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Chairman Stevens, Co-Chairman Inouye, and distinguished members of the Committee, I'm honored to have the opportunity to speak with you about developments in nanotechnology—in particular, the role of the National Nanotechnology Initiative (NNI) in driving the responsible development and application of nanotechnology. That is my primary message today—that the NNI has been and continues to be the major driver for developments and applications of nanotechnology in the U.S. and the world.

The NNI—now in its sixth year—is a highly successful, collaborative, cross-cutting program among 25 Federal agencies: 13 agencies involved in the NNI R&D budget and 12 others with missions related to advances in nanotechnology (see list below). For a description of the vision, goals, organization, and management of the initiative, I would direct you to the NNI Strategic Plan provided along with this written testimony. Because of the NNI, 1) Federal agencies have initiated major new programs and efforts in nanotechnology research, development, and applications that expand knowledge and understanding, address broad national goals, and support the agencies' missions; 2) an extensive infrastructure of focused centers of excellence in nanotechnology and nanotechnology user facilities has been established and continues to grow; and 3) the 25 participating agencies are working together to maximize the effectiveness of their individual and collective investment through communication, coordination, and joint programs.

As called for by you and your fellow legislators, the President's Council of Advisors on Science and Technology (PCAST), in its role as the National Nanotechnology Advisory Panel, recently reviewed the first five years of the NNI. In its report, which is provided along with this written testimony, PCAST concludes that our activities already have paid significant dividends, such as "advancing foundational knowledge, promoting technology transfer for commercial and public benefit, developing an infrastructure of user facilities and instrumentation, and taking steps to address societal concerns." PCAST members believe the NNI "appears well positioned to maintain United States leadership going forward," that "the money the U.S. is investing in nanotechnology is money very well spent," and that "continued robust funding is important for the Nation's long-term economic well-being and national security."

With a total Federal investment of more than $1 billion per year, the U.S. is the acknowledged world leader in nanotechnology R&D as evidenced by research output measured by patents and publications. With only one quarter of the total international funding in nanotechnology, U.S. researchers are the leading producers of nanotechnology patents and publish over half of the nanotechnology papers in high-impact journals worldwide.

The investment of such funds must lead to commercialization, however, in order to contribute to our economy. The NNI has also been effective in moving science from the bench to products in the marketplace. The U.S. leads in the number of nanotechnology-based startup companies, many of which have received Federal support. More than 160 companies supported by Small Business Innovation Research grants are now producing nanotechnology-

based products or providing related commercial services. Many of these are among the 600 "pure play" nanotechnology companies formed in the United States since 2001 identified in a recent survey by Small Times Media.

Technology transfer is also promoted by the creation of a large, geographically distributed network of research facilities. The NNI has established more than 50 nanotechnology research and education centers at universities and government laboratories, including more than a dozen user facilities that are open to all researchers, including those from industry. Such broad access facilitates collaborations between government, business, and university partners. (See the attached list of all centers and user facilities established by the agencies participating in the NNI.)

I'd like to take a moment to explain why the Federal Government is investing over $1 billion in nanotechnology R&D each year. Nanotechnology incorporates science, engineering, and technology at the nanometer scale. Technically, a nanometer is a millionth of a millimeter; I find it useful to think of a nanometer in terms of the thickness of a sheet of paper—100,000 nanometers. At this scale, properties of materials can differ markedly from those of individual atoms and molecules or of bulk matter. By putting these unique properties to work, scientists are developing highly beneficial products in medicine, energy, electronics, materials, and other areas. Nanoscale control over the structure of materials and their properties is already leading to a variety of innovative technologies and is expected to impact virtually all industry sectors as an "enabling" or "key" technology. Some examples of impact areas are shown in the figure below.

To focus on one of these areas, consider an example of how nanotechnology could transform our economy and enhance our national security. Sunlight is by far the largest of all carbon-neutral energy sources. More energy from sunlight strikes the Earth in one hour than all the energy consumed on the planet in a year. Sunlight has long been seen as a compelling solution to our need for clean, abundant sources of energy in the future. It is readily available, secure from geopolitical tension, and can reduce the impact of energy use on our environment. This great promise has long been recognized. But cost and low efficiency issues have stood in the way of harnessing this energy—problems that are largely due to materials limitations. Nanotechnology allows us to design materials with combinations of properties not found in previously available materials. Photovoltaic cells formed from quantum dots—nanometer-sized particles of semiconductor materials—have been engineered to absorb and convert energy from multiple parts of sunlight's spectrum to electricity, yielding devices with significantly higher efficiency than those currently in use.

Today, the cost of producing electricity from photovoltaic cells is between two and five times that from conventional systems. With new materials and devices for energy conversion, transmission, and storage, this price differential could be bridged and make photovoltaic cell production of electricity competitive with that of conventional systems.

