NEXT GENERATION INTERNET INITIATIVE

CONCEPT PAPER

July 1997

Note: On October 10, 1996, President Clinton and Vice President Gore announced their commitment to the Next Generation Internet (NGI) Initiative, based upon strong research and development programs across Federal agencies. The Large Scale Networking Working Group of the Computing, Information, and Communications R&D Subcommittee has drafted a paper that outlines the concepts and goals of the NGI initiative as part of the process for building the strongest possible program among academia, industry, and the Government.

This version incorporates the comments received from the Presidential Advisory Committee on High Performance Computing and Communications, Information Technology, and the Next Generation Internet; Members of Congress and their staff; an NGI workshop sponsored by Computer Research Association, Computer Systems Policy Project, and Cross Industry Working Team; industry; academia; and the public. Please note that both this document and the NGI Implementation Plan are based upon the Presidential requested level of funding. Congressional action may result in changes that will be incorporated into these documents after final FY98 budget approval.

Comments are always encouraged. Please send them to ngi@ccic.gov (formerly ngi@hpcc.gov) or fax them to 703-306-4727. If you need additional information, please contact the National Coordination Office for Computing, Information, and Communications at 703-306-4722.

Table Of Contents

1. Introduction

Today's Internet is an outgrowth of decades of Federal investment in research networks, such as the Defense Department's ARPANET, the National Science Foundation's NSFNET, the Department of Energy's(DOE) ESnet, the National Aeronautics and Space Administration's (NASA) Science Internet, and National Science Foundation (NSF)-initiated regional networks, which have been applied in successive evolutionary multi-agency programs that build on the successes of the previous programs. This small amount of Federal seed money stimulated much greater investment by industry and academia and helped create a large and rapidly growing market. The NGI is the next, but perhaps not the last, logical step in the cycle of evolving networking technologies and infrastructure necessary to support U.S. research and industry.

Today's Internet suffers from its own success. Technology designed for a network of thousands is laboring to serve millions. Fortunately, scientists and engineers believe that new technologies, protocols, and standards can be developed to meet tomorrow's demands. These advances will start to put us on track to a next generation Internet offering reliable, affordable, secure information delivery at rates thousands of times faster than today. Achieving this goal will require several years of generic, pre-competitive research and testing. It is appropriate that the Federal government promote and participate in this research because critical Federal missions require a next generation Internet for their success and because much of the needed research is too long-term or high-risk for the private sector to fund. As with Internet development to date, success will depend on effective partnerships among universities, the private sector, and the Federal research community.

The NGI Vision

In the 21st Century, the Internet will provide a powerful and versatile environment for business, education, culture, and entertainment. Sight, sound, and even touch will be integrated through powerful computers, displays, and networks. People will use this environment to work, bank, study, shop, entertain, and visit with each other. Whether at the office, at home, or on travel, the environment will be the same. Security, reliability, and privacy, will be built in. The customer will be able to choose among different levels of service with varying prices. Benefits of this environment will include a more agile economy, a greater choice of places to live or work, easy access to life-long learning, and better opportunity to participate in the community, the Nation, and the world.

The Next Generation Internet (NGI) initiative, together with all the investment sectors illustrated in Figure 1, will create a foundation for more powerful and versatile networks of the 21st century. It will foster partnerships among academia, industry, and Government that will keep the U.S. at the cutting-edge of information and communications technologies. It will accelerate the introduction of new networking services for our businesses, schools, and homes. This initiative is possible because of the very strong Federal agency programs that are currently underway. The Large Scale Networking R&D crosscut for FY 1998, for example, is $288.3 million, which includes the $100 million for

NGI. This document focuses directly on the concepts and goals of the $100 million NGI initiative.

NGI: "The Programs"

