The Role of the National Science Foundation in Supporting Advanced Network Infrastructure: Views of the Research Community

American Association for the Advancement of Science

Research Competitiveness Program

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EXECUTIVE SUMMARY

During the first half of 1999, at the request of the National Science Foundation (NSF), the American Association for the Advancement of Science (AAAS) obtained input from the academic research community on the future role of NSF in supporting advanced network infrastructure. AAAS brought together 125 faculty, research administrators, graduate students, and postdocs in an initial workshop and a high-level review panel, reflecting a broad spectrum of research disciplines and universities. In addition, input was received from more than 20 other individuals in response to a draft report that was posted on the AAAS web site. This report represents a distillation of the ideas and views expressed by the participants and other contributors to the AAAS study.

Value of Network Infrastructure to Research

Advanced academic network infrastructure has become an enabling tool of great importance to researchers, providing mechanisms for support of collaborations spanning diverse disciplines and institutions and new applications such as collaboratories, remote instrumentation, and interactive distributed simulations. Future investments should build upon NSF's pioneering work in this area and should help to overcome limitations in today's academic networks that constrain the productivity of research.

Desirable Characteristics of an Advanced Network Infrastructure

The primary purpose of an advanced network infrastructure should be to support research, but support for education and academic outreach are also vital, since academic scholarship is inextricably linked to the other functions of the university. Participants described a number of specific characteristics of an infrastructure that they regard as desirable. These fall under three major headings: (a) performance and reliability; (b) ubiquity and ease of access; and (c) effective deployment.

Performance and reliability

- The network infrastructure should exhibit basic properties of **flexibility, reliability, stability and performance** while providing **ubiquitous access** to remote computational, archival, embedded and human resources.
- It should **support both those users who want reliability and those who would stretch its capabilities** in order to do research on the network itself.
- It should be able to **guarantee quality of service to users**.
- It should **provide an effective but minimally-intrusive security environment**, and well as tools for users to troubleshoot the network.
- It should fully **support multicasting technology**.

Ubiquity and ease of access

- The infrastructure should **extend to the desktop** of each researcher who could benefit from connectivity.
- It should be **transparent to users** and **access to resources should be seamless** across multiple platforms and providers.
- It should seek to **address problems of equity of access and the needs of smaller and more remote institutions** and should **incorporate wireless connections** where appropriate.

Effective Deployment

- Deployment should be **characterized by cooperation between the universities, federal agencies (led by NSF), and the private sector**.
- It should **involve more than one commercial provider**.
- It must **include education and training of users and development of applications**.
- It should be deployed in a manner that **supports education as well as research**.

Recommendations for NSF Support of Network Infrastructure Development

The role of NSF should be to provide standards, models, intellectual and financial resources, and incentives to encourage productive activity by other stakeholders in advanced network infrastructure development. Participants made five specific recommendations for NSF's Advanced Networking and Infrastructure Division (ANIR):

1. **NSF should take a consistent, long-term, strategic view** of investments in infrastructure development. This includes developing a **transitional plan** from the current vBNS program to its successor, and providing for **continuity and stability** in infrastructure innovation.

2. **NSF should work to facilitate deployment** of new infrastructure technologies and the **personnel necessary** for their operation, **balancing these investments** with those in other types of computational resources and other forms of research infrastructure. Its role should **include developing best practices and models for building intra-campus networks** for universities.

3. **NSF should support collaborative development of middleware and applications**, in order to extend the value of the new infrastructure**. Information retrieval and access** are areas of particular need. NSF **should facilitate interdisciplinary and inter-institutional collaborations** that use the network and it should bring users and developers together in forums and workshops.

4. **NSF should help promote equity of access** to the network infrastructure, **by seeking new and creative solutions to problems of access by rural and remote institutions** and by supporting programs of **outreach from research universities to smaller and undergraduate colleges**.

5. **NSF should work to optimize the performance** of the new network infrastructure, supporting the **development of quality of service differentiation and scheduling**, considering the establishment of a **virtual "network scheduling center**," and investigating ways to **reduce demands for bandwidth**.

<u>**Recommendations for Broader NSF Policy**</u>

In addition to the recommendations directed at ANIR, the study yielded a number of suggestions that relate to NSF more broadly. Specifically, NSF should:

1. **Balance investments in network infrastructure with basic research on networks**.

2. **Encourage collaboration** amongst its directorates and between NSF and other federal agencies in order to support the advanced networking needs of NSF-funded projects and other research.

3. **Foster the appropriate involvement of the private sector** in NSF-supported investments and **support the transfer of technology developed** under NSF support.

4. **Allow for the support of high-bandwidth network access as a budget line-item or as an indirect cost in research grant budgets**.

5. **Support the development of standards** for advanced network infrastructure.

6. **Address the need for qualified network professionals at universities.**

7. **Address intellectual property concerns** and issues surrounding the sharing of information

8. **Publicize the existence and capabilities of advanced network infrastructure** throughout the research community.

In sum, the National Science Foundation should take a leadership role in advancing the infrastructure, consonant with its mission. The support that it offers to universities; coupled with contributions from academic, industrial, nonprofit and other government partners, should help to create a national infrastructure that will allow the American scientific and engineering community to maintain its world leadership in the 21st Century.

ACKNOWLEDGEMENTS

Many individuals contributed to the conduct of this project and the preparation of this report. AAAS is grateful to the 100 faculty members, graduate students, postdocs, and administrators from 25 universities nationwide who took part in the February workshop; to the many visitors to the web site who contributed their thoughts and suggestions on the draft report during the public comment process; to the 25 vice-presidents for research and graduate deans who participated in the May review; and to the staff of the National Science Foundation's Advanced Networking Infrastructure and Research Division and our program officer, Bill Decker, for generous funding and support.

I. INTRODUCTION

A. Purpose of the Report

This report presents the results of a process developed by the American Association for the Advancement of Science (AAAS) to provide guidance to policy makers at the Advanced Networking Infrastructure Program of the National Science Foundation (NSF) as they plan the program's future investments. In addition, the report should prove a useful guide to other agencies and to university administrators as they consider their own investments in advanced research networks. Although the report focuses on research as a primary driver for an advanced academic network infrastructure, it also considers education and academic outreach applications which require such support, since the researchers that contribute to this project recognized that academic scholarship is inextricably linked to the other functions of the university.

The questions addressed by this report include:

- What is the value of an advanced academic research network infrastructure?
- What is the nature of the infrastructure that should be developed?
- What approaches should NSF consider to support the development and deployment of network infrastructure?
- What are the implications of the answers to these questions for broader NSF policy?

B. Background

Of the many types of infrastructure required to support cutting-edge academic research programs, perhaps the most rapidly evolving is that involving telecommunications and computing. Along with traditional forms of research infrastructure like appropriate instrumentation and suitable laboratory facilities, the wires, switches, routers and software that make up network infrastructure are now essential to the conduct of research.