Another vital element of the NNI is research directed at environmental, health, and safety (EHS) impacts. The U.S. is the world leader in funding EHS research on the implications of engineered nanoscale materials. Further, the Federal Government has been coordinating research activity in this area since 2003, when the National Toxicology Program began a new program on several engineered nanoscale materials and the Nanotechnology Environmental and Health Implications (NEHI) Working Group was formed within the NNI. NEHI brings together representatives from some 24 agencies that support nanotechnology research or that have regulatory responsibilities to exchange information and to identify, prioritize, and implement research needed to support regulatory decision-making processes. Through the efforts of the NEHI Working Group, regulatory agencies have been proactively engaged with each other and the research agencies, leading to earlier awareness of relevant issues and expedited activities to address them. In addition, those agencies that are primarily focused on research have a greater appreciation for the issues confronted by the regulatory bodies.

My colleague Dr. Buckias will report on NSF's support of programs aimed at improving nanotechnology education at all ages, including through informal venues, such as science museums. NSF is also to be commended for the creation, in the fall of 2005, of the Network for Nanotechnology in Society. That network will engage economists, social scientists, and non-scientists in looking at how nanotechnology could impact society economically, socially, legally, and how nanotechnology fits into the ethical dialogue on potential outcomes of emerging technologies. Engaging various publics in discussions regarding nanotechnology development is another function of this network.

Because technological innovation is a global phenomenon, international cooperation and coordination on many of the pre-competitive and non-competitive aspects of nanotechnology will encourage development to occur in a responsible and beneficial manner. The United States takes the position that all countries will benefit from cooperating and coordinating efforts in many of the formative areas of nanotechnology R&D, such as technical norms and standards; intellectual property rights; environment, health, and safety; and education. In 2005, the NSET created an informal working group on Global Issues in Nanotechnology, whose

purpose is to develop, coordinate, and support U.S. Government international activities related to nanotechnology.

The GIN working group has supported numerous international activities in the past year, including those involving the Organization for Economic Co-operation and Development (OECD). At an October 2005 meeting of the OECD Committee for Scientific and Technological Policy (within the Science, Technology and Industry Directorate), the U.S. proposed the creation of a Working Party on Nanotechnology. This new Working Party would provide an international governmental forum to help OECD Member States and Observers more effectively utilize their nanotechnology R&D investments in furtherance of the CSTP goals of stimulating science and innovation, enhancing economic growth, providing societal benefits, and promoting innovation through international science and technology cooperation. In parallel, following a workshop hosted by the United States on the safety of manufactured nanomaterials, a proposal has been made to create within the OECD Environmental Directorate a working group focused on EHS risk assessment and management of nanomaterials.

A critical aspect of protecting health and the environment are standardized tools and methods for measuring and monitoring exposure; developing standardized methods for characterizing properties of personal protective equipment, etc. Accordingly, the International Organization for Standardization (ISO) established in late 2005 the Nanotechnologies Technical Committee. The Working Group on Health, Safety, and Environmental Aspects of Nanotechnologies under the Technical Committee will be led by the U.S. I was privileged to lead the U.S. delegation to the ISO inaugural nanotechnology-related meeting and also chair of the American National Standards Institute (ANSI)-accredited U.S. Technical Advisory Group (TAG) for nanotechnology standards.

The U.S. delegation to that ISO meeting submitted the National Institute for Occupational Safety and Health document on "Approaches to Safe Nanotechnology" to the ANSI TAG for consideration as a possible work item. Following further development and approval of the draft by the ANSI TAG, the document will be put forth to the ISO Working Group as a draft work item toward an ISO Technical Report. Once approved by the ISO Technical Committee, the document will be issued as an ISO Technical Report, an informational document available for use by all countries.

The work of the NNI has been broad. Still, there are challenges ahead. Among them is strong competition from other countries and regions, particularly the EU, Japan, and China, an issue with both economic and national security implications, and also for retaining our finest scientists.

I hope I have been able to communicate that the NNI has been a major driver for developments and applications of nanotechnology in the U.S. and the world. The NNI leadership sees tremendous opportunity ahead and fully realizes that much work remains to be done. We have a vigorous program underway to launch a new era in science and technology in the U.S., thanks to the support of the Administration and Congress. With continued support the NNI will advance discoveries in medicine, energy, security, and other areas that will bring us closer to achieving some of our greatest national and societal goals.

List of Federal Agencies Participating in the NNI During 2006

Federal agencies with budgets dedicated to nanotechnology research and development

Department of Agriculture, Cooperative State Research, Education, and Extension Service (USDA/CSREES)
Department of Agriculture, Forest Service (USDA/FS)
Department of Defense (DOD)
Department of Energy (DOE)
Department of Homeland Security (DHS)
Department of Justice (DOJ)
Department of Transportation (DOT)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)
National Institute of Standards and Technology (NIST, Department of Commerce)
National Institute for Occupational Safety and Health (NIOSH, Department of Health and Human Services/Centers for Disease Control and Prevention)
National Institutes of Health (NIH, Department of Health and Human Services)
National Science Foundation (NSF)

