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Hearing on:

"Promoting Economic Development Opportunities Through Nano Commercialization"

Written Testimony of:

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I would like to thank Subcommittee Chairman Gordon Smith, Ranking Member Byron Dorgan, and the Members of the Senate Subcommittee on Trade, Tourism and Economic Development for holding this hearing on promoting economic development opportunities through nanotechnology commercialization.

My name is David Rejeski, and I am the Director of the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars. The Project on Emerging Nanotechnologies is an initiative launched by the Wilson Center and The Pew Charitable Trusts in 2005. It is dedicated to helping business, government and the public anticipate and manage the possible health and environmental implications of nanotechnology. The Project collaborates with researchers, government, industry, nongovernmental organizations (NGOs), and others concerned with the safe applications and utilization of nanotechnology.

Our goal is to take a long-term look at nanotechnologies, to identify gaps in the nanotechnology information, data, and oversight processes, and to develop practical strategies and approaches for closing those gaps and ensuring that the benefits of nanotechnologies will be realized. We aim to provide independent, objective information and analysis which can help inform critical decisions affecting the development, use, and commercialization of nanotechnologies throughout the globe.

In short, both the Wilson Center and The Pew Charitable Trusts believe there is a tremendous opportunity with nanotechnology to “get it right.” Societies have missed this chance with other new technologies and, by doing so, forfeited significant social, economic, and environmental benefits.

As the Subcommittee knows, nanotechnology is expected to become the transformational technology of the 21st century. It is the world of controlling matter at the scale of one billionth of a meter, or around one-100,000th the width of a human hair. Researchers are exploring new ways to see and build at this scale, reengineering familiar substances like carbon and gold in order to create new materials with novel properties and functions.

As the National Science Foundation (NSF) highlights, the ability to create novel properties in materials and systems at this scale implies that nanotechnology eventually could impact the production of virtually every human-made object—everything from automobiles, tires, and computer circuits to advanced medicine and tissue replacements—and lead to the invention of products yet to be imagined.[1] Nanotechnology will fundamentally restructure the technologies currently used for manufacturing, medicine, defense, energy production, environmental management, transportation, communication, computation, and education.

[1] M.C. Roco, R.S. Williams and P. Alivisatos. Nanotechnology Research Directions: IWGN Workshop Report. Berlin, Germany: Springer, 2000, p. iii-iv.

THE LANDSCAPE OF NANOTECHNOLOGY COMMERCIALIZATION

It would have been difficult to address the state of commercialization just one year ago. In March 2006, our project released the first public inventory of nanotech-based consumer products.[2] This suite of already-commercialized products tells us something about the emerging face of the nanotechnology industries and the challenges we face as we begin to introduce nanotechnology into the marketplace. It is a test. Our ability to reap the long-term benefits of nanotechnology – in areas from medicine to energy and food production – will depend heavily on how we manage the introduction of this first generation of consumer products. More complex products, with large societal implications, will soon be upon us. For example, there are currently 130 nano-based drugs and delivery systems and 125 devices or diagnostic tests in preclinical, clinical, or commercial development—an increase of 68% percent since last year.[3] We are about to be inundated with hundreds, if not thousands, of new products.

In analyzing our nanotechnology consumer products inventory, we found that:

- There are 230 products on the market. We believe this number is a significant underestimate because the inventory only contains nanotechnology products self-identified by the manufacturer. This does not include the "over 600 raw materials, intermediate components and industrial equipment items" that EmTech Research projects are currently in use by manufacturers.[4]

- These consumer products have been commercialized predominantly by small and medium sized enterprises (our estimate is that roughly two-thirds of products are from small or medium sized businesses).[5]

- Products are entering the marketplace in areas where regulations and oversight are weak, for instance, in the areas of cosmetics (31 products), dietary supplements (13 products), and consumer products (at least 135 products). Many of the products we found have high exposure potential, being used directly on the body or actually ingested. In short, we are facing a situation in which nano-based products are entering the market at precisely the points where government