As the existing Internet becomes ever more commercial and congested, the academic research community increasingly needs advanced networks that support both the development of new applications and the reliable performance of important existing tools. Advanced network infrastructure can be characterized as that which provides improvements over commercial Internet services in terms of any of the following:

- Higher traffic flow rates (bandwidth)
- Shorter waits between sending and receiving (latency)
- Guaranteed traffic flow rates for specific types of traffic (quality of service guarantees)
- Decreased loss of information in transmission
- Greater consistency of transmission (reduced jitter)
- The ability to efficiently transfer large amounts of information to multiple recipients (multicasting)

Advanced network infrastructure has many uses. Among them are providing access to and facilitating the use of computational resources (like remote supercomputers), archival resources (like digital libraries), embedded resources (like scientific instrumentation) and human resources (such as through videoconferencing and shared virtual environments).

From the early days of academic networking, American higher education has been able to supplement university investments with federal contributions. The National Science Foundation (NSF) has long supported the development of academic network infrastructure. In its organic act, NSF was given the authority "to foster and support the development and use of computer and other scientific and engineering methods and technologies, primarily for research and education in the sciences and engineering."[1] In support of this objective, NSF has played a significant role in improving the national technology infrastructure. Its support of leading-edge networked communications among researchers and educators dates to its sponsorship of the NSF-Net, precursor to the Internet.

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[1] The National Science Foundation Act, 42 U.S.C. 1862 (a) (4).

In recent years, NSF's interest and commitment have been expressed through a cooperative agreement with MCI to operate the Very High Performance Backbone Network Service (vBNS) and through the High Performance Connections Awards Program,[2] which provides funding for universities to establish a connection to the vBNS or a comparable high-performance network such as Abilene.[3] By the year 2000, the NSF High Performance Connection Awards Program is projected to reach as many as 150 institutions and operate at 2.4 gigabits per second. This program is intimately related to other initiatives originating in other federal agencies in the area of high performance networking and serves as a major component of the federal Next Generation Internet (NGI). The program has also served to facilitate an early, high-performance connection for some Internet-2 university members. The vBNS cooperative agreement is scheduled to end in the year 2000, and the future of the High Performance Connections Award program is not yet planned. Accordingly, NSF policy makers must soon decide whether and how to pursue the next stage of advanced network support.

Significant new resources for advanced network infrastructure may become available in FY 2000 from specific Congressional appropriations, as a part of the President's Information Technology for the Twenty First Century (IT-squared) initiative or through the Congressional Networking and Information Technology Research & Development Act (H.R. 2086). Within NSF, a major portion of these funds, should they become available, ought to be allocated to support advanced network infrastructure with broad application throughout science and engineering. Sound policy formulation requires that decision-makers consider the needs and perspectives of the communities that they serve. Academic researchers from a variety of disciplines and research administrators form one such community of primary stakeholders in this area.

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[2] See program announcement at www.nsf.gov/pubs/1998/nsf98102/nsf98102.txt

[3] www.nsf.gov/od/lpa/news/media/fs325.htm

C. NSF Process for Soliciting Policy Guidance

The Advanced Networking Infrastructure and Research (ANIR) division at the NSF has cast a broad net in order to solicit comments on future program directions from all of its stakeholders. At NSF's request, several organizations have organized events to solicit input from their constituents.[4] These include:

- EDUCAUSE - on behalf of academic network managers and chief information officers
- The Cross Industry Working Group - on behalf of private sector stakeholders
- The National Computational Science Alliance (NCSA) and the National Partnership for Advanced Computational Infrastructure (NPACI) - on behalf of their partners
- The Computing Research Association (CRA) - on behalf of computer scientists, network researchers and computer engineers
- The American Association for the Advancement of Science (AAAS) - on behalf of academic researchers and research administrators at all levels and in all departments

This report, therefore, speaks to the priorities of the AAAS research constituency, as collected and aggregated through the process described in the following section.

D. Methodology

The AAAS Research Competitiveness Program (RCP, part of the AAAS Directorate for Science & Policy Programs) implemented a three-step process in order to develop and refine input from as broad a cross-section of the academic research community as possible. An initial workshop developed the issues in the form of a draft report for review and comment by the general research community during a two-month web-based public comment period. The results of the workshop and comments from the web site were then edited by AAAS staff, and were provided to a panel of university research vice-presidents for further development and review.

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[4] The reports of these groups, along with other useful references, are listed in Appendix A.

1. The Workshop

On February 22 and 23, 1999, 100 representatives from 25 universities nationwide gathered at AAAS headquarters in Washington, DC, to develop an initial framework for policy guidance. We offered invitations to representatives from a variety of Carnegie Research I, Research II, Doctoral I and Doctoral II-class universities.[5] Each university delegation included the Vice-President for Research or his or her designee, a senior faculty member with experience as a principal investigator on NSF-funded grants, a faculty member who had not yet achieved tenure, and a graduate student or postdoctoral fellow. These four participants represented at least three different Ph.D.-granting departments at their schools. The meeting[6] began with presentations by several leading thinkers in the area of advanced networking infrastructure support to research and concluded with extensive working breakout and plenary sessions to develop the substance of the draft recommendations.

2. The Web Site

The policy agenda that resulted from this workshop was posted to the AAAS web site and opened for public comment from March 8, 1999 to May 15, 1999. Notices calling attention to the web site and soliciting comments were published in *Science* and in *The Chronicle of Higher Education*. During the period that it was active, four thousand seven hundred pages were downloaded from the web site and twenty-five detailed, substantive comments were received.

3. The Review Panel

On May 27, 1999, AAAS convened a meeting of 25 vice-presidents for research selected from research and doctoral institutions that did not participate in the initial workshop. Each participant was asked to read the full report and to review one chapter in detail in advance of the meeting. The vice presidents met in Leesburg, Virginia, where they reviewed and edited the framework developed at the

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[5] The schools participating in the initial workshop and the members of the final peer review panel are listed in Appendix B.

[6] The agenda for the February workshop is attached as Appendix C.

initial workshop, along with the comments received from the web site. Participants in this workshop were also given an opportunity to review a draft of the present report before its final submission to NSF.

Since this report reflects a distillation of the views of over 150 representatives from universities nationwide, it is necessarily a composite and cannot reflect the full range of views and ideas held by all participants. Rather, the AAAS staff has attempted to capture the richness of opinion and perspective expressed in the process, as refined by the review described above. As a result, the following chapters comprise a set of guidelines broadly representative of the research community within which NSF and others can work to develop specific policies for future advanced network infrastructure program development. It should be noted that the views and opinions here are those of the participants and AAAS staff and do not necessarily reflect the views of the AAAS Board or Council.

This report consists of four chapters in addition to this introduction. Chapter II describes the value of government support of advanced network infrastructure development to the U.S. research community. Chapter III presents the research community's vision of the characteristics of the advanced network that NSF should strive to realize. Chapter IV suggests ways in which NSF might approach support for advanced network infrastructure development. The final chapter discusses aspects of NSF infrastructure support that should be pursued within the broader institutional context, which includes the activities of universities, the private sector and other government agencies.

