Testimony to the House Subcommittee on Research and Science Education

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Introduction

Mr. Chairman and members of the Subcommittee, thank you for inviting me to testify at this hearing. My name is Clayton Teague and I am the Director of the National Nanotechnology Coordination Office (NNCO). The NNCO supports the efforts of the multi-agency National Nanotechnology Initiative (NNI). I am pleased to have the opportunity to update this Subcommittee on the extensive efforts underway in the NNI to address the needs for research on the environmental, health and safety (EHS) aspects of nanotechnology.

Since its inception, the NNI has supported research along two fundamental paths: research toward promising, highly beneficial uses of nanotechnology for our society and our nation's economic growth and research to protect public health and the environment. By integrating the results and new knowledge from these two paths of research, the NNI can expedite progress toward maximizing the benefit-to-risk ratio in the development of nanotechnology.

Further, EHS research is and has been a top priority of the Administration and the NNI. The Directors of the Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB) have highlighted EHS research in each of the annual Research and Development Budget Priorities memoranda issued since 2004. During fiscal years 2005 through 2008, it is estimated that NNI agencies will have invested nearly $180 million in research whose primary purpose is to address the EHS implications of nanomaterials. With these investments, the United States leads all other countries in the world by a wide margin in support for such research. The 2008 request for this area is $58.6 million, an increase of 55% over 2006[1], the last year for which we have estimates of actual funding. This growth reflects intentional and systematic program development by the NNI for nanotechnology-related EHS research.

I have been asked to describe the NNI's approach to prioritizing and addressing EHS research related to nanotechnology. Our approach—our strategy—consists of four major elements. **1) Successful coordination:** The NNI is effectively coordinating Government-funded research and the multi-disciplinary expertise of participating agencies on the EHS aspects of nanotechnology; **2) Comprehensive planning and**

[1] See Table 6 in the NNI Supplement to the President's FY 2008 Budget, http://www.nano.gov/NNI_08Budget.pdf, p. 11, which shows an estimated actual R&D investment for FY 2006 of $37.7 million and the amount stated for the FY2008 request in the PCA for research whose primary purpose was EHS implications of nanotechnology.

guidance: Through ongoing analysis of available research results by government subject matter experts, along with inputs from program managers, funding decision makers, and the public, the NNI has published and is drafting further planning documents to provide guidance for agencies, industry, and academia on EHS research needs; 3) **Leveraging forefront science through collaboration:** The NNI is supporting a growing portfolio of EHS research and is leveraging its investment through collaborations among multidisciplinary research groups, with industry, and with other governments worldwide; 4) **Periodic review**: The NNI plans to conduct periodic reviews of the state of EHS research to determine new developments or discoveries that would require changes in emphases or directions of research.

This four-element strategy for planning and implementing nanotechnology EHS research enables the NNI to adapt to the dynamic aspects of research and to pursue appropriate paths that address identified research needs. Equally, practicing these elements in an iterative long-range fashion accelerates progress toward producing the information necessary to assess safety of nanomaterials and to responsibly develop products enabled by nanotechnology.

Successful Coordination

The Nanoscale Science, Engineering, and Technology (NSET) Subcommittee's Nanotechnology Environmental Health Implications (NEHI) Working Group serves centrally and effectively to coordinate the planning and implementation of the U.S. Government's EHS nanotechnology-related research and activities. This interagency approach aligns the agencies' mandates, missions, authorities, and resident expertise with EHS research planning and implementation.

Twenty of the 26 NNI agencies participate in the NEHI Working Group. Thirteen of the agencies fund safety-related research in the field and/or have regulatory authorities to guide the safe use of nanomaterials.

The NEHI Working Group is co-chaired by Dr. Norris Alderson, Associate Commissioner for Science in the U.S. Food and Drug Administration, and Dr. George Gray, Assistant Administrator for the Office of Research and Development in the Environmental Protection Agency. Under their combined leadership, NEHI creates the framework that supports a robust, proactive process for identifying and addressing EHS research related to nanotechnology.

