United States House of Representatives
Committee on Science & Technology

Hearing on:

The National Nanotechnology Initiative Amendments Act of 2008

Testimony of:

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Executive Summary

Nanotechnology has vast potential to address some of the greatest challenges facing society, including global climate change, poverty and disease. And with this potential comes the possibility of stimulating sustainable economic growth and job creation. The success of nanotechnology, however, is not a foregone conclusion. Alongside the challenges of developing the underlying science are broader issues that will influence its success or failure:

- How can we learn to use such a powerful technology wisely?
- Who will decide how it is used, and who will pay the cost?
- How can innovative science be translated into successful products?
- And in an increasingly crowded and connected world, how will the supposed beneficiaries of nanotechnology be engaged in its development and use?

These questions will not be answered without a clear strategy. And without vision and strong leadership, the future of safe and successful nanotechnologies will be put in jeopardy.

This committee should be applauded for having the foresight to author in 2003 the 21st Century Nanotechnology Research and Development Act—an act that has enabled the United States to lead the world in developing research programs to unlock the potential of the nanoscale. Yet as nanotechnology has increasingly moved from the laboratory to the marketplace, the challenges have shifted from stimulating innovative research to using this research in the service of society. This is why it is so important that the National Nanotechnology Initiative Amendments Act of 2008 builds on the strengths of the 2003 act, and establishes a framework that will support nanotechnologies that can deliver on their promise. In particular, it is vital that the reauthorization addresses the potential for nanotechnologies to cause harm—and how this can be avoided.

Real and perceived risks that are poorly identified, assessed and managed will undermine even the most promising new technologies, and nanotechnology is no exception. In this context, the 2008 act needs to explicitly address five areas if it is to establish a sound framework for enabling safe, sustainable and successful nanotechnologies:

1. **Risk Research Strategy.** A top-level strategic framework should be developed that identifies the goals of nanotechnology risk research across the federal government, and provides a roadmap for achieving these goals. The strategy should identify information needed to regulate and otherwise oversee the safe development and use of nanotechnologies; which agencies will take a lead in addressing specific research challenges; when critical information is needed; and how the research will be funded. This top-level, top-down strategy should reflect evolving oversight challenges. It should be informed by stakeholders from industry, academia and citizen communities. It should include measurable goals, and be reviewed every two years.
2. **Funding for environmental safety and health research.** A minimum of 10% of the federal government's nanotechnology research and development budget

should be dedicated to goal-oriented environment, health and safety (EHS) research. At least $50 million-per-year should be directed towards targeted research directly addressing clearly-defined strategic challenges. The balance of funding should support exploratory research that is conducted within the scope of a strategic research program. Funding should be assessed according to a top-level, top-down risk research strategy, and be overseen by cross-agency leadership.

3. **Leadership for risk research.** A cross-agency group should be established that is responsible for implementing a nanotechnology EHS research strategy, and is accountable for actions taken and progress made. A coordinator should be appointed to oversee this group, as well as given resources and authority to enable funding allocations and interagency partnerships that will support the implementation of a strategic research plan.

4. **Transparency.** Government-funded nanotechnology EHS research investment should be fully transparent, providing stakeholders with information on project activities, relevance, funding and outcomes.

5. **Public-Private Partnerships.** Partnerships that leverage public and private funds to address critical nanotechnology oversight issues in an independent, transparent and timely manner should be established, where such partnerships have the capacity to overcome the limitations of separate government and industry initiatives.

Nanotechnology is a truly revolutionary and transformative technology, and we cannot rely on past ways of doing things to succeed in the future. Without strong leadership from the top, we run the risk of compromising the whole enterprise—not only losing America's technological lead, but also jeopardizing the good that could come out of nanotechnology for other countries and the world.

Already, the hubris surrounding nanotechnology research and development (R&D) funding is giving way to a sobering reality: Based on the federal National Nanotechnology Initiative (NNI)-identified risk-relevant projects, in 2006, the federal government spent an estimated $13 million on ***highly relevant*** nanotechnology risk research (approximately 1% of the nano R&D budget), compared to $24 million in Europe,[1] despite assurances from the NNI that five times this amount was spent on risk-related research in Fiscal Year 2006.[2]

Nanotechnology will not succeed through wishful thinking alone. Instead, it will depend on clear and authoritative leadership from the top. If we are to fully realize the benefits of this innovative new technology, we must bridge the gap between our dreams and reality.

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[1] These figures are based on an assessment of published U.S. and European risk-related research projects, and their relevance to addressing potential risks. See Annex A and Annex B for further information. Full access to the information used in the assessment is available at www.nanotechproject.org/inventories/ehs/ (accessed 4/15/08).

[2] NNI (2008). Strategy for nanotechnology-related environmental, health and safety research, National Nanotechnology Initiative, Washington, DC.

When I look back on the origins of the NNI, I am impressed by the foresight and quality of leadership exerted by congressional visionaries from both sides of the aisle, the president and executive branch, scientists and engineers, businesspeople, and educators.[3] Perhaps because of the tremendous successes achieved in the laboratory since its creation, we risk losing sight of the importance of meeting the challenges involved in taking the NNI to the next level of research, education, governance and commercialization. It is my belief that enactment of the proposed legislation—coupled with the continued vigilance of this committee—will assure that this does not happen.

[3] Lane, Neal and Kalil, Thomas, "The National Nanotechnology Initiative: Present at the Creation," Issues in Science and Technology, Summer 2005.

Introduction

I would like to thank Chairman Bart Gordon, ranking Republican Ralph Hall, and the members of the House Committee on Science & Technology for holding this hearing on the National Nanotechnology Initiative Amendments Act of 2008.

My name is Dr. Andrew Maynard. I am Chief Science Advisor to the Project on Emerging Nanotechnologies (PEN) at the Woodrow Wilson International Center for Scholars. Through my research and other activities over the past 15 years, I have taken a lead in addressing how nanotechnologies might impact human health and the environment, and how we might realize the benefits of these exciting new technologies without leaving a legacy of harm. I was responsible for stimulating government research programs into the occupational health impact of nanomaterials in Britain towards the end of the 1990's. I spent five years developing and coordinating research programs at the Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH) that address the safety of nanotechnologies in the workplace. While at NIOSH, I represented the agency on the Nanoscale Science, Engineering and Technology (NSET) Subcommittee of the National Science and Technology Council (NSTC), and was co-chair of the Nanotechnology Environmental and Health Implications (NEHI) Working Group from its inception.

In my current role as Chief Science Advisor to PEN, I work closely with government, industry and other groups to find science-based solutions to the challenges of developing nanotechnologies safely and effectively. PEN is an initiative launched by the Woodrow Wilson International Center for Scholars and The Pew Charitable Trusts in 2005.[4] It is dedicated to helping business, government and the public anticipate and manage the possible health and environmental implications of nanotechnology. As part of the Wilson Center, PEN is a non-partisan, non-advocacy policy organization that works with researchers, government, industry, non-governmental organizations (NGOs), and others to find the best possible solutions to developing responsible, beneficial and acceptable nanotechnologies.

In this testimony, I will lay out essential components of an overarching framework to cultivate the growth and innovation of the emerging field of nanotechnology that also provides safeguards for the environment, health and safety (EHS) and comment on the extent to which the current draft of the National Nanotechnology Initiative Amendments Act of 2008 addresses these components.

The two aims of stimulating innovation and avoiding harm need not be, nor should be, mutually exclusive. A successful strategy of scientific and technological innovation, integrated with EHS research, will ensure that the promised benefits of such a technology are not thwarted by potential EHS disasters. With nanotechnology, we have the opportunity to do things differently. It is my belief that the proposed reauthorization of the National Nanotechnology Initiative (NNI) will redefine how emerging technologies are developed successfully and safely.

[4] For further information see www.nanotechproject.org. Accessed April 4, 2008.