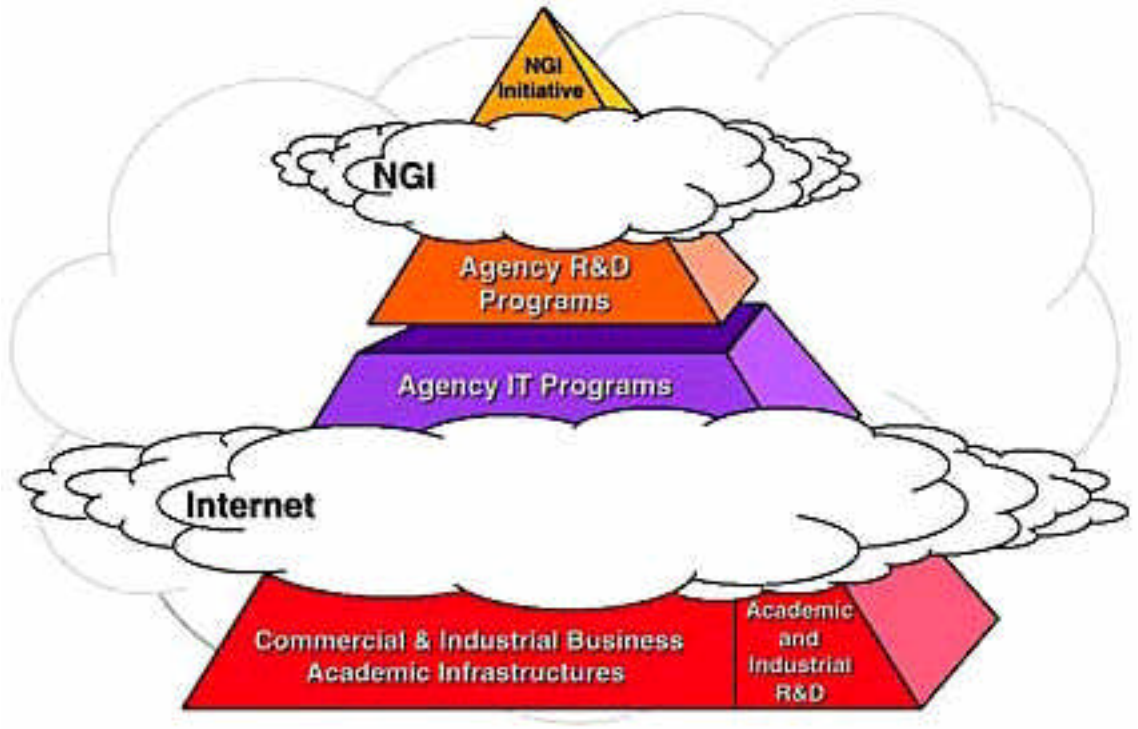

Figure 1.

The most important part of a network is what people do with it -- their applications. But applications require adequate network services and infrastructure. The NGI initiative will conduct research to advance all three areas together: applications, services, and infrastructure.

As one of its goals, the NGI initiative will enable advanced network-based science, health, education, and environmental applications. These applications will be selected from the participating with agencies and from other Government missions and will be carried out in partnerships between the initiative and other programs. The role of applications in the initiative will be to demonstrate the value of advanced networking and to test advanced networking services and technology.

Another goal of the initiative will develop and test new network services and technologies. These will include advances such as transaction security, ease-of-use, quality of service, and tools for network monitoring, management, and accounting. Many of these new services and technologies already exist as individual components, but substantial system integration and testing at sufficient scale will be required for them to provide seamless support for advanced applications.

In order for the applications and new technologies to be developed, the initiative will also have a goal to develop a prototype high-performance network infrastructure, or testbed, to provide system-scale testing of advanced services and technologies and to support testing of advanced applications that enable new paradigms of use. This testbed will emphasize end-to-end performance to the user. Therefore significant upgrades of local infrastructure within participating sites will be needed as well as high-performance links among sites.

Advanced services and technology will be key to the success of this testbed and its overall utility in delivering applications. As an analogy, consider the country's system of highways and streets. The ribbons of concrete and asphalt, the raw capacity of the system, are like the fiber-optics, copper, and computers of the network. The intelligent features of the highway system— traffic lights, HOV lanes, lane markers, street signs -- are like the services and technology of the network. The utility of both highways and networks depends on the proper mix of size, technology, and services. The system must be engineered as a whole: interstate highways dumping traffic directly onto narrow streets are like high-bandwidth network links dumping packet traffic into slow local-area networks.

The initiative will be built on partnerships: partnerships between researchers developing advanced networking technologies and researchers using those technologies to develop advanced applications; and partnerships between federally funded network testbeds and commercial network service and equipment providers that participate in these testbeds to test concepts for the future commercial Internet. In addition, it will focus and stimulate other federal programs, from research and development to shaping future information technology procurement visions.

On October 10, 1996, in Knoxville, TN, the President and Vice President announced their "commitment to a new $100 million initiative, for the first year, to improve and expand the Internet.... " This NGI initiative carries out that commitment.

The Administration has made an initial three-year $300 million funding commitment of $100 million per year, for which it will seek bipartisan Congressional support in its budget submissions. Built on the base of current Federally-funded research and development, the initiative will also call on substantial matching funds from private sector partners, as well as seek commitments from major applications developers.

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

2. Goals, Strategies and Metrics

2.1 Introduction

The U.S. Government created the ARPANET as a research network more than 25 years ago to prototype the technology and community needed for a new type of network. In this new technology and community—which became today's Internet—sites are interconnected

openly with other sites through a flexible, richly connected fabric that allows users to exchange data and information freely and easily. Through the development of the Internet, the U.S. Government has led the world into a new way of communicating and stimulated industry which has provided numerous jobs.

Now we are on the threshold of a next generation Internet (NGI), one that has the potential again to create a new type of interconnected community. This NGI community will be able to exchange information in far richer ways and with far less delay and risk than using today's Internet. To reach that vision, there are three goals for this NGI initiative, each with a strategic approach and each with metrics of success. The three goals are:

(1) Experimental Research for Advanced Network Technologies

(2) Next Generation Network Fabric

(3) Revolutionary Applications

The nature of research implies that success in reaching goals is never guaranteed. The NGI commitment to the definition and use of metrics will, however, assure that NGI resources are targeted at clear objectives and will signal when those objectives are achieved.

Guide to the Remainder of Concept Paper

Sections 2.2 through 2.4 describe the three specific goals of the NGI initiative, summarize the strategies for achieving each goal, and define the metrics of success. These sections also summarize specific transition strategies for each goal.

Section 2.5 summarizes the strategies for transferring results to the broader public and private Internet community, including the commercial sector. Sections 3 and 4 detail the expected deliverables and benefits respectively. The management interrelationships and dependencies are contained in Section 5.

2.2 Goal 1: Experimental Research for Advanced Network Technologies

Promote experimentation with the next generation of network technologies.

