Statement of Jack Waters
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To the Subcommittee on Technology, Innovation and Competitiveness
Committee on Commerce, Science and Transportation
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Mr. Chairman and Members of the Subcommittee, my name is Jack Waters, and I am Executive Vice President and Chief Technology Officer of Level 3 Communications. Thank you for the opportunity to testify today on behalf of Level (3) Communications. We believe that high-performance networking is an essential element of high-performance computing, critical to our nation's competitiveness and should be a central part of Federal policy regarding the nation's cyber-infrastructure.

First, let me commend the Subcommittee for its work in approving the American Innovation and Competitiveness Act (S.2802). I share the Subcommittee's view that a renewed commitment to basic research will go a long way to ensuring the competitiveness of the United States and to maintaining and improving the United States' innovation in the 21st Century by: increasing research investment, increasing science and technology talent, and developing the nation's "innovation infrastructure." I believe that high performance computing and the high-performance networks that interconnect and facilitate information-sharing between the high-performance computing centers are key elements of the nation's "innovation infrastructure," and are essential to ensuring our Homeland Security, the strength of our national Defense, and ultimately, our continued economic competitiveness in the global economy.

Level (3) Communications is a US company focusing on international communications and infrastructure services. Our network has more than 36,000 fiber route miles and provides high-bandwidth services in 15 countries. Level 3 Communications constructed and now operates one of the largest Internet Protocol (IP) and optical transport backbone networks in the United States and Europe, utilizing the latest fiber and optical technologies. Level 3 is regarded as one of the most technologically advanced carriers in the world, recognized by the Smithsonian Institution for building "The world's first upgradeable international fiber optic network to be completely optimized for Internet Protocol technology…"

The Federal government has played a vital role in both high performance computing and high performance networking for several decades. In 1979, after the successful deployment of the ARPAnet (originally a military network funded by the Department of Defense) the National Science Foundation saw the need to link computer science researchers across the nation and funded a basic network called CSnet. In 1984, with several advancements in high performance computing occurring, the NSF funded the construction of five Supercomputer centers across the country and connected these centers with a network called the NSFnet. Although more than twenty years ago, these investments, along with subsequent others by the Federal government, have helped drive many technology innovations that all of us use every day. A few examples will help me illustrate my point.

Today, we all know and use the Internet in both our personal and professional lives. The NSFnet mentioned previously, was a key piece of the early infrastructure that started it all. This network which interconnected 5 Supercomputer Centers in 1985 and 50,000 networks in 1995, the time of its decommissioning, was the platform on which the commercial Internet that we know today was founded.

Another key piece of Internet technology came from one of the five Supercomputer Centers that the NSF funded. Although Tim Berners-Lee is quite rightly credited with the idea of the World Wide Web, the first widely used Internet Browser was developed at the University of Illinois' National Center for Supercomputing Applications. This browser, named Mosaic, became an overnight success allowing early Internet users the ability to find information across the vast global network. All of this happened in 1993, many years before the world really understood what the Internet would be, through our government's foresight and financial support.

Increasingly, advanced research in the United States and around the globe is accomplished collaboratively by researchers and data sources which are geographically distributed. The quantities of empirical and higher-order data used in this research are also increasing at an incredible pace. As such, the need to share large quantities of information in a timely manner among geographically distributed research centers becomes an essential part of accomplishing the objectives of these advanced research programs. Let me use several examples to illustrate this point:

The Large Hadron Collider (LHC), located at the European particle physics research center, CERN (*Conseil Européen pour la Recherche Nucléaire*), cost approximately $8 Billion to construct and is planned to begin operation in 2007. Once on-line, the Collider will produce an output stream of data approaching a Terabit (one trillion bits) per second which will be shared with 34 research centers around the world. The existing network infrastructure is not sufficient to handle this demand.

In the field of medical research, the newest 1.25 MeV (Mega-electron volts) ultra high-voltage electron microscopes, which allow detailed structural studies of biological specimens, produce network bandwidth requirements that approach 100 Gigabits per second—a requirement equivalent to the capacity planned for the largest American research network, Internet2 now under construction.

Today the Tera-grid network, which recently received increased funding from the National Science Foundation, links seven U.S.-based supercomputing and research centers. Tera-grid has 200 teraflops (one trillion floating point operations per second) of computational capacity, 20 terabytes of storage and will reach sustained data flows between these centers approaching and eventually exceeding 1 terabit per second.

