Statement of Ambassador Richard M. Russell
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Before the
Subcommittee on Science, Technology, and Innovation
Committee on Commerce, Science and Transportation
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I. Introduction

Chairman Kerry, Ranking Member Ensign and Members of the Subcommittee, I am pleased to appear before you to discuss the National Nanotechnology Initiative (NNI) and issues associated with its upcoming reauthorization. First of all, I would like to thank this Committee on behalf of the Administration and the NNI for its bipartisan support for nanotechnology research, as well as for the good working relationship the Committee has established with our office and the representatives of the NNI.

In my testimony today, I would like to provide an overview of the NNI organization, activities, and funding, and communicate the Administration's policy priorities with respect to the upcoming reauthorization of the program, in the context of the NNI's newly updated strategic plan.[1] I also want to go into particular detail on nanotechnology-related environmental, health, and safety (EHS) issues.

Established in 2000 to coordinate Federal nanotechnology research and development (R&D), the NNI is built on the voluntary association of 25 Federal agencies that have activities and interests related to nanoscale science and technology. The management of the NNI is led by the Office of Science and Technology Policy (OSTP), which oversees the National Science and Technology Council (NSTC) and the National Nanotechnology Coordination Office (NNCO). The participating agencies of the NSTC's Subcommittee on Nanoscale Science, Engineering, and Technology (NSET) coordinates the NNCO. The NNCO provides technical and administrative support to the NSET Subcommittee, serves as a central point of contact for Federal nanotechnology R&D activities, and provides public outreach on behalf of the NNI. By providing a locus for communication, cooperation, and collaboration the NNI provides effective avenues for each individual agency to leverage the resources and expertise of all participating agencies.

The NNI has become a successful model for interagency cooperation and coordination in science and technology. From the broader perspective of the U.S. Government as a whole, this cooperation and coordination creates synergy that makes the NNI greater than the sum of its

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[1] http://www.nano.gov/NNI_Strategic_Plan_2007.pdf

parts. The coordination in addressing potential EHS implications of nanotechnology has been particularly strong, and successful: never before have regulatory and research agencies successfully communicated so effectively on a topic of common interest, and among such a large number of agencies. Through the NNI the member agencies have been working hard to understand—and to think strategically about—nanotechnology-related EHS issues in a systematic, coordinated fashion.

The NNI enterprise does come with some "overhead" expenses. As long as those expenses are relatively modest, the voluntary interagency cooperation that has been the hallmark of the NNI will continue. But in an era when so-called "discretionary funding" accounts in the Federal budget, including R&D funding, are under extreme pressure, we need to be particularly careful not to increase the overhead expenses unduly. These expenses include not just the budget for the NNCO, but also the personnel costs at each of the agencies associated with managing a complex interagency coordinated effort like this.

The Administration believes the organization, structure, and management of the NNI is appropriate and effective, and accordingly I urge Congress to proceed with caution in considering any fundamental changes in this area.

II. Overview and Status of NNI Goals

The NNI now represents a cumulative investment of almost $10 billion since its inception in fiscal year 2001, including the President's requested NNI budget for Fiscal Year 2009. The requested investment for 2009 of $1.5 billion and the substantial growth in this investment since 2001 reflects a shared appreciation by both this Administration and Congress of the potential for nanoscale science and technology R&D. Managed under the auspices of the NNI, these investments will expand our fundamental knowledge of this field and make important contributions to national priorities such as economic competitiveness, homeland and national security, and public health. A summary of the FY 2009 NNI Budget request broken down by agency and program component area is attached in appendix I.

The NNI recently released an updated strategic plan that outlines the following four basic goals for the initiative:

Goal 1: Advance a world-class nanotechnology research and development program.

Towards this goal, the NNI has funded thousands of individual R&D projects since its inception, contributing to U.S. world leadership in nanotechnology. As indicated in the recently released President's Council of Advisors on Science and Technology (PCAST) review of the NNI,[2] identifying meaningful metrics for evaluating U.S. global leadership in nanotechnology is challenging. But by many of the measures that we do have available, the United States continues to lead in both basic and applied research in nanoscale science and technology.

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[2] http://ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf

As shown in the PCAST report, U.S.-based researchers dominate in publication of nanotechnology-related papers in three of the world's premier scientific journals, *Science*, *Nature*, and *Proceedings of the National Academy of Sciences*, rising from about 60 percent at the inception of the NNI in 2000 to over 70 percent in 2006. U.S. papers also are cited far more frequently in peer reviewed journal publications than are papers from any other country – another clear indicator of the "world-class" quality of U.S. nanotechnology research. This leadership in citations has also been sustained over the initial years of the NNI, even while other nations have also substantially increased their investments in nanotechnology R&D.

Finally, and perhaps most significantly, U.S. inventors lead the world by far in nanotechnology-enabled patents, including patents filed in three or more international patent offices. This is a clear indicator of leadership in nanotechnology intellectual property, which we would expect to ultimately translate into leadership in commercialization of nanotechnology-based products.