II. VALUE OF NETWORK INFRASTRUCTURE SUPPORT TO RESEARCH

A. Advanced academic network infrastructure has become an enabling tool of great importance to researchers.

The applications of academic networking span all scientific disciplines and allow researchers from around the nation and the world to share information, expertise and technological resources. Powerful global trends shaping the American research enterprise are changing the way that university researchers conduct their work. Increasingly, research problems are interdisciplinary and draw upon expertise that is not located in a single institution. Multi-institutional centers of excellence are becoming the norm for large projects. In the context of these centers, researchers are able to form multidisciplinary partnerships across several institutions and focus on complex problems that are beyond the capability of individual researchers to solve. In addition, it is now possible for researchers to operate extremely sophisticated pieces of equipment that are beyond the budgets of a single institution or researcher remotely, allowing for effective cost-sharing.

Many applications have been and could be developed that take advantage of advanced network infrastructure. Some examples include:

- **Collaboratories –** Researchers in multiple locations are sharing work and interacting in real time, through video, audio, shared whiteboards, and shared laboratory notebooks available to all collaborators online. This application can be applied in virtually any research field.

- **Telemedicine –** Remote diagnosis, therapy and even surgery have wide application in rural areas and in bringing specialist knowledge to bear on remote patients who do not readily have access to such care. Many demonstrations have been held and these applications are ripe for development and application in the near future.

- **Interactive distributed simulations –** Linking high-powered computational resources with remote users and other computers has applications in many fields including weather prediction and molecular modeling.

- **Distributed virtual reality –** Immersive environments can be used to support manufacturing, design and research among geographically distributed teams.

- **Remote instrumentation –** The ability to control of remote instruments and experiments in real time can be invaluable in any research field that uses large, expensive instruments or that depends on unusual field environments, from the bottom of the ocean to the surface of another planet. Instruments that can be accessed remotely include telescopes, Long Term Ecological Research (LTER) sites and future space-based laboratories.

- **Processing and visualization of large data sets –** Distributed computation can be used effectively in many areas, including high energy physics and climate modeling.

- **Distance learning –** These technologies are beginning to enhance education in every field and to make expertise available to populations who might not otherwise have access to it.

- **Video teleconferencing –** Transmission of video via high-speed, large-bandwidth connections has broad applicability and supports many other applications, including meetings among distributed research teams.

- **Access to interdisciplinary databases –** Information access tools are already being used in many areas including bioinformatics and environmental monitoring. Many new research applications have been proposed.

- **Field work –** Effective wireless connectivity to advanced networks could bring the resources of the home laboratory to researchers in many disciplines in the most remote field stations.

The U.S. research community has sufficient knowledge of and experience with early applications to recognize the enormous potential value of these network-based applications. Yet, we have taken only the first steps toward realizing that potential. The presence of advanced network infrastructure will provide a competitive advantage to those universities that are connected. It will accelerate the advance of research in these areas, as well as in many others. The critical need is to get advanced network resources into the hands of people who want to use them to empower their research.

B. Early NSF investments in advanced networking infrastructure have been invaluable and should be built upon.

The research community recognizes the invaluable leadership of NSF in its past and present support of networking. Thanks to the support of NSF, American research universities have remained at the leading edge during the recent growth of the Internet. Universities participating in the High Performance Connections Awards Program have received early access to the most powerful tools, while network developers have been provided with real-world applications to try out their systems. Continued support by NSF can help keep these universities at the forefront of network-supported research and also expand the capabilities of other research universities in the nation. An appropriate level of investment in network infrastructure is necessary to that end. In recent years, a high performance network backbone has been put in place. Now, there is need to extend the backbone network and to create a functional nationwide grid of accessible resources.

C. Weaknesses in the current networking infrastructure limit the productivity of research.

Several aspects of the current academic network stand in the way of its providing optimal support to research. Significant differences between the current environment and that ideal scenario include:

- Insufficient levels of access for many research universities,
- Outdated intra-campus network infrastructure in many places,
- Artificial barriers that impede the use of remote resources through advanced networks,
- Poor user-friendliness of network technologies and interfaces,
- Lack of appropriate security mechanisms, and
- Insufficient methods for assessing network problems.

III. DESIRABLE CHARACTERISTICS OF AN ADVANCED NETWORK INFRASTRUCTURE

The primary purpose of an advanced network infrastructure should be to support research, but support for education and academic outreach is also vital, since academic scholarship is inextricably linked to the other functions of the university. The new infrastructure should not just be another version of the current Internet, but should serve as a vehicle for innovation in support of research, teaching and outreach. The emphasis should be on scholarship, and investments should continue to benefit quality academic scholarship, including research and teaching. In science and engineering, as well as other disciplines, teaching and research are inseparable. New tools developed to improve research should be extended to all appropriate aspects of education.

Beyond this statement of purpose, participants described a number of the characteristics of an advanced network infrastructure that they feel are desirable from the perspective of the academic research community. These characteristics fall under three major headings: (a) performance and reliability; (b) ubiquity and ease of access; and (c) effective deployment.

A. Performance and reliability

1. The network infrastructure should exhibit basic properties of flexibility, reliability, stability and performance while providing ubiquitous access to remote computational, archival, embedded and human resources.

The ideal advanced network infrastructure would support a variety of applications, provide reliable and dependable connectivity and improve performance in the areas of bandwidth, latency, quality of service, loss, jitter and multicasting. Access points to the network would be as ubiquitous as electrical outlets and as easy to use. The network infrastructure would connect researchers and students to supercomputing power, vast libraries of stored information, remote instruments and facilities and to other researchers and students worldwide. It should be an overarching goal at the national level to minimize the obstacles to achieving connections among these resources.

2. The infrastructure should support both those users who want reliability and those who would stretch its capabilities in order to do research on the network itself.

The infrastructure should accommodate network developers' research into improving the network, as well as use by a broad range of other science and engineering researchers that depend on reliable service. There is need to be able to partition the network (either in reality or through software simulation) so that some researchers can stress it or do other experimentation without intruding on the operational side. To stimulate innovative research in advanced networking architectures, test beds and flexible, extensible environments will be required of various architectures. As advanced networks are developed, both experimental and reliable environments should be provided.

3. The infrastructure should be able to guarantee quality of service (QOS) to users.

For a number of reasons, advanced network applications can require predictable network performance. A major advance in meeting research and education needs would be the ability to provide such predictability to specific users when it is demanded. To address this current weakness in the infrastructure, technology should be developed and deployed to allow for prioritization of access to network resources, based upon the nature of the traffic or the willingness of the user to pay extra for a premium level of service. This so-called "quality of service" (QOS) guarantee would entail the ability to reserve or schedule network services (e.g. latency or bandwidth) for a specific application that demands those services that only advanced networks can provide.

