and upkeep of the network-wide routing databases. This function is currently performed by MERIT for the NSFNET and in the new architecture will be the responsibility of the Routing Arbiter. The Routing Arbiter, who is excluded from serving as a network service provider, will initially be centralized to ensure the stability of the network during its transition phase. However, the Routing Arbiter function needs to evolve into a distributed and delegated system as soon as possible in order to realistically address the expected growth and complexity of networks, and to enhance the opportunities for commercial service providers to interoperate among themselves and with the research and education community. The separation of the administration and implementation of the routing database from the actual switching of packets will make the introduction of differing services easier while maintaining the stability of the routing database.

Backbone Service Provider

The third element of the architecture of the next generation NSFNET Backbone Services is a very high speed Backbone Network Services (vBNS) Provider to establish and maintain a vBNS which will be connected to all NAPs and all of whose NSFNET vBNS traffic must be in compliance with the NSF Acceptable Use Policy (AUP). In the tradition of NSFNET, the vBNS Provider will be expected to demonstrate leadership in the development and deployment of high performance data communications networks. Initially (Spring, 1994), it is expected that the vBNS will operate at a speed of 155 Mb/s (OC-3). The vBNS provider will be expected to raise the speed during the lifetime of the agreement with the NSF to 622 Mb/s (OC-12) or higher as technology permits and demand warrants. This component of the architecture will: provide for high speed interregional connectivity; enable distributed computing applications; enable multimedia applications such as visualization, collaboration, and distant learning; and, promote the development and deployment of advanced routing technologies.

For reliability, all networks involved in NREN service provisioning must adhere to and support a basic set of operational and administrative capabilities. The NAPs will be required to be as fault tolerant as possible and all networks assisted by the NSF, including the R&E regional networks, will need to enhance and extend their operational capabilities in order to realize this goal.

3.2.2. DOE's/NASA's Interagency Interim NREN implementation plans

The joint DOE/NASA project is designed to address the HPCC/NREN and other leading edge science requirements of both agencies. The mission agencies have HPCC goals and objectives that require high performance access to powerful supercomputers, huge data repositories, and geographically distributed communities of science investigators. Thus DOE and NASA focussed on an Interagency Interim NREN architecture which will use commercial cell-relay services to increase transmission speeds from the current 1.5 Mb/s to 45 Mb/s, with initial deployment early in 1993. Transitions to higher speeds including 622 Mb/s second will be made when such services become commercially available, agency budgets permitting. Deployments of these high performance technologies will be systematically engineered by DOE and NASA networking experts in close collaboration with industry and the research community. Through such collaborations with router vendors and communications carriers, DOE and NASA can evaluate cell relay technologies on an early availability basis and can stimulate development and deployment of cell-relay products and services, thereby providing strategic advantages for the U.S. telecommunications industry in the world marketplace.

DOE and NASA will be spearheading the technology evaluation and deployment of cell relay services and protocols at the Open Systems Interconnect (OSI) Layer 2. These Layer 2 services and virtual private networks (VPNs) allow for greater resource management, accounting, and control than typically provided by traditional Layer 3 networks. In addition, DOE and NASA's choice of Layer 2 services is based on the Broadband ISDN standards advocated by the telecommunications industry as establishing the future direction for communications systems. Therefore, DOE and NASA will be in full accord with the evolving worldwide telecommunications infrastructure and will be able to interoperate with the general research and education community as new telecommunications products and services emerge and become commercially available.

The DOE and NASA networks will initially interconnect at FIXes, along with the next generation of the NSFNET backbone - which is itself targeting advances in routing and peering technologies at OSI Layer 3. These parallel advanced network deployments by NSF and DOE/NASA are fully complementary, with each approach playing a vital role in energizing the U.S. telecommunications and networking industries and creating a seamless interoperable and interconnected Interagency Interim NREN.

By choosing early availability service offerings and adopting industry standards, DOE and NASA will satisfy their high speed HPCC Grand Challenge requirements and also promote the deployment of marketable products and services for nation-wide consumption.

3.3. Commercial Use of the NREN

Industry involvement in NREN use and development occurs in several ways. Many U.S. industrial firms have contributed significant resources to the NREN research program activities. Some of these firms and others have also provided grants and/or subsidies to various universities or other research and educational institutions to support Interagency Interim NREN connectivity. In addition, many commercial firms now also participate in the Interagency Interim NREN and thus provide some funding for NREN connectivity as participants.

There are no NREN restrictions on traffic whose purpose is to engage in or support R&E consonant with NREN Program goals, irrespective of whether the source or target of that traffic is public or private, for-profit or not-for-profit, a commercial or noncommercial enterprise. Many vendors routinely use the network to support their R&E customers, and the number of commercial (for-fee) information providers offering their services over the network is increasing. On the other hand, use for purposes not in support of R&E is in general prohibited. Federal NREN funds are for the support of R&E, not to provide a network for traffic in support of unrestricted commercial purposes, whether the source or target of that traffic is public or private, for-profit or not-for-profit, a commercial or noncommercial enterprise.

There is, however, an administrative issue since commercial traffic is not entirely excluded from the Internet. In contrast with Federal agency networks (such as ESnet, NSI, and the NSFNET Backbone), many regional networks such as NEARNET, SURANET, WESTNET and others - which collectively provide the vital second tier (or mid-level) infrastructure to the NREN Program - allow unrestricted commercial traffic. They offer these unrestricted commercial services because NSF funding, together with the fees collected from their R&E clients, is insufficient to support their service offering to the R&E community. Their commercial customers allow them to serve economically the R&E community. In fact, although some regional networks have fee structures that do not distinguish between commercial and R&E customers, others deliberately subsidize R&E customers with their commercial revenues.

Although connectivity between the regional networks for unrestricted commercial purposes is prohibited over the NREN backbone network components of the Federal agencies, this connectivity is already provided for the private sector - primarily by members of the Commercial Internet Exchange, (CIX), a 501c(6) trade association of private providers of Internet access and carriage. Fair and equal access of private providers to regional networks and their customers is offered today at NSFNET Backbone nodes. In the upcoming competitive solicitation for NSFNET Backbone facilities, the Backbone architecture has been specifically designed to achieve full symmetry and equal access among all backbone networks through "Network Access Points" (NAPs) open to all.

Private network providers (e.g., CIX members) have an expectation, which currently is largely realized, of being able to reach non-R&E customers at low cost using the facilities of the regional networks via NSFNET Backbone nodes (now) or NAPs (later). However, some regional networks (e.g., CONCERT, the network serving the State of North Carolina) are prohibited by their primary funding agencies (for CONCERT, the state government) from carrying non-R&E traffic. Reaching non-R&E customers in regions such as North Carolina where the regional network prohibits non-R&E traffic is thus more expensive for the private providers, since they must duplicate at their own expense existing facilities of the regional network.

The NREN Program policy position on this issue is that such issues must be worked out between the affected private providers and those regional networks that prohibit non-R&E traffic. Federal agencies that provide partial funding for regional networks (primarily the NSF, but also DARPA and indirectly DOE and NASA through institution and Principle

Investigator funding) do not interfere in local decisions, and specifically do not mandate that the regional network restrict traffic.

A basic problem is that the determination as to whether network traffic is "commercial" or not depends not on the network user, nor the user's employer, nor on the user's employer's tax exempt status, but rather on the particular and instantaneous use in progress. "Labeling" traffic to allow the traffic to be routed in accord with criteria of acceptable use is one feature of so-called "Type of Service" (ToS) routing which is not available in current off the shelf technology, although it is under vigorous development within the vendor community. Labeling will also make cost accounting easier. Several proposals offering different ways to label traffic are currently being considered by the Federal Engineering Planning Group (FEPG) and the Internet Architecture Board (IAB - the relevant standards setting body), but a solution may not be generally deployable in the network for a year or more.

The FNC and its Advisory Committee have deliberated on the issue of commercialization of the NREN and have agreed to a policy in this area. The intent is to promote the creation of new, commercially viable data communications products and services, to promote the growth of private sector sources, and to encourage the acquisition of services, as they become generally available, from private sector sources.