These are all strong indicators that the United States is indeed advancing a world-class nanotechnology research and development program, in large part under the auspices of the NNI. However, we must not be complacent in evaluating our international competitiveness in nanotechnology. Also as indicated in the new PCAST report, Europe as a whole leads the world in nanotechnology publications in the Science Citation Index (SCI) database, and China and other Asian countries are rapidly gaining on the United States and Europe in SCI publications. Therefore we must continue to sustain and increase our strategic investments in this critical area of science and technology.

Goal 2: Foster the transfer of new technologies into products for commercial and public benefit.

The NNI has put in place a number of efforts targeted to enhance the transfer of research results into practical applications and commercialization. Examples of successful technology transfer efforts under the NNI are included in appendix II. Specific NNI activities supporting this technology transfer/commercialization goal include the following:

- U.S. leadership in nanotechnology patenting, an essential step in commercialization. The U.S. Patent and Trademark Office (USPTO) is working hard to assure efficient and appropriate processing of nanotechnology-related patents by creating a nanotechnology patent cross reference collection, including patents and patent applications spanning the wide range of fields of science and engineering that now involve nanoscale science and technology. USPTO is also conducting training sessions for its examiners to improve their understanding of nanotechnology.

- Agency-specific programs support application and use of nanotechnology (DOD, NASA, NIH, etc.). For example, DOD has led the way in development of electronics and sensing applications of nanotechnology, as well as in development and deployment of specialized coatings, e.g., to reduce wear and maintenance costs on moving parts in the Navy fleet. NASA has led in the development of nanotechnology-enabled sensors. NIH has led in funding the development of numerous biomedical applications of nanotechnology, including a number of promising novel approaches for early detection and treatment of cancer.

- Industry liaison groups and public/private partnerships. These groups assist in exchanging information on NNI research activities and industry needs and in leveraging funds for cooperative R&D. Industry liaison groups with the electronics, forest products, and chemical industries, and with the industrial research management community, are continuing, while formation of comparable groups with other sectors (e.g., the construction industry) is under consideration. One successful example is the collaboration between NSF, NIST, and the industry-led Nanoelectronics Research Initiative (NRI), where industry and government representatives collaborate in setting long-term research priorities for nanoelectronics, reviewing proposals and supporting pre-competitive research. In another example, NIH is formulating a "NanoHealth Enterprise," which is envisioned as a partnership with other Federal agencies, private industry, and international partners to address research needs for safe development of nanoscale materials and devices.

- NNI support for the development of international standards for nanotechnology. Such standards are critical to future commercialization activities. NNCO Director Clayton Teague chairs the U.S. Technical Advisory Group (TAG) to the International Organization for Standardization (ISO) Technical Committee on Nanotechnologies (ISO TC 229). NNI agencies have provided initial financial support to the American National Standards Institute's Nanotechnology Standards Panel (ANSI-NSP) and the ANSI-accredited TAG that represents the United States on ISO TC 229. The ANSI-NSP leads the ISO TC 229 working group on EHS aspects of nanotechnology.

- Workshops facilitating technology transfer of NNI research results. Two workshops have been held to bring together representatives from state and regional nanotechnology commercialization initiatives to learn best practices and exchange information. Other workshops have been convened to discuss opportunities and priorities for nanotechnology research in specific sub-fields, where industry participants are invited to provide input, but also where they can learn about NNI-funded research that may be of interest to their companies. In particular, the NNI agencies are now organizing a series of workshops to address research priorities in specific areas of nanotechnology-related EHS.

- Research on manufacturing at the nanoscale, or "nanomanufacturing." Nanomanufacturing will be key to the large-scale application of nanotechnology innovations for commercial and public benefit. The NNI places a special emphasis on nanomanufacturing research, as one of its eight program component areas (or PCAs). For example, NSF has established a new program dedicated to nanomanufacturing supporting individual projects and the National Nanomanufacturing Network. Several workshops have been conducted to help guide the NNI nanomanufacturing research agenda and coordinate it with industry; several more are planned for the near future.

- Industry participation in NNI research. Another way in which technology transfer takes place is within the interdisciplinary research centers and user facilities around the country. In these collaborative environments, researchers from academia and industry can interact, allowing for rapid diffusion of knowledge and increasing the likelihood of innovation.

Goal 3: Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology.

One of the chief overarching achievements of the NNI is the successful development and deployment of a unique infrastructure of nanotechnology research centers and user facilities, one that is second to none in the world. Part of the original NNI plan, this extensive network of over 60 research centers, user facilities and other infrastructure for nanotechnology research (more than 80 if you count other related centers and affiliated institutions), is now largely established. This mature infrastructure serves to accelerate nanotechnology research and development and enables researchers from across various sectors to broadly leverage their interdisciplinary intellectual and technological capital.

