Testimony of
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Next Generation Internet and Large Scale Networking

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Mr. Chairman, members of the subcommittee, thank you for allowing me the opportunity to testify on the National Science Foundation's role in fostering the next stages of the information revolution.

I am pleased to be here today. This is a topic of utmost importance for the future of our nation's economy and the well-being of our fellow citizens. A healthy, long-term federal investment in high speed networking and information technology overall is critical if the United States is to remain a world leader – not only in science and engineering – but in our economy, national security, health care, education and overall quality of life.

My prepared remarks today will include a short history of NSF's support for cutting edge concepts in high-speed networking and their transfer to the private sector along with a brief discussion of the following topics:

- NSF's participation in the multi-disciplinary Federal Information Technology Research and Development Initiative (IT R&D) for which NSF is the lead agency;

- NSF's participation in the Next Generation Internet Program – an integral component of the IT R&D initiative – our cooperation with private industry through the rich transfer of new ideas to the private sector, our cooperation with the other NGI agencies;

- NSF's efforts to promote connectivity and access for all, including our efforts to improve connectivity for rural and minority-serving institutions and our strong support for cutting-edge education activities designed to ensure that our citizens will have the scientific, mathematical, engineering, and technological expertise needed to excel in tomorrow's knowledge-based economy.

NSF Support for High-Speed Networking: A Record of Accomplishment

Mr. Chairman, this subcommittee has long been a strong, bipartisan supporter of the federal investment in IT R&D. In the early 1980's, this subcommittee strongly encouraged NSF to invest in high-performance computing resources for the nation's academic scientists and engineers. The subcommittee also was a leader in the enactment of the High Performance Computing Act of 1991. This leadership continued with the passage of the bipartisan Next Generation Internet Act of 1998.

With this backing from the subcommittee and the entire Congress, NSF has continued to support some of the most successful and innovative computer-communications concepts and technologies at their earliest, most experimental stages. NSF funded university-based supercomputer centers in the mid-1980's to provide academic scientists and engineers with access to state-of-the-art computing power.

To facilitate access to the centers, NSF began a parallel effort in networking. It built on fundamental investments by DARPA in a more restricted environment, and resulted in the formation of the national NSFNET backbone network and regional networks connecting university students and faculty to the supercomputing centers. In a very brief period of time, NSFNET and the regional networks began performing important communication and information access functions in addition to supercomputer center access. Through this development and its subsequent privatization, the Internet industry was born.

Mr. Chairman, the story of NSF's longstanding support for backbone networks is now well known but it is only one example of how fundamental IT investments by NSF and other agencies have paid huge dividends for the nation. Support of fundamental networking *research* has received less publicity but is equally important to the future of information science and technology.

For example, it was David Mills, an NSF grantee at the University of Delaware, who made it possible to have one Internet as opposed to a Tower of Babel of competing electronic networks. Mills developed the first widely-used Internet routers -- the gateways and switches that guide the bits and bytes of data around the globe at the speed of light. That's why many people say NSF put the "inter" in Internet. Today CISCO Systems – the premier maker of Internet router technology – now has a market capitalization of $454 *billion* dollars.

Knowledge Transfer Not Just Technology Transfer

Innovations like the Internet router only occurred through sustained, long-term federal investments in information science and engineering by many agencies. One might think that these past successes assure us of an equally bright future. Unfortunately, in a fast paced, technologically-rooted information age, the worst thing we could do is rest on our laurels.

The key point is that the IT R&D conducted by private industry – be it performed by large or small firms – is now primarily near-term and product-focused. There are many reasons for this trend. With increased global competition, increasingly rapid product cycling and high expectations from shareholders, IT industry managers tend to focus on activities that maximize short-term payoffs. Market pressures are often too great and technology changes too rapid to allow for major investments with a long-term perspective.

When the subject of technology transfer is brought up, there is one aspect of the impact of basic research that is often overlooked – the role of NSF's investments in people. NSF's Engineering Directorate recently sponsored a set of studies on today's leading technologies: areas like cell phones, fiber optics, and computer assisted design. It's well known that the great majority of the seminal work in these areas was performed by private industry--at labs like Corning, AT&T, and Motorola.

Does that mean that NSF had no role? Hardly. When you go back and look at the work, a clear pattern emerges. Scientists and engineers who went to graduate school on NSF fellowships and research assistantships often brought the key insights to industry. In a number of cases, they became the entrepreneurs who created new firms and markets.