Underpinning Sustainable Nanotechnologies

The promise of nanotechnology

Nanotechnology has the potential to revolutionize the world as we know it. The increasing dexterity at the nanoscale provides opportunities to greatly enhance existing technologies and to develop innovative new technologies. When you couple this capability with the unusual and sometimes unique behavior of materials that are engineered at near-atomic scales, you have the basis for a transformative technology that has the potential to impact virtually every aspect of daily life. Some of these emerging technologies will benefit individuals, while others will help solve pressing societal challenges like climate change, access to clean water and cancer treatment. And many will provide companies with the competitive edge they need to succeed. In all cases, nanotechnology holds within it the potential to improve the quality of life and economic success of America and the world beyond.

Unconventional behavior

The benefits of nanotechnology, however, will not be realized by default. Nanotechnology is taking our understanding of what makes something harmful and how we deal with that, and turning it upside down. New engineered nanomaterials are prized for their unconventional properties. But these same properties may also lead to new ways of causing harm to people and the environment.[5] Research has already demonstrated that some engineered nanomaterials can reach places in the body and the environment that are usually inaccessible to conventional materials, raising the possibility of unanticipated harm arising from unexpected exposures. And studies have shown that the toxicity of engineered nanomaterials is not always predictable from conventional knowledge.[6] For instance, we now know that nanometer-sized particles can move along nerve cells; that the high fraction of atoms on the surface of nanomaterials can influence their toxicity; and that nanometer-diameter particles can initiate protein mis-folding, possibly leading to diseases.

The need for foresight

Moving towards the nanotechnology future without a clear understanding of the possible risks, and how to manage them, is like driving blindfolded. The more we are able to see where the bends in the road occur, the better we will be able to navigate around them to realize safe, sustainable and successful nanotechnology applications. But to see and navigate the bends requires the foresight provided by strategic science.

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[5] Maynard, A. D., Aitken, R. J., Butz, T., Colvin, V., Donaldson, K., Oberdörster, G., Philbert, M. A., Ryan, J., Seaton, A., Stone, V., Tinkle, S. S., Tran, L., Walker, N. J. and Warheit, D. B. (2006). Safe handling of nanotechnology. *Nature* 444:267-269.

[6] Oberdörster, G., Stone, V. and Donaldson, K. (2007). Toxicology of nanoparticles: A historical perspective. *Nanotoxicology* 1:2 - 25.

With over 600 products currently listed on the PEN's Consumer Products Inventory[7] and with hundreds more commercial nanotechnology applications on the market or under development, the question is no longer *whether* nanotechnologies will impact society but *how significant* the impact will be. The question for policy makers is *how* these impacts will be manifest, and how we will manage the consequences.

Avoiding harm

Central to developing sustainable nanotechnologies is an understanding of how new materials and products may harm people and the environment, and how possible risks may be avoided or otherwise managed.

Everything has the potential to cause harm. If we are smart, we learn how to avoid harm. And if we are very smart, we work out the rules of safe use ahead of the game. In a world of more than six billion people, everything that occurs has an impact on some place and someone. And as a result, each emerging technology forces us to think harder about what the consequences might be, and how to avoid them.

Ignoring the signs of adverse consequences will only result in poor decision-making by governments, business and individuals. While nanotechnology undoubtedly has the potential to do great good, the consequences of getting it wrong could be devastating. Already, research is indicating that many nanomaterials behave in unusual and unconventional ways that may lead to human and environmental harm if not addressed early on.

A new mindset for a new technology

Twenty-first century technologies like nanotechnology present new challenges to identifying and managing risks, and it would be naïve to assume that twentieth century assumptions and approaches are up to the task of protecting health and the environment in all cases. In the case of engineered nanomaterials, the importance of physical structure in addition to chemical composition in determining behavior is making a mockery of our chemicals-based view of risks and regulation.

As a simple example, imagine picking up two common kitchen implements—a skillet and a knife. Each can be used for very different purposes—for instance, the knife for slicing an onion and the skillet for frying it. Likewise, each implement can cause harm in different ways. Yet the chemical makeup of each implement is very similar—it is predominantly iron. The very different rules for safe use are intuitive, because one can see how the different shapes of the implements influence behavior.

Nanomaterials are the same, in that how they behave—for good or bad—depends on their shape as well as their chemistry. But this is where nanotechnology becomes counter-intuitive. Because we cannot see these intricate nano-shapes unaided, we forget that they are important. If one were to hold up a jar of nanometer-sized titanium dioxide particles,

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[7] An inventory of nanotechnology-based consumer products currently on the market. http://www.nanotechproject.org/inventories/consumer/. Accessed 3/30/08.

all that would be seen is a white powder, indistinguishable from many other powdered materials. Yet the potential for this material to be used in new applications, and possibly to cause harm in new ways, lies within the nanoscale structure of the material that can only be seen using advanced microscopy techniques.

Leadership

In thinking through how the potential risks of nanotechnologies can be proactively addressed and the technologies can be developed safely, some things are clear. Safe nanotechnologies will not happen without help—nanotechnologies are simply too unconventional and counter-intuitive. Neither will safe nanotechnologies emerge if the promoters of the technology are calling all the shots. And in a similar vein, safe nanotechnologies will not come about through wishful thinking and "spin."

Instead, there needs to be strong independent leadership, and a framework within which safe and sustainable nanotechnology can be developed. These must ensure adequately funded research is targeted towards understanding and addressing counter-intuitive behavior, that the process of developing safe and sustainable nanotechnologies is transparent and inclusive, and that activities are coordinated and directed towards developing solutions to developing and using nanotechnologies as safely as possible.

Only then will it be possible to develop the foresight necessary to ensure emerging nanotechnologies are as safe and as useful as possible. Having set the pace of nanotechnology development in the U.S. through the 21^{st} Century Nanotechnology Research and Development Act, the House Committee on Science & Technology now has the task of ensuring these emerging nanotechnologies deliver on their promise: benefiting society without causing harm.

Taking Action

Risk Research Strategy

We are unlikely to arrive at a future where nanotechnology has been developed responsibly without a strategic plan for how to get there. Like all good strategies, this should include a clear idea of where we want to be, and what needs to be done to get there. A top-level, top-down strategic framework should be developed that identifies the goals of nanotechnology risk research across the federal government, and that provides a roadmap for achieving these goals. The strategy should identify information needed to regulate and otherwise oversee the safe development and use of nanotechnologies; which agencies will take a lead in addressing specific research challenges; when critical information is needed; and how the research will be funded. It should reflect evolving oversight challenges; be informed by stakeholders from industry, academia and citizen communities; include measurable goals; and be reviewed every two years.

Developing an effective roadmap to addressing these challenges is not as simple as prioritizing research needs. As I discovered while developing recommendations on research strategies in 2006,[8] it is necessary to work back from what you want to achieve, and map out the research steps needed to get there. This inevitably leads to complex and intertwined research threads. Yet if this complexity is not acknowledged, the result is simplistic research priorities that look good on paper, but are ineffective at addressing specific aims. And without a clear sense of context, it is all too easy to highlight research efforts that appear to be strategically important, but are in reality only marginal to achieving the desired goals.

The bottom line is that for such a strategy to be effective, it will require top-down leadership. Establishing provisions for an effective nanotechnology risk research strategy to be developed, funded and implemented in the National Nanotechnology Initiative Amendments Act of 2008 will be essential to underpinning the success and safety of current and future nanotechnologies, as well as ensuring America's continued leadership in this area.

Funding for Environment, Safety and Health Research

To be effective, a nanotechnology risk-research strategic framework needs adequate funding to support proposed research, as well as sufficient expert personnel to oversee its development and implementation. In 2006, the U.S. spent an estimated $13 million on highly-relevant research addressing the impacts of nanotechnology on human health and the environment.[9] By comparison, European countries invested approximately $24 million, including $13 million from the European Union as a central funding organization. But these figures fall far short of what is needed to address even the most urgent nanotechnology EHS questions.

In my testimony to this committee on September 21, 2006,[10] and more recently on October 31, 2007[11], I made the case for a minimum of $50 million annually to be spent on targeted nanotechnology risk research within the U.S. This was based on an assessment of critical short-term research needs, and only covered highly-focused research to address these needs.[12] This estimate still stands. However, I must be clear that such an investment would need to be directed towards addressing a very specific

[8] Maynard, A. D. (2006). Nanotechnology: A research strategy for addressing risk, Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington, DC.

[9] See Annex A, and supporting information in Annex B.