3.3.1. Information products and services

Among the network's constituents, there are a variety of views about what information products and services should be accessible over the Internet. Private providers, naturally, wish for no restrictions on traffic. The NREN Program policy has been that at least certain federally funded segments should be restricted: the NSFNET Backbone should be limited to R&E traffic and the mission agency networks should be limited to traffic in support of their respective missions. It is important to understand that these restrictions are neither on content nor on source, but rather relate to the intent of the agency mission. Although such restrictions may be difficult to enforce, it has the salutary implication that from the point of view of those who desire broader access to information products and services, that no information provider (public or private, for free or for fee) should be denied a connection to the net a priori unless it can be demonstrated that the information and/or service to be provided cannot possibly be used for mission support or in support of R&E. There is the further implication that, in accessing such providers, the onus is on the end user to use the information/service only for appropriate purposes.

There is a potential conflict between "carrier" constituents (e.g., FARNET, CIX) who wish neither responsibility nor liability for the content of the information on the network and wish to be treated in this regard as common carriers, and the "provider" constituents, such as the library and database communities, who are concerned about preventing copyright violation and the protection of intellectual property generally. These issues and views are not unique to the NREN Program. The agencies plan to participate in and support workshops in this area during FY 1992 and 1993. Technical work will continue as well, primarily as part of work to ensure the security of Network information.

4. Protection

4.1. Principles

Most of the protection issues concerning the NREN are not new. They exist for communications systems that are accessible to the public in general. It is important that protection policies and mechanisms developed for the NREN be consistent with those that already exist. Wherever possible, it is useful to seek models that apply to the NREN, or can be generalized to apply to the NREN. For example, the "common carriage" model fits the role of NREN network providers in many ways. The time tested rules and responsibilities applied to common carriers may well be appropriate to network providers.

With the exception of performance capabilities, high speed digital networks are not inherently different from digital telephone networks, or any other point-to-point switched communications system. It may be a sound principle to adhere to the rules applicable to such systems, unless it can be demonstrated that the change in speed renders a particular rule ineffective or inappropriate.

4.2. Protection of Copyrights

The technical mechanism appropriate to protect copyright of material distributed over the Network is as yet unclear. Electronic information is much easier to copy and transmit than that recorded on paper. Fewer identifying markings that show the source of the information exist or are retained in electronic copies. As cited in an Office of Technology Assessment (OTA) report, "Finding a Balance: Computer Software, Intellectual Property, and the Challenge of Technological Change," the rapid pace of technological change in computer hardware and software contributes to the complexity of this topic.[10] Further, another OTA report, "Intellectual Property Rights in an Age of Electronics and Information" states that this technological paradigm is "outpacing the legal structure that governs the system, and is creating pressures on Congress to modify the law to accommodate these changes."[11]

For example, the current legal precedent for access to and protection of copyrights of material accessed via modems over telephone lines does not assign legal responsibility to enforce copyright to the common carriers whose lines are used. The fair use of copyrighted materials, a feature of the Copyright Act and essential to scientific research, is an example of a concern that combines technical and legal issues. There must be a balance between the rights of copyright proprietors and the rights of the public. The courts or other legal proceedings will hopefully recognize that "arguments that equate copyright with royalty income run counter to this principle and might be inconsistent with the intent of the framers of the Constitution."[12] Any technical means to assure copyright protection on the NREN must provide for fair use, as must any legal arrangement.

The agencies plan to participate in and support workshops in this area during FY 1993. Technical work will continue as well, primarily as part of work to ensure the security of

Network information. Because consensus has not been reached in this complex area, implementation of technical measures on the Network has not yet been scheduled.

4.3. Security and Privacy

A report, "Mathematical Foundations of High Performance Computing and Communications" to the National Research Council, clearly recognizes that the security of any national network is of major concern. Issues of valid user access to the Network and the information resources, authentication, and integrity of network connections among collaborating users all require a high level of security.[13]

Appropriate policies to ensure the security of resources and the privacy of users are addressed via four policy areas. First, the FNC has coordinated the development of a draft NREN security policy. A second aspect of security is the responsible and proper use of Network resources. Thus, the FNC also has been developing, in consultation with the non-Federal communities, an Appropriate Use Policy. In addition, P.L. 102-476 broadens the NSF's organic act and authorizes the NSF to foster and support access by the research and education communities to computer networks, which may be used substantially for purposes in addition to research and education in the sciences and engineering, if the additional uses will tend to increase the overall capabilities of the networks to support such research and education activities.

The Computer Security Act specifies a third policy requirement to ensure security of resources and protection of privacy. That Act requires each agency to create computer security plans for Federal computer and telecommunications systems which process or transmit sensitive, unclassified information. It also requires security and awareness training of Federal employees and contractors who use sensitive Federal computer and telecommunications systems. These activities, while not presented in this document, are separately reported by each agency through its Information Resources Management activity.

Finally, the privacy protection of users is provided for, to some extent, by the Privacy Act. That Act governs access to information about individuals maintained by Federal agencies that is contained in "systems of records," as defined by the Act. In addition, the Electronic Communications Privacy Act protects Network communications from unlawful interception. Both these Acts may need to be updated given the rapid advances in and proliferation of networking technology.

Information and system security and user privacy can be enhanced by technical security measures. Tools are available today that can protect information travelling across the Network. Encryption may be one approach to securing information that is transmitted via the NREN and other public networks.

4.4. Security of the NREN

The Federal Networking Council (FNC) is actively investigating methods for enhancing the security of the NREN. The NSF, in conjunction with NIST, has sponsored a security workshop on methods for enhancing the network access and site security for the NSF supercomputer centers. The results of this workshop are expected to be applicable to all supercomputer centers and the sites, scientists, and educators accessing them via the NREN. These results and techniques are expected to provide a "proof of concept" and act as a basis for enhancing security for the NREN and the Internet at large. Other workshops on network security were held during 1992 by the Department of Energy and by DARPA's Software Engineering Institute in its role as coordinator for Computer Emergency Response Teams (CERTs) nationwide. NIST coordinates and contributes to the development of security technology, guidelines, and standards that are related to the NREN component of the HPCC Program. NSA, in its capacity as an advisor on national security systems, participates in identifying potential security issues that may arise due to the development of the NREN Program and conducts research and develops information security products used to secure and protect national security systems.

The Federal Networking Council has chartered the Security Working Group to develop a Security Policy for NREN sponsored networks. Its charge is to develop a high level policy which; establishes a common foundation for the development and use of security services and mechanisms to be used in the NREN Program; defines the responsibility for security among the users, managers, administrators, vendors, service providers and overseers of the NREN; and provides the basis for refining the high level policy as experience is gained in NREN operation. Public input will be sought prior to adoption by the FNC and final publication. As recommended by the Coalition for Networked Information (CNI), the full suite of laws, policies, memorandum of agreements, and current schema, etc., will be reviewed and evaluated for potential applicability to implementing an effective NREN security program.[14]

5. Constituencies and Concerns

The ARPANET, the ancestor of the current Internet system and of NREN, was a continental U.S. network operated on DARPA funding for a small and relatively homogeneous group of academic and industrial researchers in the area of information processing technology. In little more than two decades, the network has spread beyond the borders of the United States to 39 or more countries worldwide with usage by - and financial support from - national governments (including several U.S. Federal Agencies), supranational entities such as the European Commission and the United Nations, regional and local governments; small, medium, large and multinational commercial and industrial businesses; educational institutions at every level; and private citizens.

Internet's suppliers of network access and carriage have increased from DARPA's single contractor for the ARPANET, to a variegated collection of private businesses, both for-profit and not-for-profit, large (e.g., US Sprint) and small (e.g., Performance Systems International), and even the post, telephone, and telegraph agencies of some foreign governments.

Although the amount of network traffic has grown phenomenally, even more astonishing is the growth in type and variety of the traffic. Segments of the Internet with substantial support from the U.S. Federal Government are subject to restrictions, typically to usage consistent with the mission of the funding agency (e.g., "Research and Education", in the case of the NSF). As noted in section 3.3, some state networks have similar restrictions, but others recognize the network as a potentially vital adjunct to commercial activity and industrial development, and not only allow but encourage network use by business, commerce, and industry. In Europe, restrictions on the use of even government funded networks are the exception, rather than the rule, and use by the commercial sector is substantial.

With the growth in number and type of suppliers, number of users, and variety of usage, it is not surprising that the unity of intent and custom that characterized the early and homogeneous ARPANET has to a degree dissipated, leading to the emergence of a number of distinct constituencies. Below are discussed several of the concerns they frequently express with the federally funded part of the network - particularly the NSFNET Backbone.

Section 5.4 will briefly describe how the newly adopted NSFNET architecture provides a framework for dealing with the concerns of these various constituencies in a constructive and equitable manner.