Starting with initial, informal meetings beginning in 2003 and formally established by the NSET Subcommittee in 2005, the NEHI Working Group has the following objectives:

- provide for the exchange of information among agencies and non-Government parties that support nanotechnology research and those responsible for regulation and guidelines related to nanoproducts
- facilitate the identification, prioritization, and implementation of research and other activities required for the responsible research, development, utilization, and oversight of nanotechnology

- promote communication of information related to research on environmental and health implications of nanotechnology to other Government agencies and non-Government parties

The NEHI Working Group operates on a consensus basis, thereby leading to reports and other documents that have broad approval from all member agencies. Moreover, representatives to the working group involve appropriate experts within their agencies in the development and review of any working group product. Such involvement can be time consuming, however the result is strong awareness of and support for the ultimate output. Consensus-building among key decision makers produces agency commitments to carry out their parts in generating needed information through research activity.

With this support, the NNI, through its multi-agency participation and access to the wide range of subject matter expertise, is successfully coordinating EHS research among the NNI agencies, with industry and academia, and with other nations. Doing so enables us to leverage all available resources and to accelerate the pace of progress toward generating safety-related information.

The NEHI Working Group is the most active working group of the NNI and has been described by agency representatives as the most effective interagency collaboration they have witnessed or in which they have participated. This is a clear indication of the NEHI Working Group's success.

NNI agencies have expressed strong satisfaction with the coordination and collaboration opportunities stimulated by their participation in the NNI. Some example endorsements are presented in Appendix A: *How the Interagency Process Helps Individual Agencies*. The Administration through its Budget Priorities memoranda and Congress through the 21st Century Nanotechnology Research and Development Act also have emphasized coordination of EHS research.

Nonetheless, some have called for a centralized office with budgetary authority to oversee the NNI's EHS research program. It is the consensus of NEHI Working Group members that such an approach would have significant detrimental effects:

- No one agency or centralized organization would have the breadth of scientific expertise and knowledge of regulatory authorities and needs currently represented by the 20 agencies participating in the NEHI Working Group.
- Creation of a new central authority would undermine the existing successful interagency coordination.
- Moving the management of all nanotechnology EHS research into a single office would likely decouple such research from related efforts within NNI agencies and from the knowledge base in the agencies that is currently networked into the NNI's EHS research effort.
- Creating a separate office would, on the one hand, give mission agencies a disincentive for doing nanotechnology-related EHS research. They would reasonably assume that another agency is responsible, and they therefore could redirect their limited resources to address other priorities. A likely result could

be that the level of research would actually decrease. Conversely, creating a separate office could lead to duplicative work being funded, thereby wasting tax dollars and not optimizing progress.

Comprehensive Planning and Guidance

The NNI strategy for addressing EHS research needs for engineered nanoscale materials consist of five steps.

Step one – Identify research needs: In September 2006, the NNI published its assessment of the research needed to support risk assessment and risk management decision-making. This guidance was contained in the document, *Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*[2], henceforth referred to as the *Research Needs* document. Comments submitted during the public comment period acknowledged the comprehensiveness of the document to guide the breadth of research needed to inform safety assessment. The research needs are organized into five categories: instrumentation, metrology, and analytical methods; nanomaterials and human health; nanomaterials and the environment; health and environmental exposure assessment; and risk management methods.

Step two – Prioritize research needs: In August 2007, the NNI published a prioritization of the identified research needs on the NNI website www.nano.gov as an interim document for public comment. These priority needs were identified following extensive dialogue among the subject matter experts and careful analysis based on principles outlined in the *Research Needs* document and public comments received.

It is important to underscore that EHS-research planning and implementation have been taking place simultaneously for several years. The processes, like those of the research itself, are not linear. The NNI agencies have been funding basic research at increasingly higher levels and through this research have been producing information critical to this field.