[10] United States House of Representatives Committee on Science. Hearing on Research on Environmental and Safety Impacts of Nanotechnology: What are Federal Agencies Doing? Testimony of Andrew D. Maynard. September 21, 2006.

[11] United States House of Representatives Committee on Science. Hearing on Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation under the National Nanotechnology Initiative. Testimony of Andrew D. Maynard, October 31, 2007.

[12] See also: Maynard, A. D. (2006). Nanotechnology: A research strategy for addressing risk, Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington, DC.

suite of problems that regulators and industry need answers to as soon as possible. This is not envisaged as a general pot of money to be assigned to research that does not address specific and urgent nanotechnology risk goals. In other words, this is an investment that needs to be directed towards the right research.

What is more, such an investment would not necessarily generate more general knowledge to effectively address emerging nanotechnology EHS issues. For this, an additional investment is needed in goal-oriented exploratory research—both specifically focusing on aspects of nanotechnology that might lead to harm, and bridging the worlds of applications and implications research.

To address both targeted and exploratory research needs, a *minimum* 10% of the federal government's nanotechnology research and development budget should be dedicated to goal-oriented EHS research. A minimum of $50 million annually should go to targeted research directly addressing clearly-defined strategic challenges. The balance of funding should support exploratory research that is conducted within the scope of a strategic research program. Funding should be assessed according to an interagency risk research strategy, be overseen by cross-agency leadership and tied into the strategic research plan.

Targeted research primarily should address specific questions where answers are urgently needed to make, use and dispose of nanotechnology products as safely as possible. I would envisage that much of the necessary research would be funded by or conducted within mission-driven agencies, such as the National Institute for Occupational Safety and Health (NIOSH) and the Environmental Protection Agency (EPA). In addition, we must ensure that regulatory agencies, including the Food and Drug Administration (FDA) and the Consumer Product Safety Commission (CPSC), either have access to resources to fund regulation-relevant research, or input to research that will inform their decision-making.

There will also be a role for science-oriented agencies such as the National Institutes for Health (NIH) and the National Science Foundation (NSF) in funding targeted research, where the missions of these agencies coincide with research that informs specific oversight questions. For example, these two agencies are ideally positioned to investigate the science behind nanomaterial properties, behavior and biological interactions in a targeted way, with the aim of predicting health and environmental impact. But ensuring that targeted research conducted within these agencies is relevant to addressing risk identification, assessment and reduction goals will be critical, and underscores the need for a robust cross-agency, risk-research strategy and pool of designated funds.

Exploratory research, on the other hand, primarily would be investigator-driven (within determined bounds), and so would preferentially lie within the remit of NSF and NIH. However, in ensuring effective use of funds, it will be necessary to develop ways of supporting interdisciplinary research that crosses the boundary separating these agencies, and combines investigations of basic science with research into disease and environmental endpoints, with the goal of informing oversight decisions.

Exploratory research should not be confined to these two agencies alone, as there will be instances where goal-oriented but exploratory research will fit best within the scope of mission-driven agencies, and will benefit from research expertise within these agencies. For example, researchers at NIOSH are currently engaged in exploratory research that is directly relevant to identifying and reducing potential nanotechnology risks in the workplace.[13]

At present, there is no pot of "nanotechnology" money within the federal government that can be directed to areas of need. Rather, the NNI simply reports what individual agencies are spending. Yet if strategic nanotechnology risk research is to be funded appropriately, mechanisms are required that enable dollars to flow from where they are plentiful to where they are needed. Extremely overstretched agencies like NIOSH and EPA cannot be expected to shoulder their burden of nanotechnology risk-research unaided, and agencies such as FDA and CPSC currently have no listed budget whatsoever for nanotechnology EHS research. If the federal government is to fully utilize expertise across agencies and enable effective nanotechnology oversight, resource-sharing across the NNI will be necessary.

Leadership for Risk Research

Without clear leadership, the emergence of safe nanotechnologies will be a happy accident rather than a foregone conclusion.

This is a collection of technologies that is counter-intuitive and as a result, safe and sustainable nanotechnologies will not emerge without help. Accepted mechanisms of technology development and transfer—including investigator-driven research, generation of intellectual property, knowledge diffusion and market-driven commercialization—will not ensure the information and approaches needed to proactively ensure the safety of emerging nanotechnologies on their own. Instead, clear and authoritative top-down leadership is needed to enable the generation and application of information that will support safe nanotechnology development.

As a result, it is recommended that a cross-agency group be established that is responsible for implementing a nanotechnology EHS research strategy, and is accountable for actions taken and progress made. A coordinator should be appointed to oversee this group, and given resources and authority to enable funding allocations and interagency partnerships that will support the implementation of a strategic research plan. A key role for this coordinator would be to ensure agencies are motivated and able to work within their missions and competencies toward a common set of established goals. They would also provide leadership to the broader stakeholder community involved—both nationally and internationally—in developing safe nanotechnologies.

[13] NIOSH (2008). Strategic plan for NIOSH nanotechnology research. Filling the knowledge gaps. Draft, February 26 2008 (Update). National Institute for Occupational Safety and Health, Washington, DC.

Transparency

Without transparency, effective development, implementation and review of a strategic research framework will be hampered, stakeholder engagement will be impossible, and trust in the government to underpin safe nanotechnologies will be severely compromised. As a result, it is recommended that government-funded nanotechnology EHS research should be fully transparent, providing stakeholders with information on project activities, relevance, funding and outcomes.

Activities to date within the federal nanotechnology initiative have been less than transparent, to the detriment of an effective strategy for nanotechnology development and use. For example, a PEN analysis of current research projects listed in the NNI's "Strategy for Nanotechnology-Related Environmental, Health, and Safety Research" found that only 62 of the 246 projects listed were highly relevant to addressing EHS issues (the remaining projects had some relevance, but in general were focused on exploiting nanotechnology applications).[14] These 62 projects accounted for an estimated $13 million in research and development funding for 2006—a far cry from the $68 million cited by the NNI document as being focused on EHS research.[15] Each of these 246 projects has some relevance to addressing nanotechnology safety, and the NNI was right to list them. But by not categorizing the relevance of the research or including funding figures for each project, the stated $68 million being invested has little credibility—and as has just been shown, is indeed highly misleading.

Lack of transparency such as this can only hinder the development of new knowledge that is essential to ensuring safe and successful nanotechnologies. This is such a critical issue to underpinning progress towards safe and successful nanotechnologies that I would suggest any assessment of research investment, relevance or direction that is *not backed up by publicly accessible project-specific data* is worthless. It is for this very reason that the Organization for Economic Cooperation and Development (OECD) Working Party on Manufactured Nanomaterials is developing a soon-to-be-launched comprehensive database on risk-relevant nanotechnology research around the world.[16]

[14] See Annex A, with supporting information in Annex B. Project specific data underpinning this analysis can be found in the Project on Emerging Nanotechnologies Environment, Health and Safety Research Inventory (http://www.nanotechproject.org/inventories/ehs/, accessed 4/15/08). This inventory is in the process of being adopted and updated by the Organization for Economic Cooperation and Development, Working Party on Manufactured Nanomaterials.

[15] Further independent assessment of research funded in 2006 reveals funding for highly-relevant risk research was closer to $20 million (http://www.nanotechproject.org/inventories/ehs/, accessed 4/8/08). The discrepancy appears to be due to relevant research that that the NNI missed in their analysis—another indicator that the government is not on top of what research is being funded, and lacks sufficient transparency for effective accountability.

[16] The OECD nanotechnology risk research database is based on the Project on Emerging Nanotechnologies inventory of nanotechnology environment, health and safety research (http://www.nanotechproject.org/inventories/ehs/, accessed 4/8/08). Due to be launched in June 2008, it will include information on project relevance to addressing nanotechnology risks and funding levels. For further details, see http://www.oecd.org/dataoecd/34/6/37852382.ppt (accessed 4/8/08).

Public-Private Partnerships

Often, partnerships between public and private organizations have the capacity to address critical challenges in a manner that is beyond the scope of either partner in isolation. To expedite progress towards ensuring the safety of emerging nanotechnologies, it is recommended that partnerships are established that leverage public and private funds to address critical nanotechnology oversight issues in an independent, transparent and timely manner and to overcome the limitations of separate government and industry research.