The NGI initiative will develop and demonstrate the advanced network service technologies needed to support next generation applications. For NGI to be successful, it is not sufficient merely to deploy a testbed that can move bits at 100 million bits per second (Mbps) to 1 billion bits per second (Gbps) because an Internet is not merely the movement of bits, and a next generation Internet is not merely faster movement of bits.

The NGI applications will require a rich collection of advanced network services. For example, high-quality team collaboration and videoconferencing support requires several types of network services not available on the Internet today. These services must be richer in features, higher in performance, and deliverable at reasonable cost. Achieving all three of these apparently conflicting subgoals simultaneously will drive NGI technology. The NGI initiative will succeed only if it deploys faster networks without also developing and demonstrating the richer, more flexible, and affordable network service technologies needed by next generation applications.

The main areas of network services and corresponding protocols that need to be developed and demonstrated are the following:

- Quality of service (QoS)
- Security and robustness
- Network management, including the allocation and sharing of bandwidth
- Systems engineering and operations, including definitions and tools for service architectures, metrics, measurement, statistics, and analysis
- New or modified protocols for routing, switching, multicast, reliable transport, security, and mobility
- Computer operating systems, including new requirements generated by advanced computer architectures
- Collaborative and distributed application environments.

Strategy for Goal 1

The primary strategy for achieving goal 1 is to fund Federal, industry, and university R&D organizations to develop and deploy the services, protocols, and functionality required by the network infrastructure and applications. This will be done in an open technology transfer environment within the framework of collaboration as exemplified by the IETF, Asynchronous Transfer Mode (ATM) Forum, and Educom.

This strategy, which contributed to the success of the original Internet, is one in which good ideas are funded and open versions of products and services are made available to the community. Organizations use openly published software and specifications to provide both "freeware" and commercial products. This strategy provides for effective and highly efficient development, selection, and distribution mechanisms for successful technologies. Hugely successful companies such as Sun Microsystems, Cisco Systems, and Fore Systems are the by-products of this strategy, as are widely used freeware products such as Mosaic and Eudora. This strategy has resulted--and will again result--in speedy transition of successful technologies into the marketplace. These technologies will appear as competitively priced and aggressively marketed products that enable U.S. companies to develop and promote new products for new domestic and international markets.

Metrics for Goal 1

The primary metrics of success for goal 1 are the following:

- **Quality of service.** The quality of service (QoS) actually achieved end-to-end over the network are measurable quantities. Such QoS metrics as end-to-end latency, packet loss, and packet arrival jitter, as well as guaranteed minimum/maximum bandwidth allocation, are used in defining the technical specifications for the service needs of the next generation of applications. Developers will specify, continuously measure, and report key QoS metrics and report them for all applications.
- **Security and robustness.** Measures of security and robustness will be developed as part of goal 2. These measures will quantify the security and robustness deficiencies of today's Internet in a way that improvements can be planned and measured. The goal in

this area is to implement the type of network that individuals and businesses can trust to carry their private and company-confidential information, safe from disclosure or alteration, as well as providing for authenticated transactions and access.

- **Other subgoal measures.** The NGI management team will associate quantitative metrics with each of the other important network services that are adopted as primary subgoals of goal 1. The team will use each of these subgoal metrics actively to plan and validate the technologies developed under goal 1.
- **Extent to which technologies are adopted by commercial Internet suppliers.** NGI will maintain reports and measurements of NGI-developed technologies that have been incorporated into commercially available products. A primary part of this goal is the transition of successful technologies quickly to the commercial sector. The strategy of working openly—"Internet style"—will achieve this in the quickest possible way. This may be done by requiring no-cost licenses for the use of NGI-developed technologies or by other means identified by the teams described in Section 5. Management.

2.3. Goal 2: Next Generation Network Fabric

Develop a next generation network testbed to connect universities and federal research institutions at rates that are sufficient to demonstrate new technologies and support future research.

The networks developed under the NGI initiative will connect at least 100 NGI sites--universities, Federal research institutions, and other research partners--at speeds 100 times faster than today's Internet. Although changing over time, we will assume that the average speed in 1997 is 1.54 Mbps and will connect on the order of 10 NGI sites at speeds 1,000 times faster than the current Internet.

This goal addresses end-to-end connectivity (to the workstation) at speeds from 100+ Mbps up to 1+ Gbps. Although some networks have already achieved OC-12 speeds (622 Mbps) on their backbone links and some experimental links are running at 1+ Gbps, end-to-end usable connectivity is typically limited to less than 10 Mbps because of bottlenecks or incompatibilities in switches, routers, local area networks, and workstations. This goal addresses these shortcomings by developments and demonstrations involving two sub-goals.

- **Subgoal 2.1 (high-performance connectivity)** Develop a wide-area demonstration network fabric that will function as a distributed laboratory, delivering 100X current Internet performance end-to-end (typically greater than 100+ Mbps end-to-end) to at least 100 interconnected NGI sites demonstrating highly important applications. This demonstration network fabric must be large enough to provide full-system, proof-of-concept tests of hardware, software, and protocols required in the commercial next generation Internet. Moreover, it must be broadly-based geographically to incorporate research institutions in every area of the country.