With respect to education and workforce development, education is among the chief objectives of NNI-funded university research. In addition, there are specific programs targeted at K-12 education, educating the public about nanotechnology, and improving nanotechnology curricula in our schools and universities. For example:

- Educational impact is among the key review criteria for NSF proposals. As a result of the NNI, thousands of undergraduate and graduate students have received training in nanoscale science and technology, providing the pipeline for nanotechnology workers and researchers that industry needs to commercialize the results of basic research in nanoscale science and technology. NSF annually supports education for about 10,000 students and teachers in the field of nanotechnology.

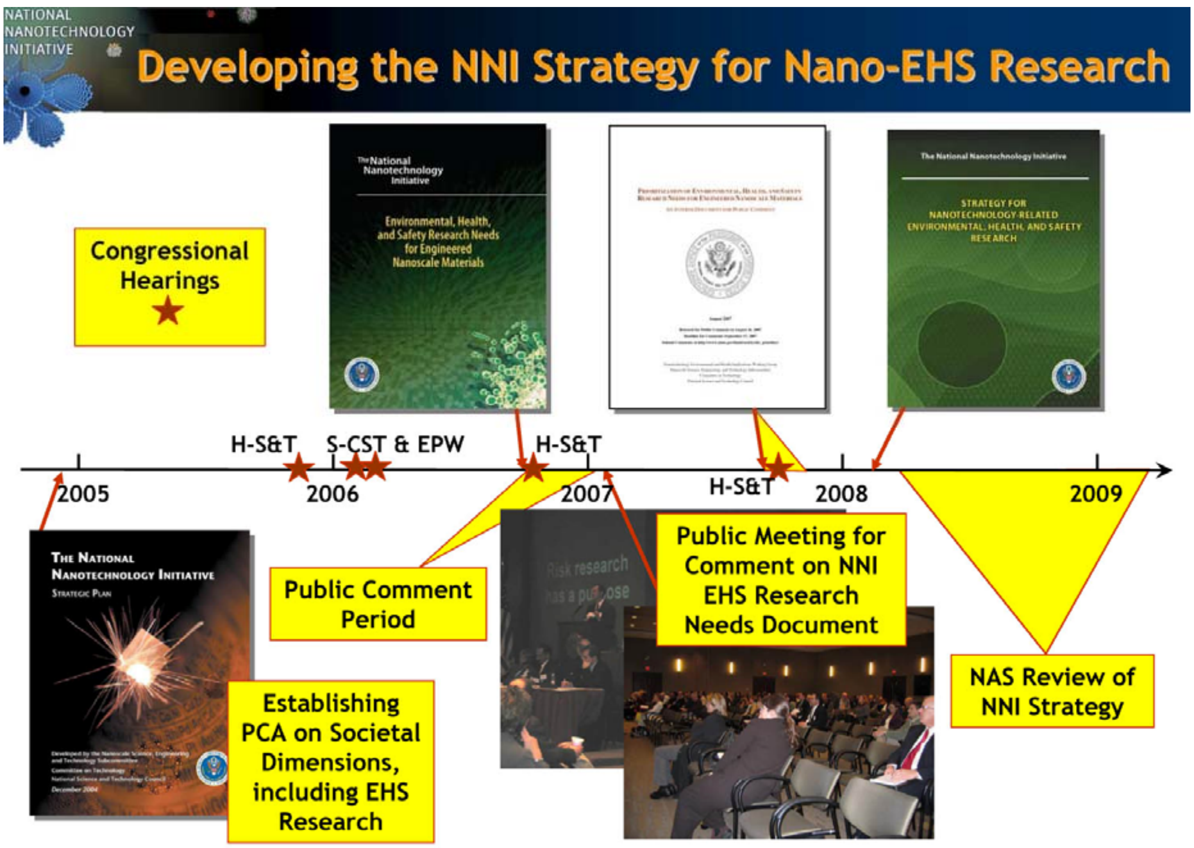
- The NNI has created strong incentive for interdisciplinary research at our major research institutions, and a new cadre of multi-disciplinary researchers, trained in multiple fields previously considered "diverse" and highly distinct, such as biology and solid state physics. While we retain a strong appreciation for the importance of building a solid foundation for our researchers of the future in the traditional disciplines of science and engineering, it is this "silo busting" new culture of interdisciplinary research, and the new generation of multidisciplinary researchers emerging from the NNI-funded centers, that I consider to be one of the greatest achievements of the NNI. It is at the intersection of the traditional disciplines where we are seeing some of the most interesting and potentially beneficial applications of nanotechnology emerge.

- In addition to the general educational impact of the NNI discussed above, NNI agencies, particularly NSF, have also engaged in a number of initiatives to improve nanotechnology education, curricula, and workforce development specifically. These include the Nanotechnology Center for Learning and Teaching (NCLT) and the Nanoscale Informal Science Education (NISE) Network. Details are available in the NNI Supplement to the President's Budget for FY 2008.

