Testimony of Dr. C. Edward Oliver
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before the
Subcommittee on Technology, Information Policy,
Intergovernmental Relations and the Census
Committee on Government Reform
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Mr. Chairman and members of the Committee: I commend you for holding this hearing. I appreciate the opportunity to testify on behalf of the Department of Energy's (DOE) Office of Science (SC) on a subject of importance to this Nation, Information Technology Research. I will focus today on those areas where DOE-SC directs its efforts: high-performance computing, large-scale networks, and the software that enables scientists to use these resources as tools for scientific discovery.

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Mr. Chairman, for more than half a century, every President and each Congress has recognized the vital role of science in sustaining this Nation's leadership in the world.

Ever since its inception as part of the Atomic Energy Commission immediately following World War II, the Office of Science has blended cutting-edge research and innovative problem solving to keep the U.S. at the forefront of scientific discovery. In fact, since the mid-1940's, the Office of Science has supported the work of more than 40 Nobel Prize winners, testimony to the high quality and importance of the work it underwrites.

The Office of Science is the single largest supporter of basic research in the physical sciences in the United States, providing more than 40 percent of total Federal funding. It oversees – and is the principal Federal funding agency of – the Nation's research programs in high-energy physics, nuclear physics, and fusion energy sciences.

The Office of Science manages fundamental research programs in basic energy sciences, biological and environmental sciences, and computational science. In addition, the Office of Science is the Federal Government's largest single source of funds for materials and chemical sciences, and it supports unique and vital parts of U.S. research in climate change, geophysics, genomics, life sciences, and science education.

The Office of Science manages this research portfolio through six interdisciplinary program offices: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy Physics and Nuclear

Physics.

The Office of Science also manages 10 world-class laboratories, which often are called the "crown jewels" of our national research infrastructure. The national laboratory system, created over a half-century ago, is the most comprehensive research system of its kind in the world. The 10 Office of Science laboratories are: Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Thomas Jefferson National Accelerator Facility, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory and the Stanford Linear Accelerator Center.

The Office of Science oversees the construction and operation of some of the Nation's most advanced R&D user facilities, located at national laboratories and universities. These include particle and nuclear physics accelerators, synchrotron light sources, neutron scattering facilities, supercomputers and high-speed computer networks. Each year these facilities are used by more than 18,000 researchers from universities, other government agencies and industry.

The Office of Science is a principal supporter of graduate students and postdoctoral researchers early in their careers. About 50 percent of its research funding goes to support research at 250 colleges, universities, and institutes nationwide.

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The Administration recognizes the importance of high-performance computing for the Nation. A recent plan developed by the High End Computing Revitalization Task Force (http://www.itrd.gov/pubs/2004_hecrtf/20040510_hecrtf.pdf.) encourages DOE's Office of Science and other Federal agencies to work together to develop the next generation of advanced scientific computational capability for the benefit of America's scientific enterprise.

The elements of this plan include a coordinated research strategy to address critical barriers in high-performance computing for key Federal missions in science and national security as well as a strategy for providing a portfolio of high-performance computing resources for scientists and engineers in the U.S. The Office of Science invests in high-performance computing and networks to deliver the full benefit of this revolution to U.S. science. Of course in these areas of IT research DOE-SC works with other Federal agencies to deliver the science and the facilities the nation needs. To the maximum possible degree, access to these resources should be open to all U.S. researchers--whether they work for the government, universities, or industry--on a competitive, peer reviewed basis.

Advanced scientific computing is central to DOE's missions. It is essential to simulate and predict the behavior of nuclear weapons and aid in the discovery of new scientific knowledge. The importance of advanced scientific computing and networks to DOE is underscored in the DOE strategic plan (http://strategicplan.doe.gov/full.pdf)

> Strategy 6: Significantly advance scientific simulation and computation, applying new approaches, algorithms, and software and hardware combinations to address the critical science challenges of the future.