To quote from the study--"NSF emerges consistently as a major--often the major, source of support for education and training of the Ph.D. scientists and engineers who went on to make major contributions...." It is this transfer of people – the highly trained scientists and engineers supported by NSF and other agencies – that is making a tremendous impact on our knowledge-based economy.

The NGI program is a tremendous success in this regard. In a preliminary review of the NGI program, the President's Information Technology Advisory Committee (PITAC) found that numerous NGI-funded scientists, engineers and students – first funded at universities – have gone on in just a few short years to found start-up companies with an estimated market capitalization of over $27 billion.

Information Technology Research (ITR)

The impact of information technology on our society has been much wider and much more pervasive than anyone could have anticipated just a few years ago. Advances in computing, communications, and the collection, digitization and processing of information have altered the everyday lives of all our citizens.

There is no question that as Internet growth has gone through the roof, IT has become the essential fuel for the nation's economic engine. Even the ever-cautious Fed Chairman Alan Greenspan has pointed to innovations in IT as the driving force behind our strong economic growth.

The numbers speak for themselves. As Neal Lane has mentioned, more than a third of our economic growth in the past five years has resulted from Information

Technology. IT investments have spurred an enormous upswing in worker productivity that has fueled the current economic boom. The challenge now is to sustain this record of success.

Last year, the PITAC concluded that federal support for long-term research on information technology has been “dangerously inadequate.” In its words "support in most critical areas has been flat or declining for nearly a decade, while the importance of IT to our economy has increased dramatically." This has led to the government-wide initiative in Information Technology R&D for which NSF is the lead agency.

The Information Technology Research Initiative at NSF will emphasize research and education on a broad range of topics. Focus areas include:

- ***Advancing computer system architecture***; research on software, hardware, system architectures, operating systems, programming languages, communication networks, as well as systems that acquire, store, process, transmit, and display information.

- ***Improving information storage and retrieval****;* research on how we can best use the vast amount of information that has been digitized and stored.

- ***Connectivity and access for all***; research that aims to overcome the digital divide separating the information “haves” from the “have-nots” and research on inequality of access to and use of computing and communications technology.

- ***Scalable Networks of Embedded Systems***; As the scale of integration of systems that may be achieved continues to grow, systems must be designed with both hardware and software aspects treated from a unified point of view.

- ***Novel approaches*;** new models of computation and physical processes such as molecular, DNA and quantum computing. These efforts are deeply anchored in the mathematical and physical sciences and the biosciences.

Through our part of the multiagency IT R&D program, the Information Technology Research (ITR) initiative, NSF will seek to strengthen **Education** in IT, including:

- programs that provide scholarships, fellowships and traineeships;

- improved undergraduate research participation;
- encouragement of graduate students to participate in K-12 education; and develop new curriculum; and
- research aimed at understanding the causes of underrepresentation of various segments of society in the workforce.

NSF will also increase research on **Applications** of IT across fields of science and engineering. This will also be a critical component of the ITR initiative. This includes simulation to tackle research problems across the frontiers of science and engineering. Important networking applications include:

- Collaboration Technologies
- Digital Libraries
- Distributed Computing
- Remote Operations and
- Security and Privacy issues

Finally through the ITR Initiative, NSF will increase it's support for **Infrastructure** including the Next Generation Internet Program. Support for infrastructure will include:

- computing facilities ranging from single workstations to clusters of workstations to supercomputers of various sizes and capabilities;
- large databases and digital libraries, the broadband networking, data mining and database tools for accessing them;
- appropriate bandwidth connectivity to facilitate interactive communication and collaboration and software to enable easy and efficient utilization of networked resources; and
- networks of large and small physical devices.

NGI Connections at NSF: A Tremendous Success

Mr. Chairman, the NGI program has been a great success. Enabled by fundamental advances in optical networking under supported by DARPA and NSF, the number of very high performance networks has increased and the available bandwidth for research and education has had phenomenal growth.

A diverse array of US universities in all 50 states now have high-speed connectivity thanks to NGI investments. In fact, many more institutions than originally anticipated now have high-speed access thanks to the program. Connectivity to Alaska and Hawaii has improved dramatically as well.