- **Subgoal 2.2 (next generation network technologies and ultra-high-performance connectivity)** Develop the ultra-high speed switching and transmission technologies and demonstrate end-to-end network connectivity at 1000X current Internet performance end-to-end (typically greater than 1+ Gbps end-to-end and many Gbps in backbone circuits.) Because of its high risk and pioneering nature, this subgoal will be

achieved in smaller wide-area demonstration networks involving about ten NGI sites and applications. These applications must be drivers of the properties of very-high-speed networks; that is, they must stress the network hardware, software, and protocols to determine the true benefits, characteristics and limitations of the system and its components under the heavy loading needed for a commercial NGI.

Strategy for Goal 2

The primary strategy for achieving this goal is for Federal agencies to build high-performance, collaborative networks in partnership with the telecommunications and Internet provider industries and top federal research institutions. These network test beds must include enough sites to test whether proposed technologies scale to large networks and to support the demonstration of widely distributed applications. This is an example of Metcalfe's law that the value of a network scales as the square of the number of sites.

The subgoal 2.1 networks would interconnect most of the top research universities and federal research institutions in the country through a fabric delivering 100+ Mbps end-to-end in an interoperable mesh richly interconnecting Federal Networks such as vBNS, ESnet, NREN, DREN, and other appropriate networks. The subgoal 2.2 network would seek to demonstrate a few high-end applications at a small subset of the above sites with much higher end-to-end performance.

To accomplish the technology envisioned, this initiative will fund universities, industry R&D and federal research institutions to explore innovative ideas of switching and transmission.

The NSF Very High Bandwidth Network Service (vBNS), the Energy Sciences Network (ESnet), and the NASA Research and Education Network (NREN) are examples of the network partnership arrangements strategy for achieving subgoal 2.1. These arrangements have provisions allowing the agencies and the providers to work together to build prototype networks with various combinations of cost discounting, flexible service provisioning, and pre-competitive technology partnering.

The subgoal 2.1 network fabric would include the vBNS augmented by the NSF Connections program, ESnet, NREN, and opportunities that emerge from the Internet2 project. NSF's vBNS/Connections is now interconnecting many U.S. research universities with a next generation fabric using leading-edge network technologies as building blocks. Also included in subgoal 2.1 will be ESnet and NREN. The subgoal 2.1 NGI initiative will enable many more universities and federal research institutions to connect to the evolving next generation Internet infrastructure at a faster pace than can be without NGI funding. Internet2 is a community-based project of about 100 universities working to dramatically improve their campus infrastructure and Internet connectivity. The NGI initiative will work directly with the Internet2 project to facilitate tying their high-performance campus backbones into the NGI infrastructure.

The subgoal 2.2 network -- the ultra-high-performance part of NGI -- could be a separate network fabric with links to the subgoal 2.1 network fabric, but may also be implemented on some of the same infrastructure as goal 1 and 2.1. This network will have Gb/s end-to-end connectivity, advanced network management, and negotiated quality of service functions.

The subgoal 2.1 network must be very reliable except under carefully planned and implemented experiments because it must support at least 100 institutions developing software and applications. The subgoal 2.2 network fabric would involve very early implementations of ultra-high-performance technologies and should be expected to break periodically under normal daily operations.

The goal 2 strategy of having Federal agencies take the lead in building the networks in partnership with telecommunications companies, network service providers, and research institutions is modeled after the way the existing Internet was developed. This approach will ensure that successful network technologies developed under this program are immediately available commercially and will be widely marketed and fairly priced. The immediate availability will come about because the networks will be provided by commercial partners under contracts and cooperative arrangements. The partners will be able to market commercial versions of these next generation technologies and services as soon as the technologies and services are commercially viable. The partners, working through the existing Internet organizations such as the IETF and ATM Forum, will ensure that the lessons learned are widely disseminated and freely available to all.

Metrics for Goal 2

The primary metrics of success for goal 2 are the following:

- **Number of institutions connected.** The first part of goal 2 is to develop the network testbed to accommodate goal 1 research results and goal 3 applications.

- **End-to-end performance.** The second part of goal 2 is to achieve 100+ Mbps end-to-end performance over the subgoal 2.1 network fabric and 1+ Gbps end-to-end performance over the subgoal 2.2 network fabric. "End-to-end" means between applications operating within the NGI testbed network. NGI will carry out standard end-to-end performance measurements between user systems. The NGI public web page will report the results of these measurements for each participating site, and the experimenters will analyze and report the results in technical conferences and journals.

- **Number of institutions connected.** The third part of goal 2 is to connect at least one hundred NGI sites to the subgoal 2.1 network fabric and at least 10 sites to the subgoal 2.2 network fabric. Therefore, a primary metric is the number of sites connected. The list and status of NGI sites will be continually updated and available on the public web page maintained by NGI.

2.4 Goal 3: Revolutionary Applications

Demonstrate new applications that meet important national goals and missions.

A fundamental objective for the NGI is to demonstrate a wide variety of nationally important applications that cannot be achieved over today's Internet. Ideally, these applications will include Federal agency mission applications, university and other public sector applications, and private sector applications. These applications will improve U.S. competitiveness in existing business areas, and they will demonstrate the potential for

entirely new business areas based on commercializing the technologies developed within this initiative.