Step three – Obtain a snapshot of the government portfolio of EHS research in categories identified in Step one: In order to enable a more detailed assessment of funded research in this area, OMB collected data from the NNI research agencies on all FY2006 spending for research related to the five categories outlined in the *Research Needs* document. Note that this call captures research reported in several Program Component Areas (PCAs) as reported in the NNI Supplement to the President's 2006 Budget. For example, some research in the PCA for Instrumentation Research, Metrology, and Standards was found to be highly relevant.

Step four – Analyze data from OMB on EHS research portfolio: The NEHI Working Group is analyzing the responses to the OMB data call to perform a systematic evaluation of the NNI's EHS research portfolio. NEHI experts have retrospectively categorized research funded by NNI agencies in FY2006 according to the priority research needs.

Preliminary results from the NEHI analysis are summarized in the following table.

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

Category	*Estimated Funding*
Instrumentation, Metrology, & Analytical Methods	$27 M
Nanomaterials & Human Health	$24 M
Nanomaterials & the Environment	$13 M
Health & Environmental Exposure Assessment	$1 M
Risk Management methods:	$3 M
Totals	$67 M

NEHI's preliminary analysis indicates strong alignment of ongoing research and the priority needs. NEHI members are continuing to analyze those data as they complete this step toward drafting the NNI EHS research strategy document. While this step is not yet completed, the initial analysis indicates that many of the areas identified by experts are already receiving significant support. An initial analysis of OMB's call for data on research in the five categories of the NNI *Research Needs* Document is provided in Appendix B.

Step five – Provide research strategy document as guidance:

The single most important outcome of this process is the creation of a science-based EHS research strategy document that the NNI recommends to individual agencies, the Administration, and Congress for use as guidance in their decisions for funding and program support.

Within the NNI EHS research strategy document, the management of R&D programs, as with all other NNI research and funding activities, will remain within the agencies that have the appropriate jurisdiction, expert staff, and expertise to manage day-to-day research activities and funding decisions.

Agencies whose missions are reflected in a research category of the *Research Needs* document will be noted in the NNI EHS research strategy document to be published shortly.

Agencies will use the NNI EHS research strategy document to:

- Understand where their mission-related research fits into the overall strategy
- Identify opportunities for collaboration or cooperation
- Identify critical needs within their missions which have not gotten sufficient attention
- Understand their relationship to other agencies and their research

We understand that some would like to have seen the initial NNI EHS research strategy document published yesterday. However, the NNI has undertaken thorough, time-consuming activities such as highly specific data collection, and the solicitation and synthesis of expert and public input to ensure that the strategy would have scientific integrity and would reflect real data and information needs and thus have the credibility to guide agencies in decisions concerning their research funding and

activities. And as noted earlier, the lack of a published strategy has not delayed getting started on high priority research.

To provide some insight into the complexity of this process, it is helpful to note the range of expertise sought through consultations, a public hearing, and two highly constructive public-comment periods. World-renowned scientists from academia, industry, NGOs, and government all have provided input. Within the Government alone, some 100 subject matter experts across agencies reviewed and contributed to this comprehensive document. Among those who informed the development of this strategy were experts in:

- quantum mechanical properties of engineered nanoscale materials
- characterization of the physical and biological properties of these nanoscale materials through transmission electron microscopy, dynamic light scattering, and *in vitro* and *in vivo* toxicology
- absorption, distribution, metabolism, and elimination of materials in mammalian systems
- environmental toxicology and pharmacokinetic models of toxicity
- interactions of materials with the body at the molecular, cellular, and tissue levels
- metrics for measuring exposure, fate and transport of materials in the environment
- occupational health and exposures; and risk assessment and management practices.