These concerns cut across the three issue categories introduced in Section 1 of this report -- Funding, Transition, and Protection -- and the six HPC Act topics. As such they give a flavor of the complexity of the issues that the evolution of the Network raises.

5.1. Broadening the Availability of Network Information Sources

The library community is concerned that the libraries function as channels for users to access information service vendors and individual agencies providing information from diverse sources at predictable, economical, and equitable costs.[15] Nearly all research libraries and some college, public, school, special, and state libraries are already connected, but no NREN funding has been targeted specifically for library connectivity. However, the Department of Education has targeted the nation's public libraries as access points to its network, SMARTLINE. This is an example of opportunities that exist to enhance library connectivity through research and education objectives.

The number and diversity of network accessible information resources continues to grow rapidly. Many are available without charge but most undoubtedly will not be. An intermediate position is that the offerors of for-fee resources make indices and possibly summaries accessible without fee; this would allow such automatic search programs as WAIS and others to find the resources, which should result in increased volume and lowered cost for all. Other concerns expressed by the information services industry and specifically by the Information Industry Association (IIA) include: a) stable pricing mechanisms to access the network; b) network reliability; c) comprehensive user directory services; and d) clear mechanisms for settling policy disagreements.[16]

5.2. Computer Industry Concerns

The Computer Systems Policy Project (CSPP) and other industry groups cite the need to address interoperability, privacy and security, standards, the need for an industry voice in policy setting, and the desirability of wide access. Privacy and security are being vigorously developed in both the private and public sectors. Examples include: federally sponsored workshops; a workshop at Carnegie Mellon University entitled, "The Fourth Workshop on Computer Security Incident Handling"; and an industry led initiative on privacy enhanced electronic mail sanctioned by the Internet Architecture Board. Internet standards are adopted by a formal procedure after community comment and demonstrated interworking among independent implementations. The standards setting process is the most open in the telecommunications industry. The resulting standards are open and nonproprietary, and they are in widespread use, insuring interoperability the world over. The NREN will acquire, as appropriate and when viable, the ISO protocol standards as identified by the GOSIP Federal Information Processing Standard (FIPS), and provisions for interworking the GOSIP and TCP/IP protocol suites are being made.

The Federal Networking Council Advisory Committee (FNCAC), provides a channel for industry inputs into NREN policy. Representatives of the telecommunications and computer industries are members of the FNCAC. All meetings of the FNCAC have been open to the public, and special interest groups (including industry representatives) have participated.

5.3. Expanding the Vision for Education

EDUCOM members and others wish assurances that the higher education community have a voice in policy, advocating that the network support services for higher education and research. They are concerned about the lack of apparent incentives for the participating Federal Agencies to invest in common network infrastructure rather than mission specific facilities. They feel there is also a need to examine a vision of the NREN beyond HPCC. Just as in the case of the CSPP, the formal channel for EDUCOM's influence on policy is the FNCAC. Currently, higher education is represented on the FNCAC both institutionally by EDUCOM staff and other members. The NSF supported a September 1992 workshop in Monterey on NREN Policy sponsored by the Computer Research Association, EDUCOM, and the IEEE to help develop a consensus on major NREN policy issues.

In addition, the FNC has created an Ad Hoc Task Group (see Appendix A.3 (5)) to develop a report on the issues and to prepare a plan to support educational requirements within the constraints of the HPCC budgets and capabilities.

5.4. Plans and Mechanisms to Address Significant Issues

This section summarizes plans and mechanisms for addressing several significant issues related to the NREN Program. These policy issues cut across many constituencies and are discussed here as separate topics. Many of these topics have no final solution yet, but progress is being made on all of them. The FNC invites public comment on many of these through its FNCAC as well as through public forums such as the NREN Policy workshop in Monterey sponsored by EDUCOM, Computing Research Association (CRA), and the IEEE-USA Committee on Communications and Information Policy. In many instances, the Federal networking coordination has proven to be an effective means to advance experimental services while progressing towards a fairer resolution of various policy issues. This section illustrates the policy issues and details the progress being made. In addition, public meetings and workshops will continue to be held to clarify these issues and to build consensus for approach or coordination.

5.4.1. Ownership

All networks in the NREN Program are value-added overlays on the nation's privately owned telephone network's fabric of switches, fibre optic and copper lines, and microwave links. Mission agency participants in NREN such as DOE and NASA own a small amount of networking hardware, such as routers and network monitoring workstations. The NSF does not own any network hardware or systems as it obtains network services through assistance grants. The grant holder or their subcontractors, if any, hold title to any equipment. DoD operates TWBnet and DARTnet through subcontractors. that are part of the NREN Program. These ownership and operational relationships allow the mission agencies to maintain access to advanced network services in order to satisfy critical mission requirements. The FNC is developing a policy statement regarding "Transition to Commercial Services" which deals with the ongoing evolution of the networking infrastructure and ownership.

5.4.2. Operation

There is important ongoing cooperation between several agency members of the Federal Internet community in the FNC Engineering and Operations Working Group. The ESNET (DOE) and NSI (NASA) networks are operated by government and contractor staffs at DOE and NASA facilities, respectively, with policy and programmatic oversight provided by agency headquarters in Washington, D.C. The NSF, in Washington, provides overall policy and guidance for the NSFNET (Backbone + regionals) project, but does not operate any networks. The regional networks are operated by independent business entities, some of which receive assistance grants for their purposes from the Foundation. The NSFNET Backbone network is provisioned by Merit, Inc., through a Cooperative Agreement with the NSF. Merit subcontracts operations to Advanced Network and Services, Inc. (ANS) a nonprofit corporation. The five year Cooperative Agreement was awarded in November, 1987 after competitive solicitation and panel review. Under this Agreement, Merit deployed 1.5 megabit per second (T1) services and is in the process of deploying 45 megabit per second (T3) services which will be accessible to all NSFNET Backbone clients by the end of 1993. The T3 development entails design, implementation and experimentation with hardware and software for storing, routing and dispatching traffic. In 1991, the National Science Board authorized the Foundation to seek an extension of the Cooperative Agreement for a period not to exceed eighteen months, in order to allow time for another competitive solicitation for a follow-on Agreement, and for "overlap" time to allow an orderly transition if needed. This subsequent NSF solicitation involves a process that includes a period of months for public comment on a draft solicitation; approval of a final solicitation by the National Science Board of NSF; issuance of the solicitation in early 1993; competitive peer review of an award by the Summer of 1993; and start of operations of a new Backbone by Spring 1994.

5.4.3. Acceptable use

An NREN services Acceptable Use Policy (AUP) policy is now in draft for comment from Federal and external parties. It is anticipated that an NREN AUP will be finalized within a year. Each Federal agency will also implement an AUP policy on their own networks that is in line with their mission and objectives. There is also P.L. 102-476 that broadens the NSF’s organic act and authorizes the NSF to foster and support access by the research and education communities to computer networks which may be used substantially for purposes in addition to research and education in the sciences and engineering, if the additional uses will tend to increase the overall capabilities of the networks to support such research and education activities.

Apart from such a legal broadening of the NSF charter, the NSF solicitation for the next phase in network technology development and deployment ("Request for Public Comment: Solicitation Concept", NSF, June, 1992) calls for an industrial partner to provide Network

Access Points (NAPs) which will be AUP-free. The existing backbones, ESNet, NSI and NSFNET, will have no privileged access to the NAPs, but they are expected to continue interconnecting via the FIXes. Each interested vendor (network service provider or regional network) may connect to one or more NAPs (for a fee) and provide whatever network services are deemed profitable and useful. However, as before, commercial traffic on the new incarnation of the NSFNET backbone will be limited to services that enhance R&E.

5.4.4. Fair competition for network services

The Backbone Network System of the Interagency Interim NREN is emerging as a set of technology driving and precompetitive service offerings including the advanced ATM services being acquired by DOE for use of ESnet and the NSI, and the OC-3 service that is the subject of the NSF solicitation. Although mission agencies may for a time continue directly to operate critical portions of the Interagency Interim NREN, direct Federal funding of commodity services is minimized. As such the marketplace for competitive offerings by the private sector will not be distorted by Federal involvement. In particular, future NSF funding of mid-level networks will not in general be for the purpose of subsidizing the provision of commodity services in competition with private businesses.Such funding will be for enhanced services such as white and yellow pages directories, and outreach to K-12 schools and other nontraditional communities (e.g., Public Health Service clinics on reservations). In the solicitation for NSFNET Backbone Services, the proposed restriction that the Routing Arbiter and NAP Operator may not also be a network service provider ensures that the NAPs provide a "level playing field" for the private sector.