[2] See http://www.nanotechproject.or/consumerproducts and Rick Weiss, "For Now, Nanotechnology Means Little More Than Better Golf Balls," *The Washington Post*, March 10, 2006.
[3] "2006 Nanomedicine, Device & Diagnostics Report." *NanoBiotech News.* Atlanta, GA: National Health Information, LLC, 2006.
[4] "Nanotechnology White Paper," Washington, DC: United States Environmental Protection Agency, December 2, 2005. Available at http://www.epa.gov/osa/pdfs/EPA_nanotechnology_white_paper_external_review_draft_12-02-2005.pdf.
[5] Applying a definition commonly used by the Small Business Administration that a small business has fewer than 500 employees.

regulation and oversight are imperfect and imprecise and potential exposure is high.

- Commercialization is already global. We found products from 15 countries.[6] Nanotechnology will continue to mature in a global digital economy where products can be bought and sold on the Internet and flow quickly across international boundaries through both business-to-consumer and business-to-business Internet transactions. This trend in global e-commerce will present new challenges for our oversight system, as products can be shipped, transported, and traded between nations with varying environmental, health, and safety laws. The lack of international agreements on labeling products that contain nanomaterials further complicates this issue.

In late March in Germany, the world experienced what may be the first nanotechnology incident resulting in adverse health effects—from a bath and tile treatment called "Magic Nano." The product allegedly had significant health impacts, with 100 people affected with respiratory problems and six hospitalized with pulmonary edemas.[7] Other issues have since emerged around "Magic Nano" that are critical to our ability to commercialize new nanotechnology products in the future, including:

- A lack of disclosure concerning the ingredients in the product has prevented a timely resolution of the case and determination of whether and how nanotechnology might have been implicated. A panel of German government experts was unable to determine whether nanomaterials were the cause of health problems because "the distributors of the two sealing sprays were unable to supply the full formulations because information was missing from their upstream suppliers."[8]

- It appears that a third party testing seal, highly trusted by the German public (TÜV), was misused on this product. The head of the Federation of German Consumer Organizations noted that "It is irresponsible to give the consumers a mistaken sense of security by falsifying stamps."[9] This case has been referred to the district attorney, and there are calls for a criminal investigation against the

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[6] Countries include: United States, Mexico, United Kingdom, France, Germany, Switzerland, Finland, Sweden, China, Korea, Japan, Taiwan, Australia, New Zealand, and Israel.

[7] David Graber and Pat Phibbs. "German Institute Working to Understand Why 'Magic Nano' Cleaner Caused Ailments." *Daily Environmental Report*, April 12, 2006.

[8] "Cause of intoxications with nano spray not yet fully elucidated," Berlin, Germany: Federal Institute for Risk Assessment, April 12, 2006. Available at http://www.bfr.bund.de/cms5w/sixcms/detail.php/7750.

[9] "Nano Poison Scandal: Misuse of a Major German Testing 'Seal of Approval,'" Berlin, Germany, Federation of German Consumer Organisations, April 14, 2006. Available at http://www.vzbv.de/go/dokumente/502/4/17/index.html.

manufacturer for suspected violation of Germany's product safety laws. This is analogous to the misuse of the Underwriters Laboratories (UL) symbol in the United States, which has occurred recently with respect to fireplaces[10], extension cords[11], and table saws[12]. Further complicating this issue is that these third-party certification bodies test products more for performance than for potential health or environmental risks. Even if such bodies were called upon to test products containing nanomaterials, no clear, agreed-upon test protocols exist.

Regardless of how this case plays out, the lack of transparency and issues with independent testing have serious implications for public perceptions. When asked what would help increase public trust in government to manage the risks posed by nanotechnology, a number of studies conducted around the world have reached two conclusions: greater transparency/disclosure and the use of third party, independent safety testing. The "Magic Nano" case indicates that both of these principles can be violated and that a similar situation could occur just as easily in the United States or other developed countries. The incident may be local, but the press is global.

CHALLENGES FACING NANOTECHNOLOGY COMMERCIALIZATION

Lack of Effective Oversight Mechanisms

Something is going right – products are being commercialized – but, clearly, things can go wrong if we fail to provide the adequate oversight, as the "Magic Nano" case in Germany illustrates.