NSF's original goal under the NGI program was to connect 100 universities using the vBNS network and the Internet2 Coalition's Abilene network. Today NSF is excited that over 170 university connection awards have now been made. This includes over 40 universities in EPSCoR states – nearly one-quarter of the total.

This increase in connectivity has resulted in interest in high performance networking in both academia and industry. It has had enormous impact on the knowledge transfer I mentioned earlier. Having so many more scientists, engineers and students from across the nation involved in high-speed networking activities has dramatically increased the available talent pool for industry.

Universities form a rich, fertile proving ground for new network ideas and concepts that can be quickly transferred to the private sector. Without consistent federal funding, such a well-spring of ideas could run dry.

What's Next for NGI: The Next-Next Generation Internet

In marking our 50th anniversary, we are celebrating vision and foresight. The recently retired hockey-great, Wayne Gretzky, used to say, "I skate to where the puck is going, not to where it's been."

Mr. Chairman, at NSF, we try to fund where the fields are going, not to where they've been. We have a strong record across all fields of science and engineering for choosing to fund insightful proposals and visionary investigators.

It is our job to keep all fields of science and engineering focused on the furthest frontier. Our task is to recognize and nurture emerging fields, and to support the work of those with the most insightful reach. And, we prepare future generations of scientific talent.

In this tradition, NSF is looking at new directions for the NGI program. One trend is clear: high-speed fiber backbone networks are rich seed beds for new capabilities.

Now that connectivity has been dramatically increased, new fundamental research problems must be tackled. In today's networked world, dramatic increases in backbone speed do not automatically translate into dramatic increases in performance. Many of these problems will not be easily solved without new, novel approaches.

Today, achieving high performance from end user to end user – the so called Broadband Last Mile Problem – remains difficult. Some commentators have remarked that the current situation is like having a four-lane highways beginning and ending with dirt roads.

To increase backbone speed, efficiency and stability, we will need fundamental research into new middleware network service capabilities. This includes research in user authentication and verification, distributed computing services, and distributed storage services. Also, NSF will support research dealing with satellite and other wireless technology to help reach into areas where wireline and fiber are not possible or practical.

We will also need research into new optical access technologies. In the future optical backbones will use more and more optical routing. Research is needed to discover how to appropriately extend the reach of these technologies. This will correspondingly extend the reach of networks and ensure that institutions not now taking advantage of high performance networking have the opportunity to do so.

Bridging the Digital Divide

This brings me to my last point. Today we find ourselves on a precipice--looking down into that worrisome gap known as the digital divide. We are all here today because we believe in the power of information technology to bring about the most democratic revolution in literacy and numeracy the world has ever known.

We also know that if we're not careful, this same power could be economically divisive. We imagine universal connectedness, with talk of “tetherless networks” that anyone could tap into anytime, anywhere.

But we could also broaden the gap between the information rich and the information bereft. In our own nation, sociologists have identified groups whose access to telephones, computers, and the Internet lag far behind the national averages.

These information gaps appear among nations as well. Most of those who live in the Third World have never used a telephone. Our worldwide web is a thinly stretched one. Less than two percent of the world is actually on the web. If we subtract the United States and Canada, it's less than one percent.

The report by the President’s Information Technology Advisory Committee (PITAC) spells out some of these gaps. “For instance,” says the committee, “whites are more likely than African-Americans to have Internet access” at home or work. “We expect there are similar gaps with other minority groups, such as Hispanics and Native Americans. Recent research...suggests that the racial gap in Internet use is increasing.”

In September 1999 NSF made a four-year $6 million award to EDUCAUSE to help minority-serving institutions develop campus infrastructure and national connections. The award addresses Hispanic, Native American, and Historically Black Colleges and Universities. The scope includes:

- Executive awareness, vision, and planning
- Remote technical support centers
- Local network planning
- Local consulting and training
- Satellite/wireless pilot projects
- New network technologies: Prototype installations
- Grid applications

Conclusion

To conclude Mr. Chairman, let me again thank you for holding this hearing so that we may exchange views on the future direction of this important area. Let me also restate NSF's willingness to work with you, the subcommittee and the full committee to ensure a robust federal IT investment including the NGI program. The PITAC report has raised important concerns over our lack of federal investment in fundamental IT research and we at NSF are responding to the challenge. We look forward to extending the federal IT partnership to help ensure U.S. world leadership in IT.

Thank you.