Potential application areas for the NGI include the following:

- Health care: Telemedicine, emergency medical response team support
- Education: Distance education, digital libraries
- Scientific research: Energy, earth systems, climate, biomedical research
- National security: High performance global communications, advanced information dissemination
- Environment: Monitoring, prediction, warning, response
- Government: Delivery of government services and information to citizens and businesses
- Emergencies: Disaster response, crisis management
- Design and manufacture: Manufacturing engineering

Many of these areas are of particular Federal interest since they represent Federal mission-critical applications that require advanced networking services and capabilities. The Federal Government's information technology services and Federally supported communities have networking requirements that cannot be met with today's Internet technology. Higher speed networks with more advanced services and functionality will enable a new generation of applications that support these fundamental governmental interests.

Although NGI will not provide funding support for applications per se, the initiative will partner with the application communities--Federal agencies, the public sector, and private companies--to incorporate new networking technologies and capabilities developed under NGI goals 1 and 2 into applications of importance to each community and which the community cannot achieve over today's Internet. The technology community will derive technologies and services of the next generation Internet from essential and common features required by the applications demonstrated under goal 3.

Strategy for Goal 3

While the applications that will benefit from the Next Generation Internet may span a very large range of human activity, there are several foundation-applications that are fundamental to large classes of applications. These foundation-applications are above network services (such as IPv6, Quality of Service, etc.), but are not tailored to only one domain. Two classes of applications have already been accepted as foundation-applications.

1. *Distributed computing* applications recognize that the network seeks to provide very high bandwidth coupled with low latency close to that determined by the speed of light. Examples of specific applications currently incorporating distributed computing include global ocean-atmosphere climate models, quantum mechanical materials models, and coupled hydrodynamic-radiation transport models.

2. *Collaborative* applications require moderate to high bandwidth and also the ability to reserve a piece of the network pipe for high quality video and audio streams regardless of what other processes may be using the net. Examples of specific applications currently incorporating collaboration include remote use of experimental facilities, distance learning, and collaborative engineering design.

Other foundation-applications will be identified as the program progresses. Candidates to be added to the list include:

a. National security response and crisis response which require nomadicity and dynamic network reconfiguration.

b. Distance education and service to the citizen which require extreme scalability at nominal cost.

c. Teleoperation which requires extreme reliability coupled with guaranteed delay bounds.

These foundation-applications are independent of any one knowledge domain, but can be extended by mission agencies to suit their own application-specific needs. Taken together, these foundation-applications will be chosen to completely test the new network capabilities developed by the NGI. If these applications are successful, they will demonstrate that the set of new services are robust, complete, and ready for commercialization.

The strategy for achieving goal 3 is to identify a small number of demonstration applications for each participating mission agency and other significant applications from academia and industry. Applications will be chosen to leverage significant application funding from the respective agencies, industry consortia, or other university research funding sources. NGI will provide funding for specific testbed connectivity, functionality, services, and software that maximize the value of the infrastructure connectivity and services deployed by this initiative.

Each demonstration will partner advanced networking technologies with advanced application technologies. Each community will bring its knowledge, skills, and methods to the partnership. Each application organization will have to provide the bulk of the resources needed to implement its application and will be required to work within the framework of the NGI initiative to develop and demonstrate its application over the high-performance networking technologies provided by other parts of the initiative.

Potential sponsoring organizations will choose applications to demonstrate within the NGI because their candidate applications require next generation internetworking technology to demonstrate advanced functionality and performance. The proof-of-concept opportunities provided by this initiative will give substantial visibility to new approaches for meeting important Federal missions as well as those of other institutions. For this reason, it is essential that the NGI select applications that will be perceived as important by the private sector and the general public.

This strategy of required user-organization funding will accelerate transition of successful applications to the mission agencies. If the applications delivered under goal 3 turn out to

be faster, better, or cheaper, it will be in the agencies' own interests to use these applications, thus improving the delivery of mission services to their user communities.

Metrics for Goal 3

The primary metrics of success for goal 3 are the following:

- **Institutions demonstrating NGI-type applications.** For NGI to be successful, nearly all of the participating NGI sites must be developing and demonstrating at least one NGI-type application. (There may be a few participating institutions that only develop technologies under goal 2; those technologies would be provided to organizations developing applications under goal 3.) Each application proposed for the NGI initiative would be required to define application-specific success metrics. These metrics would be evaluated and reported for each application with validation being a required part of the application demonstrations. NGI will maintain a web site that reports successfully validated application demonstrations.
- **Value of applications in testing network technologies.** The objective of the technologies and networks in goals 2 and 1 is to enable applications. Each application project proposed for this initiative would identify the required NGI network technologies and would be required to develop measurements of the effect of those technologies on the application. Even qualitative technologies such as security and network management would have definable effects on applications, and these effects can be assessed by appropriate means identified by the application projects. The measurements of these effects would be reported as part of the validation process for each application.
- **Demonstration of new paradigms for network use**. It is anticipated that several unforeseen opportunities will emerge from the experimentation and applications of the NGI networks. These will result in new paradigms that enable a new class of applications and technologies. In the past, examples have included things such as sophisticated point-and-click interfaces or web browsers and their successors. This metric will define, document, and demonstrate these new paradigms.

2.5 Transition Strategies

This initiative is designed throughout for transition to the private sector. Specific strategies to accelerate transition of the deliverables resulting from each goal are summarized in Sections 2.2 through 2.4 and in the action plans for the specific goals. The broad agenda for transition includes the following elements.