While network bandwidth may always be scarce, QOS guarantees would allow, for example, the traffic controlling a remote telescope to take priority over routine e-mail. Since current users of networks must compete with all other users of the same network, both research and commercial, implementation of QOS guarantees in the advanced network infrastructure would allow for broader usage while continuing to sustain core applications. A user needs to be able to say, "I want to do this, and I will need this kind of response to be guaranteed for this long." Even better, the system should recognize what resources are needed by specific applications and provide them without a specific request from the user.

Differentiation of classes of service would be a good step in this direction. While not as powerful as full QOS guarantees, by grouping applications or users in broad types, a network would be able meet on-demand real-time requirements while continuing to support "mass media" (e.g., e-mail) needs. In developing and implementing QOS improvements, consideration should be given to allocation of costs and equitable scheduling. Should research users pay more to guarantee their higher class of service? Should heavy users pay more than light users? At the other end of the spectrum, perhaps some classes of service could be free but degrade if the load is high. More research is needed to address these questions.

4. There is a need for the development of an effective security environment that is both minimally intrusive to users and capable of protecting sensitive systems from unauthorized access.

Security has become a critical problem. Networks make it possible to hop from site to site, while remaining anonymous or pseudonomyous. Hacking incidents are doubling every couple of months. There is a need for a uniform security model and standards that are minimally restrictive of authorized users and that do not require the users to learn the details of how the security is achieved. The security system should not be allowed to impede research. There is a need for research and middleware development to achieve these ends. Common standards for different security systems and greater inter-operability should be supported. Better monitoring and surveillance of security is required. Related to this, authentication and verification of information is also important. There should be reliable methods to determine the authenticity and accuracy of network-accessible or network-submitted data.

5. Users should have access to new tools for troubleshooting the network.

Many users reportedly abandon multimedia or cross-disciplinary projects because nobody can tell them what's wrong when a problem occurs. If there is a problem with the network, it is difficult for an end-user to find out where the blockages are. There is a need for easily accessible (e.g., on the web) information on the quality of service available that indicates the state of networks and provides for accountability in the event of failures. A Master's Degree in Networking and Systems Administration is currently required to effectively utilize existing diagnostic tools that explain what's wrong when performance is poor or non-existent. This situation should be rectified. Research into network metrics, including monitoring requirements is needed.

6. The network should fully support multicasting technology.

Multicasting allows for the efficient simultaneous transmission of similar messages to many remote users. This technology could be instrumental in supporting a wide variety of applications, ranging from collaboratories to distance education. Existing multicasting technology can be very hard to use, particularly for novices. Sometimes problems occur when interconnecting a network that supports multicasting with others that do not. There is a need to address the entire range of issues that inhibit multicasting.

B. Ubiquity and Ease of Access

1. The infrastructure should extend to the desktop of each researcher who could benefit from its connectivity.

The so-called "last level" problem is keeping many from using the network. Much has been said about solving the "last mile" problem of getting the network to the campus, but less attention has been paid to getting network connections from the campus point of presence to researchers' desktops. The backbone is useless without campus connectivity.

Solving the last mile problem serves no useful purpose if universities are unwilling or unable to solve the "last inch" problem. Many campuses do not have centralized support of campus-area networks, leaving their design and operation to individual departments. More coordination is called for within each such university. Sometimes there is a lack of understanding among administrators of the need to invest in intangible, expensive network infrastructure. Nevertheless, it is imperative for schools to allocate the resources to bring advanced networks to the desktops of researchers.

2. Access to resources through the networking infrastructure should be seamless across multiple platforms and providers.

Current networks are often made of many sub-nets that are not necessarily well integrated. In the future, high speed, seamless movement of data and access to resources across the network will be needed to enable science to advance in many areas. This service should resemble today's electric utility service where most consumers need not know nor care whether electricity is produced by burning coal or by hydroelectric energy. It will be important to avoid interface problems between providers, as has occurred with previous advanced networks. Without compatible standards and efficient interconnections, service to the end-user can be severely degraded.

Cooperation and coordination of efforts will help to assure seamless interconnections between the networks of various providers. Seamless access depends upon agreement on standards and enforcement of these agreements. Policy and regulatory coordination should parallel development of the technical resources in order to provide the best environment for development and deployment of needed infrastructure technologies.

3. For most users, the infrastructure should be transparent.

The Internet did not move out of academic circles until web protocols and browsers made it easy to use. High-performance networking will not move widely, even into the academic community, until its usability is improved significantly. High-performance end-user networking tools with straightforward user interfaces should be developed. Access to tools and services should be made transparent and as simple as possible, except for those engaged in network research and experimentation. In most cases, users should not need to know or care what is happening to support their network connection. On the other hand, if researchers want to know what supports their network infrastructure, it should be relatively easy to find out.

4. The infrastructure should seek to address problems of equity of access and the needs of smaller, more remote institutions.

Academic institutions that are not connected to the advanced network infrastructure will be severely disadvantaged. If an institution is connected, the faculty and students will have access to all of the electronic resources available at large research universities. There are two primary dimensions to the question of equity of access: institutional size and geography. While smaller institutions will not have the breadth of major research universities, they can have world-class programs in focused areas. Without connectivity, maintaining such centers of excellence becomes difficult, if not impossible. Ultimately, all colleges and universities will need access to advanced networks. Getting them all connected provides a large and expensive challenge to which the solution is yet unclear.

Geographical equity is an issue that must be addressed. One of the unique characteristics of the Internet is that it can make distance irrelevant. The ideal implementation of advanced network infrastructure allows collaboration with colleagues around the world regardless of their physical distance. Nonetheless, there are significant initial advantages of proximity to a network point of presence. While the backbone connectivity cost is similar for all institutions, the individual connection costs vary, by an order of magnitude or more. The cost of extending telecommunications connections to remote locations is currently much higher than that required for connection in urban centers near a network point-of-presence. This could lead to a caste system that will be very difficult for rural schools to overcome.

Since the cost of access to high-performance network infrastructure depends on geographic factors, attention should be paid to how geographically disadvantaged rural institutions can achieve appropriate access. Research and development in search of lower cost connectivity is one path to pursue. Meanwhile, there is a need to develop an equitable and rational scheme for the distribution of network and network-connected infrastructure resources. Of particular concern is the fact that many of these disadvantaged institutions are situated in EPSCoR states, where restricted access can only compound their existing obstacles to research competitiveness.

5. Wireless resources should be considered as a part of the networking infrastructure.
Conventional definitions of networking infrastructure focus on fiber optic and other cables as vehicles for information transfer. Where appropriate, the advanced networking infrastructure should incorporate wireless connections. Wireless allows for much more flexibility in certain applications; for example, in communications with remote research field stations and in allowing ubiquitous access to data. The full extent to which wireless devices can replace or enhance physically connected devices is not yet clear, but these devices should be considered where appropriate.

