H.R. 766, NANOTECHNOLOGY RESEARCH AND DEVELOPMENT ACT OF 2003

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

MARCH 19, 2003

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H.R. 766, NANOTECHNOLOGY RESEARCH AND DEVELOPMENT ACT OF 2003

WEDNESDAY, MARCH 19, 2003

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 10:04 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert (Chairman of the Committee) presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

H.R. 766, Nanotechnology Research and Development Act of 2003

Wednesday, March 19, 2003
10:00 am
2318 Rayburn House Office Building (WEBCAST)

Witness List

Panel 1

Honorable George Allen
Member
U.S. Senate

Honorable Ron Wyden
Member
U.S. Senate

Panel 2

Mr. Richard M. Russell
Associate Director for Technology
Office of Science and Technology Policy

Dr. Thomas N. Theis
Director of Physical Sciences
IBM Research Division
Thomas J. Watson Research Center

Dr. James Roberto
Associate Laboratory Director for Physical Sciences
Oak Ridge National Laboratory

Dr. Carl A. Batt
Co-Director of the Nanobiotechnology Center
Cornell University

Mr. Alan Marty
Executive-in-Residence
JP Morgan Partners

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

H.R. 766, Nanotechnology Research and Development Act of 2003

WEDNESDAY, MARCH 19, 2003
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

PURPOSE

On Wednesday, March 19, 2003, the House Science Committee will hold a hearing to examine federal nanotechnology research and development (R&D) activities and to consider H.R. 766, the *Nanotechnology Research and Development Act of 2003,* which would authorize these programs.

2. WITNESSES

Panel I

Senator George Allen (R–VA), a former Governor of the State of Virginia and a former Member of the House of Representatives, serves on the Senate Committee on Commerce, Science and Transportation. Senator Allen chaired the GOP High Tech Task Force in the 107th Congress and is one of the lead sponsors, along with Senator Wyden, of S. 189, The 21st Century Nanotechnology Research and Development Act, the Senate companion to H.R. 766.

Senator Ron Wyden (D–OR), the senior Senator from Oregon and a former Member of the House of Representatives, serves on the Senate Committee on Commerce, Science, and Transportation. Senator Wyden chairs the nonpartisan Forum on Technology & Innovation and is the lead sponsor, along with Senator George Allen (R–VA), of S. 189, The 21st Century Nanotechnology Research and Development Act.

Panel II

Mr. Richard M. Russell is the Associate Director for Technology at the Office of Science and Technology Policy (OSTP), the White House science office. Prior to joining OSTP he worked on the Presidential Transition Teams for the Department of Commerce, the National Science Foundation and OSTP. From 1995–2001, Mr. Russell served in various positions for the Committee on Science of the U.S. House of Representatives, including as Deputy Chief of Staff for the full Committee.

Dr. Thomas N. Theis is the Director of Physical Sciences in the IBM Research Division at the Thomas J. Watson Research Center in Yorktown, New York. He is responsible for IBM's world-wide investments in research in the physical sciences. Dr. Theis serves on the advisory board for the National Science Foundation's National Nanofabrication Users network and was a member of the National Academy of Sciences committee that reviewed the National Nanotechnology Initiative.

Dr. James Roberto is the Associate Laboratory Director for Physical Sciences at the Oak Ridge National Laboratory (ORNL) in Tennessee, where he oversees ORNL's physics, chemistry, and materials science research. Dr. Roberto led the effort to develop a nanotechnology roadmap for the laboratory, including research plans for the Center for Nanophase Materials Sciences, a national nanotechnology user facility currently under construction. He is a past President of the Materials Research Society and a past Chair of the Division of Materials Physics of the American Physical Society.

Dr. Carl A. Batt is co-Director of the Nanobiotechnology Center at Cornell University, a National Science Foundation Science and Technology Center designed to advance interdisciplinary programs in nanobiotechnology. Dr. Batt is also the Project Leader for the Alliance for Nanomedical Technologies, a nanotechnology center supported by the State of New York. He is a professor of food science at Cornell and he is the founder of Agave BioSystems, a technology company focused on developing optical biosensors for the detection of microorganisms in food and the environment.

Mr. Alan Marty is Executive-in-Residence for JP Morgan Partners with responsibility for leading the firm's nanotechnology investments. Previously Mr. Marty was General Manager of Hewlett-Packard's (HP) worldwide integrated circuit business with responsibility for all aspects the enterprise. He also served as General Manager of Agilent Technologies' microdisplay business, one of the earliest commercial applications of nanotechnology.

3. OVERARCHING QUESTIONS

The hearing will address the following overarching questions:

1. What is the state of nanotechnology science and engineering? Are major new federal investments warranted in this area?
2. What are the principal findings and recommendations of the National Academy of Sciences review of the National Nanotechnology Initiative? Are the findings and recommendations adequately addressed in H.R. 766?
3. Among the challenges identified by the Academy review panel were the need to promote interdisciplinary research and education, and the need to effect greater interagency coordination. How can these challenges best be met? Are they adequately addressed in H.R. 766?
4. What is the potential for future economic growth associated with nanotechnology developments? To what extent is the private sector investing in this area?

4. BRIEF OVERVIEW

- Nanotechnology is the science of manipulating and characterizing matter at the atomic and molecular level. It is one of the most promising and exciting fields of science today, involving a multitude of science and engineering disciplines, with widespread applications in electronics, advanced materials, medicine, and information technology. For example, nanotechnology likely represents the future of information processing and storage, as computer chips and magnetic disk drive components will increasingly depend on nanotechnology innovations.
- The National Nanotechnology Initiative (NNI) is an $849 million (FY04 request) research initiative involving 10 federal agencies—one of the President's most significant new commitments to continued U.S. leadership in science and technology.
- The National Academy of Sciences conducted a review of the NNI in 2002 and spoke favorably of the quality of the research and the opportunities for rapid technological innovation.
- On February 13, Chairman Boehlert and Mr. Honda introduced H.R. 766, the *Nanotechnology Research and Development Act of 2003,* which authorizes a federal nanotechnology research and development (R&D) program in statute thus assuring stable, long-term support. The bill also authorizes appropriations for nanotechnology R&D in those agencies within the Science Committee's jurisdiction that currently participate in the NNI. A companion bill, S. 189, has been introduced in the Senate by Senator Wyden and Senator Allen.
- H.R. 766 supports the President's initiative but adds review and oversight mechanisms to assure that new funds are used in the most effective manner possible. The bill also addresses a number of the issues raised by the National Academy of Sciences and other outside experts.

5. ISSUES RAISED BY THE NATIONAL ACADEMY OF SCIENCES REVIEW OF THE NATIONAL NANOTECHNOLOGY INITIATIVE

In 2002, the National Academy of Sciences conducted a review[1] of the National Nanotechnology Initiative (NNI), a national nanotechnology R&D program involving 10 federal agencies. In general, the Academy review panel was impressed with the leadership of NNI and the engagement of the participating agencies. The panel indicated that the quality of the research and the potential return to society are both high. The panel did flag some issues, however, and made a number of recommendations, including:

[1] *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative,* National Academy Press, Washington, DC, 2002.