- The NNI has recently engaged the Departments of Education and Labor, and the research agencies are now working with staff from those departments to develop additional initiatives aimed at education and workforce development.

Goal 4: Support responsible development of nanotechnology.

The activities and issues associated with this goal have received a great deal of attention by the NNI. The original NNI implementation plan of July 2000 included a substantial section on "Societal Implications of Nanotechnology," and requested significant resources for this activity. As potential EHS concerns about nanomaterials began to emerge in the early years of the initiative, the NNI also led the way, holding in August 2003 the first interagency meeting on this subject, which eventually led to the establishment of the formal Nanotechnology Environmental and Health Implications (NEHI) interagency working group.



In December 2004 the NNI released a strategic plan calling out EHS research for special attention, as part of a Program Component Area (PCA) on Societal Dimensions of Nanotechnology. In early 2005 the NEHI Working Group began work on a cross-agency EHS research needs document, building on an earlier effort in 2004 to inventory existing EHS research funded under the NNI. In March of 2005 the NNI released its Supplement to the President's FY 2006 Budget,[3] which for the first time reported EHS research investments

[3] http://www.nano.gov/NNI_06Budget.pdf

separately. In the fall of 2005 NNI began preparation of a research needs document. The resulting document, *Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*,[4] released in September 2006, identified 75 research needs within five general categories of EHS research. It also set out a plan for "next steps" for the NNI to address this issue, including further prioritization of the research needs identified in the report, evaluation of the existing NNI EHS research portfolio, a gap analysis based on a comparison of the prioritized research needs and the existing research portfolio, coordination of the NNI agencies' research programs to address the priorities, and development of a process for periodic review and updating of research needs and priorities.

The NEHI Working Group then proceeded to follow that "next steps" agenda. The research needs document was posted for public comment in the fall of 2006, followed by a public meeting to gather input on the document in January 2007. Based on this input, the NEHI Working Group in August 2007 released an interim document for public comment entitled *Prioritization of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials.*[5] That document narrowed the list of EHS research needs down to five in each of the categories, for a total of 25 high-priority research needs. Based on input on that interim document and extensive further analysis by the EOP and the agencies involved, in February 2008 the NEHI Working Group released its first comprehensive *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research.*[6]

This strategy for the NNI's EHS research presents a path for coordinated interagency implementation of research to address the needs identified in earlier reports. It is based in part on a detailed analysis of the Federal Government's FY 2006 nanotechnology-related EHS research portfolio, a $68 million investment in 246 projects. Experts from the NEHI Working Group analyzed how these activities addressed the priority research needs and then proposed emphasis and sequencing for future research efforts. Agency-specific research and regulatory needs, public comments on the prior documents, and considerations of the state of EHS research in the national and international nanotechnology communities all played an important role in shaping the strategy. It reflects a strong commitment among the NNI member agencies to the roles they will assume, consistent with their respective missions and responsibilities, to move the Federal efforts in nanotechnology-related EHS research forward. The comprehensive detail in the document demonstrates that the NNI is working hard to understand—and to think strategically about—nano EHS issues in a systematic, coordinated fashion. As indicated in both the initial EHS research needs document and in this new strategy document, the strategy will be updated periodically. Furthermore, as indicated in the timeline above, the National Research Council (NRC) is now under contract from the NNCO to assess the EHS strategy. Once the NRC assessment is complete, their recommendations will be incorporated, as appropriate, into an updated strategy.

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[4] http://www.nano.gov/NNI_EHS_research_needs.pdf

[5] http://www.nano.gov/Prioritization_EHS_Research_Needs_Engineered_Nanoscale_Materials.pdf

[6] http://www.nano.gov/NNI_EHS_Research_Strategy.pdf

I think the NNI has made tremendous progress towards the goal of supporting responsible development of nanotechnology. Funding for EHS research in particular has more than doubled since FY 2005, from $35 million to $76 million in the FY 2009 request. This is only counting the narrowly defined "primary purpose" EHS R&D. Beyond just increasing the funding, the NNI agencies have come up with an excellent strategy that all the relevant agencies support, to carry forward these investments in the most effective way possible. The increasing emphasis on EHS is notable and important.

I believe the Federal Government needs to ensure that nano-EHS research needs are adequately addressed. To this end, the NNI has systematically (1) identified research needs, (2) prioritized those needs, (3) developed an associated inventory from which a gap analysis can be performed, and (4) developed a strategy for addressing the prioritized needs that are not currently being addressed. The Administration believes this systematic approach is the right way to address EHS research needs. The Administration therefore does not support establishing an arbitrary EHS set-aside.

