

Statement of Dr. Lloyd Whitman
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to the
Committee on Science, Space and Technology
Subcommittee on Research and Technology
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Hearing on
Nanotechnology: From Laboratories to Commercial Products
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Chairman Bucshon, Ranking Member Lipinski, and Members of the Committee, it is my distinct privilege to be here with you today to discuss nanotechnology and the role of the National Nanotechnology Initiative in promoting its development for the benefit of the United States.

What is Nanotechnology?

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers. A nanometer is one billionth of a meter; a sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. Encompassing nanometer-scale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. Unusual physical, chemical, and biological properties can emerge in materials at the nanometer scale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules, and can enable novel applications not possible in bulk materials of the same chemical composition.

For example, in bulk form gold is chemically inert, while gold nanoparticles can act as catalysts to speed up chemical reactions. Gold nanoparticles may appear pink, purple, red, or other colors depending on their size and shape, and are under investigation for a wide variety of applications, including diagnosing and treating cancer. Bulk carbon (“soot”) is considered a waste byproduct of combustion, whereas nanostructured carbon in the form of nanotubes or graphene (the subject of the 2010 Nobel Prize in Physics) exhibit remarkable electrical and mechanical properties that could enable the next generation of computers, composites that are stronger and lighter than steel, and a myriad of other potential applications. Semiconductor nanoparticles known as “quantum dots” are now being used in flat-panel TVs and light bulbs to provide more vivid and accurate colors. There are countless other examples; nanotechnology opens up an entirely new dimension in enabling the development of materials with tailored properties previously unknown or considered impossible.

The unique properties of nanostructured materials are already in use in a wide variety of nanotechnology-enabled products on the market today, from electronics to energy conversion,

medicine, and advanced manufacturing.¹ These early applications are only the beginning of a revolution in technology and industry that will have a profound impact on our economy, health, and national security, and that can excite a new generation of students to choose careers in science, technology, engineering, and math.

What is the National Nanotechnology Initiative?

Recognizing this exciting potential, President Clinton created the National Nanotechnology Initiative (NNI) in 2000, and Congress formally authorized the NNI under the 21st Century Nanotechnology R&D Act of 2003.² Since then, with bipartisan support from three presidents and eight Congresses, Federal funding for nanotechnology across 11 Federal departments, agencies, and independent commissions has grown to over \$1.5 billion per year, with a cumulative investment of over \$20 billion since 2001. A total of 20 agencies with missions and activities related to nanotechnology participate in the NNI, which is coordinated through the National Science and Technology Council (NSTC). The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the NSTC's Committee on Technology coordinates planning, budgeting, program implementation, and review of progress for the Initiative. The NSET Subcommittee is composed of representatives from participating agencies and the Executive Office of the President. The National Nanotechnology Coordination Office (NNCO), which I direct, acts as the primary point of contact for information on the NNI; provides technical and administrative support to the NSET Subcommittee, including the preparation of multiagency planning, budget, and assessment documents; develops, updates, and maintains the NNI website www.nano.gov; and provides public outreach on behalf of the NNI.

The NNI is a coordinated multi-agency initiative, not a distinctly funded “program” with a centralized budget. Each year the Office of Management and Budget sends a request to the participating agencies for data on their current and proposed spending on nanotechnology; the sums of these figures are reported to Congress in the NNI Supplement to the President's Budget, a document that also serves as the annual report to Congress called for in the Act.³ Through the NSET Subcommittee and its working groups, and with support from the NNCO, the NNI fosters coordination and collaboration across agencies, leverages funding and avoids duplication of efforts, and provides a framework by which agencies work towards common goals and objectives that are outlined in the NNI Strategic Plan,⁴ updated every three years (most recently in February 2014), also per the Act.

¹ Nanotechnology-enabled products are already valued at an estimated \$1 trillion in annual sales today, projected to grow to \$3 trillion by 2018, per Lux Research, Feb. 2014, *Nanotechnology Update: Corporations Up Their Spending as Revenues for Nano-enabled Products Increase* (available by subscription at <http://portal.luxresearchinc.com/>).

² Hereinafter referred to as “the Act.”

³ http://www.nano.gov/sites/default/files/pub_resource/nni_fy15_budget_supplement.pdf. Includes a list of all NNI participating agencies and descriptions of their current and planned activities.

⁴ http://www.nano.gov/sites/default/files/pub_resource/2014_nni_strategic_plan.pdf. Includes complete list of all NNI goals and objectives, discussion of each agency's interests in and activities related to nanotechnology, and an explanation of the Program Component Areas, or budget categories, for 2013 and beyond.