Moreover, in the new competitive solicitation for the NSFNET Backbone, the NSF will centrally fund only a precompetitive 155 (or greater) Mb/s national Backbone. The Backbone will be accessible through several "Network Access Points" (NAPs) which will be implemented as Acceptable Use policy-free facilities to which regional networks and private network providers may, for a fee, attach and exchange both routing information and packet traffic. Regional networks will be given grants to attach by acquiring NAP-connectivity competitively from private network providers, or by leasing circuits and equipment (and paying the NAP attachment fee) to manage NAP connectivity themselves.

The NAP-based architecture guarantees equal access to all "retail" providers of network service (i.e., private providers and regional networks) to each provider’s customers in full competition for unrestricted traffic exchanges. Equal access to the high speed NSFNET Backbone for R&E traffic is available to all networks attached to the NAPs. The NAPs provide a consistent and symmetric view of the networking world to both the high speed backbone and to a private provider who attaches to all the NAPs.

5.4.5. Interoperability

The FNC Engineering and Operations Working Group has proven to be an effective mechanism to insure interoperability. The agencies have worked together following DARPA's introduction of important standards for network protocols and routing procedures. The NSF and other Federal Agencies have followed this lead and have aggressively promoted the use of these methods as de facto standards. The de facto standards originally developed by DARPA (embodied in documents known as "Requests for Comment", or "RFCs") are openly accessible at no charge electronically over the Internet or on paper for the cost of reproduction and postage. This policy of ready availability has encouraged small and medium sized businesses in the U.S. and abroad to enter the networking business. The effort has been largely successful in this respect and has had a major impact not only domestically, but also internationally.

In those cases where different protocols are used by networks that must meet and exchange traffic, "application layer gateways" are used to perform the necessary conversions. The benefits and limitations of this technology are well understood and the necessary hardware and software are available from commercial vendors. For example, gateways between the two open standards based electronic mail systems (CCITT's X.400 and the Internet standard RFC822) are maintained at the Universities of Michigan and Wisconsin, and in several countries in Europe, and the high energy physics laboratory CERN in Geneva maintains gateways between the file transfer protocols of the Internet (ftp), the International Standards Organization (ftam), and the German national research network (dfn file transfer).

The Interagency Interim NREN must provide seamless interoperability to a diverse research and education community while evolving continuously to achieve its infrastructure enhancement and technology development goals. In planning NREN's evolution, the FNC Engineering and Operations Working Group (EOWG) will need to strike a balance between common carrier developed telecommunications technologies documented in voluntary industry standards and more experimental computer network technologies that may be documented in de facto NREN standards. Use of voluntary standards is mandated in the FNC's NREN Transition Policy and in OMB Circular No. A-119, and is a powerful means of accelerating the deployment of advanced technologies, such as SONET and ATM, in public networks. Selective implementation of more experimental technologies is required to achieve NREN research objectives, and the documentation of such technologies in de facto standards can expedite their commercialization and acceptance in public standards forums.

Aggressive liaison between the EOWG and voluntary telecommunications standards forums will be required to balance common carrier and computer network perspectives in shaping the NREN and its public network counterparts. Liaison with Committee T1 and CCITT is particularly important because of the strong role these organizations play in public telecommunications planning. The EOWG should integrate public network technologies specified in emerging T1 standards and CCITT Recommendations in NREN when such initiatives will accelerate their deployment in public networks or substantially enhance the services provided to NREN users. The EOWG should provide NREN research results to voluntary standards organizations whenever such contributions will substantially benefit public network providers and their users.

5.4.6. Availability

Network access at 1.5 Mb/s per second or greater is currently available to all National Laboratories, major DOE academic contractors, NASA centers and contractors/grantees, and (through the NSFNET infrastructure) to nearly all universities in the top four categories of the Carnegie classification. Availability is being extended both in depth as well as breadth. Service over the NSFNET Backbone and that specified in the recent DOE award is increasing to 45 Mb/s per second with planned upgrades to higher speeds only if funding permits. The NSF Connections Program, and similar programs sponsored by other Federal Agencies, are extending basic network service to an additional hundred or more institutions each year. Institutions being connected in the latter category include medical school campuses (under NIH sponsorship), and agricultural extension services.

5.4.7. Copyright protection

The problems in protecting and granting fair usage of information in electronic form are not unique to the NREN. These problems exist in all forms of electronic exchange of information. The rights of the creators of information, and the rights of the library and users of this information need to be balanced. The FNC will be looking to the legal community to aid in developing appropriate guidelines.

The fair use of copyrighted materials, a feature of the Copyright Act essential to scientific research, is an example of a concern that combines technical and legal issues. Any technical means to ensure copyright protection must provide for fair use, as must any legal arrangement.

The agencies plan to participate in and support workshops in this area during FY 1993. Technical work will continue as well, primarily as part of work to ensure the security of Network information. Because consensus has not been reached in this complex area, implementation of technical measures on the Network has not yet been scheduled.

5.4.8. User base

The user base, although intended to be limited to the R&E communities, is extensive and rapidly growing. U.S. efforts also play an important role in developing network technology world wide. The Internet can reach a user community estimated to be between 5 and 10 million, using more than 1 million computers on 7,500 interconnected networks worldwide. The U.S. user community is easily 1 to 2 million, and has 80% of the host computers. It should be noted that the R&E communities include commercial and industrial users and information suppliers, not just users from the academic and government sectors. Moreover, the Internet's commercial sector, which includes many U.S. corporations, both large and small, represents the most rapidly growing segment of the Internet.

Traffic on the NSFNET Backbone network, in addition to DOE's ESnet and NASA's NSI network, which together form the principal large-scale structure of the domestic Internet, is growing at an exponential rate of 10% per month. The number of accessible networks is also growing, though not quite as rapidly. Thus, both the number of users per network and the traffic per user are growing dramatically.

Appendix A. Management/ Coordination of the HPCC Program

This section summarizes the HPCC management and coordination processes that help implement the NREN activities. Section A.4 and A.5 were developed by the participating agencies and represent their agreed upon roles and responsibilities in implementing the NREN Program.

The principal management mechanism of the overall HPCC Program is coordination. The NREN Program is implemented in the model of the HPCC Program as a partnership among Federal Agencies and other organizations. Major portions of the HPCC Program are cost-shared and leveraged by the participation of industry and universities. Leadership for the HPCC Program is provided by the Office of Science and Technology Policy, through the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) Committee on Physical, Mathematical, and Engineering Sciences (PMES). The membership of PMES includes senior executives of many Federal Agencies. Planning for the HPCC Program is coordinated by the PMES High Performance Computing, Communications, and Information Technology (HPCCIT) Subcommittee.

This process provides for agency participation through agency proposal development and review, budget crosscut development and review, and interagency program coordination. Agency programs are reviewed against a set of evaluation criteria for merit, contribution, readiness, linkages to industry, and other factors.

The schedules, roles, and responsibilities of the agencies participating in the U.S. HPCC Program for the planning and budget process for each fiscal year are outlined in Section A.4. In accordance with the Federal Budget Process for the HPCC Program and other crosscut budget activities, member agencies of PMES must submit to OMB their HPCC budget requests and supporting documentation, as reviewed by senior agency officials and the PMES committee. These requests must be described and justified relative to the goals, objectives, and research priorities of the HPCC Program. The PMES then develops and submits to the OMB and PMES member agencies a combined, integrated, multi-agency budget recommendation that reflects the goals, objectives, and integrating priorities of the HPCC. PMES members then submit to OMB their resulting HPCC Program requests as part of their total fiscal year budget submission.

Under the HPCCIT there are currently four special groups which coordinate activities in specific areas including; Applications, Networking, Research, and Education. From time to time, individual agencies are assigned responsibility to lead the coordination of the HPCCIT and these groups.

The coordinating methods that evolved among the agencies participating in the HPCC Program produced a consistent and effective set of managerial mechanisms. In addition, HPCCIT explored and considered several options for strengthening the interagency coordination while retaining the strengths of the current management structure, namely:

- effective multi-agency budget advocacy;
- tight coupling with agency programs and missions; and
- diverse applications, requirements, and technical approaches to ensure accomplishment of HPCC objectives and technology transfer.

In response to these needs, HPCCIT has established a permanent National Coordination Office for the HPCC Program that will combine the functions of the current HPCCIT Chairman with the necessary supporting functions of a permanent staff office.