Recommendations from the National Academy of Sciences

Establish an Independent Advisory Board: the Academy panel recommended the establishment of an independent standing advisory board on nanotechnology composed of leaders from industry and academia with scientific, technical, social science, or research management credentials to provide advice on research investment policy, strategy, program goals, and management processes.

Develop a Strategic Plan: the panel recommended the development of a crisp, compelling, overarching strategic plan that articulates short- (1 to 5 years), medium- (6 to 10 years), and long-range (beyond 10 years) goals and objectives, emphasizing goals that move results out of the laboratory and into the service of society.

Effect Greater Interagency Coordination: the panel noted that the current interagency coordination mechanism—the Nanoscale Science, Engineering and Technology (NSET) Subcommittee of the National Science and Technology Council—is a strong foundation upon which to build an NNI that adds up to more than the sum of its parts, but that more meaningful interagency coordination and collaboration is required.

Promote Interdisciplinary Nanotechnology R&D: the panel noted that nanotechnology is leading researchers along pathways where many different disciplines converge—biology, physics, chemistry, materials science, mechanical engineering, and electrical engineering, to name several. The panel noted further that our educational system is not producing researchers who are capable of engaging in research that crosses disciplinary boundaries and that many of the customs of academic research, including the way research grants are evaluated and the way faculty are judged for tenure and promotion, reinforce disciplinary boundaries and may frustrate interdisciplinary research. Accordingly, the panel recommended strong support for the development of an interdisciplinary culture of nanotechnology research.

Address Potential Societal and Ethical Concerns: the panel noted that the social and economic consequences of nanotechnology promise to be diverse, difficult to anticipate, and sometimes disruptive. The increasing rate of innovation associated with nanotechnology developments has the potential to compress the time from discovery to full deployment, thereby shortening the time society has to adjust to these changes. The panel recommended that research on the potential societal and ethical concerns associated with nanotechnology, and research directed toward improving our understanding of how technical and social systems affect each other, should be an integral part of any federal nanotechnology R&D program.

6. ISSUES ADDRESSED IN H.R. 766

H.R. 766 authorizes the President's National Nanotechnology Initiative in statute, providing a basis for sustained, long-term funding nanotechnology research. The bill adds review and oversight mechanisms to assure that new monies included in the President's fiscal year 2004 budget request are used in the most effective manner possible. H.R. 766 addresses a number of the issues raised by the National Academy of Sciences and other outside experts, through the following provisions:

Provisions in H.R. 766 That Address Issues Raised in the Academy Review

Advisory Committee: responding to the first recommendation of the National Academy of Sciences review panel, H.R. 766 establishes an advisory committee—appointed by the President and consisting of outside experts qualified to provide advice on nanotechnology R&D, education, technology transfer, commercial application, and societal and ethical concerns—to conduct a broad assessment of federal nanotechnology R&D activities and issue a biennial report. This provision has stirred minor controversy. Citing expense and limited resources, the Administration has indicated that it would prefer not to convene a new Presidential advisory committee devoted to nanotechnology. Instead, the President's Council of Advisors on Science and Technology (PCAST) has been tasked with conducting ongoing review and oversight of federal nanotechnology programs.

Interagency Committee: responding to the Academy review panel's call for more meaningful interagency coordination and a strategic plan, H.R. 766 establishes in statute an interagency committee, similar to the existing subcommittee on Nanoscale Science, Engineering and Technology (NSET), to oversee the planning, management, and coordination of all federal nanotechnology R&D activities. The bill designates the Director of the Office of Science and Technology Policy to serve as chair of the Interagency Committee and requires the Committee to include representatives of participating federal agencies, as well as representatives from the

Office of Management and Budget. H.R. 766 requires the Interagency Committee to establish goals and priorities, establish program component areas to implement those goals and priorities, develop a strategic plan to be updated annually, consult widely with stakeholders, and propose a coordinated interagency budget for federal nanotechnology R&D.

Coordination Office: the bill also authorizes in statute the Administration's National Nanotechnology Coordination Office, with full-time staff, to provide technical and administrative support to the Interagency Committee and the Advisory Committee, to serve as a point of contact for outside groups, and to conduct public outreach.

Interdisciplinary Research and Education: responding to the Academy review panel's recommendation, and similar recommendations offered by other outside experts, H.R. 766 authorizes sustained support for interdisciplinary nanotechnology R&D through grants to researchers and through the establishment of interdisciplinary research centers and advanced technology user facilities. The bill requires the activities of the National Nanotechnology R&D Program to ensure that solicitation and evaluation of proposals under the Program encourage interdisciplinary research.

Societal and Ethical Concerns: again responding to the Academy's recommendation, H.R. 766 establishes a research program to identify societal and ethical concerns related to nanotechnology and requires that such research be integrated into nanotechnology R&D programs insofar as possible.

Periodic External Review: H.R. 766 requires the Director of the Office of Science and Technology Policy to contract with the National Academy of Sciences to conduct a review of federal nanotechnology R&D programs every three years, including an assessment of technical progress, managerial effectiveness, and adequacy in addressing societal and ethical concerns.

7. BACKGROUND

The recent National Academy of Sciences review describes nanotechnology as the ". . .relatively new ability to manipulate and characterize matter at the level of single atoms and small groups of atoms.. . . This capability has led to the astonishing discovery that clusters of small numbers of atoms or molecules often have properties—such as strength, electrical resistivity, electrical conductivity, and optical absorption—that are significantly different from the properties of the same matter at either the single-molecule scale or the bulk scale." Scientists and engineers anticipate that nanotechnology will lead to "materials and systems with dramatic new properties relevant to virtually every sector of the economy, such as medicine, telecommunications, and computers, and to areas of national interest such as homeland security."

A variety of nanotechnology products are already in development or on the market, including stain-resistant, wrinkle-free pants and ultraviolet-light blocking sunscreens. Other applications involve Kodak's use of scratch-free, transparent coatings and Samsung's new high-brightness displays. Experts agree that more revolutionary products will emerge from nanotechnology research currently underway. Many small start-up companies have been founded to develop new technologies and new products based on breakthroughs in our understanding of materials at the atomic and molecular level.

The National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI), formally established in 2001, is the President's most ambitious interagency, interdisciplinary science and technology program. Ten federal agencies actively participate in research and development efforts that involve physicists, chemists, biologists, engineers, and researchers from many other disciplines. The initiative has grown rapidly from an initial budget request of $464 million in fiscal year 2001 to the $849 million requested for fiscal year 2004 (although these numbers are not strictly comparable as some ongoing research programs have, over time, evolved into nanotechnology research).

While each agency involved in the NNI focuses its research on that agency's unique mission, the overall effort is organized at the White House level through the articulation of Grand Challenges—or broad, mission-related, technical goals. These include nanotechnology-based innovations in manufacturing, energy production and storage, information technology, medicine, robotics, aeronautics, and defense and homeland security applications.