Though agencies have been meeting to discuss oversight and the EPA has begun developing a voluntary data collection program, our approach on the regulatory side so far has been ad hoc and incremental, with no vision. It is particularly worrisome that many nanotechnology-based consumer products are entering the market in areas with little government oversight, such as cosmetics and dietary supplements. The U.S. government approach has been limited by the following:

- A focus on single statutes such as the Toxic Substances Control Act (TSCA) rather than taking an integrated, multi-statute approach;

- A focus on products more than the facilities and processes where production occurs;

- A general lack of concern with the full life-cycle impacts of emerging nanotechnologies (an approach recommended in the 2004 U.K. Royal Society Report)[13];

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[10] See http://www.ul.com/media/newsrel/nr031406.html.
[11] See http://www.ul.com/media/newsrel/nr030106.html.
[12] See http://www.ul.com/media/newsrel/nr040606.html.
[13] *Nanoscience and nanotechnologies: opportunities and uncertainties.* London, U.K.: The Royal Society and Royal Academy of Engineering, July 2004. Available at http://www.nanotec.org.U.K./finalReport.htm.

- Too little resources devoted to pollution prevention and the "greening" of nanotechnology products and production processes, which could help industry and society ultimately avoid potential risks from the beginning; and

- Inadequate discussion of the resource constraints to effective oversight (for instance, do we have the personnel, expertise and dollars in the agencies needed for enforcement or testing?).

Most important, we have not looked forward to consider where nanotechnology is heading, assuming instead decades-old risk management policies and analogies to the past will help us respond to the risks of the future. Today, nanotechnology is largely chemistry and materials science. But it is quickly becoming chemistry and biology. After that, we will be dealing with multifunctional machines operating at the interface of classical and quantum physics, and, eventually, the convergence of nanotechnology, biotechnology, information technology, and cognitive science.

Many of the assumptions that governed our approach to chemicals regulation may no longer hold. Because the risks of nanomaterials are poorly related to mass (and depend on other characteristics like surface area, chemistry, charge, etc.), governments and industry will have to rethink the mass-based approaches that have historically shaped our toxicology, regulations, and regulatory-related monitoring systems. In addition, as nanomaterials become more complex and multi-functional, new properties will emerge that are not predictable from the simple chemical approach of current regulations.

We need a systemic analysis across agency statutes and programs, across agencies, and across the international landscape. This should include existing regulations, voluntary programs, information-based strategies, state and local ordinances, and tort law. All these measures need to be evaluated not just in terms of their applicability to nanotechnology today, but also in terms of their efficacy in five or ten years. We need an oversight blueprint that is proactive, transparent, and, for industry, predictable both now *and into the foreseeable future*.

Lack of Public Engagement

We know from public surveys and polls that the government and industry will have to win the public's trust on nanotechnology. The emergence of viable markets depends on strong and growing consumer confidence.

However, in the midst of nanotechnology's commercialization, publics throughout the world remain largely in the dark. A major study, funded by NSF and conducted in 2004 by researchers at North Carolina State University (NCSU), found that 80-85% of the American public has heard "little" or "nothing" about nanotechnology.[14]

[14] Michael D. Cobb and Jane Macoubrie. "Public Perceptions about Nanotechnology: Risk, Benefits and Trust." Raleigh, NC: North Carolina State University, 2004. Available at

This is consistent with similar polling results in Europe and Canada. Anecdotally, some researchers believe that an even higher percentage of the public remains uninformed about nanotechnology. These same citizens are now meeting nanotechnology products in their local store or on the Internet. The public will increasingly have to make sense of competing claims, complex science, and emerging risk research, all with little or no preparation or support. Into this mix enter an increasing number of NGO groups interested in shaping public opinion in various directions, some of which may have large strategic implications for business and government.[15]

In 2005, the Project on Emerging Nanotechnologies commissioned a new report by Senior Associate Jane Macoubrie, who co-authored the North Carolina State University study in 2004. This new report, "Informed Public Perceptions of Nanotechnology and Trust in Government," provides an in-depth look at American attitudes toward nanotechnology.[16]

It indicates that U.S. consumers, when informed about nanotechnology, are eager to know and learn more. They generally are optimistic about nanotechnology's potential contribution to improve quality of life. The key benefits the public hopes for are major medical advances, particularly greatly improved treatment for cancer, Alzheimer's, and diabetes.