Where research needs fall between the gap of government and industry (because of their different goals), public-private research partnerships provide an important mechanism for bridging the gaps. Industries investing in nanotechnology have a financial stake in preventing harm, manufacturing safe products and avoiding long-term liabilities. Yet many of the questions that need answering are too general to be dealt with easily by industry alone. Perhaps more significantly, the credibility of industry-driven risk research is often brought into question by the public and NGOs as not being sufficiently independent and transparent. For many nanomaterials and nanotechnologies, the current state of knowledge is sufficient to cast doubt on their safety but lacks the certainty and credibility for industry to plan a clear course of action on how to mitigate potential risks. Getting out of this "information trap" is a dilemma facing large and small nanotechnology industries alike.

Cooperative science organizations like public-private partnerships provide one way out of the "trap" where they are established to generate independent, credible data that will support nanotechnology oversight and product stewardship. Such organizations would leverage federal and industry funding to support targeted research into assessing and managing potential nanotechnology risks. Their success would depend on five key attributes:

Independence. The selection, direction and evaluation of funded research would have to be science-based and fully independent of the business and views of partners in the organization.

Transparency. The research, reviews and the operations of the organization should be fully open to public scrutiny.

Review. Research supported by the organization should be independently and transparently reviewed.

Communication. Research results should be made publicly accessible and fully and effectively communicated to all relevant parties.

Relevance. Funded research should have broad relevance to managing the potential risks of nanotechnologies through regulation, product stewardship and other mechanisms.

As I discussed in my comments to the House Committee on Science & Technology Subcommittee on Research and Science Education last October,[17] a number of research organizations have been established over the years that comply with many of these criteria. One of these is the Health Effects Institute (HEI),[18] which has been highly successful in providing high-quality, impartial, and relevant science around the issue of air pollution and its health impacts. The Foundation for the National Institutes for Health[19] also has been successful in developing effective public-private partnerships, and the International Council on Nanotechnology (ICON)[20] is a third model for bringing government, industry and other stakeholders to the table to address common goals. PEN is currently exploring these and other models as possible templates for public-private partnerships addressing nanotechnology risks.

Irrespective of which model is the best suited for nanotechnology, the need is urgent to develop such partnerships as part of the government's strategy to address nanotechnology risks. Nanotechnologies are being commercialized rapidly—going from $60 billion in manufactured goods in 2007 to a projected $2.6 trillion in nanotechnology-enabled manufactured goods by 2014—or 15% of total manufactured goods globally.[21] And knowledge about possible risks is simply not keeping pace with consumer and industrial applications.

Conclusions

The nanotechnology future is calling us forward, and the U.S. is at the forefront of the race to get there as fast as possible. But we are skating on thin ice, and are in danger of missing the warning signs. Nanotechnology is counter-intuitive, and we cannot rely on past ways of doing things to succeed in the future. Without strong leadership from the top, we run the risk of compromising the whole enterprise—not only losing America's lead, but also jeopardizing the good that could come out of nanotechnology for other countries.

Already, the hubris surrounding nanotechnology R&D funding is giving way to a sobering reality: Based on NNI-identified risk-relevant projects, in 2006, the federal government spent an estimated $13 million on ***highly relevant*** nanotechnology risk research (approximately 1% of the nano R&D budget), compared to $24 million in

[17] United States House of Representatives Committee on Science & Technology, Subcommittee on Research and Science Education. Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation under the National Nanotechnology Initiative. Testimony of Andrew D. Maynard. October 31 2007.

[18] For further information see The Health Effects Institute, www.healtheffects.org. Accessed Oct 13 2007.

[19] For further information see The Foundation for the National Institutes of Health, www.fnih.org. Accessed Oct 13 2007.

[20] For further information, see the International Council On Nanotechnology, www.icon.rice.edu. Accessed Oct 13 2007.

[21] Lux Research (2007). The nanotech report. 5th edition., Lux Research Inc., New York, N.Y.

Europe, despite assurances from the NNI that five times this amount was spent on risk related research in Fiscal Year 2006.

But nanotechnology will not succeed through wishful thinking alone. Instead, it will depend on clear and authoritative leadership from the top. If we are to fully realize the benefits of this innovative new technology, we must bridge the gap between our dreams and reality.

In my personal view, the proposed National Nanotechnology Initiative Amendments Act of 2008 goes a long way towards bridging this gap. I particularly commend the committee for promoting transparency through a public database for projects funded under EHS; education and societal dimensions; and nanomanufacturing program component areas, with sub-breakouts for education and ethical, legal and social implications (ELSI) projects. This database will complement the public international EHS database expected to be launched by the Organization for Economic Cooperation and Development (OECD) in June 2008, and will provide an essential resource for evaluating the federal government's progress towards addressing critical research questions, as well as developing future research strategies.

In addition, I believe the proposed act takes an important step in assigning to a single coordinator the responsibility for ensuring that a top-down strategic plan for nanotechnology EHS research is developed and implemented; that EHS research is appropriately funded with *at least* 10 percent of the total NNI budget; and that public-private partnerships are established that leverage government and industry research initiatives.

Finally, as the committee knows, my in-depth experience lies in the area of the EHS implications of nanotechnology. But as one of the many scientists and engineers deeply involved in nanotechnology development for over 20 years, I am genuinely concerned about the education and "nano-readiness" of America's students, teachers, and workforce. For this reason, I personally endorse the establishment of partnerships to help recruit and prepare secondary school students to pursue postsecondary education in nanotechnology. I also support enhancements to nanotechnology undergraduate education, faculty development, and acquisition of equipment and instrumentation at the undergraduate level. When today China has as many scientists and engineers working on nanotechnology as the U.S., it is critical to support initiatives in nanotechnology education aimed at our young people.

Similarly, the U.S. public and consumers are woefully unprepared for the nano-age. Polling, focus groups and social science research commissioned by PEN since its inception show that Americans' awareness of nanotechnology remains abysmally low, with seven in 10 adults having heard just a little or nothing at all about it.[22] This, in my opinion, is a significant failing of the NNI. Too few resources and too little expertise has been devoted to educating and engaging the public about the implications of what I believe is one of this century's most exciting areas of science and engineering. I

[22] "Awareness of And Attitudes Toward Nanotechnology And Federal Regulatory Agencies" conducted on behalf of the Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars by Peter D. Hart Research Associates, Inc., September 25, 2007.

particularly urge the committee to address this problem as it works on the National Nanotechnology Initiative Amendments Act of 2008.

When I look back on the origins of the NNI, I am impressed by the foresight and quality of leadership exerted by congressional visionaries from both sides of the aisle, the president and executive branch, scientists and engineers, businesspeople, and educators.[23] Perhaps because of the tremendous successes achieved in the laboratory since its creation, we risk losing sight of the importance of meeting the challenges involved in taking the NNI to the next level of research, education, governance and commercialization. It is my belief that with the proposed act—and with the continued vigilance of this committee—this will not happen.

[23] Lane, Neal and Kalil, Thomas, "The National Nanotechnology Initiative: Present at the Creation," Issues in Science and Technology, Summer 2005.

Annex A. Assessment of U.S. Government Nanotechnology Environmental Safety and Health Research for 2006

1. Assessment of research listed in the 2008 NNI nanotechnology risk research strategy[24]

a. Research projects **highly relevant** to nanotechnology environment health and safety accounted for an estimated **$12.8 million** in federal research funding in 2006.

b. Research that was either **highly or substantially** relevant to nanotechnology EHS accounted for an estimated **$28.9 million**.

c. The majority of the research projects listed by the NNI as being relevant to nanotechnology EHS have only limited relevance.

Listed research was categorized according to its relevance to addressing potential nanotechnology risks (highly relevant, substantially relevant, having some relevance, or having marginal relevance—as defined below). Projects specifically addressing engineered nanomaterials, as well as projects generally applicable to any source of nanoparticles, were included in the analysis.

The methodology for categorizing research relevance was the same as that used in the Project on Emerging Nanotechnologies online inventory of nanotechnology EHS research,[25] and in the forthcoming OECD database of nanotechnology EHS research.[26] This approach allows a sophisticated and transparent assessment of research investment. The categorization is based on published project abstracts, and how these relate to addressing risk-specific issues.