Other participating agencies

Bureau of Industry and Security (BIS, Department of Commerce)
Consumer Product Safety Commission (CPSC)
Department of Education (DOEd)
Department of Labor (DOL)
Department of State (DOS)
Department of the Treasury (DOTreas)
Food and Drug Administration (FDA, Department of Health and Human Services)
International Trade Commission (ITC)
Intelligence Technology Innovation Center, representing the Intelligence Community (IC)
Nuclear Regulatory Commission (NRC)
Technology Administration (TA, Department of Commerce)
U.S. Patent and Trademark Office (USPTO, Department of Commerce)

National Nanotechnology Initiative Infrastructure:
Centers, Networks and User Facilities
February 2006

NNI Center, Network, or User Facility	Agency	Host Institution
Institute for Nanoscience	DOD	Naval Research Lab
Institute for Soldier Nanotechnologies	DOD	Massachusetts Institute of Technology
Nanoscience Innovation in Defense	DOD	U California-Santa Barbara
Functional Nanomaterials (pre-operations)	DOE	Brookhaven National Lab
Integrated Nanotechnologies (pre-operations)	DOE	Sandia and Los Alamos National Labs
Molecular Foundry (pre-operations)	DOE	Lawrence Berkeley National Lab
Nanophase Materials Sciences	DOE	Oak Ridge National Lab
Nanoscale Materials (pre-operations)	DOE	Argonne National Lab
Biologically Inspired Materials Institute	NASA	Princeton U
Cell Mimetic Space Exploration	NASA	U California-Los Angeles
Intelligent BioNanomaterials & Structures for Aerospace Vehicles	NASA	Texas A & M
Nanoelectronics & Computing	NASA	Purdue
Engineering Cellular Control: Synthetic Signaling and Motility Systems	NIH	U California-San Francisco
NanoMedicine Center for Mechanical Biology	NIH	Columbia U
National Center for Design of Biomimetic Nanoconductors	NIH	U Illinois Urbana-Champaign
Protein Folding Machinery	NIH	Baylor College of Medicine
Cancer Nanotechnology Excellence	NIH/NCI	U. North Carolina
Cancer Nanotechnology Excellence	NIH/NCI	Massachusetts Institute of Technology/Harvard U
Nanomaterials for Cancer Diagnostics and Therapeutics	NIH/NCI	Northwestern U
Nanosystems Biology Cancer Center	NIH/NCI	California Institute of Technology
Nanotechnology Characterization Laboratory	NIH/NCI	NCI Frederick
Nanotechnology Excellence Focused on Therapy Response	NIH/NCI	Stanford U
Nanotechnology for Treatment, Understanding, and Monitoring of Cancer	NIH/NCI	U California-San Diego
Personalized and Predictive Oncology	NIH/NCI	Emory U/Georgia Institute of Technology
The Siteman Center of Cancer Nanotechnology Excellence	NIH/NCI	Washington U

NNI Center, Network, or User Facility	Agency	Host Institution
Integrated Nanosystems for Diagnosis and Therapy	NIH/NHLBI	Washington U
Nanotechnology: Detection & Analysis of Plaque Formation	NIH/NHLBI	Emory U
Nanotherapy for Vulnerable Plaque	NIH/NHLBI	Burnham Institute
Translational Program of Excellence in Nanotechnology	NIH/NHLBI	Massachusetts General Hospital
Nanoscale Science and Technology	NIST	NIST/Gaithersburg
Affordable Nanoengineering of Polymer Biomedical Devices	NSF	Ohio State U
Directed Assembly of Nanostructures	NSF	Rensselaer Polytechnic Institute
Electron Transport in Molecular Nanostructures	NSF	Columbia U
Extreme Ultraviolet Science and Technology	NSF	Colorado State U
High-Rate Nanomanufacturing	NSF	Northeastern U
Integrated Nanomechanical Systems	NSF	U California-Berkeley
Integrated Nanopatterning & Detection	NSF	Northwestern U
Learning & Teaching in Nanoscale Science & Engineering	NSF	Northwestern U
Molecular Function at NanoBio Interface	NSF	U Pennsylvania
Nanobiotechnology	NSF	Cornell U
Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems	NSF	U Illinois Urbana-Champaign
Nanoscale Systems & Their Device Applications	NSF	Harvard U
Nanoscale Systems in Information Technologies	NSF	Cornell U
Nanoscience in Biological & Environmental Engineering	NSF	Rice U
Nanotechnology Computational Network	NSF	Purdue and others
National Nanotechnology Infrastructure Network	NSF	Cornell U and others
Network for Informal Science Education at the Nanoscale	NSF	Museum Of Science-Boston and others
Network for Nanotechnology in Society	NSF	Arizona State U, U California-Santa Barbara, and others
Network of Materials Research Science and Engineering Centers	NSF	various
Oklahoma Nano Net	NSF	Oklahoma U, Oklahoma State U and others
Probing the Nanoscale	NSF	Stanford U
Scalable & Integrated Nanomanufacturing	NSF	U California- Los Angeles
Templated Synthesis & Assembly at the Nanoscale	NSF	U Wisconsin-Madison