- Focus on internetworking technology integration, performance, and multivendor interoperability (whereas each commercial vendor interest by itself might be to focus on proprietary solutions)
- Significant concern from the beginning for security, dependability, system scalability, manageability, integration, and interoperability
- Collaboration among research universities, federal research institutions, and industry
- Multiagency program management and execution

This requires tighter coordination and therefore more collaboration because the networks, middleware, services, and many applications must be interconnected and interoperable.

- R&D partnerships with industry and research universities-extensive use of grants and cooperative agreements requiring private investment
- Widespread leveraging of existing programs for network connections and services—vBNS/NSF connections, NASA NREN, DOE ESnet, DARPA DREN and ATDnet, CAIRN, applications
- Potential international collaboration
- Understanding of the economics of the Internet industry

  Focus resources on areas where Federal involvement is needed to influence technology and evolution. For examples, existing ISPs focus primarily on meeting today's operational needs; telcos and telecommunications equipment industries focus on building faster pipes.
- Insight and expertise of agencies with high-demand applications

  These agencies understand what technology areas are crucial to a massive scale-up of today's Internet and elimination of its systemic problems.
- Mentoring and co-op programs developed with federal research institutions, industry and university resources
- Required open standards development, specification and dissemination via processes implemented through organizations such as the IETF

This agenda will assure that NGI-delivered technology is pragmatic enough to be transitioned successfully to the real world by industry partners and research entrepreneurs.

3. Expected Deliverables

The NGI initiative will deliver new networking technologies that have the potential to advance human communications, access to information, and productivity as greatly as did the current Internet. These technologies will make the future Internet as different from today's Internet as from today’s telephone. The resulting new capabilities will dramatically improve the way in which new Federal applications will be developed and used in the future, allowing us, for example, to break the remaining barriers to activity-at-a-distance. The community that will emerge from this program will help drive these innovations to the commercial market.

The NGI initiative will develop and demonstrate new technologies within the next three years. Underlying partnerships will be crafted and managed to promote the rapid transfer of these technologies into applications, both public and private. The new capabilities will attract Federal and Federally-supported research networks to NGI technologies. Widespread adoption will elevate the technological foundation on which to build qualitatively improved Federal applications and government information service delivery. For example, improvements will be implemented in new services dealing with civil and natural emergencies. These services may require five-minute response from initial data collection through analysis, event identification, local authority identification, and notification. Such capabilities would dramatically reduce losses.

This Federal program will fund the deployment of at least an additional 100 high-performance connections to research universities and federal research institutions, and these will also be interconnected to the larger national information infrastructure. The result will be a very-high-speed network that will be available for advanced network concepts research and for focused high-end application demonstrations. Leverage will be enormous, since a great deal of the research conducted for the federal agencies involves the faculty, students, and staff of these institutions.

At least 100 science and engineering applications will successfully use these connections. University and national laboratory research in all scientific disciplines will benefit greatly from the enhanced data exchange capability, researcher interaction, and collaboratory tools and environments that result from this program. Testbed applications for improving federal information services in at least 10 application areas will also be demonstrated.

During the first year, at least thirty government-industry-academia R&D partnerships will be created to leverage this program funding by at least two-to-one. This program will also leverage existing Federal funding to establish multi-discipline research and education programs in information systems design and management. These will use federal research institutions, industry, and university resources to develop mentoring and cooperative education programs.

4. Expected Benefits

The NGI initiative will benefit society at large by providing technology that enables widely available and rapid access to information and services in many locations and forms.

As an example, consider the area of crisis management. When a crisis occurs, it will no longer be necessary to spend weeks or months assessing damage and initiating federal aid. With advanced networking, government information services will provide key decision-makers with immediate information on the scope and severity of an emergency whether it be a hurricane, tornado, earthquake, oil spill, or airliner crash. Instead of spending hours or days traveling to the scene and assembling a team, the crisis manager will have the needed information available instantly with required security. Instead of searching local records and negotiating with local officials for access to data as was required after hurricane Andrew, advanced networking services will allow the local networks to be quickly reestablished, and provide the emergency manager with secure access to information as needed. National security systems will use these same technologies to respond to domestic and international security emergencies.

Telemedicine is a second critical area that will benefit society while also driving the development of advanced networking technologies. Advanced telemedicine will improve the quality of life in all regions, not just those remote from current medical services.

Another benefit of this program will be an improvement in knowledge discovery and dissemination. More effective and efficient knowledge discovery and information dissemination will benefit research areas as diverse as energy, the environment, and biomedicine. Education, including distance learning, will benefit from advancing the NGI suite of technologies. Together, these advances will drive corresponding improvements in the practice and services of all sectors.

Scientists, who are limited today in their ability to control even a single instrument through the Internet, will be immersed in a "collaboratory" environment where they will have interactive capabilities to work with large scientific facilities, supercomputers, data banks, digital libraries, and collaborators integrated into a seamless virtual environment. The impact on the productivity will be substantial when scientists can observe and control massive experiments in real time, rather than waiting for an off-line analysis to suggest what went wrong yesterday. Virtual communities of collaborators will lead to greater insights and new approaches.

This initial deployment of the NGI will spur and leverage more significant secondary deployment of twenty-first century networks throughout the U.S. These deployments will create an environment that qualitatively differs from today's: it will encourage more creative and forward-thinking solutions for improving education and knowledge discovery at all levels.