2. A broader assessment of U.S. federally-funded risk-relevant research for 2006

The previously-released PEN inventory of EHS research contains substantially more projects than are listed in the 2008 NNI risk research strategy. Assessment of the full inventory of projects reveals that more risk-relevant research was being funded in 2006 than is identified by the NNI, but that funding levels are still low:

a. Research projects **highly relevant** to nanotechnology environment health and safety accounted for an estimated **$20.4 million** in federal research funding in 2006.

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[24] NNI (2008). Strategy for nanotechnology-related environmental, health and safety research, Washington DC, National Nanotechnology Initiative.

[25] Environment, safety and health research. www.nanotechproject.org/inventories/ehs/ (accessed 4/15/08).

[26] For further details on the OECD risk research database, see http://www.oecd.org/dataoecd/34/6/37852382.ppt (accessed 4/8/08)

b. Research that was either **highly or substantially** relevant to nanotechnology EHS accounted for an estimated **$37.8 million**.

The disparity between the figures above and NNI figures on research spending underline an urgent need for transparency in what is being funded, and it's relevance to addressing nanotechnology risk.

3. Comparison with European risk research investments

a. In 2006, European countries invested an estimated **US$23.6 million** in research that was **highly relevant** to understanding and addressing the impacts of nanotechnology on human health and the environment. The EU as a central funding organization invested an estimated US$12.6 million in highly relevant research in 2006.

These estimates are based on figures published in the document "EU nanotechnology R&D in the field of health and environmental impact of nanoparticles," published in 2008.[27] Research funding within European countries for calendar year 2006 has been estimated. The analysis includes research funded by the European Union, Belgium, Czech Republic, Denmark, Finland, Germany, Greece, Sweden, Switzerland and the United Kingdom.

4. Definitions of research relevance:

a. ***High:*** Research that is specifically and explicitly focused on the health, environmental and/or safety implications of nanotechnology. Also included in this category are projects and programs where the majority of the research undertaken is specifically and explicitly focused on the health, environmental and/or safety implications of nanotechnology. Examples of research in this category would include research to understand the toxicity of specific nanomaterials, research into exposure monitoring and characterization to further understand potential impact, research into biological interactions and mechanisms that is focused on answering specific questions associated with potential risk. Examples of research that would not be included in this category would include exploratory research into biological mechanisms outside the context of understanding impact, general instrument development, and research into therapeutics applications which also incorporate an element of evaluating impact.

b. ***Substantial:*** Research that is focused towards nanotechnology-based applications or developing fundamental new knowledge on nanoscience, but that has substantial and explicit relevance to EHS implications. Examples of research in

[27] EU nanotechnology R&D in the field of health and environmental impact of nanoparticles. DG Research, January 28, 2008.

this category would include non-targeted research into biological mechanisms which is informative to understanding risk, instrument development for assessing nanomaterials for applications *and* characterizing nanomaterials in hazard evaluations, and major programs with a significant component focused on risk research.

c. ***Some:*** Research that is focused on the application of nanotechnology and developing fundamental new knowledge on nanoscience but that has some relevance to EHS implications. Examples might include research into therapeutics applications which also lead to the generation of useful data on hazard.

d. ***Marginal:*** Fundamental nanoscience and/or nanotechnology applications-based research, which informs understanding on potential EHS implications in a marginal way. Examples might include the development of new analytical techniques such as analytical electron microscopy, where some attempt is made to apply the techniques to understanding potential risks unique to nanomaterials.

Annex B. NNI-Identified Nanotechnology Risk-Research, Listed by Relevance[28]

Highly Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-14	NIST	Single Photon Sources and detectors	
a1-23	NIST	Metrology for the "Fate" of Nanoparticles in Biosystems	
a2-12	NIST	Theoretical Models of Chemical Properties of Nanostructures	
a3-2	NIOSH	Monitoring and Characterizing Airborne Carbon Nanotube Particles	$133,333
a3-3	NIST	Nanoparticle Risk Impact and Assessment Program	
a4-2	NIH	Submicron Particles and Fibers for Toxicological Studies	$168,893
b1-1	DOD	Multidisciplinary University Research Initiative: Effects of Nanoscale Materials on Biological Systems: Relationship between Physiochemical Properties and Toxicological Properties	$1,100,000
b1-2	EPA	Impact of Physiochemical Properties on Skin Absorption of Manufactured Nanomaterials	$130,539
b1-27	NSF	Lung Deposition of Highly Agglomerated Nanoparticles	$133,333
b2-12	NSF	SGER: Aquatic Nanotoxicology of Nanomaterials and Their Biomolecular Derivatives	$30,000
b2-5	NIH	Physicochemical Characterisation and Formulation of Fullerene C60 and Titanium Dioxide	
b2-6	NIOSH	Role of Surface Chemistry in the Toxicological Properties of Manufactured Nanoparticles	$133,333
b2-7	NIOSH	Particle Surface Area As a Dose Metric	$333,333
b2-8	NIOSH	Nanoparticles: Lung Dosimetry and Risk Assessment	$166,667
b2-9	NIOSH	Generation & Characterization of Nanoparticles	$333,333
b3-1	EPA	A Rapid In Vivo System for Determining Toxicity of Manufactured Nanomaterials	$133,333
b3-5	NIH	Development of methods and models for nanoparticle toxicity screening: Applications	$120,109
b4-10	NIOSH	Pulmonary Deposition and Translocation of Nanomaterials	$300,000
b4-11	NSF	Nanotox: Biochemical, Molecular and Cellular Responses of Zebrafish Exposed to Metallic Nanoparticles	$116,667
b4-4	NIH	UTEP-UNM HSC ARCH PROGRAM ON BORDER ASTHMA	$948,159
b4-5	NIH	Skin Penetration, Phototoxicity, and Photocarcinogenesis of Nanoscale Oxides of Titanium and Zinc	
b4-6	NIH	Toxicokinetics of Quantum Dots In Rats	
b4-8	NIOSH	Role of CNT's in Cardiovascular Inflammation & Copd Related Diseases	$300,000
b4-9	NIOSH	Dermal Effects of Nanoparticles	$233,333
b5-1	DOD	Biological Interactions of Nanomaterials	$300,000
b5-2	DOD	Safer Nanomanufacturing	
b5-28	NIH	Nanoparticle Disruption of Cell Function	$122,288
b5-29	NIH	Long Term Cardiovascular Effects of Inhaled Nanoparticles	$118,611
b5-3	DOD	Identifying Critical P-C Characteristics of Np That Elicit Toxic Effects	
b5-30	NIH	Tumorigenicity of Photoactive Nanoscale Titanium Dioxide In Tg.ac Transgenic Mice	
b5-31	NIH	Mechanisms of Chemically Induced Photosensitivity	

[28] Refer to Annex A for definitions of relevance. All research projects in the document "Strategy for nanotechnology-related environmental, health and safety research, Washington DC, National Nanotechnology Initiative." (NNI, 2008) are listed; not all specifically address engineered nanomaterials though, or were funded in 2006.