Recognizing the inherently interdisciplinary nature of nanotechnology science and engineering, NNI supports research through nanotechnology centers and user facilities, designed to bring researchers from multiple disciplines together, as well as through grants to individual researchers and groups of researchers. The National Science Foundation (NSF), the Department of Energy, and the National Aeronautics and Space Administration (NASA) currently sponsor, or are in the process of establishing, a number of nanotechnology research centers and user facilities around the country. Among the NSF-supported centers, some are focused on specific industries, such as the Center for Nanoscale Systems in Information Technologies at Cornell University. Others are national user facilities, such as the nanofabrication facilities at Stanford University and Pennsylvania State University, and one, the Center on Biological and Environmental Nanotechnology at Rice University, conducts research on the societal implications nanotechnology development.

The overall federal effort is coordinated by the National Science and Technology Council's (White House coordinating council composed of the heads of the major research agencies) Subcommittee on Nanoscale Science, Engineering and Technology (NSET), which has responsibility for interagency planning and review. While each agency consults with the NSET Subcommittee, the agency retains control over how resources are allocated against its proposed NNI plan. Each agency then uses its own methods for inviting and evaluating research proposals.

Table 1. National Nanotechnology Initiative Funding ($$ Millions)

NNI AGENCY	FY 2001 Enacted	FY 2002 Enacted	FY 2003 Enacted	FY 2004 Requested	H.R. 766 for FY04
NSF	150	199	221	249	350*
DOD	123	180	243	222	--
DOE	88	91	133	197	197
NIH	40	41	65	70	--
DOC	33	38	69	62	62
NASA	22	46	33	31	31
USDA	2	2	1	10	--
EPA	5	--	6	5	5
DHS (FAA/TSA)	--	2	2	2	--
DOJ	1	1	1	1	--
TOTAL	**464**	**600**	**774**	**849**	

Note: H.R. 766 authorizes in statute a national nanotechnology R&D program to include all participating agencies as designated by the President, but appropriations are authorized only for those agencies within the jurisdiction of the Science Committee.

*FY04 authorizations in H.R. 766 conform to the President's budget request except for the NSF nanotechnology authorization, which conforms to the National Science Foundation Act of 2002 signed into law by the President last December, P.L. 107–368.

8. WITNESS QUESTIONS

Panel I

No questions for Senator Allen or Senator Wyden.

Panel II

The witnesses were asked to address the following questions in their testimony:

Questions for Mr. Richard Russell

- What are the Administration's views on H.R. 766, the *Nanotechnology Research and Development Act of 2003?*
- What are the Administration's plans for the National Nanotechnology Initiative this year?

Questions for Dr. Thomas Theis

- What are the principal findings and recommendations of the National Academy of Sciences review of the National Nanotechnology Initiative? Are there any improvements to H.R. 766 you would suggest in light of these recommendations?
- Where are you targeting IBM's nanotechnology research efforts? Are there particular industrial sectors that will benefit in the near-term from anticipated nanotechnology developments?

- Are there potential societal and ethical concerns associated with the development of nanotechnology? If so, how should they be addressed?
- Are the views of the U.S. research community adequately reflected in the research plan for the federal interagency nanotechnology research initiative? Do you believe that there would be value in establishing an external advisory committee for the initiative?

Questions for Dr. James Roberto

- Through a workshop and other planning exercises, Oak Ridge National Laboratory (ORNL) has developed a roadmap for its Nanoscale Science, Engineering and Technology research programs, establishing criteria by which staff research proposals are evaluated. ONRL's planning and management activities are analogous to the tasks assigned to the Interagency Committee established in section 3(c) of H.R. 766. In your view, would it be worthwhile to develop a national technology roadmap to guide federal nanotechnology research? To your knowledge, is such an effort underway now?
- Likewise, ORNL's Center for Nanophase Materials Sciences, currently under construction, could be a model for the interdisciplinary research centers and advanced technology user facilities authorized in section 3(b). How will the Center foster effective collaboration across academic disciplines, and among government, university, and industry researchers?
- Some individuals and groups have suggested that nanotechnology developments may raise societal and ethical concerns. Is any part of ORNL's activity devoted to addressing such concerns?
- Are the views of the research community affiliated with ORNL adequately reflected in the research plan for the federal interagency nanotechnology research initiative? Do you believe that there would be value in establishing an external advisory committee for the initiative?

Questions for Dr. Carl Batt

- How does the Cornell Nanobiotechnology Center advance nanotechnology research and development compared to what the University could accomplish on its own? Does the center actively foster collaboration across academic disciplines, for example?
- How does your center interface with the private sector? Do you host any collaborative university-industry nanotechnology research and, if the answer is yes, does the existence of the center make those collaborations easier?
- Some individuals and groups have suggested that nanotechnology developments may raise societal and ethical concerns. Is any part of your center's activity devoted to addressing such concerns?
- Are the views of the academic research community adequately reflected in the research plan for the federal interagency nanotechnology research initiative? Do you believe that there would be value in establishing an external advisory committee for the initiative?

Questions for Mr. Alan Marty

- How or where is JP Morgan Partners investing in nanotechnology? Are there particular industrial sectors that look more promising than others?
- Is the private sector primarily engaged in basic nanotechnology research or do you expect marketable products and services to be available in the near-term?
- How do federal nanotechnology research and development programs affect your investment decisions?
- Some individuals and groups have suggested that nanotechnology developments may raise societal and ethical concerns. Does this affect your investment choices? Are the companies you are involved with addressing these issues in any way?

APPENDIX I

Section-by-Section Analysis of the Nanotechnology Research and Development Act of 2003

Sec. 1. Short Title

"Nanotechnology Research and Development Act of 2003."

Sec. 2. Definitions

Defines terms used in the text.

Sec. 3. National Nanotechnology Research and Development Program

Establishes an interagency R&D program to promote and coordinate federal nanotechnology research, development, demonstration, education, technology transfer, and commercial application activities. The program will provide sustained support for interdisciplinary nanotechnology R&D through grants to researchers and through the establishment of interdisciplinary research centers and advanced technology user facilities.

Establishes a research program to identify societal and ethical concerns related to nanotechnology and requires that such research be integrated into nanotechnology R&D programs insofar as possible.

Establishes an interagency committee, chaired by the Director of the Office of Science and Technology Policy, and composed of representatives of participating federal agencies, as well as representatives from the Office of Management and Budget, to oversee the planning, management, and coordination of all federal nanotechnology R&D activities. Requires the Interagency Committee to establish goals and priorities, establish program component areas to implement those goals and priorities, develop a strategic plan to be updated annually, consult widely with stakeholders, and propose a coordinated interagency budget for federal nanotechnology R&D.

Sec. 4. Annual Report

Requires the Office of Science and Technology Policy to submit an annual report, at the time of the President's budget request to Congress, describing federal nanotechnology budgets and activities for the current fiscal year, and what is proposed for the next fiscal year, by agency and by program component area. Requires that the report include an analysis of the progress made toward achieving the goals and priorities established for federal nanotechnology R&D, and the extent to which the program incorporates the recommendations of the Advisory Committee (established in sec. 5).

Sec. 5. Advisory Committee

Establishes a Presidentially-appointed advisory committee, consisting of non-federal experts, to conduct a broad assessment of federal nanotechnology R&D activities and issue a biennial report.