The Project's report findings track closely with work done in 2004 by University of East Anglia researcher Nick Pidgeon for Great Britain's Royal Society. Pidgeon also found there were few among the British public who knew much about nanotechnology. Those that did were optimistic that it would make life better.[17] This general public optimism about nanotechnology is what I consider the "good news." This optimism is tempered by a significant amount of suspicion about industry's intentions, and skepticism about the government's commitment to effective oversight.

For policymakers, the "take home" messages that emerge from these studies are quite clear:

- Consumers want more information to make informed choices about nanotechnology's use and greater citizen engagement in shaping how the technology is developed.

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http://www2.chass.ncsu.edu/cobb/me/past%20articles%20and%20working%20papers/Public%20Perceptions%20about%20Nanotechnology%20-%20Risks,%20Benefits%20and%20Trust.pdf.

[15] Since 1990, more than 100,000 new citizens' groups have been established around the world. Trust in many of these groups has increased in direct proportion to decreasing confidence in government and industry. See: Bonini, S. M. et al (2006). "When Social Issues Become Strategic," *McKinsey Quarterly,* Number 2.

[16] Jane Macoubrie. *Informed Public Perceptions of Nanotechnology and Trust in Government.* Washington, DC: Woodrow Wilson International Center for Scholars, 2005. Available at http://www.wilsoncenter.org/news/docs/macoubriereport1.pdf.

[17] *Nanotechnology: Views of the General Public.* London, U.K.: BMRB Social Research, January 2004, BMRB/45/1001-666. Available at www.nanotec.org.U.K./Market%20Research.pdf.

- There are low levels of trust in government and industry to manage any risks associated with nanotechnology. There is little support for industry self-regulation or voluntary agreements. A majority of the public believes that mandatory government controls are necessary.

- People have clear ideas about how to improve trust. They want government and industry to practice *due diligence* to ensure manufacturing and product safety. In both U.S. and U.K. studies, this translated into strong support for research and safety testing before products go to market and a focus on better understanding long-term effects on both people and the environment.

In my view, there is still time to inform public perceptions about nanotechnology and to ensure that nanotechnology is developed in a way that citizens—as well as the insurance industry, corporate investors, NGOs, and regulatory officials—can trust. However, with the production of nanosubstances ramping up and with more and more nanotech-based products pouring into the marketplace, this window is closing fast.

Worries are already being voiced that public input will now be used simply as a "tokenistic add-on" rather than as a valuable policy-making tool.[18] Coordinated education and engagement programs will be needed, supported by both government and industry. Public engagement programs will have to be structured to reach a wide range of consumers, cutting across age, gender, and socioeconomic status, utilizing a variety of media going beyond traditional print, radio, television and film, and towards non-traditional media such as blogs and multiplayer on-line games.

Lack of Coordinated Research Strategies

There are currently no coordinated research strategies designed to address the potential environmental, health, and safety risks posed by nanotechnology. In the absence of such a risk-related research strategy, it will be difficult for the public or for small and medium sized companies to learn about the downsides of the technology and reach conclusions about where the greatest risks lie. Additional research about potential workplace hazards, environmental implications, and human health toxicity needs to be done and made readily available to small and medium sized nanotechnology corporations.

Over the past 15 years, scientific data on the health and environmental impacts of nanostructured materials has been growing slowly. However, research on the implications of manufactured nanomaterials has only been available for the past 5 years. Though much of the research undertaken so far has raised more questions than answers, a number of key points have emerged, including:

[18] Anna Saleh. "Critics say nanotech plan sidelines public," *ABC Science Online*, April 28, 2006. Available at http://www.abc.net.au/science/news/health/HealthRepublish_1625988.htm.

- Since engineered nanomaterials show behavior that depends on their physical and chemical structure, risk assessment paradigms that have been developed based on traditional, bulk chemistry alone may no longer be valid.