C. Effective deployment

1. Deployment of the advanced network infrastructure should be characterized by cooperation between the universities, the federal agencies (led by NSF), and the private sector.

As in the past, it is likely that the products of academic infrastructure investments will eventually make their way to the private sector. As in past efforts to advance network infrastructure, NSF should partner to provide support for academic research. NSF can most effectively serve as a catalyst encouraging cooperation and common purpose. Universities must contribute a fair share of the expense for advanced network connectivity and should be primarily responsible for intra-campus infrastructure. Federal agencies, led by NSF, should cooperate to maximize the effectiveness of their investments, and the private sector should contribute in-kind technologies and work cooperatively to develop academic infrastructure as a test bed and prototype. In addition to financial resources, each partner should make contributions to the planning, management and maintenance of the infrastructure.

2. Deployment should involve more than one commercial provider.

NSF should value industry co-sponsorship but beware of limiting institutions to a single funding model. By providing incentives, NSF should help to ensure that the community can select from whichever providers are most appropriate to individual needs. The success of UCAID in fielding the Abilene network confirms the wisdom of this approach, and NSF has responded positively by allowing High Performance Connection Award grants to be used for connection to either the vBNS or to Abilene. The fact that backbone costs are now considerably less of a problem than local loop access costs for universities in non-urban areas further supports this approach. Contracting with a single vendor for the backbone was a good for the inception of the Internet, however, its further development depends on the establishment of highly competitive, affordable services from a wide range of commercial service providers.

3. The education and training of users and the development of applications must be seen as important aspects of infrastructure deployment.

A network infrastructure must interact with a variety of knowledge communities to which it provides support. As high speed computing network infrastructure matures, it will be wise to direct the attention of system developers beyond issues of access to include issues of application, utility and usability.

Improved user interfaces and better user/network interfaces are critical. Researchers and teachers need user interfaces that are designed specifically to empower users who are not computer-literate.   Highly usable and transparent applications should be supported and encouraged, so that the average researcher can take advantage of the network infrastructure. Improving this situation may require significant middleware improvements.

It will be important to promote awareness of and training in high speed networking across all disciplines. Knowing how to use systems is important, and can be accomplished through education, training and customer support. New tools evoke new applications. Development of new and effective uses of the emerging network infrastructure requires increased collaboration among those who employ the new technology and between users and developers. All of this requires sensitivity to cultural obstacles to changes on the part of users.

4. The infrastructure should be deployed in a manner that supports the involvement of smaller colleges and universities and education as well as research.

It is important to recognize that high-performance networks are not just a vehicle for researchers at leading-edge research institutions. There is a need to reduce administrative barriers to access to the high speed computing network by researchers with appropriate applications who work outside the major research centers. Bandwidth should be allocated to support many users with lesser needs or for shorter times. It is helpful to encourage elite institutions to collaborate with smaller schools and encourage outreach to potential new communities of network users. The potential for advanced network-supported applications to make large contributions to science and mathematics education at all levels has been demonstrated and is likely to continue to grow.

IV. RECOMMENDATIONS FOR NSF SUPPORT OF NETWORK INFRASTRUCTURE DEVELOPMENT

Overall, participants in the AAAS project agreed that the role of NSF should be to provide standards, models, intellectual and financial resources, and incentives to encourage productive activity by other stakeholders in advanced network infrastructure development. Attention should be paid to the proper balance between demonstration projects and recurring investments in infrastructure. In any case, the support for broadly applicable advanced network infrastructure should not take a back seat to the development of software, high performance computing and other computer and information science research. Policy recommendations addressed to ANIR fell into several categories: (a) taking a consistent, long-term, strategic view of investments; (b) supporting collaborative development of middleware and applications; (c) facilitating deployment of the infrastructure; (d) promoting equity of access; and (e) optimizing the structure of new network infrastructure. Implications for broader NSF policy are discussed in Section V.

A. NSF should take a consistent, long-term, strategic view of investments in infrastructure development.

1. Develop a transitional plan from the vBNS to whatever comes next.

The NSF ANIR program shares responsibility for supporting development of an advanced academic network infrastructure and helping to reach the goals laid out in the previous section. Although NSF cannot and will not provide all of the resources to develop and implement the required infrastructure, it should formulate a long-term plan to provide for continuity of this infrastructure after its support for the vBNS comes to an end. Strategic intervention will be necessary to assure continued development of an effective infrastructure. In general, NSF's role should be catalytic – i.e., it should make possible university participation and further investments. Where the private sector or others (like the Abilene network) can provide necessary services, NSF should work to facilitate a smooth transition from NSF-supported to non-NSF supported networks. It is the underlying responsibility of NSF to assist in the development of an infrastructure that is of maximum value to the advancement of science and engineering through research and education.

2. Take a long-term view of network infrastructure needs.

NSF's planning should provide for continuity and stability in infrastructure innovation. Changes in the environment supporting advanced network infrastructure should be incremental rather than radical.

From this standpoint, the duration of the cooperative agreement supporting the vBNS was too short. Many institutions have just become connected to it and it is already coming to an end.

The nation's advanced network infrastructure is in a relatively early stage of development and is not yet well positioned to move into an open commercial environment. Researchers need time and experience with the emerging infrastructure to become familiar with the new resource at their disposal and to begin applying its full potential. Many of the most exciting problems will require a substantial amount of time to solve in an evolutionary manner. For many universities, it has been only two years since they have begun to participate in the High Performance Connections Awards program. Initial payoffs, in terms of applications and technologies, have just begun to be realized at these institutions. So-called "killer applications," which provide large payoffs from the infrastructure investment, do not emerge overnight. NSF supported the Internet for eight years before the World Wide Web took shape. The equivalent "killer application" for advanced networks has yet to develop.

B. NSF should take steps to facilitate deployment of the new infrastructure.

1. Investments in networking infrastructure must be balanced with those in other types of computational resources and in other forms of research infrastructure

While development and deployment of advanced network infrastructure should be a high priority for NSF, other computing resources should not be overlooked. For example, NSF should take care not to neglect the maintenance and development of the nation's supercomputing centers while developing new network infrastructure. Without large computing resources, many fields of research could suffer. Also, the presence of local access to supercomputing can reduce the demand for network access. Given limited resources, some universities may be forced to choose between supporting powerful computers or supporting powerful networks. In such instances NSF might provide assistance by funding evaluations of the relative merits of each approach.

New infrastructure technologies impose new and significant cost and management burdens on the universities that adopt them. There is comparatively little understanding of the benefits of investing in network infrastructure relative to other infrastructure investments such as instrumentation, computers or buildings. Research and analysis are needed into how the development of new infrastructures can support the process of innovation. It may be helpful to undertake studies of the costs and benefits of participation in high speed networking, especially for small, sporadic and new users.