IV. Summary and Conclusions

The NNI has been and remains a highly successful enterprise, due in large part to the unparalleled interagency coordination and cooperation, which in turn has been effective because of the voluntary, "bottom up" nature of that cooperation, in which all the agencies benefit. As demonstrated above and validated by external reviews, the NNI is effectively pursuing its goals of advancing world-class nanotechnology R&D; fostering technology transfer; developing and sustaining educational resources, workforce, and supporting infrastructure; and supporting responsible development of nanotechnology. The findings of the external reviews clearly indicate that the existing structure is working well, and I look forward to working with the Committee as it considers the future of this successful program.

Appendix I

NATIONAL NANOTECHNOLOGY INITIATIVE FY 2009 BUDGET & HIGHLIGHTS

The 2009 Budget provides $1.5 billion for the National Nanotechnology Initiative (NNI), reflecting steady growth in the NNI investment. This sustained major investment in nanotechnology research and development (R&D) across the Federal Government over the past nine fiscal years of the NNI reflects the broad support of the Administration and of Congress for this program, based on its potential to vastly improve our fundamental understanding and control of matter, ultimately leading to a revolution in technology and industry for the benefit of society. The NNI remains focused on fulfilling the Federal role of supporting basic research, infrastructure development, and technology transfer, in the expectation that the resulting advances and capabilities will make important contributions to national priorities, with applications across a wide range of industries including healthcare, electronics, aeronautics, and energy. Increasing investments by mission agencies in nanotechnology-related research since 2001 reflect a recognition of the potential for this research to support agency missions and responsibilities.

Table 1 provides NNI investments in 2007–2009 for Federal agencies with budgets/investments for nanotechnology R&D. Tables 2-4 list the investments by agency and by program component area (PCA). Note that the program component areas shown in these tables are those outlined in the new NNI Strategic Plan released in December 2007,[7] with nanotechnology-related environmental, health, and safety (EHS) research now reported for the first time in a separate PCA from education and other societal dimensions investments.

The 2009 NNI budget supports nanoscale science and engineering R&D at 13 agencies. Agencies with the greatest investments are the Department of Defense (DOD—investments addressing the defense mission); the National Science Foundation (NSF—fundamental research across all disciplines of science and engineering); the Department of Energy (DOE—research providing a basis for new and improved energy technologies); the National Institutes of Health (NIH, within the Department of Health and Human Services, DHHS—nanotechnology-based biomedical research at the intersection of biology and the physical sciences); and the National Institute of Standards and Technology (NIST—fundamental research and development of tools, analytical methodologies, and metrology for nanotechnology). Other agencies that are investing in mission-related research are the National Aeronautics and Space Administration (NASA), the National Institute for Occupational Safety and Health (NIOSH/DHHS), the Environmental Protection Agency (EPA), and the Departments of Agriculture (USDA—Cooperative State Research, Education, and Extension Service, CSREES; and Forest Service, FS), Homeland Security (DHS), Justice (DOJ), and Transportation (DOT—Federal Highway Administration, FHWA).

Key Points about the 2009 NNI Investments

- The 2009 NNI budget provides increased support for research on fundamental nanoscale phenomena and processes, from $481 million in 2007 to $551 million in 2009.

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[7] http://www.nano.gov/NNI_Strategic_Plan_2007.pdf

- Increases in nanotechnology R&D funding for DOE, NIST, and NSF reflect the President's continuing commitment to significantly increase funding for physical sciences and engineering research as part of the American Competitiveness Initiative.
- The proposed budget also reflects substantial ongoing growth in funding for instrumentation research, metrology, and standards (from $53 million in 2007 to $82 million in 2009) and in nanomanufacturing research (from $48 million in 2007 to $62 million in 2009). NNI agencies are gathering input and feedback from industry and the research community on these growing investments through a series of workshops.
- EHS R&D funding in 2009 ($76 million) is over double the level of actual funding in 2005 ($35 million)—the first year this data was collected. The steady growth in EHS R&D spending follows the NNI strategy of expanding the capacity to do high-quality research in this field. For tables in this document, EHS R&D is defined as research whose primary purpose is to understand and address potential risks to health and to the environment posed by nanotechnology. Therefore the proposed $76 million for 2009 does not include substantial research reported under other PCAs, e.g., on instrumentation and metrology and on fundamental interactions between biosystems and engineered nanoscale materials, both of which are important in the performance and interpretation of toxicological research. An indication of the level of funding for these broader categories of nanotechnology-related EHS research may be deduced from the detailed 2006 data collected and analyzed specifically for this purpose. This data showed that the total funding for nanotechnology-related EHS research in 2006 was about $68 million, 80% higher than that reported for "primary purpose research."
- A more detailed Budget Supplement will be released when data become available on funding for nanotechnology under the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs.