- Inhaled, nanometer-structured, insoluble particles can elicit a greater response in the lungs than their mass would suggest, indicating mechanisms of action that are dependent on particle size, surface area, and surface chemistry, among other properties. However, information is lacking on nanomaterials' structure-related behavior in the body.

- Inhaled, nanometer-diameter particles may leave the lungs through non-conventional routes and affect other parts of the body, including targeting the cardiovascular system, the liver, kidneys, and the brain. Next to nothing is known about the impact of engineered nanomaterials on these organs.

- Nanometer-diameter particles may be able to penetrate through the skin in some cases, although this is still an area of basic research and the chances of penetration appear to be significantly greater for damaged skin. The potential for nanostructured particles present in cosmetics and other skin-based products to do harm may be low, but remains unknown.

- Little information on how manufactured nanomaterials may affect ecosystems and how they might bioaccumulate.

- Virtually nothing is known about the hazard of engineered nanomaterials ingested as a food additive or by accident.

To date, the majority of research on the environmental, health, and safety (EH&S) implications of nanotechnology has focused on relatively basic engineered nanomaterials. As nanomaterials move from simple to complex materials and on to active and multifunctional materials, major knowledge gaps need to be filled before useful quantitative risk assessments can be carried out and before comprehensive, lifecycle risk management strategies can be developed.

A number of groups have developed, or are in the process of developing, lists of research priority areas and questions of interest. These organizations include EPA, NIOSH[19], Environmental Defense[20], the Semiconductor Research Corporation, the Chemical Industry Vision 2020 Technology Partnership[21], and the Project on Emerging

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[19] National Institute for Occupational Safety and Health. *Strategic Plan for NIOSH Nanotechnology Research: Filling the Knowledge Gaps.* September 28, 2005. Available at http://www.cdc.gov/niosh/topics/nanotech/strat_planINTRO.html.
[20] Richard A. Denison. "A proposal to increase federal funding of nanotechnology risk research to at least $100 million annually." Washington, DC: Environmental Defense, April 2005. Available at http://www.environmentaldefense.org/documents/4442_100milquestionl.pdf.
[21] Semiconductor Research Corporation and Chemical Industry Vision 2020 Technology Partnership. "Joint NNI-ChI CBAN and SRC CWG5 Nanotechnology Research Needs Recommendations."

Nanotechnologies. Despite the diversity of these organizations, these gap analyses are generally in broad agreement on the areas requiring further research and development. Common themes include: toxicity (human and environmental), exposure and material release/dispersion, epidemiology, measurement and characterization, control of exposure and emissions, safety hazards, risk management models, and product life cycle analysis.

However, more needs to be done to engage small and medium sized businesses in setting research agendas and outlining where knowledge gaps exist. Without such involvement, EH&S research may not be able to adequately address and provide substantial answers to many risk management questions that will emerge in both the near and long-term future for these companies. Therefore, an effective, forward-looking, internationally accepted, small and medium sized business focused, EH&S research strategy needs to be developed to fill this gap.

RECOMMENDATIONS FOR NANOTECHNOLOGY COMMERCIALIZATION

Let me provide three general recommendations to improve the overall climate for commercialization that will help companies, investors, and consumers. The goal is to ensure the benefits overweigh the risks, firms have a clear path to market, and public confidence grows.

- **We need to put our research in front of product flows to both inform oversight and regulatory strategies with good science and to provide important information on risks and benefits to the public.** There has been a surprising consensus between industry, trade associations, think tanks, and environmental NGOs concerning the urgent need for more EH&S research funds and the need to make sure these funds are *strategically* allocated to deal with existing and emerging risks. For instance, though we know there are already ingestible nanotechnology products on the market—along with a number of promised applications in the agriculture and food sectors—there is a total lack of research on the impacts of nanomaterials in the gastro-intestinal tract. Given the lag time between the initiation of research and the results, greater efforts need to be made to place research on environmental, health, and safety concerns further "upstream" in the product development process.[22] Such research needs to be coordinated at a global level, since the commerce in nanotechnology materials and products is, and will continue to be, worldwide.