The road to effectively safeguarding public health is dynamic and requires attention to alternative paths for obtaining the necessary knowledge and understanding. An ongoing evaluation of the materials being considered for use in products and new research findings must continue to inform and guide our ongoing strategic planning efforts. In the coming six months, for instance, we anticipate the publication of a large number of highly informative research papers in the field, reflecting the fruits of some of the NNI's earliest investments. These research findings could possibly provide information that calls for a stronger emphasis on current areas of research or that calls for a redirection of resources to another area of inquiry. Science is not stagnant and planning for research activity cannot be either.

The NNI strategic planning process will give the agencies ongoing guidance for funding research, and it will continue to inform industry of the most important safety issues—something that industry has asked us to provide.

We expect industry-created research plans will address in greater detail important industry needs—especially with regard to product-safety testing. Many of the plans already underway are complementary to the Federal government strategy; indeed, they were input to the formulation of the Federal strategy. This underscores the fact that multiple parties will play significant roles in gaining scientific knowledge in this field. But only the NNI process addresses the breadth of information needs of the

Federal agencies and includes the deliberations necessary for interagency cooperation. Federal agency responsibilities for safeguarding public health cannot be delegated to any other agency or group, nor can planning for how those responsibilities will be met.

Leveraging Forefront Science through Collaboration

The evaluation of research needs through the NNI strategic planning process has been guiding agency research efforts since the NNI was formed. Implementation of identified research activities also has been underway as has the development of partnerships to facilitate research collaborations among agencies and with partners from industry, academia and non-government organizations (NGOs).

The 2006 data provide a snapshot of EHS research investments and have already helped inform and direct future government research funding. Below are a few of the research activities and collaborations in priority areas:

- NNI agencies have issued three joint solicitations for research on potential EHS implications of nanotechnology:
    - One led by EPA that is now in its third year focuses on investigating fate, transport, transformation, and exposure of engineered nanomaterials (DOE is joining EPA and NSF in 2008).
    - A second solicitation starting in 2007 is focused on human health implications. It is led by NIH's National Institute of Environmental and Health Sciences and includes participation by five other NIH institutes as well as EPA and NIOSH.
    - Recently NSF and EPA issued a third joint solicitation for proposals to create a national Center for the Environmental Implications of Nanotechnology (CEIN) to conduct fundamental research and education on the implications of nanotechnology on the environment and living systems at all scales. The center will address interactions of naturally derived, incidental and engineered nanoparticles and nanostructured materials, devices and systems with the living world. The award is slated to be up to $5 million annually for up to five years, pending the availability of funds and successful review.
- NIH, FDA, and NIST are collaborating on work at the Nanotechnology Characterization Lab (NCL) of the National Cancer Institute (NCI), where a battery of characterization tests are being developed for preclinical evaluation of nanomaterials intended for cancer therapeutics.
- NIH, FDA, and NIOSH are supporting the National Toxicology Program (led by NIEHS) as it develops and carries out research and testing programs addressing health and safety issues. Collaborations are underway with NIOSH, the FDA National Center for Toxicological Research, and the NCI Nanotechnology Characterization Lab.

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Identification of detailed research needs within the broader strategic framework also is taking place through various other activities and partnerships. In January 2007, NSF and NIH supported a meeting on International Nanomaterial Environmental Health and Safety Research Needs Assessment at the NIH Campus in Bethesda, Maryland. This meeting, organized and sponsored by the International Council on Nanotechnology (ICON), focused on a piece of the research framework, bringing detail to the materials in need of study. NSF supported another ICON meeting last summer that focused on research needed to inform predictive modeling of biological interactions. In addition to providing funds, Government agencies sent representatives to plan and participate in each of these workshops.

NIST held a workshop in September 2007 to develop approaches for identifying standard materials for critical risk assessment and risk management and priority reference materials, among other things.

Two years ago, NIOSH released its *Approaches to Safe Nanotechnology*, a document that offers guidelines for working with nanomaterials, consistent with the best scientific knowledge. That document recently has been updated and NIOSH's work has been used as a basis in international forums toward drafting international recommendations for working with nanomaterials. Furthermore, EPA and FDA have developed policy papers guiding their mission-related research and information needs. These agencies and NIH each have established intra-agency nanotechnology task forces that coordinate across each agency and with the other NNI agencies.