2. Develop best practices and models for the building of intra-campus network infrastructure

NSF should play a leadership role in providing support to universities as they plan, fund and implement advanced intra-campus network infrastructure that extends connectivity to the academic end-user. NSF should identify and disseminate best practices in institutional planning for network construction and operations. NSF should fund, perhaps as demonstration grants, the development of models and examples of effective approaches that campuses can use to get high-performance networks to the desktops of their researchers. Future NSF grants that address network connectivity should gather information on how network services are being provided on campus. NSF should promote the strategic campus-wide implementation of advanced networking infrastructure in order to help achieve consistent performance throughout each university. In certain cases, it may be effective to use highly leveraged catalytic grants to encourage universities to address the "last level" problem and provide their researchers with access to advanced network services.

3. Support personnel costs

The costs of developing infrastructure involve more than just purchasing equipment and bandwidth. Research universities incur major personnel costs in establishing and maintaining a new network infrastructure. NSF should not neglect the need for management and technical support personnel assuring the utility of the infrastructure. Especially in this area, however, NSF should focus on catalytic investments that can later be assumed by universities. It is *not*, however, recommended that NSF commit to the ongoing staffing of universities' information systems offices outside of normal funding mechanisms.

4. Consider the role of statewide and regional network centers in aggregating buying power and providing services

Establishing or strengthening regional aggregations of institutions connecting to the backbone through a regional aggregation point (or gigaPOP) may be an efficient use of NSF funds. NSF should consider supporting regional networks and centers to extend the gigaPOP concept. Savings resulting from volume purchases of network services are a potential advantage of this model, helping to increase the buying power of institutions. In addition to the provision of network access, these centers could coordinate training and regional collaborations. They could support outreach and benefit both the large research institutions and the smaller colleges in the state or region. In the future, the role of these centers might include scheduling of network resources. In providing support to regional centers and gigaPOPs, NSF should take care to avoid competing with the private sector and inadvertently perpetuating inefficient models of academic network management.

C. NSF should support collaborative development of middleware and applications

1. Extend the value of the new infrastructure

While continuing to support expanded access to advanced networks, NSF, along with its academic and industrial partners, should also support development of creative applications of the new infrastructure that utilize it and extend its value. Research directed at enhancing the network, at developing educational applications of the network, and at developing network applications in support of research are specific priorities. NSF should consider the use of SGER grants for high-risk proposals involving applications or extensions of infrastructure technologies.

2. Support research on information retrieval and access

One area of particular promise is that of digital libraries containing information on a wide variety of topics. In order for this promise to be fulfilled, effective search tools across distributed resources must be available. One of the major frustrations with the current Internet is that finding desired information can be very inefficient and time consuming. Functionality of advanced network infrastructure could be enhanced with a built-in distributed dynamic information index. While such tools have broad applicability, their development would be of particular value to the research community. NSF should help to stimulate their development.

3. Facilitate interdisciplinary and inter-institutional collaborations

As it is always looking to support the best science, NSF should design research programs and projects that facilitate interdisciplinary and inter-institutional collaborations that make use and promote development of advanced network infrastructure. Such programs and projects should involve faculty and students in collaborative research. The development of user-friendly technologies to promote collaboration, such as interoperable middleware connecting campuses, should also be supported. As a part of this effort, NSF should fund research into understanding how people do research, as well as how they learn and work together at a distance using network tools.

4. Bring together users and network developers in forums and workshops

There is a need to evolve beyond the mentality of "if you build it, they will come," to a mindset of empowering researchers with the tools that they need to produce results. Computer science and engineering researchers who are developing advanced network tools and services must make their discoveries and inventions broadly available to other researchers and engage potential users in the development process. While the development of effective technologies requires interaction between developers and users at every stage of the process, there is often a communication problem between users and developers. NSF should fund work that brings together application designers and network designers with research users for their mutual benefit.

D. NSF should help promote equity of access to the network infrastructure

1. Work creatively to solve problems of geographic equity and access by rural and remote institutions

In its organic act, NSF is charged to "avoid the undue concentration" of resources related to science and engineering in specific parts of the country. In keeping with this goal, NSF maintains an Experimental Program to Stimulate Competitive Research (EPSCoR). Under this program, 18 states and the Commonwealth of Puerto Rico are eligible for targeted assistance to academic institutions to raise their level of research competitiveness. In collaboration with the EPSCoR staff, ANIR should examine creative ways to assist these schools in obtaining access to the advanced network infrastructure. Lessons learned from EPSCoR might also be applied in assisting universities in remote locations in non-EPSCoR states enhance their connectivity.

2. Support programs of outreach from research universities to smaller and primarily undergraduate colleges

NSF should provide incentives to research universities to link their network-based research and education efforts with smaller and primarily undergraduate colleges. There should be appropriate levels of access allowed for secondary schools, community colleges and the like, working in collaboration with universities.

E. NSF should work to optimize the structure of the new network infrastructure

1. Support the development of quality of service differentiation and scheduling through sponsorship of research on these topics

NSF should provide leadership and resources to develop a means for guaranteeing quality of service (QOS) for applications and users and to develop new technologies that can provide for sufficient access on demand. It should also work to promote rapid deployment of effective approaches and harmonization of standards in implementing QOS guarantees. Disciplinary societies and groups like the Internet Engineering Working Group could assist in developing standards and models in this area.

2. Consider establishment of a virtual "network scheduling center" to schedule network resources

Currently, collaborative efforts that employ network resources at more than routine levels typically require getting permissions from multiple sources. For example, if a researcher wants to use a computer, an electron microscope and the network, he or she may have to get permission from three separate allocation committees. In order to facilitate coordination of reservations in a central location, NSF should consider the establishment of a virtual network scheduling center where researchers could schedule network resources the way that computing centers schedule computing resources. The center could either be operated directly by NSF or by a contractor. It should accommodate both advance requests and those that require immediate access to network resources.

Once QOS guarantees become widely available, this resource could be accessible from the Web and might function along the lines of the DOE ESNet model, which allows for bandwidth to be reserved for conferencing. The center should be integrated with reservation systems for other computational resources and instrumentation, so as to provide "one-stop shopping." Since many of the facilities that researchers might use would not be NSF-supported, implementation of such a center would require significant inter-agency cooperation. Ideally, researchers would only have to write only one proposal, instead of petitioning multiple allocation committees to accomplish a single task. This service might function like a travel agent who can provide a hotel, a plane and a rental car with a single call.

3. Consider ways of reducing demands for bandwidth

While avoiding direct competition with private sector efforts, NSF should provide support for investigations of the better use of bandwidth. It should fund work to develop and refine mechanisms (e.g., data compression, mirror sites, caching) that will reduce bandwidth requirements on networks, both high performance and commodity. In addition, it should fund deployment of those mechanisms that prove successful into the advanced network infrastructure.

V. RECOMMENDATIONS FOR BROADER NSF POLICY

In addition to those recommendations directed to ANIR, the deliberations among participants in the AAAS project yielded a number of suggestions that transcend the direct support of network infrastructure and relate to NSF more generally.