Sec. 6. National Nanotechnology Coordination Office

Establishes a National Nanotechnology Coordination Office with full-time staff to provide technical and administrative support to the Interagency Committee and the Advisory Committee, to serve as a point of contact for outside groups, and to conduct public outreach.

Sec. 7. Authorization of Appropriations

Authorizes appropriations for nanotechnology R&D programs at the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, the National Institute of Standards and Technology, and the Environmental Protection Agency (see table below).

Agency	FY04	FY05	FY06
NSF	$350 M	$385 M	$424 M
DOE	$197 M	$217 M	$239 M
NASA	$ 31 M	$ 34 M	$ 37 M
NIST	$ 62 M	$ 68 M	$ 75 M
EPA	$ 5 M	$ 5.5 M	$ 6 M
Total	**$645 M**	**$709.5 M**	**$781 M**

Sec. 8. External Review of the National Nanotechnology Research and Development Program

Requires the Director of the Office of Science and Technology Policy to contract with the National Academy of Sciences to conduct a triennial review of federal nanotechnology R&D programs including technical progress, managerial effectiveness, and adequacy in addressing societal and ethical concerns.

APPENDIX II

See text of H.R. 766 located in Appendix 1: Additional Material for the Record, pp. 90–93.

Chairman BOEHLERT. Good morning. The hearing will come to order. It is a pleasure to welcome everyone here this morning, and I wanted to give a special welcome to Richard Russell, formerly Deputy Chief of Staff for this committee, who is returning to his old precincts. I am sure he will be able to make it through his testimony despite the pangs of nostalgia.

I am going to keep my remarks this morning brief, because nanotechnology is the subject on which there is already broad agreement: on this dais, at the witness table, and indeed in the Congress and country at large. We all understand that nanotechnology can be a key to future economic prosperity and might improve our lives and that the Federal Government needs to play a role in making that so.

With that in mind, I introduced H.R. 766 with Mr. Honda and with the senior Members of this committee on both sides of the aisle as cosponsors. Our plan is to have another hearing on this subject on April 9, that hearing focusing exclusively on societal consequences and then report out the bill in late April or early May. It should be able to move to the House floor swiftly after that. And as the welcome presence today of Senators Wyden and Allen indicates, the Senate is extremely interested in this matter and is providing some real leadership. We worked successfully with Senators Allen and Wyden on a wide range of issues last Congress, including cybersecurity, and I am pleased that our partnership continues.

The hallmarks of H.R. 766 are three-fold. It aims to increase interdisciplinary research, interagency coordination, and research, excuse me, on societal consequences. It builds on the excellent proposed budgets that have been put forward by the Administration for nanotechnology. I think it is safe to say that the bill is pretty non-controversial. It has been endorsed by leading industry groups. I know the Administration has some concerns about the Advisory Committee language, and I have no doubt that those can be worked out.

The bill is designed to usher in a day when nanotechnology is so routine that none of us feel compelled to make the tiresome puns that now always attend discussions of nano. I want to see nano become so much a part of daily life that discussions of it are nothing more than, well, small talk. I am sure we all look forward to that day.

Mr. Hall.

[The prepared statement of Mr. Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD BOEHLERT

It's a pleasure to welcome everyone here this morning, and I want to give a special welcome to Richard Russell, formerly the Deputy Chief of Staff of this committee, who is returning to his old precincts. I'm sure he will be able to make it through his testimony despite the pangs of nostalgia.

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Mr. Hall.

Mr. HALL. Mr. Chairman, because of the importance of the time of the two Senators in front of us, I won't read my entire opening statement. I just will say that I thank you for having the witnesses here today. I thank you for your time, both of you, friends of mine, long-time colleagues, have always complained that he sat between Congressman Tallson and my Chair and that we "immersed him in oil" was the way he put it. But he was always a gentleman, always helpful, always very intelligent, and a good member of the Senate. I am honored to have both of you here.

I think nanotechnology is going to have enormous consequences for the information industry, manufacturing, for medicine and health, and indeed the scope of this technology is so broad, it is to leave virtually no product untouched. So we will have a pretty wide open field, and I would like unanimous consent or ask the consent of the Chairman to put my entire opening statement, which is an outstanding statement, and some time later, I will get a chance to read all of it.

But thank you for calling this hearing on this important legislative measure, and I appreciate the attendance of the witnesses today and look forward to our discussion and yield back my time. Thank you.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

I am pleased to join the Chairman in welcoming our witnesses to today's hearing on nanotechnology.

The advancement of civilization has been tied to human capabilities to manipulate and fashion materials. For example, the stone age gave way to the bronze age, which in turn gave way to the iron age. The trend has been a better understanding of material properties at a smaller and more detailed level.

Now, we stand at the threshold of an age in which materials can be fashioned atom-by-atom. As a result, new materials can be designed with specified characteristics to satisfy specific purposes.

The word "revolutionary" has become a cliché. But nanotechnology, which is the subject of today's hearing, truly is revolutionary. As stated in a report from the National Research Council:

> "The ability to control and manipulate atoms, to observe and simulate collective phenomena, to treat complex materials systems, and to span length scales from atoms to our everyday experience, provides opportunities that were not even imagined a decade ago."

Nanotechnology will have enormous consequences for the information industry, for manufacturing, and for medicine and health. Indeed, the scope of this technology is so broad as to leave virtually no product untouched.

At today's hearing we will consider bipartisan legislation that the Chairman and Congressman Honda, along with 10 additional colleagues, have introduced to authorize the National Nanotechnology Initiative.

In addition to setting funding goals, the bill puts in place mechanisms for planning and coordinating the interagency research program. The bill also includes provision for outside, expert advice to help guide the research program and ensure its relevance to emerging technological opportunities and to industry.

I am interested in hearing the views of our witnesses on the merits of the legislation and their recommendations for ways to improve it. Our witnesses should also feel free to provide their assessments of the content and management of the current federally supported nanotechnology research effort.

I want to thank the Chairman for calling a hearing on this important legislative measure. I appreciate the attendance of our witnesses today, and I look forward to our discussion.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before this committee to discuss federal nanotechnology research and development activities and to consider H.R. 766, the *Nanotechnology Research and Development Act of 2003,* which would authorize these federal programs. The President's 2004 Budget provides $847 million for the multi-agency National Nanotechnology Initiative (NNI), a 9.5 percent increase over 2003. This investment will advance fundamental understanding of the nanoscale phenomena. This increased understanding promises to underlie revolutionary advances that will contribute to improvements in medicine, manufacturing, high-performance materials, information technology, and environmental technologies.

Nanotechnology can best be considered as a "catch-all" description of activities at the level of atoms and molecules that have applications in the real world. A variety of nanotechnology products are already in development or on the market, including stain-resistant, wrinkle free pants and ultraviolet-light blocking sunscreens.

A unique feature of nanotechnology is that it is the one area of research and development that is truly multidisciplinary. Research is unified by the need to share knowledge on tools and techniques, as well as information on the physics affecting atomic and molecular interactions in this new realm. Materials scientists, mechanical and electronic engineers and medical researchers are now forming teams with biologists, physicists and chemists.