The resulting high-performance network infrastructure will also function as a distributed laboratory and help improve the U.S. R&D effort. The NGI ultra-high-performance network infrastructure will enable leading-edge data communications research into the properties of very-high-speed networks themselves. It will also lead to a better understanding of future high-quality multimedia and real-time networks.

NGI will have important benefits for both the public and the private sectors of the economy. All citizens will benefit from improved communications, and better information will permeate our daily lives. Networks will improve the nature of telephonic communication both at work and at home. At work we will receive information more quickly and reliably; at home our Internet experience will be enhanced by faster communications, the ability to guarantee an acceptable line speed, and appropriate security protections. New applications, emerging from the availability of much faster, more reliable network services, will enhance our lives in unimagined ways. By partnering with colleges and universities, the process of developing these technologies will educate a new generation of Americans knowledgeable in the communications technologies required to thrive in the 21st century.

As these students move into industry, our national economic and technological competitiveness will increase. Finally, just as advanced networking provides exciting opportunities to improve the efficiency of government, so too will it make businesses more effective international competitors.

The Internet developments of the last decade have helped to propel the U.S. to a commanding lead in information technologies. The technology developed under this initiative will enable U.S. industry to develop hardware and software required to enhance our worldwide leadership in advanced networking services and applications.

5. Management

The Next Generation Internet Program will be coordinated within the framework of the National Science and Technology Council (NSTC). The Committee on Computing, Information, and Communications (CCIC) will be responsible for the overall high level

NGI strategy. The Computing, Information, and Communications (CIC) R&D Subcommittee is responsible for coordination across program component areas. The Large Scale Networking Working Group (LSN) is responsible for the implementation strategy of the NGI. A small, integrated NGI Implementation Team will take primary responsibility for implementing the approved plans under the direction of the LSN Working Group.

In particular, the NGI Implementation Team will:

- contain one member from each of the funded agencies plus an applications advocate who will provide linkage to NGI applications partners and to the CCIC's Applications Council
- use advanced networking and computing for effective coordination and communications
- answer to the LSN Working Group as a team (as well as to agencies as individuals)
- operate as an integrated project team for the overall NGI initiative
- be jointly responsible for execution of approved implementation plans, initiative management and evaluation, and other activities as required for successful implementation
- establish contributing partnerships and relationships
- recommend funding mechanisms and serve appropriately in the selection process

The LSN Working Group, under the CCIC process, will:

- be responsible for strategic planning, marketing, and liaison for the NGI initiative
- champion and oversee the NGI Implementation Team
- provide a forum for all participating agencies whether directly funded by the initiative or not
- report to the CIC R&D Subcommittee of the CCIC

As directed by the CCIC and the R&D subcommittee, the LSN will consult with the Presidential Advisory Committee on HPCC, IT, and NGI and other existing high-level, advisory groups as appropriate to facilitate and focus the broad community input and coordination that will be necessary for success. The LSN may charter special teams from the community as required to deal with specific issues and projects.

The LSN will actively seek opportunities for outreach with industry, education, and private industry through existing programs such as Small Business Innovation Research.

The directly funded agencies will, of course, also participate in the oversight of the NGI implementation team by, among other things, the approval processes required to expend agency resources in support of the NGI initiative.

6. Action Plan

This section expands on the description of the NGI goals laid out in section 2. Additional details and detailed milestones are described in the Implementation Plan.

6.1 Goal 1: Experimental Research for Advanced Network Technologies

Goal 1 activities will focus on research, development, deployment, and demonstration of the technologies necessary to permit the effective, robust, and secure management, provisioning, and end-to-end delivery of differentiated service classes. These activities cluster into three major tasks: network growth engineering, end-to-end quality-of-service (QoS), and security.

Although the high-speed and advanced communications capacity (developed under goals 2.1 and 2.2) will enable advanced applications for the Department of Defense (DoD), the Department of Energy (DoE), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and other agency users, increased bandwidth alone will be insufficient to meet the dependability, various classes of services, security, and real-time demands of emerging and next-generation applications, such as collaboration, wide area distributed computing, and teleoperation and control. The challenge for goal 1, then, is to ensure that the advanced capabilities of goal 2 networks can be made predictably and reliably accessible to a broad spectrum of users sharing a common infrastructure. This will involve goal 1 technologies being developed and aggressively deployed into the goal 2.1 networks. Therefore, applications must realize and plan for those instances when the goal 2.1 infrastructure may suffer temporary degradation of service as a result of the experimental alpha deployment of goal 1 technologies and goal 3's use of these technologies.

This will be joint agency effort with the Defense Advanced Research Projects Agency (DARPA) as the lead and participation by DoE, the National Institute of Standards and Technology (NIST), NASA, NSF, and other agencies.

6. 2 Goal 2: Next Generation Network Fabric

The networks developed under the NGI initiative will connect at least 100 sites—universities, Federal research institutions, and other research partners—at speeds 100 times faster than today's Internet, and will connect on the order of 10 sites at speeds 1,000 times faster than the current Internet.

This goal addresses end-to-end connectivity (to the workstation) at speeds from 100+ million bits per second (Mbps) up to 1+ billion bits per second (Gbps.) Although some networks have already achieved OC-12 speeds (622 Mbps) on their backbone links and some experimental links are running at 1+ Gbps, end-to-end usable connectivity is typically limited to less than 10 Mbps because of bottlenecks or incompatibilities in switches, routers, local area networks, and workstations. Goal 2 addresses these shortcomings by developments and demonstrations involving two sub-goals.