A. Balance investments in network infrastructure with basic research on networks.

NSF should continue to invest in infrastructure that enhances American research competitiveness. It is essential to have stable federal investment at the high end of civilian networking infrastructure in order to provide necessary resources to U.S. researchers. The overwhelming success of American research depends, in large measure, on academic access to the most modern infrastructure. At the same time, NSF needs to fund research to develop tomorrow's network technology. Network R&D is still a fairly new and immature field, but one with broad potential value.

B. Encourage collaboration amongst directorates at NSF and between NSF and other federal agencies.

NSF should strive for inter-directorate and inter-agency cooperation in order to support the advanced networking needs of NSF funded projects. Increasingly, computational models provide the conceptual framework upon which experimental work in science and engineering is based. For this reason, the approach of NSF should be team-based and should function efficiently across directorates. NSF should not expect to fund all, or even most, computational research entirely from the budget of one directorate or even entirely with NSF funds. Rather, the Foundation should adopt a strategy that provides for cross-directorate and interagency initiatives.

Within NSF, a single office should be empowered to lead the Foundation's work in advanced network infrastructure and its applications. A logical candidate for this role is the Advanced Networking Infrastructure and Research (ANIR) Program. ANIR should involve the scientific directorates in advancing the state and use of the network infrastructure through a series of joint programs to support the reciprocal advance of the sciences and the supporting technology. There should be a concerted effort by all divisions within NSF to work actively with ANIR on collaborative funding efforts. NSF should also sponsor and convene an inter-agency forum to deal with overall network solutions including security, avoiding the placement of artificial obstacles and improving cooperation in the support and use of large shared resources (like the networks and large instrumentation). Emphasis should be placed on bringing in other research-intensive agencies, like the National Institutes of Health and the Department of Energy, to participate in the forum. NSF should allocate appropriate staff resources to oversee this effort.

C. Foster the appropriate involvement of the private sector in NSF-supported investments and support the transfer of technologies developed under NSF support.

The Internet reflects one of the most effective transfers of technology ever. Much of the early development of the Internet was financed by NSF and carried out at universities. From this seed, the net has grown into today's primary communications backbone of commerce. Advanced networks will have similar impacts on society. In advanced networks, as in other areas, the private sector has the important dual role of applying the discoveries of academic research and of supporting academic research through the provision of goods and services. NSF should provide leadership and seed money to encourage and influence industry participation in advanced networking experiments and models. To leverage federal funds, the Foundation should develop programmatic mechanisms that foster research partnerships among academic institutions, state governments and private sector organizations. NSF should also attend to transitions of new infrastructure technology from research to development and commercialization, even if it is not directly involved in the latter. It should work with all stakeholders to achieve smooth transitions. The goal should be to promote the adoption by industry of solutions to critical networking problems into their products.   Potential beneficiaries of NSF-supported research include vendors of operation system software, router/networking software, and applications software.

Academic-industrial cooperative projects like the Internet2 are becoming quite effective at lowering the cost of bandwidth. It is important to provide incentives and rewards for such change. An example of a productive partnership is the agreement between UCAID, as a representative of the Internet2 community, and Qwest, as a provider of fiber. The result has been a pricing structure related to cost rather than to how many telephone calls might be carried. Working with the FCC and Congress, NSF should work to make such agreements possible as the national regulatory environment evolves.

D. Allow for the support of high-bandwidth network access as a budget line-item or an indirect cost in research grant budgets.

Increasingly, elements of the advanced network connectivity needed by universities are available for sale from commercial providers. Still, there remains an issue of how to fund the needed infrastructure. It does not seem reasonable that universities should have to use their general institutional funds for research applications. NSF should consider the modes by which universities recover the costs of advanced networking. Universities should be given maximum flexibility to support the emerging research infrastructure through cost recovery. NSF should both allow proposal budget line items that specify advanced network connection support (as it does with computing support) and, working with the Office of Management and Budget (OMB), it should make the costs of commodity networking an allowable part of a university's indirect cost recovery. The funding and operation of advanced network infrastructure should be reimbursable in the same manner as other forms of essential research infrastructure.

E. Support the development of standards for advanced network infrastructure.

The development of the Internet was greatly enhanced by the evolution of a set of *de facto* standards among the commercial providers. The current high performance network requires some similar form of broad-based oversight to coordinate infrastructure development occurring in academia, in the private sector and elsewhere. This is a critical role for NSF or a group, such as the Internet Engineering Working Group, working closely with NSF. Standards have been key to all major advances in computing and networking.

F. Address the need for qualified network professionals at universities.

Even as new advanced network technologies develop, there is a scarcity of qualified network engineers, system managers and support personnel who have sound knowledge in these areas. Competition between academic institutions and the private sector for qualified people has led to many institutions being unable to hire needed professionals. Universities, federal agencies (including NSF) and the private sector have important roles in developing the needed human resources. NSF should stimulate innovative programs for training and educating users, operators and managers of advanced networking. The NSF Directorate for Education and Human Resources (EHR) could apply its expertise in human resource development to this area. As a specific example of a targeted long-term investment in human resources, NSF should consider grants for entrepreneurial uses of the new network infrastructure by young researchers in any discipline.

G. Address intellectual property concerns and issues surrounding the sharing of information.

In order to streamline the process of network building, attention should be paid to issues of intellectual property ownership, proprietary issues, financial compensation and rules for sharing of information. In networked resources, as in other academic realms, it will be important to balance the tension between these issues and the value of open sharing of information. Tools should be developed to assist researchers in the management of proprietary data and commercial services encountered as part of research which, through networks, become widely accessible.

H. Publicize the existence and capabilities of advanced network infrastructure throughout the research community.

Since the advanced network infrastructure has both great potential and entails great expense, it is important to maximize its reach and value. More individuals at universities and at federal research agencies should be informed of the enhancements that this infrastructure could bring to their research programs. Efforts should be made to circulate information about the types of applications that can benefit from advanced network infrastructure and, by so doing, to encourage the development of applications by the academic and private sectors.

VI. CONCLUSION

Providing and sustaining an advanced network infrastructure that can support research, education, and outreach throughout the breadth of science and engineering should be a major national priority. The infrastructure should efficiently, flexibly and reliably provide access to a variety of resources that can support research and education in many disciplines. The National Science Foundation should take a leadership role in advancing the infrastructure, consonant with its mission. The support that it offers to universities; coupled with contributions from academic, industrial, nonprofit and other government partners, should help to create a national infrastructure that will allow the American scientific and engineering community to maintain its world leadership in the 21^{st} Century.