Illinois is among the leaders in nanotechnology. During the last few years, success in the areas of nanotechnology at Southern Illinois University–Carbondale (SIUC) have included patented technology for conversion of carbon dioxide into methanol and sensors to detect corrosion and stress in highway bridges. SIUC has also developed industrial partnerships and collaborations with IBM, Proctor & Gamble, and Argonne National labs to further research and development at the atomic and molecular scale.

To keep America dominant in nanotechnology, I believe we must create a coordinated interagency effort that would support long-term nanoscale research and development, increase America's competitiveness in nanoscale technology, and promote effective education and training for the next generation of nanotechnology researchers and professionals. H.R. 766 accomplishes these goals. I am interested to hear from our panel on any further recommendations zor improvements to this legislation based on the National Academy of Sciences review of the National Nanotechnology Initiative. Further, I am interested in discussing the potential societal and ethical concerns associated with the development of nanotechnology and how these concerns should be addressed.

I thank the witnesses for appearing before our committee and look forward to their testimony.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF REPRESENTATIVE NICK SMITH

I want to thank Chairman Boehlert for holding this hearing today to review the status of federally funded nanotechnology research and development activities and to review H.R. 766, which would authorize the National Nanotechnology Initiative activities (NNI) into law.

Nanotechnology is defined in H.R. 766 as "science and engineering at the atomic and molecular level." It holds incredible promise in a wide range of scientific disciplines. While relatively few nanotechnology products are on the market today, such as my stain-resistant, wrinkle-free pants, the industry is very close to achieving several important breakthroughs that include revolutionary new applications in materials science, manufacturing, energy production, information technology, medicine, and defense and homeland security applications.

Like the biotechnology and information technology sectors of 10–15 years ago, nanotechnology has reached a critical growth stage. As these emerging innovations near fruition, it is important that the Congress works pro-actively to guide the industry through the inevitable growing pains that lie ahead. To accomplish this, we will need to intensify our support for research and experimentation in nanosciences—specifically the fundamental, novel research that is too risky for the private sector to undertake. This effort, combined with strengthened coordination and management of the multi-agency NNI, will help to bridge the necessary link to the wide reach of business and industry interests eager to create new products out of that research. The bill before us today, that many of us have co-sponsored, will help us do just that.

If the information technology revolution is any guide, the nanotechnology revolution will not only improve our lives through the development of many exciting new products, its contribution to productivity gains could also help brighten future fiscal situations. As the Semiconductor Industry Association has pointed out, the Congressional Budget Office (CBO) estimation of the $1.3 trillion projected deficit that we're facing for fiscal years 2004–2013 would actually be $247 billion higher if it were not for improvements in productivity due to computers. If we succeed in our effort to harness the potential of nanotechnology, we will see productivity and revenue gains of a similar magnitude.

As Chairman of the Research Subcommittee, which maintains oversight of the National Science Foundation, we have held hearings on the potentials of nanotechnology. I am particularly interested in hearing the ideas today's witnesses may have on how to maximize NSF's contribution to the initiative. NSF is the largest federal supporter of non-medical basic research conducted at universities, and at $221 million for FY 2003, comprises almost 30 percent of the NNI budget. It is important that the cutting-edge fundamental research conducted at NSF is utilized by other agencies and the private sector and transformed into real-world applications in a manner that can improve our health, facilitate better research, and ultimately help our economy. I believe the goals and priorities for the NNI established in H.R. 766 will be an important aspect of this process.

I want to welcome all of the witnesses here today, and in particular thank our colleagues from across the street, Senator George Allen and Senator Ron Wyden, for taking the time to present testimony to the Committee. I look forward to a productive discussion.

[The prepared statement of Mr. Matheson follows:]

PREPARED STATEMENT OF REPRESENTATIVE JIM MATHESON

Nanotechnology presents incredible opportunities, not just for pure science, but for a host of interdisciplinary areas. The wide range of potential applications of this research is one of the best reasons why we, as a nation, should commit to long-term support of nanotechnology. Many of the most exciting ideas are still years from completion and even the current success stories are products of long-term research, study, and dedication.

It is also important to realize that, due to the expense of establishing top-level research infrastructure, facility sharing must also be a priority. We have an opportunity to promote relevant, needed research and every effort should be made to best utilize limited resources. I look to the national laboratories at Sandia National Laboratories, Oak Ridge National Laboratory, and at other sites to avail themselves of the scientific talent within this nation.

Finally, there exists a tremendous opportunity for today's research commitment to become tomorrow's commercial success. We need partnerships between federally funded research facilities and private industry in order to generate the ideas that will drive business in the future. I thank the Committee for its interest in this area of science and look forward to contributing to the national discourse on nanotechnology.

Panel I

Chairman BOEHLERT. Thank you very much. And it is a distinct pleasure to welcome two partners and former colleagues on the House side, who have made a mark for themselves in the Senate, who are real leaders in the nano field: Senator Ron Wyden of Oregon, and Senator George Allen of Virginia. Gentlemen, the floor is yours. Start with Senator Wyden. Turn it on.

STATEMENT OF SENATOR RON WYDEN, DEMOCRAT OF THE STATE OF OREGON

Senator WYDEN. There we are. Well, let me say first how much I appreciate being here. My old seat mate for 15 years in the House, Congressman Hall, and I go so far back. And the Chairman is absolutely right. We have teamed up on one success after another, most recently, the cybersecurity legislation. And I think I would like to put my whole statement into the record with your lead, Mr. Chairman, and just make——

Chairman BOEHLERT. Without objection.

Senator WYDEN [continuing]. A few comments this morning. Senator Allen and I have teamed up on this legislation now for several years. And I think our message is really fairly straightforward, and that is that we just think it is time for Congress to think big about the small sciences. I mean, there is extraordinary potential here. I am of the view that—and I think it was best stated by one recent expert at a conference, this is going to lead to a complete reversal in the way in which man has produced things since the dawn of time. We essentially always looked big and then tried to figure out how to go from there.

What we are talking about with nanotechnology is essentially reversing that and going from the bottoms up and revolving around the small structures that are atom and molecular size. And I think the potential in the area Ralph Hall and I have shared an interest in for years in issues like healthcare is just extraordinary. I mean, I see these structures and these appliances, for example, bulldozing their way through cancers and serious tumors and other kinds of health problems the American people will have. And I think we are going to hear more about those kinds of applications in the days ahead.

I want to take just a second and talk about how Senator Allen and I spent the previous two years, because I think there is a lot of interest in what we are trying to do differently here with nanotechnology. We have seen over a time a variety of interesting ideas come along. People get excited about them from time to time. Government converges and spends a bunch of money and sets up a variety of programs, and very often at the end, people say, "Well, this is—was sort of a textbook case of how you probably should have stepped back and been a bit more thoughtful."

What Senator Allen and I did is we essentially said when we heard about the promise of this new science, the first thing we are going to do is go out and talk to the private sector about their ideas and their initiatives. And what we found is to a person, they all thought that what the Administration was doing was constructive, that their initiative, the one that has been carried by executive branches, clearly, a step in the right direction and one we ought to support. But their message also to a person was: here is a chance to build on what the Administration is doing in some very key kinds of areas.