Subgoal 2.1: High-Performance Connectivity

The goal 2.1 demonstration network fabric will function as a distributed laboratory. It will deliver a minimum of 100 times or greater improvement over the current Internet performance on an end-to-end basis to at least 100 interconnected NGI-participating universities, national laboratories, and Federal research sites demonstrating research and other important applications that require such an infrastructure. This network fabric will be large enough to provide a full-system, proof-of-concept

testbed for hardware, software, protocols, security, and network management that is required in the commercial Next Generation Internet.

Goal 2.1 is a joint agency effort led by DoE, NSF, and NASA, with participation from DoD and other agencies.

Subgoal 2.2: Next Generation Network Technologies and Ultra-High Performance Connectivity

Goal 2.2 addresses the development of ultra-high speed switching and transmission technologies and of end-to-end network connectivity at 1+ Gbps. Because of its high risk and pioneering nature, networks involved will be initially limited to approximately ten NGI sites and a limited number of applications will be implemented. Some of the nodes of goal 2.2 will overlap with those of goal 2.1.

Attaining this goal, together with the technologies developed in goal 1, will be the pathway to terabit per second (Tbps) networks, operated by the appropriate network management and control with guaranteed end-to-end quality-of-service. Partnering with industry is the key to a shared infrastructure that can be used profitably to support high-end scientific users and large numbers of ordinary commercial users.

Goal 2.2 is a joint agency effort with the DARPA as the lead, and participation from DoE, NASA, NSF, and other government agencies.

6.3 Goal 3: Revolutionary Applications

To achieve goal 3, the participating Federal agencies established procedures to identify appropriate applications to be tested. These applications require the advanced capabilities of goals 1 and 2. Furthermore, the agencies must be willing to adapt their applications to take advantage of these advanced networking capabilities. The resulting NGI applications will integrate advanced networking and application technologies.

A coordinated selection process will be used to ensure that applications tested and demonstrated on the NGI network(s) provide robust, realistic, complete tests of technologies that are extensible and adaptable to other applications. The selection of NGI applications is an iterative process with Federal, academia, and industry participation. Applications will be derived from the federally focused applications in appropriate technology classes, e.g., digital libraries, remote operation of medicine, environment, crisis management, manufacturing, basic sciences, and Federal information services.

This joint agency effort will be coordinated among the participating agencies. Since most of the funding for applications will come from the applications themselves, leadership will be provided via domain-specific affinity groups. Participation will be encouraged from a broad spectrum of agencies with demanding networking applications. Applications will also be solicited from other interested research entities within academia and industry.

6.4 Coordination

Each agency will utilize its own method for soliciting calls for research (e.g., solicitations, broad area announcements, calls for proposals, etc.) for all goals, and will ensure coordination among the agencies through the use of other agency program managers and experts as reviewers of resulting proposals as well as through interagency program manager coordination activities such as the NGI implementation team.

The call for proposals will occur at least once at the beginning of each fiscal year. The primary selection criteria for NGI sites for goal 2.1 will be based primarily on a site's ability to demonstrate an NGI class application and its use of the technologies on goals 1, 2.1 and 2.2. The sites will also be required to demonstrate that they possess the expertise and infrastructure necessary to demonstrate these applications on an end-to-end basis. Sites that do not possess NGI applications, but do possess the necessary technology (i.e., goals 1 and 2.2) and expertise may also be considered for the proposed award.

An NGI implementation team will be established to coordinate research agendas across all goals. The team members will include appropriate agency program managers as well as experts from academia, industry and federal laboratories. These experts will meet as often as necessary to accomplish these goals, but at least four times per year after the initial implementation has been defined and accepted. The detailed implementation plans for each of the goals are described in this plan.

7. NGI Funding By Agency

Each participating agency brings specific skills and experience to the initiative. These skills and experience provide an essential base upon which the initiative is built. The strength of this base allows projection of likely success for the initiative, without which the initiative would be much more risky. Specific agency strengths include:

DARPA: long-term, general expertise in networking research, general skill in high-end network technology and testbeds, experience in managing networks.

DOE: long-term experience in managing production and research networks, specialized skills in networking technology, great strength in mission-driven applications and in system integration.

NASA: experience in network management and in specialized network testbeds, strength in mission-driven applications involving high data rates, great strength in system engineering and integration.

NSF: special relationships with the academic community, experience in network research and in managing networks, great strength in scientific applications.

NIST: long experience in standards development, networking research, metrology, computer systems security, systems integration for manufacturing applications, and in testbeds involving many industrial partners.

National Library of Medicine (NLM)/National Institute of Health (NIH): extensive experience in medical research; great strength in health care applications.

NGI FY1998 Proposed $105* Million Budget

(Dollars in Millions)

	DoD/DARPA	NSF	DoE	NASA	NIST	NLM/NIH*	TOTAL
Goal 1: Technologies	20	2	6	2	3		**32**
Goal 2: Advanced Connectivity	20	7	25	3			**55**
Goal 3: Applications		1	4	5	2	5	**18**
Total	**40**	**10**	**35**	**10**	**5**	**5**	**105**

**Note: The initiative was originally proposed at $100 million per year with funding expected from additional agencies who want to be part of the program. NLM/NIH is the first example of an additional NGI initiative partner. Therefore, the total proposed budget is now $105 million allocated as shown above.*