Appendix A

Related Publications and Information Sources

"Report of the President's Information Technology Advisory Committee"
<www.ccic.gov/ac/report/>

"Report from the EDUCAUSE Post-vBNS Forum"
<www.educause.edu/netatedu/contents/reports/postvbnsrec981116.html>

Computing Research Association, "Recommendations for Building Networking Infrastructure for Research"
<www.npaci.edu/post-vBNS/CRA/report.html>

Partnerships for Advanced Computational Infrastructure, "Recommendations for an Advanced Research Infrastructure Supporting the Computational Science Community"
<www.npaci.edu/post-vBNS/PACI/report.html>

AAAS/EPSCoR Conference, "National Policy Guidelines for Advanced Networking to Support the Mission of American Universities in the 21st Century"
<www.aaas.org/Presidents>

National Computational Science Alliance, "What, Exactly, is the Grid?"
<access.ncsa.uiuc.edu/CoverStories/WhatisGrid>

Office of Inspector General, National Science Foundation, "Review of NSFNet"
<www.nsf.gov/pubs/stis1993/oig9301/oig9301.txt>

House Science Committee, "Unlocking Our Future: Toward a New National Science Policy"
<www.house.gov/science/science_policy_report.htm>

AAAS Directorate for Science & Policy Programs, "AAAS R&D Budget and Policy Program"
< www.aaas.org/spp/R&D>

Appendix B

Universities Participating in Workshop and Forum

"National Workshop on Developing Guidance for NSF Advanced Networking Infrastructure Support"

February 22-23, 1999

AAAS Headquarters, Washington, DC

- Bowling Green State University
- George Mason University
- Iowa State University
- Louisiana State University
- Ohio University
- Oregon State University
- Southern Illinois University - Carbondale
- SUNY-Albany
- SUNY - Buffalo
- Texas A&M University
- University of Alabama-Birmingham
- University of Arkansas-Fayetteville
- University of California - San Diego
- University of Cincinnati
- University of Florida
- University of Illinois - Chicago
- University of Iowa
- University of Kansas
- University of Massachusetts - Amherst
- University of Missouri - St. Louis
- University of Oklahoma
- University of Pittsburgh
- University of Texas - Austin
- University of Utah

AAAS Review Panel on Network Infrastructure Policy Guidance to NSF

May 27, 1999

Carradoc Hall, Leesburg, VA

List of Participants

- Richard C. Alkire, Vice Chancellor for Research and Dean of the Graduate College, University of Illinois - Urbana / Champaign
- Robert Altenkirch, Vice President for Research, Mississippi State University
- Lloyd Armstrong, Jr., Provost and Senior Vice President, Academic Affairs, University of Southern California
- Gene D. Block, Vice President for Research and Public Service, University of Virginia
- Theodore J. Cicero, Vice Chancellor for Research, Washington University
- Costel Denson, Vice Provost for Research, University of Delaware
- William A. Gern, Vice President for Research, University of Wyoming
- Manuel Gomez, Vice President for Research, University of Puerto Rico
- Priscilla C. Grew, Vice Chancellor for Research, University of Nebraska – Lincoln
- Gary L. Harris, Interim Associate Vice President for Research, Howard University
- Mi Ja Kim, Vice Chancellor for Research and Dean of the Graduate College, University of Illinois - Chicago
- Charles H. Kruger, Vice Provost and Dean of Research and Graduate Policy, Stanford University
- Donald Lehman, Vice President for Academic Affairs, George Washington University
- Dennis Liotta, Vice President for Research, Emory University
- Carol Lynch, Associate Vice Chancellor for Research and Dean of the Graduate School, University of Colorado at Boulder

- Richard Magee, Associate Provost for Research, New Jersey Institute of Technology
- Thomas J. McCoy, Vice President for Research, Creative Activities and Technology Transfer, Montana State University

- James Merz, Vice President for Graduate Studies and Research, University of Notre Dame

- Theodore O. Poehler, Vice Provost for Research, Johns Hopkins University

- Y. T. Shah, Senior Vice Provost & Research Officer, Clemson University

- Allen R. Soltow, Executive Director of Research, Sponsored Programs, and Governmental Relations, University of Tulsa

- William R. Tash, Vice Provost for Research, Temple University

- Arthur Vailas, Vice Chancellor and Vice President for Research and Intellectual Property Management, University of Houston

- John Weete, Associate Provost for Research, West Virginia University

- Jack Wilson, Acting Provost and Dean of the Undergraduate School, Rensselaer Polytechnic Institute

Appendix C

National Workshop on Developing Guidance for NSF Advanced Networking Infrastructure Support

Final Agenda

Monday, February 22, 1999

7:30 - 8:30 am - Registration and continental breakfast

8:30 - 8:35 - Welcome - Al Teich, AAAS

8:35 - 8:50 - Goals for the workshop - Bill Decker, NSF

8:50 - 9:00 – CISE Directorate welcome and introduction of Keynote Speaker - Ruzena Bajcsy, NSF

9:00 - 9:30 - Keynote: Research and advanced networking infrastructure - Rita Colwell, NSF

9:30 -10:00 - History of NSF Support for high performance networking - George Strawn, NSF

10:00 - 10:15 - Break

10:15 - 11:00 - Panel #1 - The evolving environment for academic research and education

Gary Minden - University of Kansas

Bob Samors - University of Michigan

Joe Thompson - Mississippi State

11:00 - 11:45 - Panel #2 - Infrastructure to support the research and education environment

Mark Luker, Educause

Tom De Fanti, STARTAP, UIC

Ian Foster, NCSA

11:45 - 12:30 - Discussion with Panels # 1 and 2

12:30 - 1:15 - Lunch

1:15 - 1:30 - Discussion of Breakout Process - Scott Hauger, AAAS

1:30 - 3:30 - Breakout Discussion #1 – Identifying the Nature of and Needs for a National Research and Education Infrastructure

Breakout Assignments:

- **Vice-Presidents for Research** - AAAS Facilitator: Scott Hauger
- **Senior Faculty** - AAAS Facilitator: Robert Rich
- **Non-Tenured Faculty** - AAAS Facilitator: Ed Derrick
- **Graduate Students / Postdocs** - AAAS Facilitator: Sanyin Siang

3:30 - 4:00 - Break

4:00 - 4:45 - Panel #3 - Proposals for Developing Research Infrastructure

Dan Van Belleghem, NCSA

Micah Beck, University of Tennessee, Knoxville

Dave Staudt, EDUCAUSE

4:45 - 5:30 - Plenary Discussion with Panel # 3

5:30 - 6:30 - Reception

6:30 - 8:00 - Dinner and Speaker: Tom Kalil, National Economic Council

Tuesday, February 23, 1999

7:30 - 8:30 am - Continental breakfast

8:30 - 10:30 - Breakout Discussion # 2 - Models for Developing a National Research and Education Infrastructure: Possible Roles for NSF Support

10:30 - 11:00 - Break

11:00 - 11:45 - Group Reports

11:45 - 12:45 - Plenary Discussion on Approaches to Advanced Networking Infrastructure Support (Chair: Al Teich, AAAS)

12:45 - 1:00 - Summary and Next Steps

1:00 pm - Adjournment