If you look at our legislation, for example, with respect to the ethical concerns, that is a new development. We try to consolidate what government is doing right now. Some of the nanotechnology efforts are essentially strewn across the Federal Government. They are in a variety of different places. We think we can do a better job of coordinating those efforts. And I think we have tried to say, in issues particularly relating to PCAST, that it would be very helpful to have some people who are expert just on nanotechnology so that we could have some people who would zero in on those initiatives. But it is fair to say that Senator Allen and I are very supportive of what the Administration is doing. I note of the case in this committee on a bipartisan basis, we just think that we can be bolder and more aggressive, and we ought to pursue those kinds of efforts. So I think we really have set our—a path here that can show that we have learned from the past and we are not likely, in nanotechnology, to see a few years hence the people say, "Well, there was something promising. The government threw a bunch of money at it. It really didn't work," and people have regrets.

The last point that I would make, Mr. Chairman, is that given what is going on around the world, this is not a time for us to miss opportunities. This is a time for us to mine the opportunities, because clearly Europe and other parts of the world are blasting ahead very aggressively, and we ought to make similar kinds of efforts.

Let me at this point, if I could, yield to my good friend and colleague, Senator Allen. I was the Chair of the Subcommittee last time, so I introduced the legislation. He and I have teamed up on this at every single step of the way, just as you and I have. There is absolutely nothing partisan about this particular issue. And my friend, Senator Allen, because of Virginia's interest in technology very much parallels Oregon's interests in technology, he and I have been partners on all of these issues, and I am grateful to have a chance to——

Chairman BOEHLERT. Well, I just want to thank you, Senator Wyden, and you, Senator Allen, for the leadership you are providing day after day, year after year. This is a very important area, and I like your phrase, "Let's think big about small science." Senator Allen.

[The prepared statement of Senator Wyden follows:]

PREPARED STATEMENT OF SENATOR RON WYDEN

In the 107th Congress, as Chair of the Senate Commerce Subcommittee on Science, Technology & Space, I introduced, along with my good friend here, Senator Allen, the Wyden-Allen 21st Century Nanotechnology Research and Development Act. That bill, with its strong bipartisan support, was unanimously passed out of the Commerce Committee.

This Congress, the Wyden-Allen 21st Century Nanotechnology Research and Development Act is back with strong bipartisan support. Senator McCain has assured me that we will have a hearing in the Senate on nanotechnology and we are determined to pass the bill out of Committee and this time bring the bill to the floor for a vote. I am confident that in this Congress, with the Senate bill and with Chairman Boehlert's leadership on the House bill, the President will sign into law a strong federal policy that will guarantee that the United States will *not* miss, but will *mine* the opportunities of nanotechnology.

Right now, the National Nanotechnology Initiative (NNI) is organized under the White House National Science and Technology Council. In effect, it exists at the whim of this and future Administrations. Efforts in the nanotechnology field are strewn across a half-dozen federal agencies. With the Wyden-Allen legislation and the House bill, and a strong partnership between the two chambers, America can marshal its various nanotechnology efforts into one driving force to remain the world's leader in this burgeoning field.

The global nanotechnology race has so many implications for this country that it's hard to know where to begin. If I had to summarize—and I bet you'd like me to do that instead of speaking for 90 minutes—I would say the global nanotechnology race matters for America on three distinct levels. It is rapidly becoming an economic issue and a geopolitical issue. Eventually, every American may have a personal stake in nanotechnology as well.

If science on the molecular scale is incomprehensible to some folks, pretty much all of us can understand money. There is a *lot* of money coming in nanotechnology. In the next decade or so the global nanotechnology market should be worth about $1 trillion.

It will be worth that because of the awesome products nanotechnology will yield. Imagine how a material 100 times stronger than steel at one-sixth the weight could revolutionize the building industry. Americans are already buying stain-resistant pants and scratch-resistant eyeglasses. The *world* will line up for smart drugs to treat cancers, cheap flat-screen TVs the size of living room walls, and self-repairing concrete highways.

From a purely economic standpoint, America can't afford to miss the nanotechnology revolution. The potential not just for direct revenue, but also for jobs and the growth of related industries, is too huge.

Nanotechnology's significance extends beyond America's bankbook, though. If private industry and the Federal Government fail to provide organized, goal-oriented support *now,* this nation could fall behind others who recognize nanotech's potential.

Major programs are underway in the EU, China, Japan, Taiwan and across East Asia. Just this month Shimon Peres called on the Knesset for a quote, "superhuman effort" to put Israel at the forefront of nanotechnology. U.S. spending on nanotechnology is just about 25 percent of the world's total. Worldwide spending may reach $2 billion this year.

America has to keep up not only financially, and scientifically; America must also educate a competitive new generation of science experts to move this field forward. In this respect, our nation may be seriously unprepared.

American school children learn considerably less math and science that their counterparts abroad. A significant percentage of this country's math and science graduate students come from other countries and return there after graduation. American nanotechnology and other disciplines are facing a terrible shortage of human resources.

The U.S. has a deep well of untapped potential in women, who are terribly underrepresented in the math and science fields. Last year I started a push to end the disenfranchisement of women in the hard sciences. These efforts need to bear fruit. The National Science Foundation estimates that over the next decade, America will need 800,000 to 1 million nanotechnology workers. The time to start encouraging those folks is now.

An investment in nanotechnology education now could beget major advances for every American school child. That's just the beginning of the personal impacts of nanotech.

I've said before that this field has the potential to change America on a scale equal to, if not greater than, the computer revolution. Nanotechnology experts predict that research could lead to $20 hand-held computers. That sounds great for all of us techies here.

But imagine the impact on America's rural and inner-city schools if every school could afford a computer for every child. *The digital divide would close.* Think about the enormity of that statement. All the kids who don't have much of a chance now could have the tools to learn and compete alongside the kids who've always had options.

Nanotechnology will eventually be a matter of life and death. When revolutionary medicines are able to target cancers and kill them with little or no damage to surrounding tissue—well, I bet all of us can think of someone who might be alive today with that technology.

So the personal implications range from getting a better shot in life to literally living longer. If that doesn't convince people that America needs to commit to nanotechnology, I don't know what will.

The Wyden-Allen 21st Century Nanotechnology Research and Development Act provides a smart, accelerated, and organized approach to nanotechnology research, development, and education. In my view, there are three major steps America must take to ensure the highest success for its nanotechnology efforts. My legislation puts us on the path to take these steps.

First, a National Nanotechnology Research Program should be established to superintend long-term fundamental nanoscience and engineering research. The program's goals will be to ensure America's leadership and economic competitiveness in nanotechnology, and to make sure ethical and social concerns are taken into account alongside the development of this discipline.

Second, the Federal Government should support nanoscience through a program of research grants, and also through the establishment of nanotechnology research centers, including State-supported centers. These centers would serve as key components of a national research infrastructure, bringing together experts from the various disciplines that must intersect for nanoscale projects to succeed. As these research efforts take shape, educational opportunities will be the key to their long-term success. This bill guarantees a commitment to helping students who would enter the field of nanotechnology. This discipline requires multiple areas of expertise. Students with the drive and the talent to tackle physics, chemistry, and the material sciences simultaneously deserve all the support we can offer.