Highlights of the National Nanotechnology Initiative

Our current Federal research and development program in nanotechnology is strong. The NNI agencies continue to further the NNI's goals of (1) advancing nanotechnology R&D, (2) fostering nanotechnology commercialization, (3) developing and maintaining the U.S. workforce and infrastructure, and (4) supporting the responsible and safe development of nanotechnology. The NNI Supplement to the President's 2015 Budget (see footnote 3 above) highlights progress of the NNI agencies with respect to each of these goals. In support of goal 1, R&D, the NNI is sustaining a broad R&D investment portfolio across 11 Federal departments, agencies, and independent commissions. In support of goal 2, commercialization, the NNI agencies are using programs such as Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and the National Science Foundation (NSF) Innovation Corps to fund and support small business activities and commercialization. Agencies are also engaged with public-private partnerships to leverage industry resources and expertise.⁵ With respect to goal 3, infrastructure, the NNI is sustaining its long-standing investments in research centers and user facilities, and in nanotechnology education at all levels. Regarding responsible development of nanotechnology (goal 4), as part of agency efforts to ensure that new nanomaterials and nanotechnology-enabled products will be safe for public use from their inception to their disposal, the NNI released a comprehensive environmental, health, and safety (EHS) research strategy in 2011.⁶ The NSET Subcommittee and its Nanotechnology Environmental and Health Implications (NEHI) Working Group continue to coordinate, facilitate, and monitor progress towards its implementation. NNI funding for EHS research has roughly tripled since 2006, and now represents over 7% of the annual NNI R&D investment.⁷ The NNI also continues to support research on ethical, legal, and other societal implications issues associated with nanotechnology.

The most recent reviews of the NNI by the National Nanotechnology Advisory Panel (NNAP)⁸ and by the National Academies⁹ (called for by the Act) both concur that the initiative is strong. However, there is always room for improvement, as also suggested by the NNAP and the National Academies. The coordination and implementation of the NNI has been a dynamic process designed for continuous improvement as the Initiative progresses. For example, specific objectives designed to strengthen Federal nanotechnology activities under each of the NNI goals are enumerated in the 2014 NNI Strategic Plan. This year's plan, released in February, also sets out new Program Component Areas (or budget categories), including one for the Nanotechnology Signature Initiatives, which spotlight areas of national significance that can be more rapidly advanced through focused and closely coordinated interagency collaboration. This updated plan addresses NNAP and

⁵ Examples include the SRC Nanoelectronics Research Initiative, and P3Nano, a partnership between USDA Forest Service Forest Products Laboratory and the U.S. Endowment for Forestry and Communities formed to advance the commercialization of cellulosic nanomaterials.

⁶ http://www.nano.gov/sites/default/files/pub_resource/nni_2011_ehs_research_strategy.pdf

⁷ <http://nanodashboard.nano.gov/>

⁸ http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST_2012_Nanotechnology_FINAL.pdf

⁹ http://www.nap.edu/catalog.php?record_id=18271

National Academies recommendations, as well as input from a wide variety of stakeholders, gathered through workshops and Federal Register notices.

Congress plays a critical role in strengthening Federal nanotechnology R&D activities, providing oversight as well as the resources needed to carry out the activities described in the NNI Strategic Plan and the NNI Supplement to the President's Budget.

The sustained, strategic Federal investment in nanotechnology R&D combined with strong private sector investments in the commercialization of nanotechnology-enabled products has made the United States the global leader in nanotechnology. The most recent (2012) NNAP report analyzed a wide variety of sources and metrics and concluded that "... in large part as a result of the NNI the United States is today... the global leader in this exciting and economically promising field of research and technological development."¹⁰ A recent report on nanomanufacturing by Congress's own Government Accountability Office (GAO) arrived at a similar conclusion, again drawing on a wide variety of sources and stakeholder inputs.¹¹ As discussed in the GAO report, nanomanufacturing and commercialization are key to capturing the value of Federal R&D investments for the benefit of the U.S. economy. The United States leads the world by one important measure of commercial activity in nanotechnology: According to one estimate,¹² U.S. companies invested \$4.1 billion in nanotechnology R&D in 2012, far more than investments by companies in any other country. The NNI's Federal investments are relatively modest in comparison, but play a very different role, supporting a critical pipeline of basic research, generating new innovations that will provide opportunities for future industry investments in applied R&D, and demonstrating the Government's commitment to the field—critical to sustaining private sector investments in commercializing nanotechnology-based products.

The 21st Century Nanotechnology Research and Development Act of 2003 has provided an excellent framework over the past decade for the coordination and oversight of the NNI, in turn helping to establish and maintain U.S. global leadership in nanotechnology. Over these years, the NNI has brought together the agencies to develop and implement a national strategy for nanotechnology R&D, as called for in the Act in the form of periodic strategic plans, resulting in a strong Federal community of interest. The participating agencies actively communicate, coordinate, and collaborate within the NNI structure, which has enabled enhanced awareness of ongoing and planned activities within the agencies aligned with their respective missions, thus ensuring the greatest possible leveraging of resources for the American taxpayer. In particular, the Act has been very effective in helping the NNI agencies develop a robust, well-coordinated program of environmental, health, and safety research.