- **For commercialization to succeed, we need an oversight system that is transparent, efficient, and predictable.** We do not have that now. Companies are often confused about the regulatory intentions of the government, investors and insurers are insecure, and the public is suspicious. In his report on the

[22] Recently, our project finished the first phase of a study with the University of Minnesota, in which we analyzed over 150 research projects where nanotechnologies were being developed for food and agricultural applications. This study allowed information to be generated on what products might reach the market first, which oversight mechanisms would be triggered, who might be exposed to risks, etc. See: http://www.nanotechproject.org/50/live-webcast-agrifood-nanotechnology-reserach-and-development.

subject, Dr. J. Clarence Davies noted that "nanotechnology is difficult to address using existing regulations," since they "either suffer from major shortcomings of legal authority, or from a gross lack of resources or both."[23] Short of new legislation, which must be seriously considered, there is much more government and industry can do to provide adequate oversight on emerging products. One approach is applying a portfolio-of-initiatives strategy to key product areas.[24] Using cosmetics as an example, one could assemble a portfolio which combines the FDA's Voluntary Cosmetic Registration Program (VCRP)[25], the Cosmetic, Toiletry & Fragrance Association's (CFTA) Cosmetic Ingredient Review (CIR)[26], labeling guidelines, and consumer education efforts by industry and government. Such a multi-faceted system could be used to "fast-track" the review of key nanomaterials, such as carbon fullerenes, that are already being used in high-exposure cosmetic products. Integrating industry, government, and association efforts would help bolster the insufficient level of human resources that exist in the regulatory agencies.[27] Such a portfolio-based approach requires not only integrating initiatives, but a constant evaluation of progress and a willingness on the part of government and industry to make midcourse corrections if necessary.

- **Finally, resources for public engagement need to be increased by orders of magnitude and engagement activities need to be rapidly accelerated.** We have waited far too long to begin engaging the public about nanotechnology. Successful commercialization without strong consumer confidence is impossible. How consumers find out about nanotech, from whom, and with what messages will be critical to nanotechnology's long-term success. Key impressions will be formed over the next two years that will affect consumer confidence far into the future. The "21st Century Nanotechnology Research and Development Act" requires the government ensure that **"**public input and outreach…be integrated into the Program by the convening of regular and ongoing public discussions, through mechanisms such as citizens' panels, consensus conferences, and educational events."[28] However, nothing along these lines has occurred in over a year and half, and the first meeting on this topic will take place at the end of this May to discuss *how* to do public engagement, not to actually engage the public.

[23] J. Clarence Davies. *Managing the Effects of Nanotechnology.* Washington, DC: Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, 2006.
[24] The use of a portfolio-of-initiatives approach is often recommended as a strategy for dealing with uncertainty. See: Bryan, Lowell (2002). "Just-in-time Strategy for a Turbulent World," *McKinsey Quarterly*, Special Edition, or Courtney, Hugh (2001): *20/20 Foresight: Crafting Strategy in an Uncertain World*, Harvard Business School Press.
[25] See http://www.cfsan.fda.gov/~dms/cos-regn.html.
[26] See http://www.cir-safety.org.
[27] Though the federal government has continually maintained that it has sufficient statutory authority to deal with nanotechnology, it has said nothing about the resources needed to back up existing statutes, which are as critical to success as the statues themselves.
[28] "21st Century Nanotechnology Research and Development Act," S. 189, Washington, DC: United States Congress, 2003.

The longer we wait, the greater the danger that the public will see such efforts as disingenuous, "after the fact," and tokenistic.[29]

These three steps should be taken together, properly resourced, and integrated. Frankly, with products flowing into the market at an increased rate, we do not have a lot of time. There is no "pause button" for technological innovation that government can conveniently push to create time for research, testing, policy deliberation, or a few more public meetings. By the time we have settled on nomenclature for the first generation of nanomaterials, the next generation will be upon us; by the time we have characterized risks of early nano-based substances, newer, more complex materials will be on the market. Without better foresight, our answers will be for yesterday's questions.