Third, the government should create connections across its agencies to aid in the meshing of various nanotechnology efforts. These could include a national steering office, and a Presidential Nanotechnology Advisory Committee, modeled on the President's Information Technology Advisory Committee. This committee would be composed of experts with intimate knowledge of the nanotechnology field. The joke these days in the world of science is that everyone is doing nano work. Just as the '90s saw everyone putting "dot com" after titles, today, everyone is putting "nano" before their sciences. We must ensure that the Presidential Nanotechnology Advisory Committee is not composed of "nano-come-latelys," but is instead composed of leaders in the field who will best guide us in our efforts to nurture and develop the strongest possible applications of nano research funding.

I also believe that as these organizational support structures are put into place, rigorous evaluation must take place to ensure the maximum efficiency of our efforts. Personally, I would call for an annual review of America's nanotechnology efforts from the experts—the Presidential Nanotechnology Advisory Committee—and a periodic review from the National Academy of Sciences. In addition to monitoring our own progress, the U.S. should keep abreast of the world's nanotechnology efforts through a series of benchmarking studies.

In my view, the U.S. is poised to maximize nanotechnology's economic potential, its political potential, and its personal potential for every American. I believe that decisive support from the government and a strong partnership between Senate and House proponents of this science are absolutely essential to grow this field. I encourage the passage of the House legislation as well as the Wyden-Allen Act in the Senate.

STATEMENT OF SENATOR GEORGE ALLEN, REPUBLICAN OF THE STATE OF VIRGINIA

Senator ALLEN. Thank you, Mr. Chairman. And I thank you and all of the Members of this committee, this wonderful Committee on Science, for calling today's hearing. I was—as Senator Wyden, I was listening to him, and I agree with everything he said. And I love this quote from Proverbs you have here: "Where there is no vision, the people perish." It reminds—and then you have here, "They see the vision of the future of a world and all the wonders that could be." It reminds me of the view of observations of America in the early 1800's that the only things that haven't been done are those that have yet to be imagined. And that is what we are talking about here, that same spirit.

And Mr. Chairman, I will have my remarks put into the record, if I could, as well——

Chairman BOEHLERT. Without objection, so ordered.

Senator ALLEN [continuing]. Hopefully as excellent as those of Congressman Hall's record. However, I do want to commend you for your leadership on this, visionary leadership, as well as that of Congressman Honda and Ehlers and others on these matters. We have worked together on cybersecurity, homeland security, a variety of issues. What Senator Wyden, who is my teammate on the Senate side on these issues, what we want to do is take the best of our ideas, of the ideas here on the House, improve the bills that we have introduced, make sure there is complete symmetry and synergy there so that we take the best ideas as we move forward in nanotechnology.

As you said and Senator Wyden said, there is so much potential here. We recognize it. Sadly, I would say, no more than five percent of Senators and House Members understand what nanoscience is, nanotechnology. It is something that all Members need to be more conversant upon, but leadership is needed. We need to, as elected leaders, and the government ensure that the right conditions precedent are there for those who are researching whether in the private sector, state sponsored, colleges, universities, the institutes, variety of institutes, federal institutes, all are working together that there is that sort of domestic and international efforts to the extent we can to contribute to these results.

Now our nation, from the very beginning, has always been on the forefront of technological or industrial revolutions. That needs to be the same in nanoscience. My friend, Senator Wyden, and I introduced Senate Bill 189, *The 21st Century Nanotechnology Research and Development Act.* It is very similar to yours. Before this is all through, they will be identical.

It is, for example, to get with the great work that is going on right now with the National Institutes of Health where there is great promising potential for precise medical treatments and therapies and bioscience technologies that are exciting and really lifesaving in many regards. And we know those stories about—you get the nanochip that gets to the exact cancer cell as opposed to right now you get these shotgun blasts killing all sorts of cells, weakening the body, with nanoscience, you can get right to the cells that need to be destroyed, the cancerous cells. So that is exciting. That is promising for a better quality of life. Ours is a strategic goal, as is yours, to get everyone to work together.

Now I am one, Mr. Chairman and Members of the Committee, that is competitive. And the United States needs to be ready to compete and succeed in this area of nanoscience. I feel that we are falling behind. Japan, Korea, China, the European Union all are really, I believe, ahead of us right now as far as research and development in the applications of nanoscience. It is important for healthcare, for communications, for commerce, for manufacturing, for aeronautics, and indeed for our national security that the United States is a leader in this nanotechnology or nanoscience revolution.

There are, as was said by others, great opportunities in a variety of areas. One other example, right now for the archives, the National Archives and all of the volumes in the Library of Congress, it takes up rooms of storage space, you know, for the processors. With nanoscience, all of that can be put into a processing chip, so to speak, the size of a sugar cube. That is the promise as far as technology is concerned.

And we are proud that our states, my state of Virginia, Oregon, California, New York, Texas, Pennsylvania are proud of their efforts. We need to be at the forefront working there. The United States Government has an important role to play. It is important for our security, for our health, and for our future. And I really am excited and invigorated by the opportunity to work with you, Mr. Chairman and Members of this esteemed committee, to make sure that the United States is in the lead in improving the lives of Americans and also our security.

[The prepared statement of Senator Allen follows:]

PREPARED STATEMENT OF SENATOR GEORGE ALLEN

Chairman Boehlert (Sherwood Boehlert, R–NY), Ranking Member Hall (Ralph Hall, D–TX) and Members of the Science Committee, thank you for calling today's hearing and for allowing me the opportunity to testify.

Your visionary leadership on science and technology issues is a model for the members of this committee and the House of Representatives. I enjoy working with you as a teammate advocating and championing these initiatives in the Senate.

Speaking of teammates, last September, Senator Wyden and I held the first Congressional hearing on the topic of Nanotechnology. We posed similar questions to those before your Committee today.

As many of you know, Nanotechnology is still in its infancy and as this field matures it will undoubtedly have a substantial positive impact on our daily lives.

America has historically valued and encouraged innovation and entrepreneurship in virtually every emerging industry and nanotechnology should be no different.

Our role as elected leaders should be to create the conditions and precedent to position our researchers and innovators to compete, contribute and succeed both domestically and internationally.

Our nation has been at the forefront of almost every important and transformative technology since the Industrial Revolution, and we must continue to lead the world in the Nanotechnology revolution. That is why, working with Senator Wyden, we introduced S. 189, the 21st Century Nanotechnology Research & Development Act.

Similar to legislation before this committee (H.R. 766 introduced by Chairman Boehlert) and in response to many of the recommendations from the National Academy Sciences; our legislation looks to provide an organized and collaborative approach to nanotechnology research and commercial economic development.

S. 189 capitalizes on the fantastic work already taking place at the National Nanotechnology Initiative (within the National Science Foundation), and will build on existing interagency coordination with the 10 federal agencies already working on nanotechnology. For example, within the National Institutes of Health there is the potential for promising and precise medical treatment therapies and bioscience technologies that are exciting and life saving.