International Coordination and Collaboration

Although the United States is leading the world in the level of effort aimed at EHS research, it can not—and should not—go it alone. The U.S. Government conducts many of its planning and implementation activities in coordination with other nations and international organizations. The NEHI Working Group, with assistance from another body of the NSET Subcommittee, the Global Issues in Nanotechnology Working Group, coordinates the U.S. position and participation in international activities related to environmental, health, and safety implications of nanotechnology. For example, NNI representatives are leading national and international collaborations that ensure coordination of the U.S. strategic priorities with those of the International Organization for Standardization (ISO) and the Organisation for Economic Co-operation and Development (OECD).

Standards are imperative for accurate and reliable measurement and characterization of nanomaterials, which in turn is vital for assessing exposure and its effects. NSET Subcommittee members are active participants in the ISO Technical Committee on Nanotechnologies (ISO TC229). The NSET Subcommittee has provided initial financial support to the American National Standards Institute (ANSI) accredited Technical Advisory Group (TAG) that represents the United States on the ISO TC229. The NNCO Director chairs the TAG and heads the U.S. delegation to ISO TC229. The United States holds the convener position for the ISO TC229 working group whose charter is the development of science-based standards in the areas of health, safety, and environmental aspects of nanotechnologies. The U.S. TAG also is participating actively in the working group on terminology and nomenclature and the working group on metrology and characterization.

The U.S. Government was instrumental in the formation of two nanotechnology-related working parties at the OECD, and U.S Government representatives currently chair the bureaus of each working party. This work is not limited to the 30 OECD member countries. Non-OECD countries and regions including the European Commission, Argentina, Brazil, China, India, Israel, Russia, and Thailand are active participants, as well as the nanotechnology and chemicals industries, ISO, and NGOs.

International efforts to better understand the potential health, environmental, and safety implications of manufactured nanomaterials are being developed by the Working Party on Manufactured Nanomaterials (WPMN) under OECD's Chemicals Committee. Its objective is to promote international cooperation in health and environmental safety aspects of manufactured nanomaterials, in order to assist in their safe development. This will help ensure that approaches to assessment of hazard, exposure, and risk are of a high, science-based standard. The United States is heavily involved in all the current WPMN activities, which include:

- International coordination to assess ongoing EHS research and identify mechanisms to address future research needs
- Testing a representative set of manufactured nanomaterials in collaboration with industrial partners, in order to develop a foundation data set of their physical and chemical properties as well as their fate, safety, and health and environmental effects
- Developing guidelines for EHS-related testing of nanomaterials, building upon already developed methods where possible
- Exchanging information on risk assessment approaches for manufactured nanomaterials and making recommendations to fill gaps in current approaches
- Sharing information on voluntary data collection and regulatory activities.

The second OECD body is the Working Party on Nanotechnology (WPN) under the Committee for Scientific and Technological Policy. The objective of the WPN is to promote international cooperation that facilitates research, development, and responsible commercialization of nanotechnology in member countries and in non-member economies. WPN activities relevant to EHS matters include evaluating the

regulatory concerns of businesses utilizing nanotechnology, and public communication issues.

Conclusion

In closing, the NNI effectively **coordinates** EHS research planning and multi-disciplinary expertise across the 26 participating federal agencies. This ensures systematic and **comprehensive planning** across the broad spectrum of research programs needed to support risk assessment and risk management and to inform decision-makers.

The NNI agencies support **forefront research**, and leverage this research through collaborations. These research programs have generated and will continue to generate research that informs decision-makers. I am highly confident that the forthcoming NNI EHS Research Strategy will provide the needed framework for the development and support of research programs that provide new knowledge as needed for risk assessment and risk management regarding the use of nanomaterials.