FOCUSED RECOMMENDATIONS

In addition to creating a more strategic and forward-looking approach to research, oversight, and public engagement, there are also a number of more focused activities that can be undertaken to accelerate the commercialization of nanotechnologies.

First, our commercialization policies and programs need to be informed by rigorous data about nanotech firms, their products, their issues, and needs. We have virtually no government-derived data to guide commercialization strategies, a situation that is dangerous given our multi-billion dollar investments in nanotechnology. The Department of Commerce should work to collect and continually update survey data on nano businesses, especially startups, working, as needed, with the Bureau of Labor Statistics, the Census Bureau, or other data collection arms of the U.S. government. As with other sectors and industries, data should be collected on demographic characteristics of the labor force, R&D expenditures, revenues, environment/health/safety issues, injuries/illnesses, exports, and the geographic profile of the firms. We should also better understand who could best help these firms with which issues. Will they access websites, use technical assistance programs at nearby universities, or prefer peer-to-peer mentoring from other firms? The Project on Emerging Nanotechnologies is presently working with Yale University and the University of Massachusetts at Lowell to survey the environmental, health and safety concerns/needs of nano startups in the New England area, but data collection of this type should be undertaken broadly by the government and conducted over long periods of time as firms change and mature.[30]

Second, we should create a one-stop-shop at a federal level focused on helping firms with issues around commercialization—an Interagency Nano-Business Office—INBO, where companies in need of help can be quickly directed to the appropriate federal programs. The existing National Nanotechnology Coordinating Office (NNCO) was set up to coordinate science, not to drive innovation to market and deal with commercialization challenges. Its function needs to be complemented and

[29] This problem occurred in the U.K. after the government launched a project on public engagement around genetically-modified food (GM Nation), after such products were already on the market.
[30] Another model for this is the Sloan Foundation's Industry Studies Program, started in 1990, which is based on rigorous, observation-based research in firms. See: http://www.industry.sloan.org/.

expanded. The creation of various Nanoscience to Commercialization Institutes around the country does not mitigate the need for a centralized locus in the federal government. INBO needs to be structured and staffed to work well with the business and investor communities, and will need the capability to deal with international business issues involving trade, export and intellectual property protection.

Third, we should use the purchasing power of the government, or quasi-governmental organizations, to help create early markets for critical nanotech-based products, especially in the energy sector. The federal government purchases approximately 2 percent of all things sold in the United States, with state and local governments purchasing an additional 5 percent. Key players in terms of procurement are the Postal Service, General Services Administration, Department of Defense, and Department of Homeland Security as well as state and municipal agencies with significant buying power. Large procurements can increase economies of scale and prove critical in reducing costs for early stage technologies. The Postal Service cut the per unit cost of energy-saving LED exit signs almost in half by committing to purchase 15,000 units, a change which saved them more than $300,000 per year in energy and maintenance costs.[31] In the energy sector, key nano-based technologies that could benefit from early adoption strategies by government are: batteries, photovoltaics, fuel cells, and lighting.

Fourth, the United States should become the world leader in the development and commercialization of environmentally benign, "green" nanotechnology production processes and products as well as a new generation of nano-based environmental technologies. At the beginning of what may be another industrial revolution, we have a unique window of opportunity to engineer significant risks out of products and processes. Instead, we are creating a long-term employment program for risk assessors and toxicologists. In terms of research funding, we have set up a false dichotomy between applications and implications research, often creating a zero-sum game where we must chose between eliminating or preventing risks or studying them, after the fact. There are already examples that new nano production processes can be both environmentally beneficial and cost effective. For instance, ongoing research at the University of Oregon is being directed at the cleaner and greener production of gold nanoparticles, a process that also reduces the cost of synthesizing these materials from $300,000 per gram to $500 per gram.[32] Though there are over 100 projects being funded by the National Science Foundation that are focused, at some level, on the "green" application of nanotechnology to the environment, more work needs to be done in this area and U.S. leadership established as a means of creating a global niche for our firms and expertise.