A.1. Management/Coordination of the NREN Program

During 1990, in order to provide for broader and more inclusive coordination of research and education communities, the NSF, as part of its HPCCIT network task group activities, created the Federal Networking Council (FNC) and initiated the creation of an FNC Advisory Committee (FNCAC) consisting of non-Federal scientists and network users to serve as an NSF advisory committee. The FNC is based on the successful model of the Federal Research Internet Coordinating Committee (FRICC) - an informal body established by core Federal Agencies in 1987 to coordinate their networking activities and expenditures. The FNC consists of representatives from Federal Agencies that have requirements for operating and using networking facilities, mainly in support of research and education, and for advancing the evolution of the Federal portion of the Internet.

First level management of the NREN Program is accomplished through normal agency structures. Multi-agency NREN coordination is achieved through the PMES and its HPCCIT subcommittee. The HPCCIT Networking group, currently led by the NSF, coordinates network integration activities and works closely with the FNC, which is responsible for coordinating the efforts of government HPCC participants and other Interagency Interim NREN governmental constituents, in addition to providing a liaison to non-Federal communities interested in the Federal program. The FNC and its Executive Committee set policy and address operational and management issues through its working groups and ad hoc task forces. Currently, the chair of the HPCCIT Networking group also serves as the chair of the FNC, thereby providing the liaison and coordination necessary between the HPCCIT and the FNC.

Each of the participating agencies has enhanced their HPCC and NREN management functions. DOE's NREN management is located within the Energy Research (ER) Program's Scientific Computing Staff, to which the ESnet network manager reports directly on issues relating to the ESnet and its role in the NREN Program. NASA's NREN Program management structure is derived from a matrix organization, in which the Network manager for both NASA's Scientific and HPCC networks, reports directly to both NASA's HPCC (Code R) and Science Board (Code S) programs. The NSF has instituted an HPCC coordinating committee with budget, planning, and oversight responsibilities. The NSF's NREN Program works with the NSF HPCC coordinating committee and the NSFNET Executive Committee on NSFNET and NREN issues. The NSF has created a NREN Program

Director position to handle NREN and interagency issues. DARPA has created a High Performance Computing Joint Program Office to coordinate advanced technology development within the DoD and cooperatively with other agencies. Efforts are clustered together for more effective administration. For example, the DARPA/NSF testbeds are jointly overseen by DARPA and NSF, with a coordinating committee to insure inter-testbed exchanges, annual jamborees, and the like. As gigabit technology becomes more widely available and used by multiple agencies, Federal efforts will be coordinated by working groups under the Research Working Group of the FNC.

A.2. Federal Networking Council

The Federal Networking Council (FNC) consists of representatives from Federal Agencies that have requirements for operating and using networking facilities, mainly in support of research and education, and for advancing the evolution of the federally funded portion of the Internet. The FNC works closely with the appropriate FCCSET committees to provide a broader forum for discussion and resolution of networking plans, operations, and issues.

Specifically, the FNC is responsible for establishing policies and guidelines to promote coordination among its various committees and agency program managers. The FNC also guides the evolution of NREN services to promote U.S. competitiveness as well as to broaden the community, including commercial availability.

The FNC chairperson is appointed by the HPCCIT networking task group chairperson. The duration of the term is normally 18 months. The FNC will operate through an Executive Committee that will be responsible for decision making and implementation (generally on a consensus basis), through working groups that will address ongoing areas of interest or activity, and ad hoc task groups established to work on specific tasks with set deadlines.

(1) FNC Management and Committee Structure

The FNC structure is explained below.

(2) Federal Networking Council Advisory Committee (FNCAC)

The Federal Networking Council Advisory Committee shall provide the FNC with technical, tactical, and strategic advice from the constituencies involved in the NREN Program. Constituencies include the following: the research and scholarly communities who are the end users of the networks; organizations that need connectivity to the NREN; transmission and other facilities providers; industrial organizations that develop and provide relevant technology and services; and experts in networking and computer science who provide technical guidance.

The FNCAC is advisory in nature and shall work on areas of policy and technical direction and user/program needs and requirements, excluding budgets and funding. Membership is limited and meetings of the FNCAC occur at least two times per year. The FNCAC must draft a charter to be approved by the FNC. FNCAC members are appointed by the FNC chairperson in response to recommendations by the FNC. The FNCAC can, with FNC approval, create subcommittees with open membership to provide assistance to the FNC on appropriate issues.

(3) FNC Executive Committee

The FNC's Executive Committee comprises representatives of the participating HPCC agencies with major network initiatives and others as designated by the FNC chairperson. The Executive Committee provides support to the FNC chairperson and serves as primary decision making and implementing body of the FNC to coordinate with the FCCSET HPCCIT Subcommittee on HPCC crosscut budgets, plans, and activities. It will also perform annual reviews of FNC working groups and task groups with regard to membership, purpose, and continuing need in order to make changes as appropriate.

The FNC Executive Committee may charge any of the working groups to perform specific tasks or studies, or create a focused ad hoc task group with a specific deadline and lifetime to do so, as deemed necessary to accomplish FNC goals. The FNC Executive Committee may also request working groups or task groups to produce or to present reports on specific topics to the FNC Executive Committee or to the FNC within two weeks of such requests.

A.3. FNC Working and Ad Hoc Task Groups

Working and ad hoc task groups of the FNC address issues that require interagency coordination or have policy implications. The working groups are: (1) Engineering and Operations; (2) Security; (3) Research; and (4) Policy. One ad hoc task group currently exists for Education. These groups meet as appropriate to carry out their responsibilities and report regularly to the FNC. Group membership may include non-Federal employees as appropriate to provide technical expertise or other required consultation or coordination. By January 1 of each year, each working or task group will submit to the FNC a summary document outlining the accomplishments during the previous year and the goals for the coming year for activities within their purview.

(1) Engineering and Operations Working Group (EOWG)

The Engineering and Operations Working Group is responsible for integrating new network technologies into the Interagency Interim NREN and providing support to the Federal HPCC Program. The EOWG oversees the ongoing operation of the Federal research and education portion of the Internet and has overall responsibility for coordinating the requirements, engineering, and operational activities, for both domestic and international research and education requirements, for implementing the Interagency Interim NREN.

(2) Security Working Group (SWG)

The Security Working Group is responsible for addressing network security technology, management, and administration issues related to maintaining and improving the availability, integrity, and confidentiality of Interagency Interim NREN resources. The SWG will develop, coordinate, and propose to the FNC a security policy for use of the Interagency Interim NREN. It will also review security requirements of the evolving NREN and propose technical developments, operational guidelines, and administrative procedures needed to meet them. It will prepare input to the FNC, as needed, on security related matters. The SWG will work closely with other organizations developing or defining security policies, standards, services, and mechanisms in fulfilling these duties.

(3) Research Working Group (RWG)

The Research Working Group is responsible for coordinating research and development activities in network technologies. The Research Working Group will coordinate federally sponsored research required for the development of the NREN. The RWG defines and prioritizes gigabit research areas, develops research plans, and coordinates these plans with the FCCSET task group on High Performance Communications.

(4) Policy Working Group (PWG)

The Policy Working Group is responsible, in conjunction with the other FNC working groups and the FNC at large, for identifying, documenting, and reviewing policy issues affecting the development of the NREN. The PWG develops plans and proposals for managing the NREN and for the operation of the FNC, and identifies policy issues associated with the operation and evolution of the NREN and develops policies and plans to address these issues. The PWG responds similarly to issues referred to it by other FNC Working Groups. The PWG is then responsible for presenting its results as recommendations to the FNC.

(5) Education Ad Hoc Task Group

The FNC ad hoc Education Task Group will prepare a report on issues, requirements, and recommended FNC activities with regard to educational networking support needs and benefits.

A.4. Agency NREN Program Management Responsibilities

The agencies participating in the FNC have established a Charter and worked to define their respective roles. The FNC has approved the following set of agency responsibilities:

(1) Agencies participating in the FNC who have requirements for the use or development of NREN facilities (i.e., federally funded equipment, software, services, etc., which are part of the Interagency Interim NREN or NREN funded testbeds) or who have approved

budgets for the HPCC, should, as appropriate, in coordination with the HPCCIT Subcommittee:

· provide representation to and actively participate in the FNC;

· use the NREN Program facilities;

· coordinate their NREN Program development as part of the interagency NREN Program;

· coordinate their research and education data network installations, upgrades, modifications, and activities, both national and international, through the FNC and as part of the coordinated interagency NREN Program;

· coordinate the development of plans and budgets for NREN activities through the FCCSET crosscut budget process for each fiscal year budget submission;

· coordinate their network research activities through the FNC and as part of the interagency NREN Program;

· submit an implementation plan for NREN activities for FNC interagency coordination prior to the start of each fiscal year; and

· participate in the development of annual NREN implementation and gigabit research plans.