Table 1
NNI Budget, 2007-2009
(dollars in millions)

	2007 Actual	2008 Estimate*	2009 Proposed
DOD	450	487	431
NSF	389	389	397
DOE**	236	251	311
DHHS (NIH)	215	226	226
DOC (NIST)	88	89	110
NASA	20	18	19
EPA	8	10	15
DHHS (NIOSH)	7	6	6
USDA (FS)	3	5	5
USDA (CSREES)	4	6	3
DOJ	2	2	2
DHS	2	1	1
DOT (FHWA)	1	1	1
TOTAL	**1,425**	**1,491**	**1,527**

* The 2008 DOD estimate exceeds the 2008 request by $112 million but includes many Congressional earmarks that are outside the NNI plan.

** Funding levels for DOE include the Offices of Science, Fossil Energy, and Energy Efficiency and Renewable Energy.

Table 2 Actual 2007 Agency Investments by Program Component Area (dollars in millions)									
	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total
DOD	210.1	86.0	120.0	4.3	7.5	22.3			450.2
NSF	145.2	58.4	52.4	14.9	26.6	30.0	26.9	34.4	388.8
DOE	52.6	68.5	9.7	11.3	0.5	92.9		0.5	236.0
DHHS (NIH)	45.7	25.4	125.7	5.9	0.8		7.7	4.2	215.4
DOC (NIST)	24.2	7.5	22.9	14.2	12.4	5.5	0.9		87.6
NASA	0.8	9.9	9.1						19.8
EPA	0.2	0.2	0.1				7.1		7.6
DHHS (NIOSH)						1.7	5.6		7.3
USDA (FS)	0.4	1.3	0.7	0.3	0.2				2.9
USDA (CSREES)	0.5	1.0	2.1		0.1		0.1	0.1	3.9
DOJ		0.1		1.6					1.7
DHS			2.0						2.0
DOT (FHWA)	0.9								0.9
TOTAL	**480.6**	**258.3**	**344.7**	**52.5**	**48.1**	**152.4**	**48.3**	**39.2**	**1,424.1**

Table 3 Estimated 2008 Agency Investments by Program Component Area (dollars in millions)									
	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total
DOD	258.7	68.9	119.8	8.0	5.4	24.6	2.0		487.4
NSF	138.8	62.1	50.3	16.0	26.9	31.6	29.2	33.8	388.7
DOE	51.4	77.5	13.0	12.0	2.0	92.0	3.0	0.5	251.4
DHHS (NIH)	55.6	25.4	125.8	5.9	0.8		7.7	4.6	225.8
DOC (NIST)	22.5	7.4	21.7	16.1	14.4	5.8	0.8		88.7
NASA	1.5	9.7	6.2			0.4	0.2		18.0
EPA	0.2	0.2	0.2				9.6		10.2
DHHS (NIOSH)							6.0		6.0
USDA (FS)	1.3	1.9	1.2	0.4	0.2				5.0
USDA (CSREES)	0.7	1.6	3.1		0.5		0.1	0.1	6.1
DOJ				2.0					2.0
DHS			1.0						1.0
DOT (FHWA)	0.9								0.9
TOTAL	**531.6**	**254.7**	**342.3**	**60.4**	**50.2**	**154.4**	**58.6**	**39.0**	**1,491.2**

Table 4 Planned 2009 Agency Investments by Program Component Area (dollars in millions)									
	Fundamental Phenomena & Processes	**Nanomaterials**	**Nanoscale Devices & Systems**	**Instrument Research, Metrology, & Standards**	**Nano-manufacturing**	**Major Research Facilities & Instr. Acquisition**	**Environment, Health, and Safety**	**Education & Societal Dimensions**	**NNI Total**
DOD	227.8	55.2	107.7	3.6	12.8	22.1	1.8		431.0
NSF	141.7	62.5	51.6	16.0	26.9	32.1	30.6	35.5	396.9
DOE	96.9	63.5	8.1	32.0	6.0	101.2	3.0	0.5	311.2
DHHS (NIH)	55.5	25.4	125.8	5.9	0.8		7.7	4.6	225.7
DOC (NIST)	24.5	8.5	22.7	20.9	15.3	5.7	12.8		110.4
NASA	1.2	9.8	7.7			0.2	0.1		19.0
EPA	0.2	0.2	0.2				14.3		14.9
DHHS (NIOSH)							6.0		6.0
USDA (FS)	1.7	1.3	0.7	1.1	0.2				5.0
USDA (CSREES)	0.4	0.8	1.5		0.1		0.1	0.1	3.0
DOJ				2.0					2.0
DHS			1.0						1.0
DOT (FHWA)	0.9								0.9
TOTAL	**550.8**	**227.2**	**327.0**	**81.5**	**62.1**	**161.3**	**76.4**	**40.7**	**1,527.0**