Finally, we need to begin developing an export promotion strategy to help U.S. nanotech firms in what will be a tough and highly competitive global market. NSF predicts that the world market for goods and services using nanotechnologies will

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[31] David Rejeski. "An Incomplete Picture," *The Environmental Forum*, September/October, 1997.
[32] Stephen K. Ritter. "Planning Nanotech from the Ground Up." *Chemical and Engineering News,* April 17, 2006.

grow to $1 trillion by 2015. Lux Research calculates that in 2004 there was $13 billion worth of products in the global marketplace incorporating nanotechnology.[33] Worldwide about $9 billion annually is being spent by governments and the private sector on nanotechnology research and development. The thin film and photovoltaic sector is projected to be "worth over $2.3 billion in the year 2011"[34], and the use of silver nanoparticles in fields as diverse as food packaging and medical devices is "emerging as one of the fastest growing product categories in the nanotechnology industry."[35] This means engaging agencies that have been largely on the sidelines of the National Nanotechnology Initiative but that will play increasingly important roles in commercialization, including the Export-Import Bank, Federal Trade Administration, Trade and Development Agency, State Department, and Small Business Administration. These agencies will be key players in a coordinated export promotion strategy.

There is one important caveat that applies to everything I have mentioned. Any government program, policy, or strategy must work for our small businesses; they are the heart of the nanotech revolution and will remain so into the foreseeable future. According to the 2003 Census, nearly 72% of 300,000 manufacturing entities in the United States have less than 20 employees and 92% of manufacturing companies have less than 100 employees.[36] Additionally, the Small Business Administration estimates that there were approximately 22.9 million small businesses in the U.S. in 2002 and that small businesses provide approximately 75% of the net new jobs added to the economy, represent 99.7% of all employers, and represent 97% of all U.S. exporters.[37]

In closing, let me say that I applaud the Committee for focusing our attention on issues of commercialization. Nanotechnology is no longer just a large government science research project. In the long run, key social and economic benefits will only occur if we succeed in bringing innovations to market. To do that, we need to place new people, resources, and ideas behind an expanded national nanotechnology initiative.

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[33] "Sizing Nanotechnology's Value Chain." New York, NY: Lux Research, October 2004.
[34] http://www.electronics.ca/PressCenter/articles/274/1/Thin-Film-And-Organic-Photovoltaic-Market-To-Reach-%242.3-Billion-%28%24US%29-In-2011.
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Biography of David Rejeski

David Rejeski directs the Project on Emerging Nanotechnologies. Launched by the Wilson Center and The Pew Charitable Trusts in 2005 the Project is dedicated to helping business, government and the public anticipate and manage possible health and environmental implications of nanotechnology. For the past four years he has also been the Director of the Foresight and Governance Project at the Woodrow Wilson Center, an initiative designed to facilitate better long-term thinking and planning in the public sector.

He was recently an adjunct affiliated staff at the RAND Corporation and a Visiting Fellow at Yale University's School of Forestry and Environmental Studies. Before joining the Wilson Center he served as an agency representative (from EPA) to the White House Council on Environmental Quality (CEQ) and, earlier, worked at the White House Office of Science and Technology (OSTP) on a variety of technology and R&D issues, including the development and implementation of the National Environmental Technology Initiative.

Before moving to OSTP, he was head of the Future Studies Unit at the Environmental Protection Agency. He spent four years in Hamburg, Germany, working for the Environmental Agency, Department of Public Health, and Department of Urban Renewal and, in the late 1970's, founded and co-directed a non-profit involved in energy conservation and renewable energy technologies.

He has written extensively on science, technology, and policy issues, in areas ranging from genetics to electronic commerce and pervasive computing and is the co-editor of the recent book *Environmentalism and the Technologies of Tomorrow: Shaping the Next Industrial Revolution*, Island Press, 2004.

He sits on the advisory boards of a number of organizations, including the EPA's Science Advisory Board, the Greening of Industry Network, the Journal of Industrial Ecology, and the University of Michigan's Corporate Environmental Management Program. He is a member of the External Advisory Board of Nanologue, a European project to bring together leading researchers to facilitate an international dialogue on the social, ethical and legal benefits and potential impacts of nanosciences and nanotechnologies. He has graduate degrees in public administration and environmental design from Harvard and Yale.