(See Section A.5 for an explanation of the process for coordination of requirements and implementation.)

(2) The Department of Defense through:

(2.1) Defense Advanced Research Projects Agency (DARPA) shall

· be the lead agency for gigabit technology development and coordination for research on gigabit networks;

· carry out a gigabit technology research program;

· provide for basic and applied research in gigabit and other advanced communications technologies; and

· for NREN budgets and activities, develop a gigabit network research plan as part of the interagency NREN Program for coordination by the FCCSET/PMES and the FNC.

The plan shall include all proposed gigabit research activities of participating agencies and is submitted to the FNC for review and approval.

(2.2) National Security Agency (NSA) shall

· in its capacity as an advisor on national security systems, participate in identifying potential security issues that may arise due to the development of the NREN Program and assist the FNC in identifying the appropriate bodies to resolve such issue; and

· conduct research and develop information security products used to secure and protect national security systems.

(2.3) Defense Information Systems Agency (DISA) shall

· be the lead agency in planning and providing the Command, Control, Communications, Computers, and Intelligence (C4I) mission requirements for the DoD Military Departments and Agencies in the NREN Program;

· conduct research for the development of applications of high speed networking for the DoD C4I community;

· support and contribute to the development of open architecture and standards that affect the DoD C4I networks as impacted by the NREN; and

· upgrade and enhance The Wide Band network (TWBnet) and the Defense Information System Network (DISN) testbeds networking infrastructure for the DoD C4I related mission activities.

(3) National Science Foundation (NSF) shall

· coordinate the Interagency Interim NREN activities, including coordinating the development, deployment, and operations of the Interagency Interim NREN facilities and services;

· upgrade the NSF funded network as part of the coordinated Interagency Interim NREN Program;

· assist regional networks to upgrade their capabilities as appropriate and as part of the coordinated Interagency Interim NREN Program;

· serve as the primary source for information or access to and use of the Interagency Interim NREN;

· assist colleges, universities, and libraries, where appropriate, to connect to the Interagency Interim NREN;

· provide for basic research and development in gigabit and other network technologies; and

· develop an Interagency Interim NREN implementation plan, for review and approval of the FNC, as part of the interagency NREN Program, for coordination of the broad deployment of the Interagency Interim NREN working with universities, industry, and agencies having mission specific requirements. The plan shall be the basis for coordination of all participating agency NREN activities subsequent to FNC approval.

(4) Department of Energy (DOE) shall

· provide for applications based gigabit research;

· provide for energy related mission Interagency Interim NREN facilities deployment;

· upgrade and enhance the DOE Energy Sciences Network as part of the coordinated Interagency Interim NREN Program to provide quality networking infrastructure support for energy related mission activities; and

· participate in basic and applied research and development of gigabit technology.

(5) National Aeronautics and Space Administration (NASA) shall

· provide for applications based gigabit research;

· provide for Interagency Interim NREN facilities deployment for aeronautics and earth and space science missions;

· participate in Interagency Interim NREN architecture development;

· participate in the research and development of gigabit technology; and

· upgrade the NASA Science Internet and AEROnet as part of the coordinated Interagency Interim NREN Program.

(6) The Department of Commerce through

(6.1) National Institute of Standards and Technology (NIST) shall

· coordinate, research, and develop instrumentation and methodology for performance measurement of high performance networks and computer systems;

· conduct research and development on new high performance communications protocols;

· promote "Open Systems" standards to aid industry to commercialize the products of research and development, with the aid of other agencies;

· support, coordinate, and promote the development of standards within the Federal Government to provide interoperability, common user interfaces to systems, and enhanced security for the Interagency Interim NREN; and

· coordinate and contribute to the development of security technology, guidelines and standards for unclassified systems.

(6.2) National Oceanic and Atmospheric Administration (NOAA) shall

· provide access to oceanic and atmospheric research and education facilities to meet mission needs in keeping with the coordinated Interagency Interim NREN Program.

(6.3) National Telecommunications and Information Administration (NTIA) shall

· in its capacity as Executive Branch adviser on telecommunications policy issues, participate in identifying potential legal and regulatory policy issues affecting the national telecommunications infrastructure that may arise due to the development of the NREN Program and assist the FNC in identifying the appropriate bodies to resolve such issues;

· contribute to the planning and conduct of research and development of quality of service measurements on the NREN in support of network optimization and management for the public switched network; and

· support, promote, and contribute to the development of commercial communications standards that affect the public switched network, as impacted by NREN related research and development, and with the aid of other agencies.

(7) Environmental Protection Agency (EPA) shall

· provide for states environmental mission assimilation into the Interagency Interim NREN;

· develop a facility and campus-wide environmental modeling research capability and network based on Interagency Interim NREN-compatible technologies, including ethernet, FDDI, and ATM/SONET, and to include in these activities cooperative efforts with local "telephone company" communications service providers for planning and installing local and metro-area high speed interconnects compatible with the NREN; and

· begin planning with state environmental agency research and education groups for assimilation into the Interagency Interim NREN. Initial contacts and specific plans will be developed for at least five states. Relationships will be established to begin the process of technology transfer from the EPA research network to the states' environmental research and education environments.

(8) Health and Human Services (HHS) through the National Institutes of Health (NIH) shall

· provide for medical mission NREN facilities deployment as part of the coordinated Interagency Interim NREN Program; and

· provide for applications based gigabit research.

(9) Department of Education shall

· support, coordinate, and promote where appropriate, the use of the Interagency Interim NREN in the K-12 community; and

· conduct research on the applications of networking with an emphasis on the coordination of activities with libraries, school facilities, educational research groups and the general education community with respect to the advancement and dissemination of educational information to improve teaching and learning.

(10) Department of Agriculture, through its Science and Education Agencies (the Agricultural Research Service, Cooperative Extension Service, National Agricultural Library, and Cooperative State Research Service), shall

· provide for agricultural research and education mission assimilation into the Interagency Interim NREN involving the agencies named in this section and the land grant university community including local Extension and research offices.

(11) Department of Interior, through its U.S. Geological Survey, shall

· participate in the gigabit technology research program through the EROS (Earth Resources Observatory System) Data Center; and

· provide for earth science mission assimilation into the Interagency Interim NREN Program.

A.5. Interagency Interim NREN Requirements and Implementation: Coordination Process

The coordination of the multi-agency HPCC networking requirements and of their implementation is a critical activity for the Interagency Interim NREN Program. This is so because the Interagency Interim NREN is an evolving, operating system of networks that is broad both in technological scope and in communities served, yet also serves as a proving ground for innovative networking technologies whose introduction pose certain elements of risk. This risk, however, is offset by the demanding network requirements of leading edge grand challenge research endeavors.

Coordination involves three formal activities which must be synchronized with normal agency budget processes: requirements definition, requirements analysis, and implementation and execution. Coordination is also a continuing process for the Executive Committee and the EOWG, since the treatment of de novo and ad hoc situations should not be deferred.

(1) Requirements Definition

The initial definition of networking requirements for the federally funded portion of the Interagency Interim NREN will be done separately by the participating FNC agencies, and should be submitted to the Executive Committee by the fourth quarter of the fiscal year. This requirements definition will include planned activities for the next fiscal year as well as identified requirements for the following budget year. Requirements will be identified as to type (e.g., information services, connectivity to locations and institutions, network capabilities, etc.), and will be described in enough detail to support a technical and administrative interagency coordination.

(2) Requirements Analysis

The EOWG, under the auspices of the FNC, will perform a technical analysis of the agency requirements documents and present a written summary of technically feasible solutions, including cost estimates, to the Executive Committee who will present it to the FNC. This process will be completed prior to the submission of the President's budget for the following budget year, and will allow the FNC to ensure that Federal Interagency Interim NREN requirements are coordinated and well planned.

(3) Implementation and Execution

Based upon the requirements analysis, cost estimates, and balance of infrastructural and mission specific impact, the Executive Committee will prepare a plan of action for the next fiscal year and an implementation plan, as part of the Federal Budget Process for the HPCC Program, for the following budget year. The final plan will be reviewed by the FNC and submitted as an informational item by the FNC Chairperson to the FCCSET HPCCIT Subcommittee.