Highlights of Ongoing and Planned Activities

- The extensive network of research centers, user facilities and other infrastructure for nanotechnology research, originally envisioned as a key element of the NNI strategy, is now largely complete. This mature infrastructure serves to accelerate nanotechnology research and development and enables researchers from across various sectors to broadly leverage their interdisciplinary intellectual and technological capital. NNI agencies are encouraging industrial interaction with NNI-funded research centers, and are promoting broad access to the NNI user facilities by all sectors, including small businesses. While emphasis in the near future will be on maximizing the utility and utilization of the substantial infrastructure already in place, the agencies will also consider possible new needs for the longer term.
- Industry liaison and technology transfer activities are given a high priority in the new NNI Strategic Plan released in December 2007. NNI agencies are working with industry representatives to gather input on their nanotechnology-related activities and are funding increasing numbers of nanotechnology-related SBIR and STTR awards to promote technology transfer to industry. Industry liaison groups with the electronics, forest products, and chemical industries, and with the industrial research management community, are continuing, while formation of comparable groups with other sectors (e.g., the construction industry) is under consideration. One successful example is the collaboration between NSF, NIST, and the industry-led Nanoelectronics Research Initiative, where industry and government representatives collaborate in reviewing proposals and in supporting pre-competitive research. In another example, NIH is formulating a "NanoHealth Enterprise," which is envisioned as a partnership with other Federal agencies, private

industry, and international partners to address research needs for safe development of nanoscale materials and devices.

- EHS research planning is a major activity for the NNI. In August 2007, the National Science and Technology Council's Nanoscale Science, Engineering, and Technology (NSET) Subcommittee published a draft report for public comment prepared by its Nanotechnology Environmental and Health Implications (NEHI) Working Group entitled *Prioritization of Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*, and, in February 2008, completed a comprehensive *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research.* This is the culmination of two years of intensive work, including a detailed review of individual EHS research projects funded by the NNI agencies in 2006, as a guide to identification of gaps in the research portfolio compared to the designated priority research areas.
- As the NNI EHS research strategy evolves, ongoing activities to address the breadth of EHS issues proceed at an accelerating pace. A Food and Drug Administration (FDA) task force released a report in 2007 addressing scientific questions related to the application of its regulatory authorities to nanotechnology-enabled products. EPA issued a white paper on nanotechnology in 2007, and has initiated a Nanoscale Materials Stewardship Program under the Toxic Substances Control Act (TSCA) to gather and develop information from manufacturers, importers, processors and users of engineered chemical nanoscale materials. NIOSH continues to update its guidance document on best practices for safe handling of nanomaterials in the workplace, and has posted a draft document providing interim guidance on medical screening of workers potentially exposed to engineered nanoparticles. NNI agencies organized a workshop hosted by NIST in September 2007 entitled "Standards for Environmental, Health, and Safety for Engineered Nanoscale Materials." On the research front, two joint interagency solicitations addressing potential environmental and health implications of nanotechnology continue. One (led by EPA, with NSF) addresses environmental implications, while another (led by NIH, with EPA and NIOSH) focuses on human health implications. NSF and EPA will fund a new Center for Environmental Implications of Nanotechnology (CEIN) in 2008. NSF plans to form a network around it in 2009 with collaboration from EPA and other agencies.
- International collaborations in nanotechnology are progressing, with strong NNI participation. The Organisation for Economic Cooperation and Development (OECD) Working Party on Manufactured Nanomaterials, chaired by the United States, has begun its work addressing health and safety issues. A second OECD working party formed under the Committee for Scientific and Technological Policy is addressing broader issues such as economic impact, education and training, and public communication. With respect to standards development, the National Nanotechnology Coordination Office and several NSET member agencies represent the United States on the International Organization for Standardization (ISO) Technical Committee on Nanotechnologies (ISO TC 229),
and the United States leads the ISO TC 229 working group on EHS aspects of nanotechnology.

Appendix II

A Few Examples of NNI Supported Transfers of Nanotechnology Research Results from the Laboratory to Applications and Commercialization

In addition to the examples given below, the 2007 NNI Strategic Plan[8] includes several examples of early NNI successes in technology transfer (pp. 14-15), as well as a number of high-impact application opportunities that are now emerging from NNI-funded laboratories (pp. 25-34). Further, the new PCAST/NNAP report includes more examples of technologies that are being transitioned from NNI-funded research into commercial applications.