¹⁰ Op. cit., cover letter, p. iii.

¹¹ <http://www.gao.gov/assets/670/660591.pdf>, p. 17: "...forum participants viewed the United States as, overall, likely leading in nanotechnology R&D at the present time."

¹² Lux Research, Op. Cit. (reference 1 above).

Federal agencies collaborate through the NSET Subcommittee's NEHI Working Group to periodically review the status of nanotechnology environmental, health, and safety. Through joint alignment of research activities, Federal agencies participating in the NEHI Working Group have:

- Coordinated and continued to implement research needs highlighted in the 2011 NNI EHS Research Strategy, which provides guidance to NNI agencies to ensure the safe, effective, and responsible development and use of nanotechnology. This includes efforts that pertain to risk management, regulatory decision-making, product use, research planning, and public outreach in nanotechnology. A few examples are as follows:
 - Workplace safety: Federal agencies continue to establish guidelines for safe handling of nanomaterials by both research and manufacturing workers through diligent program development by the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). For example, OSHA has funded the development of a guide for laboratory workers on engineered nanomaterials (ENMs) and occupational safety and health, and has collected a compendium of resources on workplace exposure control methods for engineered nanomaterials. NIOSH has led an effort to develop methods for evaluating worker exposure using a multimetric approach (that includes mass, particle number, size distribution, and surface area). In addition, NIOSH has conducted ENM air-sampling assessments at about 40 research and industrial facilities, including laboratories at the National Institute of Standards and Technology, the National Institute of Environmental Health Sciences, and the U.S. Army Engineer Research and Development Center.
 - Consumer safety: The Consumer Product Safety Commission has established numerous agreements with other NNI agencies to quantify potential exposures and health impacts of ENMs in consumer products, including interagency agreements with NIOSH, NSF, the Environmental Protection Agency, and the Food and Drug Administration.
- Engaged stakeholders to discuss the assessment, management, and communication of potential risks associated with the use of nanomaterials. A recent workshop, held in September of 2013, facilitated stakeholder discussion of key elements needed to assess, manage, and communicate potential risks associated with use of nanomaterials and nanotechnology-enabled products.
- Supported the development of international standards for the responsible development of nanotechnology: Federal agency members have contributed to the substantial progress that has been made through coordinated international efforts to develop consensus standards pertaining to physico-chemical property measurements, biological property and EHS assays, nomenclature, and terminology for ENMs. As of April 1, 2014, more than 50 consensus standards have been released by standards development organizations supporting the areas referenced above.

As with many emerging areas of science and technology throughout history, while nanotechnology can be put to a wide variety of beneficial uses, there is potential for misuse. The NNI agencies responsible for national security have taken this potential seriously; for example, sponsoring in

2007 a workshop discussing potential applications and threats, *Nanotechnology for Chemical and Biological Defense 2030*, resulting in a comprehensive book on the topic.¹³ In addition, the international community closely monitors this topic in the context of the Biological and Toxin Weapons Convention¹⁴ and the Chemical Weapons Convention.¹⁵

It is worth noting that there has been a significant amount of R&D devoted to national security applications of nanotechnology, including detection, protection, and remediation of potential chemical, biological, radiological, and explosive threats. For example, the Defense Threat Reduction Agency has a substantial investment in nanotechnology, as documented in the NNI Supplement to the President's 2015 Budget.¹⁶ These efforts effectively leverage other investments in basic research by agencies such as NSF. The NNI's Nanotechnology Signature Initiative on "Nanotechnology for Sensors and Sensors for Nanotechnology," with participation from eight NNI agencies, is a perfect example of NNI R&D coordination and leveraging. This coordinated effort could accelerate the successful development of nanotechnology-enabled sensors for defense against weapons of mass destruction, while also enabling development of sensors for environmental, agricultural, or biomedical applications.

Concluding Statement

The NNI investment has sustained vital support for fundamental, ground-breaking R&D, research infrastructure (including world-class centers, networks, and user facilities), and education and training programs that collectively constitute a major U.S. innovation enterprise. It is essential that the United States continue to lead the way in innovation enabled by nanotechnology and other emerging technologies — the Nation's economic growth and global competitiveness depend on it. I thank the Chairman and the Members of the Committee for the opportunity to appear before you today, and I would be pleased to answer any questions that the Committee may have.

¹³ M. Kosal, *Nanotechnology for Chemical and Biological Defense* (Springer-Verlag, New York, 2009).

¹⁴ National Research Council. *Trends in Science and Technology Relevant to the Biological and Toxin Weapons Convention: Summary of an International Workshop: October 31 to November 3, 2010, Beijing, China*. Washington, DC: The National Academies Press, 2011.

¹⁵ <https://royalsociety.org/~media/policy/projects/brain-waves/2013-08-04-chemical-weapons-convention-and-convergent-trends.pdf>.

¹⁶ Op. Cit.; see in particular pp. 68-69. DOD's investments are also described in some detail in this report.