NNI ID	Agency	Project Title	Estimated Annual Funding
b5-34	NIH	Systemic Implications of Total Joint Replacement	$288,959
b5-35	NIH	Long Term Cardiovascular Effects of Inhaled Nanoparticles	
b5-36	NIOSH	Pulmonary Toxicity of Carbon Nanotube Particles	$300,000
b5-37	NIOSH	Systematic Microvascular Dysfunction Effects of Ultrafine Versus Fine Particles	$200,000
b5-38	NIOSH	Lung Oxidative Stress/Inflammation by Carbon Nanotubes	$375,000
b5-4	EPA	Effects of Ingested Nanoparticles on Gene Regulation in the Colon	$100,000
b7-2	NIOSH	Nanotechnology Safety and Health Coordination	$100,000
c1-1	EPA	Methodology Development for Manufactured Nanomaterial Bioaccumulation Test	$133,256
c1-2	EPA	The Effect of Surface Coatings on the Environmental and Microbial Fate of Nanoiron and Feoxide Nanoparticles	$133,333
c1-3	EPA	Aquatic Toxicity of Waste Stream Nanoparticles	$133,276
c4-1	DOD	Measure The Transport Of Modified Nanoparticles Through Soil	
c4-11	NSF	SGER: Particle Incorporation of PAH in Aquatic Environments: Implications to Fate and Transport	$33,600
c4-14	NSF	CAREER: Interfacial Reactions Affecting Heavy Metal Fate and Transport: An Integrated Research and Education Plan	$78,965
c4-15	NSF	Carbon Nanoparticles in Combustion: A Multiscale Perspective	$80,000
c4-17	NSF	Aggregation and Deposition Behavior of Carbon Nanotubes in Aquatic Environments	$133,333
c4-18	USDA	REACTIVITY, AGGREGATION AND TRANSPORT OF NANOCRYSTALLINE SESQUIOXIDES IN THE SOIL SYSTEM	$61,736
c4-19	USDA	COLLOID INTERFACIAL REACTIONS IN OPEN MICROCHANNEL REPRESENTING UNSATURATED SOIL CAPILLARIES	$48,001
c4-22	USDA	SORPTION AND AVAILABILITY OF METALS AND RADIONUCLIDES IN SOILS	
c4-5	EPA	Ecotoxicology of Underivatized Fullerenes (C60) in Fish	$132,269
c4-6	EPA	Carbon Nanotubes: Environmental Dispersion States, Transport, Fate, and Bioavailability	$123,962
c4-7	EPA	Biological Fate & Electron Microscopy Detection of Nanoparticles During Wastewater Treatment	$132,999
c5-5	NSF	Environmental Biogeochemistry and Nanoscience: Applications to Toxic Metal Transport in the Environment	$60,000
c5-6	NSF	Collaborative Research: Fullerene Aggregation in Aquatic Systems	$116,164
d1-1	NIOSH	Nanotechnology Research Coordination	$233,333
d1-2	NIOSH	Titanium Dioxide (TiO2) Nanoparticle Exposure Study	$133,333
d5-1	DOD	Small Business Innovation Research (SBIR): The Impact of Nanomaterials on Occupational Safety and Health	
d5-2	NIOSH	Nanoparticle in the Workplace	$133,333

Annex B. Highly Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
d5-3	NSF	Experimental and Numerical Simulation of the Fate of Airborne Nanoparticles from a Leak in a Manufacturing Process to Assess Worker Exposure	$133,333
e1-1	NIOSH	Development and Evaluation of Nanofiber-based Filter Media	$333,333
e1-2	NIOSH	Penetration of Nanoparticles Through Respirator Filter Media	$166,667
e1-3	NIOSH	Automobile Ultrafine Intervention	$333,333
e1-4	NIOSH	Assessment Methods for Nanoparticles in the Workplace	$133,333
e2-1	EPA	Comparative Life Cycle Analysis of Nano – and Bulk-materials in Photovoltaic Energy Generation	$100,000
e3-1	NIOSH	Developing a Web-Based Nano-Information Library	$300,000
e5-1	NIOSH	Nanotechnology Information Dissemination	$200,000
e6-2	DOD	WINGS™-Web-Interfaced Nanotechnology ESH Guidance System for Force Health Protection	
e6-5	NSF	NIRT: Nanotechnology in the Public Interest: Regulatory Challenges, Capacity, and Policy Recommendations	$350,000
e6-6	NSF	NIRT: Evaluating Oversight Models for Active Nanostructures and Nanosystems: Learning from Past Technologies in a Societal Context	$305,191

Substantially Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
a2-13	NIST	Nanocharacterization - NCI	
a2-1	DOE	Single Molecule Fluorescence In Nanoscale Environments	
a2-2	DOE	The Reaction Specificity of Nano Particles In Solutions	
b1-16	NIH	Near-Infrared Fluorescence Nanoparticles for Targeted O*	$578,922
b1-18	NIH	NIR Absorbing Nanoparticles For Cancer Therapy	$152,591
b1-19	NIH	A Tumor-Specific Nanoimmunocomplex Markedly Improves MR Imaging	$460,490
b1-23	NIH	CNS Gene Delivery and Imaging in brain Tumor Therapy	$552,763
b1-24	NIH	Nanoparticles for siRNA delivery to mammalian neurons	$166,709
b1-25	NIH	Bioengineering of the blood-brain barrier permeability	$199,169
b1-26	NIH	Reuse in RI: A State-based Approach to Complex Exposures	$2,784,592
b1-4	NIH	Design of Targeting Enhancement for Drug Delivery	$184,653
b1-5	NIH	Nanoparticles for efficient delivery to solid tumors	$111,028
b2-1	NIH	Multifunctional Nanoparticles for Intracellular Delivery	$271,029
b3-4	NIH	Hybrid Nanoparticles in Imaging and Therapy of Prostate*	$585,773
b4-2	NIH	Training in Pharmacometrics and the Therapeutic Application of Nanotechnology	$147,236
b5-20	NIH	Nanoparticles As Promoters of Cell Longevity	$368,831
b5-21	NIH	Nano-Apatite Coating of the Porous Surface of Implants	$249,124
b5-22	NIH	The Interaction of Polycationic Organic Polymers with Biological Membranes	$278,170
b5-26	NIH	Nanotechnology Characterization Laboratory	
b5-32	NIH	Micellar VIP Nanoparticles for Rheumatoid Arthritis	$257,713
a1-17	NIST	Superresolution, In Situ Microscopies for Characterization of Nanostructured Materials	
a4-3	NIST	R&D For Carbon Nanotube Reference Materials	
a4-4	NIST	R&D For Nanoparticle (non-Carbon Nanotube) Reference Materials	
a1-29	NSF	NSEC for Molecular Function at the Nano/Bio Interface	$1,820,700
a3-4	NSF	IMR: Developement of an Analyzer for Size and Charge Characterization of Nanoparticles in Research and Training	$83,676
b2-10	NSF	NIRT: Design of Biocompatible Nanoparticles for Probing Living Cellular Functions and Their Potential Environmental Impacts	$330,938
b2-11	NSF	NER: Novel Cell Culture Stylus for the Rapid Assessment of Functional Nano-Bio Interfaces	$115,300
c4-9	NSF	CAREER: Carbonaceous Particles of Tarry Origin	$110,742

NNI ID	Agency	Project Title	Estimated Annual Funding
c5-2	NSF	CAREER: An Integrated Research and Education Program in Long-Term Durability of Nano-Structured Cement-Based Materials during Environmental Weathering	$103,331
c5-4	NSF	Investigating the Surface Structure and Reactivity of Bulk and Nanosized Manganese Oxides	$109,857
c5-8	NSF	NSEC: Center for Biological and Environmental Nanotechnology	$937,984
e6-1	NSF	NSEC: Center for Nanotechnology in Society at University of California, Santa Barbara	$885,761
c1-5	USDA	CELLULAR AND MATERIALS-BASED STUDIES OF MARINE INVERTEBRATES TO ADVANCE BIOMINERALIZATION, ANTIFOULING AND NANOTECHNOLOGY FIELDS	
c5-9	USDA	THE CHEMICAL AND PHYSICAL NATURE OF PARTICULATE MATTER AFFECTING AIR, WATER, AND SOIL QUALITY.	