A.6. Public Interaction and Advisory Bodies

All HPCC agencies receive advisory input from their sister agencies via the FNC in addition to the FNC Advisory Council (FNCAC), which is a formally chartered Federal advisory committee comprised of computer vendors, telecommunications providers, representatives of the library community, and researchers and senior managers from universities, supercomputer centers, and national laboratories. In addition, each agency maintains various mechanisms for incorporating advice and information from interested parties. Involvement by the communication and computer industries is always a goal. Every gigabit testbed involves at least one common carrier, a computer manufacturer, and a university. Mutual interest guarantees technology transfer. Gigabit testbeds are always in the service of gigabit applications, so systems are evaluated both by its authors and by its users.

In order to increase end user input into the planning of NREN services, the NSF is planning to establish and charter a Users Advisory Group made up of scientists, engineers, and educators who use NSFNET and NREN services.

In the planning and conduct of its NSFNET and NREN activities, the NSF regularly consults a variety of private sector R&E networking entities, such as:

- The Federation of American Research Networks (FARNET) that includes private sector IP service providers (e.g. PSI, Sprint), State networks, and both independent and NSF subsidized regional R&E networks;

- EDUCOM, a nonprofit educational consortium;

- The Coalition for Networked Information (CNI), a nonprofit education and library consortium; and

- The Internet Architecture Board (IAB), an informal association of technical experts who have guided the technical evolution of R&E networking since the early 1980's.

Appendix B. Current NREN Program

B.1. Background

No single agency has hierarchical authority to direct and manage the HPCC Program, however, the HPCC Program and, in particular, the NREN activity is characterized by close coordination between the participating Federal agencies. The NREN Program is an integral component of the HPCC Program and is executed through the activities of several independent agencies coordinating their efforts and plans developed through the HPCC budget planning and other related program planning processes described in Appendix A.

In 1985 the Federal Coordinating Council on Science, Engineering and Technology (FCCSET) established a Network Working Group comprised of Federal agency representatives from the National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), Department of Energy (DOE), National Institute of Standards and Technology (NIST), and the National Aeronautics and Space Administration (NASA), to coordinate Federal agency research networking activities. The Network Working Group generated a FCCSET report, "Interagency Networking for Research Programs," which was published in February 1986, recommending the interconnection of existing federally supported data communications networks for research programs and the formation of an Interagency Research Internet Organization. Subsequently, network managers from NSF, DARPA, DOE, NIST, NASA, and other agencies worked together to oversee, coordinate, and manage the evolution of the Federal portion of the Internet. The results of this collaboration are stable operational relationships that now serve as the basis for interagency oversight, management, and focus for the federally funded portion of the Internet. In addition, this collaboration led to large-scale interconnectivity between the mission agencies' research data networks, the NSFNET (NSF Computer Network), and the remainder of the Internet, primarily based on the Federal Internet eXchanges (FIXs), as well as coordinated multi-agency international links.

As participation in the Federal research networking program grew, agencies recognized the need to more closely coordinate Federal research networking activities with those of industry, academia, and, in general, with other interested groups. Accordingly, the original vision of this interagency activity was extended to include additional Federal and non-Federal components.

The National Research and Education Network (NREN) Program is a multi-agency activity that will provide for the evolution from the current federally funded research and education (R&E) networks, to a gigabit network system that allows for both the interconnectivity and interoperability of federally funded R&E networks with each other and with private sector networks by the mid-1990's to support the increasing demands in R&E. As its name indicates, the NREN activity is primarily for research and education, not general purpose communication. Nonetheless, the NREN Program incorporates vital connections to industrial and governmental sectors and develops general testbeds for new communications technologies.

The principal goals of the NREN Program are to;

- advance the leading edge of networking technology and services,

- widen network access within the research and education community to high performance computing systems and other research facilities, and to electronic information resources and libraries, and

- accelerate the development and deployment of networking technology by the telecommunications industry and by the private sector generally.

The program has two principal components: the Interagency Interim NREN, and Gigabit Research and Development. The Interagency Interim NREN activity is an evolving operating network system. Near term (1992-1996) communications and networking research and development activities will provide for the smooth evolution of this networking infrastructure into the future gigabit network supporting research and education. The Gigabit Research and Development is a comprehensive program of gigabit-per-second network hardware and software technology that embodies the goal of the NREN Program evolution by the mid-1990's. This activity also develops technologies and demonstrates applications.

B.2. Scope

The Interagency Interim NREN is an evolving operational system of networks. Near term (1992-1996) research and development activities will provide for the smooth evolution of this networking infrastructure into the future gigabit NREN. Interagency Interim NREN activities will achieve this goal by expanding the connectivity and enhancing the capabilities of the federally funded portion of today's research and education networks, and by deploying advanced technologies and services as they mature. The Interagency Interim NREN, which is primarily based on DARPA's Internet technology, builds on the NSF's NSFNET, DOE's Energy Sciences Network (ESnet), NASA's Science Internet (NSI) and other networks supporting research and education.

Today's Interagency Interim NREN is used to support collaboration among people through electronic mail and bulletin boards, access to information sources through file transfer, and access to remote computers and other laboratory facilities through remote log-in. It is anticipated that the next generation of applications will require a radical extension of not just the speed of the network, but of the capabilities. For example, collaboration among people through real-time digital multimedia conferencing or remote access to visualize supercomputer experimental results requires new capabilities, not just a faster version of today's capabilities. The NREN Program for the federally funded portion of the NREN is intended to provide a radical extension beyond existing capabilities of current hardware and software. The goal is to spur the deployment of the most advanced networking services that support the ever-increasing networking demands of high performance computing to the extent feasible, while assuring a stable and consistent level of services for the advanced HPCC R&E community.

The underlying strategy of the HPCC Program has been to support the solution of important scientific and technical problems of broad national significance in collaboration with all interested sectors in government, industry and universities. In the networking area this strategy has led to a unique collaboration in both the research and operational aspects of the NREN activity.

At each stage of its evolution, the Interagency Interim NREN activity consists of an infrastructure of multi-protocol value-added services carried on the nation's existing underlying telecommunications fabric. Both components of the NREN Program are designed for participation of the private sector to maximize the leverage of Federal funds. It is intended that Federal operation and ownership of network facilities and services, already minimal, be continuously reduced even further as the program develops.

Although the NREN is an R&E network program, a deliberate consequence of including substantial private sector activity is that the technology and services developed, and even the facilities themselves, may be the model for a more ubiquitous network offering developed under private, or other public efforts. In fact, many industrial research organizations and commercial establishments that support the nation's scholarly enterprise are connected. The commercial networks are the fastest growing segment. Nevertheless, HPCC Program priorities remain the central focus of the NREN Program. While other Federal and private sector participants are encouraged, the degree of their participation must be contingent on several factors, such as, program focus, cost sharing, and technology leverage.

DARPA has the HPCC lead role for developing gigabit class technology for the NREN activity. This work is complementary to Interagency Interim NREN work done elsewhere and DARPA's own defense related research in network technology.

The NSF coordinates the broad deployment of the Interagency Interim NREN Programs and systems, and supports the HPCC Program by: coordinating interagency network activities; providing backbone services to the general R&E community; providing information services on access and use of the network; assisting regional R&E networks to upgrade and enhance their own services; and supporting the development and deployment of gigabit technologies.

Currently, and at the end stage of this development, the Interagency Interim NREN Program activity will result in a comprehensive service offering to the nation's community of researchers and scholars at all levels. It will interconnect them to one another and to the facilities and other resources they use in their scholarly endeavor, such as, databases and libraries, laboratories, scientific instruments, and computation centers. As a facilitator and enabler of intellectual activity, the Interagency Interim NREN system will include connectivity to supporting organizations, such as, publishers and hardware and software vendors. International connections that serve the national interest are also included.

Important features of the NREN Program are:

- use of existing telephone company facilities, and not the laying of fiber or building a physical network; and

- driving technology and broadly seeding the market, while avoiding competition with the private sector.

Because of this latter aspect, success of this part of the program inevitably leads to tension and concerns that government services not remain in place once a technology offering has been demonstrated and seeded. It is the policy of the NREN Program to seek to accelerate this transition to the private sector, while not compromising the need for stable and consistent services by the R&E community.