Previous reviews of the NNI by the National Research Council (NRC) and the President's Council of Advisors on Science and Technology (PCAST) in its capacity as the National Nanotechnology Advisory Panel called for by the 21st Century Nanotechnology Research and Development Act, confirm the effectiveness of our coordinated, collaborative approach. The 2006 NRC review of the NNI[3] was complimentary of the NNI's coordinated interagency approach in addressing EHS research and regulatory issues. PCAST is in the process of performing its second review of the NNI later this year. The NRC will take a comprehensive look at the NNI EHS research strategic process upon its completion.

We will of course welcome any recommendations these outside reviewers have as to how to make our strategy even more effective.

Thank you for the opportunity to speak with you on this important subject today.

[3] *A Matter of Size: Triennial Review of the National Nanotechnology Initiative,* http://books.nap.edu/openbook.php?record_id=11752&page=92.

Appendix A

How the Interagency Process Helps Individual Agencies

The effectiveness of the NNI for the participating agencies has been described by individual agencies as follows:

The Consumer Product Safety Commission (CPSC): While CPSC does not have the resources for research at this point in time, we have benefited greatly from the ability to make our research needs known to other agencies who have research funding and who share similar needs for toxicity and exposure data, etc. The concept of ensuring collaboration/communication across Federal agencies to leverage limited research dollars is an important one.

U.S. Food and Drug Administration: The NNI collaboration has provided FDA the opportunity to discuss, review, and influence the priority of Federally funded research organizations in their research programs. This has been particularly true in the areas of EHS needs. It is clear that the current activities of NCI/NCL, with NIST and FDA as partners, has benefited from the collaborative activities under NEHI. As a regulatory agency, FDA's research program provides the science support for current regulatory issues. Through the activities of NEHI, FDA has had the opportunity to assist in developing a research focus for issues that are a primary concern for nano-engineered materials as components of FDA regulated products. Through NEHI, FDA can leverage the resources of the funded research organizations to address those areas of concern that are shared with other regulatory agencies.

Department of Energy (DOE): DOE has included funding for new efforts in understanding the fate and transport of nanoscale materials in the environment in the FY 2008 budget request, and has joined with EPA and NSF in issuing a call for proposals in these areas. This interagency solicitation has been made possible by the interactions between DOE and the other participating agencies in the NSET and NEHI venues.

U.S. Environmental Protection Agency: The EPA is leveraging its research and development strengths by partnering with other Federal agencies such as NIH, NCI, NIEHS, NIOSH, NSF, DOE, and NIST. The NEHI Working Group provides the agency with the forum and opportunity to engage in fruitful collaborative ventures. Many of our collaborative efforts have been enabled through dialogues and cooperation afforded by the NEHI Working Group and the NSET Subcommittee member meetings. The NEHI venue is especially advantageous for three critical reasons:

1. Direct communication of agency-to-agency information on engineered nanomaterial EHS issues is enabled.
2. Ways to enhance the understanding of agency-specific EHS issues are discussed.
3. Input on complex EHS issues from different agency viewpoints is provided that results in more rapid and tenable solutions.

U.S. Geological Survey: The USGS is in the planning phase of its activities with respect to nanotechnology, but has participated in the coordination activities of the NEHI Working Group and NSET Subcommittee. This involvement has given the USGS the opportunity to see where our scientific strengths will be best utilized within the set of research priorities, and to avoid duplication of effort. The involvement has also enabled us to get to know nanotechnology scientists and science leaders in other agencies in order to develop collaborative scientific projects that play to our strengths. The structure of the interagency interaction fostered by the NNCO provides forums for agencies to discuss research facilities that can be shared, thus increasing the value of the limited research dollars by enabling agencies like USGS to avoid duplicating expensive facilities.