And Goal 6 of the Office of Science Strategic Plan (http://www.science.doe.gov/Sub/Mission/Strategic_Plan/Feb-2004-Strat-Plan-screen-res.pdf)

> Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

In fact, in fulfilling its mission over the years, the Office of Science has played a key role in scientific computation and networking. Consider some of the innovations and contributions made by DOE's Office of Science:

- helped develop the Internet;
- pioneered the transition to massively parallel supercomputing in the civilian sector;
- began the computational analysis of global climate change;
- developed many of the computational technologies for DNA sequencing that have made possible the unraveling of the human genetic code;
- simulated combustion reactions with the goal of reducing emissions.

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Computational modeling and simulation rank among the most significant developments in the practice of scientific inquiry in the latter half of the 20th century and are now a major force for discovery in their own right. In the past century, scientific research was extraordinarily successful in identifying the fundamental physical laws that govern our material world. At the same time, the advances promised by these discoveries have not been fully realized, in part because the real-world systems governed by these physical laws are extraordinarily complex. Computers help us visualize, test hypotheses, guide experimental design, and most importantly determine if there is consistency between theoretical models and experiment. Computer-based simulation provides a means for predicting the behavior of complex systems that can only be described empirically at present. Since the development of digital computers in mid-century, scientific computing has greatly advanced our understanding of the fundamental processes of nature, e.g., fluid flow and turbulence in physics, molecular structure and reactivity in chemistry, and drug-receptor interactions in biology. Computational simulation has even been used to explain, and sometimes predict, the behavior of such complex natural and engineered systems as weather patterns and aircraft performance.

Within the past two decades, scientific computing has become a contributor to essentially all scientific research programs. It is particularly important to the solution of research problems that are (i) insoluble by traditional theoretical and experimental approaches, e.g., prediction of future climates or the fate of underground contaminants; (ii) hazardous to study in the laboratory, e.g., characterization of the chemistry of radionuclides or other toxic chemicals; or (iii) time-consuming or expensive to solve by traditional means, e.g., development of new materials, determination of the structure of proteins, understanding plasma instabilities, or exploring the limitations of the "Standard Model" of particle physics. In many cases, theoretical and experimental approaches do not provide sufficient information to understand and predict the behavior of the systems being studied. Computational modeling and simulation, which allow a description of the system to be constructed from basic theoretical principles and the available experimental data, are keys to solving such problems.

We have moved beyond using computers to solve very complicated sets of equations to a new regime in which scientific simulation enables us to obtain scientific results and to perform discovery in the same way that experiment and theory have traditionally been used to accomplish those ends. We must think of computation as the third of the three pillars that support scientific discovery, and indeed there are areas where the only approach to a solution is through high-end computation.

High performance networks play a critical role as well in allowing researchers to overcome the geographical distances that often hinder science. The Office of Science maintains a state-of-the-art high-speed Energy Science network, ESnet, which ensures that scientific resources are readily available to scientists around the world. DOE-SC works closely with the National Science Foundation and university consortia such as Internet 2 to ensure that scientists at universities can seamlessly access unique DOE facilities and their scientific partners in DOE laboratories.

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To develop systems capable of meeting the challenges faced by DOE, universities, and industry, the Office of Science invests in several areas of computation: high-performance computing, large-scale networks, and the software that enables scientists to use these resources as tools for discovery. The FY 2005 President’s Request for the Office of Science includes $204 million for ASCR for IT R&D and approximately $20 million in the other Offices to support the development of the next generation of scientific simulation software for SC mission applications.

As a part of this portfolio the Office of Science supports basic research in applied mathematics and the computer science needed to underpin advances in high-performance computers and networks for science.

In FY 2001 the Office of Science initiated the Scientific Discovery through Advanced Computing (www.science.doe.gov/SciDAC/) effort to leverage our basic research in mathematics and computer science and integrate this research into the scientific teams that extend the frontiers of science across DOE-SC. We have assembled interdisciplinary teams and collaborations to develop the necessary state-of-the-art mathematical algorithms and software, supported by appropriate hardware and middleware infrastructure, to use terascale computers effectively to advance the fundamental scientific research at the core of DOE’s mission.