B.3. Vision

The NREN is both a goal of the HPCC Program and a key enabling technology for success in the other components. As used in this report, the NREN is the future realization of an interconnected gigabit computer network system supporting HPCC. The NREN is intended to revolutionize the ability of U.S. researchers and educators to carry out collaborative research and education activities, regardless of the physical location of the participants or the computational resources to be used. As its name implies, NREN is a network for research and education, not general purpose communication. Nonetheless, its use as a testbed for new communications technologies is vital. A fundamental goal of the HPCC Program is to develop and transfer advanced computing and communications technologies to the private sector of the U.S. as rapidly as possible, and to enhance the nation's research and education enterprise. The development and deployment of advanced applications, such as image visualization and distributed computing, will be applied to problems such as medical diagnosis, aerodynamics, advanced materials, and global change, and will provide the impetus necessary for transferring the supporting technologies and capabilities throughout the U.S. science, technology, and education infrastructure. These capabilities and technologies will be developed through the cooperative effort of U.S. industry, the Federal Government, and the educational community.

The interagency High Performance Computing and Communications (HPCC) Program has undertaken the Interagency Interim NREN activity, not solely as support for the HPCC Program including the solution of Grand Challenge problems, but also as an infrastructure for community wide connectivity for broad support of the Nation's intellectual activity. In doing this, the focus remains on providing advanced, leading edge, and in some cases, prototype network services to the Nation's R&E community, rather than attempting to serve as a general public computer network.

For the long term, DARPA is developing technology today which will be the foundation of the NREN from 1995-2000. It is not simply a matter of more of today's technology; this will not do the job. The NREN research program, under DARPA coordination, includes a broad effort to develop a set of complementary gigabit networks based on common carrier standards (e.g. ATM), satellite, wireless, optical and others. New internetwork architectures use these as building blocks for new sets of coherent services such as global file systems, multicast delivery, and other services. There are issues involving: smooth scaling to multi-gigabit speeds, universal access, multimedia, real time, policy controls, and other services which do not exist in today's Interagency Interim NREN that need to be addressed. This technology development will track Interagency Interim NREN developments, and early use of new commercial technologies, to insure that there is a clear technical and policy roadmap to smooth transition from today's systems to those of the future.

In summary, the NREN Program comprises a spectrum of coordinated networking activities by the several Federal Agencies that ranges from providing a framework for commodity offerings by the private sector, through the funding of an infrastructure of precompetitive networking technologies. The program is designed to serve the most advanced scientific and educational demands, and foster an aggressive collaboration with private industry in the development of next generation network systems that will operate in the gigabit-per-second, and beyond, range of speeds by the mid-1990's.

B.4. Current NREN Program Status

As mentioned above, the NREN component of the HPCC Program is comprised of two related and complementary subprograms, the Interagency Interim NREN subcomponent, and the Gigabit Research and Development subcomponent.

The Gigabit Research and Development subcomponent is aimed at providing the research and technology base needed to achieve, at a minimum, gigabit speeds and advanced capabilities in the NREN Program. Gigabit network development already underway includes the joint DARPA/NSF gigabit testbed program and gigabit network exploitation of the ACTS satellite with National Aeronautics and Space Administration (NASA), and programs to foster development of low cost gigabit LANs for workstation environments. These development efforts are complemented by research efforts in less developed areas, such as, all optical networks. Advanced Internet technology will tie these networks together. The DARPA Advanced Research Testbed Network (DARTNET) is the testing ground for new capabilities developed at over a dozen research sites. Multimedia, and resource allocation work is nearing the maturity necessary for wide use, while multicast and policy routing are already transitioning into the Interagency interim NREN. Future efforts will develop gigabit LAN interoperability agreements.

The Interagency Interim NREN Program is an evolving operational network system that supports early deployment of networking technologies and systems for the high performance computing R&E community. It is this part of the NREN Program that is attracting the widest interest from various constituencies as they become aware of the potential use of this developing technology base. This in turn has led to serious concerns regarding various issues such as, ownership, funding, operation, commercialization, etc. The main purpose of this report is to present the context for the discussion of these issues and the Federal agency plans for dealing with them.

Appendix C. Glossary

ANS
Advanced Network and Services, Inc., a nonprofit corporation

ANSI
American National Standards Institute

ARPANET
primarily a continental U.S. computer network that preceded the Internet and was operated by DARPA

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

AUP
Acceptable Use Policy

Backbone Network
a high capacity electronic trunk connecting lower capacity networks, e.g., NSFNET backbone

CCITT
International Consultative Committee for Telegraphy and Telephony

CERTs
Computer Emergency Response Teams

CIA
Central Intelligence Agency

CIX
Commercial Internet eXchange

CLNP
ConnectionLess Network Protocol

CNI
Coalition for Networked Information, a nonprofit education and library consortium

CONCERT
regional network serving the State of North Carolina

CRA
Computing Research Association

CSPP
Computer Systems Policy Project

C4I
Command, Control, Communications, Computers and Intelligence

DARPA
Defense Advanced Research Projects Agency

DARTNET
DARPA Advanced Research Testbed Network

DISA
Defense Information Systems Agency, formerly the Defense Communications Agency

DISN
Defense Information Systems Network

DOC
Department of Commerce

DOD
Department of Defense

DOE
Department of Energy

DS1
a multiplexed channel of 24 DS0 channels (i.e., one DS0 channel carries one voice grade channel equivalent of data at 64 Kb/s)

DS3
a multiplexed channel of 28 DS1 channels

ED
Department of Education

EDUCOM
a non-profit, primarily academic consortium for information technology

EOWG
Engineering and Operations Working Group of the Federal Networking Council

EPA
Environmental Protection Agency

ESnet
Energy Sciences Network

FARNET
Federation of American Research Networks

FBI
Federal Bureau of Investigation

FCCSET
Federal Coordinating Council for Science, Engineering, and Technology

FEPG
Federal Engineering Planning Group, operational arm of the Federal Networking Council's Engineering and Operations Working Group

FIPS
Federal Information Processing Standard

FIX
Federal Internet eXchange

FNC
Federal Networking Council

FNCAC
Federal Networking Council Advisory Committee

GOSIP
Government Open Systems Interconnection Profile

HHS
Health and Human Services

HPC
High Performance Computing

HPCC
High Performance Computing and Communications

HPCCIT
High Performance Computing, Communications, and Information Technology subcommittee

IAB
Internet Architecture Board, an Internet group originally chartered by DARPA for the ARPANET

IEEE
Institute of Electrical and Electronics Engineers

Internet
the global set of interconnected computer networks of which NSFNET, ESnet, and NSI are components

IP
Internet Protocol

ISDN
Integrated Services Digital Network

ISO
International Standards Organization

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

NAP
Network Access Point, a set of nodes interconnecting NREN backbone networks

NASA
National Aeronautics and Space Administration

NCO
National Coordination Office for the High Performance Computing and Communications Program

NEARNET, SURANET, WESTNET
regional computer networks in New England, the Southeast, and Western parts of the U.S.

NIH
National Institutes of Health

NIST
National Institute of Standards and Technology

NOAA
National Oceanic and Atmospheric Administration

NREN
National Research and Education Network, consisting of the Interagency Interim NREN component and the Gigabit Research and Development component

NSA
National Security Agency

NSF
National Science Foundation

NSFNET
NSF Computer Network

NSI
NASA Science Internet

NTIA
National Telecommunications and Information Administration

OC-3
network transmission speed of 155 Mb/s

OC-12
network transmission speed of 622 Mb/s

OMB
Office of Management and Budget

OSI
Open Systems Interconnection, a protocol suite of the ISO

OSTP
Office of Science and Technology Policy

PMES
FCCSET Committee on Physical, Mathematical, and Engineering Sciences of the Office of Science and Technology Policy

PWG
Policy Working Group of the Federal Networking Council

RA
Routing Arbiter, entity that will be selected under new NSF Backbone cooperative agreements to stabilize the network

R&E
Research and Education

RFCs
Requests for Comments

RWG
Research Working Group of the Federal Networking Council

SMDS
Switched Multimegabit Data Service, a new networking technology being deployed by the telephone companies

SWG
Security Working Group of the Federal Networking Council

T1
network transmission of a DS1 formatted digital signal at a rate of 1.5 Mb/s

T3
network transmission of a DS3 formatted digital signal at a rate of 45 Mb/s

TCP/IP
Transmission Control Protocol/Internet Protocol, the communications protocols currently being used on the Internet

ToS
Type of Service

TWBnet
DARPA's Terrestrial Wideband Network

vBNS
very high speed Backbone Network Services

VPNs
Virtual Private Networks

WAIS
Wide Area Information Service

List of References

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