The Nanotechnology Characterization Laboratory (NCL): The NCL at Frederick is an example of interagency coordination fostered by the NEHI Working Group. The laboratory is the result of a formal collaboration between three NEHI participating agencies: the National Cancer Institute (NCI) at the National Institutes of Health, the U.S. Food and Drug Administration (FDA), and the National Institute of Standards and Technology (NIST) within the Department of Commerce. The NCL's charter is to conduct safety testing of nanomaterials intended for medical applications; it is a resource available to investigators in academia, industry, and government laboratories toward facilitating the rapid transition of nanotechnology-based drugs and imaging agents into commercial products.

In its three years of operation, the NCL has characterized over 100 nanoparticle types, including titanium oxide (TiO2), fullerenes, dendrimers, gold colloids, polymers, and liposomes. In collaboration with FDA and NIST, the lab has developed over 20 "best practice" protocols for characterizing these particles; several of these are now being adopted by formal Standards Developing Organizations such as ASTM and ISO.

Through its association with NEHI Working Group, the NCL also has recently engaged the National Toxicology Program (NTP); the NTP now has a seat on NCL's Scientific Oversight Committee and utilizes NCL data to inform its own nanomaterial characterization strategy and to avoid duplication of effort.

National Institute for Occupational, Safety and Health (NIOSH): NIOSH has had a good experience working with the NSET Subcommittee and NEHI Working Group for sharing information, networking, and identifying possible collaborations. This interaction also has helped provide feedback on the NIOSH Nanotechnology Program and review of NIOSH documents. NIOSH has had a broad range of collaborations with other agencies that have evolved as a result of being an early entrant into the field. Involvement with the NSET Subcommittee and the NEHI Working Group has provided an opportunity to promote and enhance some of those collaborations, including

1. An MOU developed with OSHA regarding control banding and hazard communication

2. A collaborative arrangement with EPA to work on the Nanoscale Material Stewardship Program
3. Collaborations with DOE, DOE, and NASA to develop site-specific practices and with NIST to develop reference materials
4. Collaborations with OSHA and EPA on international conferences
5. Joint Requests for Applications with EPA, NSF, and NIH, since 2004
6. NIOSH active participation in OECD's Working Party on Nanotechnology and Working Party on Manufactured Nanomaterials (WPMN), including leadership of the WPMN's activity on Cooperation on Exposure Measurement and Exposure Mitigation.

The National Institute of Standards and Technology (NIST): Interactions with the NNI and NEHI Working Group, in particular, have supported the establishment of nanotechnology as a research direction for NIST with direct emphasis on innovation and traceable measurements, not only to advance the development of a measurement-and-standards infrastructure for nanotechnology enabled products, but also those standards necessary to support the EHS aspects of nanomaterials and products that contain them.

Examples of EHS program developments at NIST as a result of NIST-NEHI interactions include

- 2005 Advanced Technology Program Project: Development of 2- and 3-Dimensional Analysis Methodology for Determining the Fate of Nanoparticles in Biological Tissues
- 2006 Innovative Measurement Science Program: Metrology for the Fate of Nanoparticles in Biosystems
- 2008 (if appropriated): Metrology for Nano EHS

NIST's interactions with the NEHI Working Group member agencies has facilitated advances needed by NIST to leverage nanotechnology standards development work among other Federal programs, to establish direct collaborations with other Federal agencies, and to work with representatives from the risk assessment and regulatory communities representing not only government, but also academia, industry, and the international community.

National Institutes of Health (NIH): Through the NIH/National Institute of Environmental Health Sciences, active participation in the NEHI activities has provided a broad, inter-agency perspective that has enhanced its research program. NIH/NIEHS has worked on teams with representatives from CPSC, OSHA, and FDA, as well as funding agencies such as NIOSH, EPA and NSF. This interaction enhanced the NIH/NIEHS understanding of regulatory issues and informed the development of the NIH/NIEHS NanoHealth Initiative, the trans-NIH research strategy for environmental health and safety research. Additionally, NEHI was instrumental in providing the opportunity for NIH/NIEHS to participate in two inter-agency RFAs that have addressed the interaction of engineered nanomaterials with biological systems and in international dialogue on nanotechnology health and safety issues.