- One of the original motivations for the NNI was the need for more basic research in nanotechnology-enabled electronics, photonics, and magnetics research, to keep the semiconductor industry on the "Moore's Law" curve of continuous improvement in cost/performance of semiconductor devices that has been so important to our economic prosperity in the past 50 years. While semiconductor device design rules have been in the sub-100 nanometer range for several years now, at the time of the NNI's inception, leaders in the industry were predicting that future progress would soon be hitting a "brick wall" where continued scaling of traditional CMOS devices would be difficult or impossible due to current leakage, heat dissipation problems, and interference by quantum effects that begin to dominate device behavior in the nanoscale size range. They called on the Government to conduct an intensified basic research program under the auspices of the NNI to address these problems, including the specific goal of developing a completely new paradigm to replace the electronic "switch" that is at the heart of both logic and memory devices. The collaboration by NSF and NIST with industry in the Nanoelectronics Research Initiative referred to above was one of the NNI responses to this problem. As a result of this and other NNI investments in nano-electronics, -magnetics, and –photonics research and infrastructure, progress in addressing this problem has been faster than had been expected previously. At a meeting of the President's Council of Advisors on Science and Technology on January 8, 2008 George Scalise, President of the Semiconductor Industry Association, stated that, for the roadmaps the semiconductor industry has laid out, their consensus is that they are two years ahead of where they thought they would be just a few years ago, thanks in part to the NRI and the NNI. Dr. Scalise also said that for the next generation switch, most of the new ideas are coming from the United States, not from abroad.

- Another major thrust of the NNI that has emerged in recent years is the applications of nanotechnology related to human health – i.e., to diagnosis and treatment of disease. The budget for nanotechnology research at the National Institutes of Health (NIH) has increased dramatically, from $40 million in 2001 to a proposed $226 million in 2009. With this NIH has established 21 new research centers focused on nanomedicine and cancer nanotechnology R&D. The range of biomedical applications of nanotechnology under investigation is extremely broad, spanning almost all of the NIH institutes. Widespread clinical application of the results of this research is likely to take many years, given the careful review and approval

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[8] http://www.nano.gov/NNI_Strategic_Plan_2007.pdf

processes needed for such applications. But we can cite a couple of interesting examples that are nearing fruition in the cancer and regenerative medicine arenas, as follows:

- o Researchers at Northwestern University have developed a diagnostic biobarcode assay based on nanotechnology that is able to detect each of the three markers simultaneously at concentrations multiple orders of magnitude below that detectable by the standard immunoassay. The biobarcode assay can simultaneously detect trace levels of multiple biomarkers (including DNA and proteins) associated with human cancers using oligonucleotide- and antibody-coated gold nanoparticles. Nanoparticle-tagged oligonucleotide biobarcodes have been developed to detect three cancer-related protein biomarkers: prostate specific antigen (PSA); human chorionic gonadotrophin (HCG), a marker for testicular cancer; and α-fetoprotein (AFP), a liver cancer marker. The ability to detect low-levels of protein biomarkers directly in serum in a multiplexed manner will enable more powerful diagnostic methods to detect early-stage malignancy. The nanotechnology biobarcode assay is being commercially developed now; so far the FDA has cleared its use for two molecular diagnostic tests associated with blood disorders.

- o Another group at Northwestern has developed an engineered nanomaterial that can be injected into damaged spinal cords and could help prevent scars and encourage damaged nerve fibers to grow. The liquid material contains molecules that self-assemble into nanofibers, which act as a scaffold on which nerve fibers grow. *Researchers have reported that treatment with the material restores function to the hind legs of paralyzed mice.* A spinoff company has now been founded, with the objective of developing this therapy for humans. Initial in vitro tests have shown no apparent toxicity to human cells. The next step will be to make a material that meets FDA standards for clinical trials. This example is particularly interesting for several reasons: (1) it represents a collaboration between a materials scientist much of whose work was initially funded by the National Science Foundation and a stem cell biologist, working in a field with a strong history of NIH funding. As such it is a sterling example of both interdisciplinary collaboration and interagency collaboration that has become a hallmark of the NNI. (2) We have been hearing rumors of this work and seeing private presentations on it for several years now. Only in the past month were the results of this particular breakthrough published in the open literature. As such, we think this example is just the beginning of a flood of new biomedical applications of nanotechnology that are likely to come to light in coming years, as innovations make their way through the long pipeline between initial conception, early exploratory research, initial application experiments, in vitro safety testing, in vivo animal model safety and effectiveness testing, and finally to human clinical trials. Given this long timeline and the large potential payoffs of this type of research, it is understandable that researchers are careful about when they publish results in open literature.

- There are numerous examples of potential applications of nanotechnology in energy production, conversion, storage, transmission, and conservation. Just one of these examples addressed in the recently released PCAST report concerns the use of nanotechnology to enhance the efficiency and lower the cost of converting energy in sunlight directly into electricity, known as photovoltaics. Thin-film photovoltaic technology has improved over the last decade to a point where it can now convert sunlight to electricity as efficiently as all but the most expensive silicon-based solar cells. New low-cost production methods could help make these thin-film cells an important contributor to the Nation's energy needs. One company that has received substantial funding from NNI agencies, Nanosolar, Inc. is using printing presses instead of vacuum deposition equipment to make solar panels based on a semiconducting material called copper indium gallium diselenide (CIGS). The presses deposit nanostructured ink, which is then processed to create the light-absorbing nanoarchitecture at the heart of the solar cell. Nanosolar has recently shipped its first utility-scale panels.