Research with Some Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-32	NSF	Molecular Simulation of Chemical Warfare Agent Adsorption	$35,000
a1-33	NSF	NSEC: Center for Hierarchical Manufacturing	$814,472
b5-33	NIH	Curcumin and Curcumin Derivatives for Alzheimer's	$206,829
a1-34	NSF	Nanoscale Science & Engineering Center for Integrated Nanopatterning and Detection Technologies	$2,117,092
a1-35	NSF	CAREER: Engineering Nucleic Acid Devices	$81,407
a1-36	NSF	NSEC: Center Of Integrated Nanomechanical Systems (COINS)	$1,915,697
b5-39	NSF	NIRT: Controlling Interfacial Activity of Nanoparticles: Robust Routes to Nanoparticle-based Capsules, Membranes, and Electronic Materials	$300,000
a1-1	NIH	A study of model beta-cells in Diabetes Treatment	$298,020
a1-3	NIH	Implantable 16-256 channel data system for sleep in mice	$402,601
b1-3	NIH	Nanoparticle, Raman-based Fiber-optic Glucose Sensor	$377,105
a1-4	NIH	Power Harvesting in Implanted Neural Probes	$190,505
a1-5	NIH	Surface Plasmon-coupled Fluorescence Microscope to Study Ion Channel Dynamics	$186,713
a1-6	NIH	A Turnkey, Wireless, EEG/EMG/Biosensor Measurement	$336,588
b1-6	NIH	Engineered intelligent micelle for tumor pH targeting	$268,607
a1-7	NIH	Cut Nanotube Capsules for MR Imaging (RMI)	$144,603
b1-7	NIH	Carolina Center of Cancer Nanotechnology Excellence	$3,325,006
a1-8	NIH	Flourescent Ceramic Nanoprobes	$323,657
b1-8	NIH	Center of Nanotechnology for Treatment, Understanding, and Monitoring of Cancer	$3,839,972
a1-9	NIH	Targeted MRI with Protein Cage Architectures (RMI)	$354,053
b1-9	NIH	Emory-GA Tech Nanotechnology Center for Personalized and Predictive Oncology	$3,523,612
a1-10	NIH	MFe2O4-Loaded Polymer Micelles as Ultra-Sensitive MR Molecular Probes (RMI)	$351,746
b1-10	NIH	Nanomaterials for Cancer Diagnostics and Therapeutics	$3,695,651
a1-11	NIH	Membrane Topography of Cell Signaling Complexes	$259,841
b1-11	NIH	The MIT-Harvard Center of Cancer Nanotechnology Excellelence	$3,905,825
a1-12	NIH	Non-viral Liver-targeted Gene Delivery	$297,630
b1-12	NIH	The Siteman Center of Cancer Nanotechnology Excellence	$330,773
a1-13	NIH	Morphogen Gradients in Microfluidic Cultures	$138,118
b1-13	NIH	Center of Cancer Nanotechnology Excellence Focused on Therapy Response	$3,806,915
b1-14	NIH	DNA-linked dendrimer nanoparticle systems for diagnosis	$468,218

NNI ID	Agency	Project Title	Estimated Annual Funding
b1-15	NIH	NANOTHERAPEUTIC STRATEGY FOR MULTIDRUG RESISTANT TUMORS	$345,707
a1-15	NIST	Quantum Optical Metrology	
a1-16	NIST	Nano-scale Engineered Sensors for Ultra-low Magnetic Field Metrology	
b1-17	NIH	Polymer chelate conjugates for Diagnostic cancer imaging	$239,418
b1-20	NIH	In vivo imaging of diabetogenic cytotoxic T-lymphocytes	$253,117
b1-21	NIH	Imaging Tumor Blood Vessels in Bone Metastases from Breast Cancer	$322,971
b1-22	NIH	Early Detection of Renal Injury	
a1-24	NSF	SST - Ferroelectric Thin-Film Active Sensor Arrays for Structural Health Monitoring	$150,667
a1-25	NSF	CAREER: Hybrid Nanomaterials for Multi-Functional Sensors - Synthesis and Characterization of Nanocomposite Thin-Films for Device Applications	$80,000
a1-26	NSF	CAREER: Integrated Research and Education in Nano- and Microscale Photoacoustic and Photothermal Microscopy	$80,000
a1-27	NSF	REU Site for Nanoscale Structures and Integrated Biosensors (NSIB)	$130,400
a1-28	NSF	Selective Filling of Nanostructured Packings for Chromatographic Chip Systems	$75,000
b1-28	NSF	Nanostructured Interfaces for Targeted Drug Delivery	$25,000
b1-29	NSF	Materials World Network: Designer Nanodiamonds for Detoxification	$157,000
b1-30	NIH	Integrated Nanosystems for Diagnosis and Therapy	$2,713,460
a1-31	NSF	IGERT: Nanoparticle Science and Engineering	$475,747
c2-1	NSF	Environmental Molecular Science Institute: Actinides and Heavy Metals in the Environment - The Formation, Stability, and Impact of Nano- and Micro-Particles	$920,292
b2-2	NIH	Local Anesthetic Cardiotoxicity: Nanotechnology Therapy	$250,062
e2-2	NSF	The Life Cycle of Nanomanufacturing Technologies	$100,000
a2-8	NIH	Toxic Substances in the Environment	$153,032
a2-9	NIH	Bladder Tissue Engineering through Nanotechnology	$170,033
b2-13	NSF	NSEC: Center for Affordable Nanoengineering of Polymer Biomedical Devices (CANPBD)	$2,122,192
a2-14	NIST	Metrology for Tissue Engineering: Test Patterns and Cell Function Indicators	
c3-1	NSF	NER: Nanoscale Size Effects on the Biogeochemical Reactivity of Iron Oxides in Active Environmental Nanosystems	$114,998
a3-1	DOE	A Fundamental Study of Transport Within A Single Nanoscopic Channel	
b3-2	NIH	Polymer-Nucleotide Complexes with Cytotoxic Activity	$226,085
b3-3	NIH	Detecting cancer early with targeted nano-probes for va	$606,348
b3-6	USDA	ROLE OF CHROMOSOME ALTERATIONS IN ENVIRONMENTAL CARCINOGENESIS	
a4-1	NIH	Cryopreservation of tissue engineered substitutes	$320,356

NNI ID	Agency	Project Title	Estimated Annual Funding
b4-1	NIH	Treatment of Type 2 Diabetes with Oral Administration of Nanoencapsulated GLP-1	$140,195
c4-2	DOE	How Do Interfacial Phenomena Control Nanoparticle Structure?	
c4-3	DOE	"Frontiers In Biogeochemistry And Nanomineralogy: Studies In Quorum Sensing And Nanosulfide Dissolution Rates	
b4-3	NIH	Pediatric Pharmacology Research Unit	$413,937
a4-5	NIST	Fundamental Metrology for Carbon Nanotube Science and Technology	
a4-6	NIST	Scanning Probe Microscopy Reference Specimens	
c4-8	NIH	Sub-micrometer zero valent metal for in-situ remediation of contaminated aquifers	$64,410
c4-10	NSF	NIRT: Metal Ion Complexation by Dendritic Nanoscale Ligands: Fundamental Investigations and Applications to Water Purification	$305,750
c4-12	NSF	SGER: Metallic Nanocatalysts for Rapid Transformation of Polychlorinated Dibenzo-p-Dioxins	$25,000
c4-13	NSF	Center for Advanced Materials for Water Purification	$4,014,292
c4-16	NSF	Development of a Copolymer-Based System for Targeted Delivery of Nanoparticulate Iron to Environmental Non-Aqueous Phase Liquids	$50,000
c4-20	USDA	ELUCIDATING INTERACTIONS AND TRANSFORMATIONS OF POLLUTANTS AND ORGANIC MATTER IN SOIL	
c4-21	USDA	CONFERENCE SYMPOSIUM: ENVIRONMENTAL MINERALOGY AND TOXIC METALS	$8,500
a5-3	DOE	Directed Energy Interactions With Surfaces	
c5-3	NSF	CAREER: Gas-Phase Catalytic Processes on Metal Nanoclusters	$108,918
b5-5	NIH	Design of Targeting Enhancement for Drug Delivery	$184,653
b5-7	NIH	Pharmacology of Targeted Therapy to Brain Tumors	$365,790
c5-7	NSF	The formation rates and structure of nanodroplets	$131,333
b5-8	NIH	Nanotechnology Platform for Pediatric Brain Cancer Image	$310,464
b5-9	NIH	Multifunctional nanoparticles for targeted DNA vaccine delivery	$137,582
b5-10	NIH	Novel Lentiviral Packaging Systems	$332,556
b5-11	NIH	Translational Program of Excellence in Nanotechnology	$3,081,892
b5-12	NIH	Designing ECM-Inspired Peptide Biomaterials for Regenerative Medicine	$195,077
b5-14	NIH	Nanotechnology in Osseointegration of TMJ Implants	$298,727
a5-14	NSF	Acquisition of a Powder X-ray Diffractometer for Environmental and Materials Research at UC Merced	$93,704
b5-15	NIH	Complex Nanocomposites for Bone Regeneration	$657,312
a5-15	NSF	Engineering Research Center for Extreme Ultraviolet Science and Technology	$2,275,755
b5-16	NIH	BIOMIMETIC SCAFFOLD FOR BONE-REPAIR	$298,530