As the first two examples illustrate, the basic instrumentation in advanced research can be so costly that simple economics mandate that these essential elements be shared by the many research centers and scientists rather than duplicating the basic functions. Further, all of the examples demonstrate the trend towards distributed use of enormous quantities of basic research data. Increasingly, refined specialty and inter-disciplinary research initiatives also create an increasing need for collaboration among various research centers and inter-disciplinary research teams. These two factors, cost efficiency and the need for research collaboration among geographically distributed centers, underlie and motivate the need for efficient, high-performance networks to interconnect these various research centers.

A final case in point is the National Science Foundation's (NSF) Major Research Engineering Facility Construction (MREFC) Program, which provides funding for complex research instruments at 10 centers across the United States, plus one in Antarctica. Each of these centers has an instrumentation and discipline-specific focus -- such as ecology, physics, magnetism, etc. The basic data produced by these instruments are shared among the scientific community by manual transference of data or, more efficiently, across networks which can speed the researchers' access to these basic data streams.

It is clear that the Federal Government has historically recognized the need to fund both high performance computing and high performance networking. The investments made two decades ago have left a proud legacy for the benefit of the entire world. It is also clear that this Subcommittee and the Federal government recognize the need for continued funding and research in the network component of the nation's "cyber-infrastructure" and have taken important steps to address these issues. Examples include:

- ✓ In 2003, the NSF Blue Ribbon Advisory Panel, published a report entitled "Revolutionizing Science and Engineering through cyber-infrastructure" in which it stated, "High-speed networks are a critical cyber-infrastructure facilitating access to the large, geographically distributed computing resources, data repositories, and digital libraries. As the commodity internet is clearly not up to the task for high-end science and engineering applications, especially where there is a real-time element (e.g. remote instrumentation and collaboration), a high-speed research network should be established and the current connections program extended to support access to this backbone as well as to provide international connections."

- ✓ The National Science and Technology Council in 2004 called for achieving aggressive networking goals such as:
  - networks with 1000 times existing capabilities,
  - with better security and trust mechanisms, and
  - development of inter-optical networks and middleware to couple networks with software.
- ✓ The National Science Foundation's recently announced plans for the Global Environment for Network Innovations (GENI) with the primary goal to enable the research community to invent and demonstrate a global communications network and related services that will be qualitatively better than today's Internet.

In addition to these important Federal initiatives is the work of our nation's Research universities. Recently, the non-profit consortium known as Internet 2, serving more than

200 research universities, took an important step towards meeting the growing bandwidth requirements of many of the United States' top research centers.

On June 15, 2006, Level (3) and Internet2 announced an agreement to design and deploy a new nationwide network and new services to enhance and support the advanced needs of the academic and research community. Internet2's new network will provide its members with 100 gigabits per second (Gbps) of network capacity between key research centers, more than 10 times that of its current backbone. Even with this big step forward, Internent 2's members have asked Level 3 to provide a network platform capable of handling even larger bandwidth demands. Accordingly, a key design characteristic of this network is the ability to quickly scale to add capacity as members' requirements evolve.

> [Visual Aid]: This map represents a small fraction of the Institutions who are members of Internet2.   This illustration also shows a number of the Federally Funded Research and Development Centers which will directly or indirectly benefit from the Internet2 backbone.

Under the agreement with Internet2, Level 3 will deploy leading edge digital optical technologies to provide multiple ten (10)Gbps wavelengths and enable rapid bandwidth provisioning across the entire network. These new optical services will allow researchers and scientists to obtain dedicated one (1)Gbps sub-wavelengths or entire ten (10)Gbps wavelengths and optimize the utilization of the network to suit the information-sharing needs of the researchers.

In addition to providing high capacity, scalable bandwidth, achieving efficient utilization of the network is critical to ensuring that researchers have the bandwidth they need when they need it. Optimal utilization of network resources improves the economic efficiency of the research, allowing more robust and dynamic use of the network. Internet 2's network and the flexible optical services it provides, will increase flexibility and support bandwidth-intensive experimental applications which have direct impact on the United States' research agenda, homeland security, national defense and our economy. Like the Federal initiatives cited earlier, Internet2 demonstrates that the network is an essential component of the nation's "cyber-infrastructure" and essential to achieving the objectives of the most advanced research being conducted in the United States and abroad.

Summary and Recommendations:

In summary, I believe that a Federal policy that achieves a balance of investment and focus on the three key elements of the nation's "cyber-infrastructure" – computing power, software, and networking – is likely to yield the greatest benefits. A balanced approach will: 1) contribute to the attainment of the goals of the American Innovation

Act; 2) work to ensure that all of the essential elements of the nation's "innovation infrastructure" are available to facilitate advanced research; 3) contribute to Homeland Security and National Defense; and 4) fortify the United States' economic and technological competitive position.

I thank you for your time and I am happy to answer any questions you have.