National Science Foundation (NSF): NSF's mission is focused on fundamental research, education, and infrastructure that support activities in universities, industry and other agencies. The NNI coordination helps in adjusting research directions, informing NSF decisions about funding centers, and developing comprehensive infrastructure and research and education programs. A few specific collaborations that have resulted from this coordination are:

- Three joint solicitations (2005, 2007, 2008) with EPA, NIEHS, NIOSH, and DOE, respectively
- The NSF-EPA MOU and their joint support for the establishment of a Center for Environmental Implications of Nanotechnology

Appendix B

Initial Analysis of OMB's Call for FY2006 Data on Research in Five Categories of NNI Research Needs Document

In 2006, five agencies performed or supported research on the *Instrumentation, Metrology and Analytical Methods*. This category was cited as providing essential tools and methods for several other categories, for example to support toxicological research. It is the category with the largest 2006 investment, consistent with this enabling role. Instruments and methods are being developed to characterize a large variety of materials in pure form and in complex media, including biological environments. Additional future emphasis may be needed on instrumentation specific to the workplace and the environment. Since 2006, work has begun to develop reference materials for calibration of instruments, examination of analytical processes to assess the chemical or physical properties of such materials, and to assess the quality or comparability of results from tests designed to determine the toxicity of similar health-benefit or drug-related materials

Six agencies funded *Nanomaterials and Human Health* research. With the most widespread investment, reported research addresses both particular nanomaterials and broad classes of materials. Effects of exposure through the lung, skin, and gastrointestinal tract are under investigation, as well as intravenous injection. Inhalation is the exposure route that is the subject of the largest number of projects. Translocation out of the exposure organ is also under study, most commonly using rodent models. As expected for a new class of materials, there is more emphasis on acute exposure than on chronic exposure. Analysis of ongoing research in this area reiterated the value that could be realized from a comprehensive database for EHS properties of nanomaterials, a concept already under development by several agencies and through our international collaborations.

Five agencies funded research in the category *Nanomaterials and the Environment*. Five broad classes of manufactured nanomaterials (metals, quantum dots, nanoceramics, carbon-based nanoparticles, and organic nanomaterials) are covered by funded projects. Studies of the effects of engineered nanomaterials on individuals of a species are underway for numerous aquatic organisms. Transport and transportation of nanomaterials in the environment are well covered. Numerous studies of physical and chemical transformation processes are underway.

Three agencies funded research on *Health and Environmental Exposure Assessment*. The investment is, in rough terms, evenly split between two categories: projects related to collecting general exposure information for workers in facilities manufacturing and using nanoscale and micro-scale titanium dioxide particles, and projects which broadly characterize and analyze factors influencing the evolution of nanoparticles emitted by production equipment in the workplace environment and its effect on the exposure potential. In 2006, this category has the smallest budget which mirrors to some extent the nascent nature of nanotechnology. Systematic collection

of exposure information is hindered by the lack of standardized methods, reference materials, protocols, and affordable instrumentation for EHS measurements. The NNI has already begun to address the need for additional research in this priority area, with NIOSH directing additional funding in FY 2007 for field evaluations in partnership with various enterprises.

Four agencies funded research into *Risk Management Methods.* About one-third of the funding addresses risk-management control measures for airborne particles in the workplace with the rest of the funding addressing more general assessment of the application of risk management methods to nanomaterials. Inhalation is likely to be the most important initial exposure route during development and manufacture of particles with nanoscale features or dimensions, and is addressed by NIOSH funding for workplace exposures. Research into risk management methods for scenarios such as such as environmental releases, ecological receptors, and consumer or incidental exposures, was not funded in 2006, but the applicability of general (as opposed to nanomaterial-specific) risk management methods to these cases has also not yet been evaluated.