All of these research efforts, as well as the success of computational science across SC, depend on a portfolio of high-performance computing facilities and testbeds and on the high-performance networks that link these resources to scientists across the country. Since the early 1950s, DOE and the Office of Science have been leaders in testing and evaluating new high performance computers and networks and turning them into tools for scientific discovery. The Office of Science established the first national civilian supercomputer center, the Magnetic Fusion Energy Computer Center, in 1975. We have tested and evaluated early versions of computers ranging from the first Cray 1s to the parallel architectures of the 1990s, to the Cray X1 at ORNL. Our current facilities and testbeds include:

- The Center for Computational Sciences (CCS) at Oak Ridge National Laboratory, which has been testing and evaluating leading edge computer architectures as tools for science for over a decade. The latest evaluation, on a Cray X1, formed the basis for ORNL's successful proposal to begin developing a new supercomputer. In his remarks announcing the result of this competition, Secretary of Energy Spencer Abraham stated, "This new facility will enable the Office of Science to deliver world leadership-class computing for science," and "will serve to revitalize the U.S. effort in high-end computing." This supercomputer will be open to the scientific community for research.

- The National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory, which provides leading edge high-performance computing services to over 2,000 scientists nationwide. NERSC has a 6,000 processor IBM SP3 computer with a peak speed of 10 Teraflops. We have initiated a new program at NERSC, Innovative and Novel Computational Impact on Theory and Experiment (INCITE), to allocate substantial computing resources to a few, competitively selected, research proposals from the national scientific community. Last year, the Office of Science selected three proposals were selected for INCITE. One of these has successfully simulated the explosion of a supernova in 3-D for the first time.

- The ESnet, which links DOE facilities and researchers to the worldwide research community. ESnet works closely with other Federal research networks and with university consortia such as Internet 2 to provide seamless connections from DOE to other research communities. This network must address facilities that produce millions of gigabytes of data each year and deliver these data to scientists across the world.

We have learned important lessons from these testbeds. By sharing our evaluations with vendors we have enabled them to produce better products to meet critical scientific and national security missions. Our spending complements commercial R&D in IT which is focused on product development and on the demands of commercial applications which generally place different requirements on the hardware and software than do leading edge scientific applications.

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To accomplish its goals the Office of Science works closely with other agencies. In the areas where DOE –SC focuses its research, High-End Computing and Large-Scale Networking, DOE-SC cochairs the relevant coordinating group. In addition to this mechanism, DOE-SC has engaged in a number of other joint planning and coordination efforts.

- DOE-SC participated in the National Security community planning effort to develop an Integrated High-End Computing plan.
- DOE-SC and DOD cochaired the HECRTF.
- DOE-SC and NSF cochair the Federal teams that coordinate the engineering of Federal research networks and the emerging GRID Middleware.
- DOE-SC is a partner with DARPA in the High Productivity Computing Systems project, which will deliver the next generation of advanced computer architectures for critical science and national security missions through partnerships with U.S. industry.
- DOE-SC works closely with NNSA on critical software issues for high performance computing.
- DOE-SC, DOE-NNSA, DOD-ODDR&E, DOD-NSA, and DOD-DARPA have developed a Memorandum of Understanding to jointly plan our research in high performance computing. This MOU will enable us to better integrate our substantial ongoing collaborative projects.

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Mr. Chairman, high-performance computing provides a new window for researchers to understand the natural world with a precision that could only be imagined a few years ago. Federal investments in advanced scientific computing equip researchers to advance knowledge and help solve the most challenging scientific problems facing the Nation. These national research investments might also provide current and prospective benefits to American industry, enabling it to use leading edge computational tools and simulation to develop new, more efficient, higher quality products for the U.S. consumer and greater competitiveness for the U.S. economy. Opportunities range from innovative design and engineering to materials development, all of which may serve to increase efficiency and safety while potentially reducing environmental effects.

Computing is an important tool in carrying out Federal agency missions in science and technology, but the government high-end computer market is simply not large enough to divert computer industry attention from the much larger and more lucrative business computing sector. The Federal Government must continue our research and prototype development on the next generation of computers, if we are to effectively carry out our scientific mission in the future.

With the continued support of this Committee, the Congress and the Administration, we in the Office of Science hope to continue to play an important role in the world of scientific supercomputing. Thank you very much.