NNI ID	Agency	Project Title	Estimated Annual Funding
b5-17	NIH	Nanotechnology Strategies for Growth of Bones and Teeth	$578,308
b5-18	NIH	Nanocoatings for Biomedical Implants	$211,480
b5-24	NIH	Stimulus-responsive, Mechanically-dynamic Nanocomposite for Cortical Electrodes	$199,718
b5-25	NIH	Mechanisms of Orthopedic Implant Osteolysis	$23,799
b5-27	NIH	Imaging Nanocomposites Targeting Tumor Microvasculature	$254,829
a6-1	NSF	Idaho Research Infrastructure Improvement	$3,000,000
e6-3	NSF	NSEC: The Center for High-rate Nanomanufacturing (CHN)	$2,033,540
e6-4	NSF	NSEC: Templated Synthesis and Assembly at the Nanoscale	$2,135,780
c7-2	NSF	Reactive Membrane Technology for Water Treatment	$101,062
c7-3	NSF	Magnetocaloric Effect in Nanoparticle Assemblies for Refrigeration Applications	$50,000
c7-6	NSF	NIRT: Active Nanoparticles in Nanostructured Materials Enabling Advances in Renewable Energy and Environmental Remediation	$278,000
c7-10	NSF	CAREER: On the Prevention of Selenium and Arsenic Release into the Atmosphere	$79,952
c7-11	NSF	Nanoscale Mineralogy and Geochemistry of Arsenian Pyrite in Ore Deposits	$71,741

Research with Marginal Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-2	NIST	Develop Fiber-Optic Confocal Microscope With Nanoscale Depth Resolution	
a1-18	NIST	Metrology of Semiconductor Quantum Nanowires	
a1-19	NIST	High Throughput Hyperspectral Data Analysis	
a1-20	NIST	Dimensional Metrology Program	
a1-21	NIST	Surface Metrology	
a1-22	NIST	Phase Sensitive Scatterfield Imaging for Sub-10 nm Dimensional Metrology	
a1-30	NSF	National High Magnetic Field Laboratory	$28,647,208
a2-3	DOE	Manipulation and Quantitative Interrogation of Nanostructures	
b2-3	NIH	Bioabsorbable Membranes for Prevention of Adhesions	$415,114
a2-4	DOE	Diffraction Studies of Glasses, Liquids, and Nanoclusters	
b2-4	NIH	NanoMedex Propofol Microemulsions: Preclinical Studies to FDA IND Application	$411,614
a2-5	DOE	New Methods and Instrumentation For the Study of Complex Magnetic Materials and Nanostructures Using Soft X-ray Spectroscopies	
a2-6	DOE	Using Plasmon Peaks In Electron Energy-Loss Spectroscopy To Determine the Physical and Mechanical Properties of Nanoscale Materials	
a2-7	DOE	Nano-structures Examined With Spin-polarized Positron Beams	
a2-10	NIH	Nano-Porous Alumina Membranes for Enhanced Hemodialysis Performance	$183,400
a2-11	NIH	Biotechnology Research Infrastructure at Albany State U*	$793,298
a5-1	DOE	Chemical Analysis of Nanodomains	
c5-1	DOE	Experimental, Theoretical, And Model-based Studies Of Crystallographically Controlled Self-assembly During Nanocrystal Growth	
a5-2	DOE	Atomic Scale Chemical Imaging In 3 Dimensions	
a5-4	DOE	Studies of Nanoscale Structure and Structural Defects of Advanced Materials	
a5-5	DOE	Microscopy Investigations of Nanostructured Materials	
a5-6	DOE	Three-dimensional Imaging of Nanoscale Materials By Using Coherent X-rays	
b5-6	NIH	USING VIRAL NANOPARTICLES TO TARGET CANCER	$726,937
a5-7	DOE	Electron Diffraction Determination of Nanoscale Structures	
a5-8	DOE	Quantitative Electron Nano-crystallography and Nano-spectroscopy	
a5-9	DOE	High Resolution Lenseless 3d Imaging of Nanostructures With Coherent X-rays	
a5-10	NIH	Thin-walled Micromolding	$336,916

NNI ID	Agency	Project Title	Estimated Annual Funding
a5-11	NIST	3-D Chemical Imaging at the Nanoscale	
a5-12	NIST	Metrology for the Manufacture of Robust Nanostructures	
b5-13	NIH	New Nanoparticles for Antimicrobial Therapy of Dental Plaque Related Diseases	$145,988
a5-13	NSF	CAREER: Multi-Scale and Multi-Disciplinary Aspects of Indentation	$79,923
b5-19	NIH	Center of Excellence in Translational Human Stem Cell Research	$893,968
b5-23	NIH	Reconfigurable Nanoengineered Extracellular Matricss	$172,163
a6-2	NSF	NNIN: National Nanotechnology Infrastructure Network	$11,180,430
a7-1	NSF	SGER: MEMS-Based Preconcentrators with Nano-Structured Adsorbents for Micro Gas Chromatography	$50,000
c7-1	NSF	New Mexico EPSCoR RII (NM NEW) Proposal	$1,687,500
c7-4	NSF	Delaware Research Infrastructure Improvement Program	$2,000,000
c7-5	NSF	Alabama Research Infrastructure Improvement	$2,066,667
c7-7	NSF	NIRT: Actively Reconfigurable Nanostructured Surfaces for the Improved Separation of Biological Macromolecules	$250,000
c7-8	NSF	NIRT: Environmentally Benign Deagglomeration and Mixing of Nanoparticles	$304,688
c7-9	NSF	CAREER: Hydroxyl Radical and Sulfate Radical-Based Advanced Oxidation Nanotechnologies for the Destruction of Biological Toxins in Water	$85,524

Biography of Andrew Maynard

Dr. Andrew Maynard is the Chief Science Advisor to the Project on Emerging Nanotechnologies—an initiative dedicated to helping business, government and the public anticipate and manage possible health and environmental implications of nanotechnology. Dr. Maynard is considered one of the foremost international experts on addressing possible nanotechnology risks and developing safe nanotechnologies. As well as publishing extensively in the scientific literature, Dr. Maynard is a well-known international speaker on nanotechnology, and frequently appears in print and on radio and television.

Dr. Maynard trained as a physicist at Birmingham University in the UK. After completing a Ph.D. in ultrafine aerosol analysis at the Cavendish Laboratory, Cambridge University (UK), he joined the aerosols research group of the UK Health and Safety Executive, where he led research into aerosol behavior and characterization.

In 2000, Dr. Maynard joined the National Institute for Occupational Safety and Health (NIOSH), part of the U.S. Centers for Disease Control and Prevention (CDC). Dr. Maynard was instrumental in establishing the NIOSH nanotechnology research initiative, which continues to lead efforts to identify, assess and address the potential impacts of nanotechnology in the workplace. Dr. Maynard also represented NIOSH on the Nanomaterial Science, Engineering and Technology subcommittee of the National Science and Technology Council (NSET), and he co-chaired the Nanotechnology Health and Environment Implications (NEHI) working group of NSET. Both are a part of the National Nanotechnology Initiative (NNI), the federal research and development program established to coordinate the U.S. government's annual $1 billion investment in nanoscale science, engineering, and technology.

Dr. Maynard continues to work closely with many organizations and initiatives on the responsible and sustainable development of nanotechnology. He is a member of the Executive Committee of the International Council On Nanotechnology (ICON), he has chaired the International Organization for Standardization Working Group on size selective sampling in the workplace, and he has been involved in the organization of many international meetings on nanotechnology. Dr. Maynard has testified before the U.S. House Committee on Science & Technology on nanotechnology policy, and is a member of the President's Council of Advisors on Science and Technology, Nanotechnology Technical Advisory Group. Dr. Maynard is an Honorary Senior Lecturer at the University of Aberdeen, UK, and has authored or co-authored over 100 scholarly publications.