Our bill also looks to support the interdisciplinary nature of nanotechnology; cutting across multiple disciplines such as: information technology, chemistry, biology, mechanical & electrical engineering, physics, and manufacturing.

Our strategic goal is logical and clear—we want to leverage the government, academic and corporate research capabilities and assets this country has available to compete and succeed worldwide. Ground-breaking nanotech projects today will mean substantial regional and national job growth in the future.

Unlike previous advances and developments in the technology industry, nanotechnology is not dominated by the United States. The NanoBusiness estimates the U.S. is being out paced in some areas of nano-development by foreign competitors from Japan, China, Korea, Russia and the European Union.

As production and innovation of nanotechnologies become faster, cheaper and more efficient, every market sector in the economy will begin to feel its impact creating an extraordinary opportunity to promote and attract more jobs and economic growth.

From computing power where memory and processing chips the size of a sugar cube will have the ability to store all the information in our nation's National Archives and the Library of Congress combined; to agriculture and energy efficiencies; health care therapies, and our Homeland security and national defenses;

nanotechnology will be the platform that generates many of the advances and discoveries in the decades to come.

State-led and regional economic clusters are developing around the nanotech industry to attract nano focused companies—New York, Texas, Oregon, California, Massachusetts, Pennsylvania and I am particularly proud of the efforts by the Commonwealth of Virginia.

The Initiative on Nanotechnology in Virginia has created a collaborative environment for universities like Virginia Tech and UVA to work with private sector companies like Luna Innovations and Nano Sonic, Inc.

In summary, Mr. Chairman, I strongly believe the Federal Government has an important role to play to ensure the United States leads the world in nanotechnology. It will be a world competition to reap the rewards and benefits of this revolutionary industry. The potential economic and societal benefits are far too great to be overlooked. As our scientist and researchers adventure boldly into this New Frontier of Nanoscience and chart new paths in lands not yet discovered, good public policy will need to be in place to serve as a catalyst to the diverse, nascent nanotechnology community.

I commend this committee's efforts and focus on this important issue. The work being done in the nanoscience field is invigorating; it's exciting, and it's important for our future economy and millions of jobs.

DISCUSSION

Chairman BOEHLERT. Thank you very much for that eloquent testimony, Senator Allen. And you two are living examples of how we do things right more often than not in this town: bipartisan, seizing an opportunity, providing leadership, working across the Capitol. We are going to move forward with this legislation, thanks to your leadership, and we will try to contribute the maximum from this side. Thank you both very much.

Senator WYDEN. Mr. Chairman, if I could, one last point from the Senate side, Chairman McCain on the Senate Commerce Committee has told Senator Allen and I that he is going to put this bill on the fast track as well. Our plan in the Commerce Committee is to have a quick hearing move ahead, so Chairman McCain has indicated that he shares your interests and wants to move this quickly.

Chairman BOEHLERT. He is excited about it. There are a lot of people, the more they know about it——

Senator WYDEN. Right.

Chairman BOEHLERT [continuing]. You know, the zeal and commitment you demonstrate, you can excite anybody about this. And that is great. Keep it up. Thank you. Any questions?

Mr. HALL. I—just one. Normally, we seek support and as this grows and they find out about it, you are going to have to make decisions of whether or not you want to share this support. Mr. Chairman, Congressman Honda, who along with you has introduced this and ten others, was not here when I had the opening statement, so I was going to yield 10, 20, or 30 seconds or five minutes to him. Could I yield the balance of my time to him to make whatever statement he wants to make?

Chairman BOEHLERT. I—by all means. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. I really—I am excited, and I share your enthusiasm. And when you say we talk about the scale of nanotechnology, the scope of it is so immense and it could be so ubiquitous and really extend what they call Moore's Law another 30 or 50 years, which will really not—do nothing but enhance our technology and enhance our economy. And I guess one of the concerns I would have is that we sustain this effort and sustain this enthusiasm by both bodies so that the Administration will continue to support the NNI at a level that it needs to so that we can move this whole movement forward. And I certainly am as excited as you are when I think of all of the potential and possibilities not only for technology, but also for biomedical advances. So I think that the reason why we need groups like advisory groups for PCAST so that we can anticipate a lot of the issues now so that it doesn't become a barrier in the future and that we can move forward in the most expeditious way.

Thank you, Mr. Chair, for this opportunity.

Chairman BOEHLERT. Thank you very much, Mr. Honda. And I want to thank both of my colleagues for coming across the center of this Capitol complex. It is always a pleasure to see you and continue your good work.

Senator WYDEN. Good point. And thank you.

Chairman BOEHLERT. A second panel to our aide consists of an alum of this very distinguished Committee: Mr. Richard Russell, Associate Director for Technology, Office of Science and Technology Policy; Dr. Thomas Theis, Director of Physical Sciences, IBM Research Division, Thomas J. Watson Research Center; Dr. Carl Batt, and I have the privilege of representing Dr. Batt, Co-Director of the Nanobiotechnology Center at Cornell University; Mr. Alan Marty, one of the great job titles in America, Executive-in-Residence, JP Morgan Partners. And for the purpose of an introduction, the Chair recognizes Mr. Davis.

Mr. DAVIS. Thank you, Mr. Chairman. It is certainly good to have on the panel today someone who works at Oak Ridge. Many of the people who live in the district I represent perform work and duties there as well. Dr. James Roberto is the Associate Laboratory Director for the Physical Sciences at Oak Ridge National Lab. He is responsible for ORNL's research portfolio and materials science, condensed matter physics, chemical and nuclear physics. He has been a distinguished member of the Oak Ridge community since 1974 and has served on three national research committees. He currently is a fellow of the American Association for the Advancement of Science. I welcome him, and I certainly look forward to him enlightening this committee on many of the activities going on there at Oak Ridge. Welcome, Dr. Roberto.

Chairman BOEHLERT. Thank you very much. And gentlemen, your statements will appear in the record in their entirety. We would ask that you try to summarize in five minutes or so. The Chair will not be arbitrary, but we do want to give an opportunity for questions.

Mr. Russell, you know the drill. You are up first.

Panel II

STATEMENT OF MR. RICHARD M. RUSSELL, ASSOCIATE DIRECTOR FOR TECHNOLOGY, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. RUSSELL. Thank you, Mr. Chairman. And let me thank you for your warm welcome. And it truly is an honor and a pleasure to be able to come back to this committee and speak before you today, especially on an issue where I think we all share the same goals. It is one of great importance to everyone. It is an issue that the Administration has spent a lot of time, energy, and money on. It is an issue that I know this committee is committed to seeing move forward in an aggressive fashion, and we really look forward to working with you and the rest of the Committee in making nanotechnology and the future of nanotechnology as strong as possible. So I appreciate the opportunity and appreciate the warm welcome and look forward to working with you on this. This is one of the issues that really makes my job worthwhile.

The Administration shares this committee's belief in the importance of federal support for nanotechnology R&D and the coordination of federal research efforts.

Nanotechnology is more than just the study of small things. Nanoscale research is the study of systems that exhibit physical and chemical properties quite different than those found on larger scales.

Carbon is an excellent example. We are familiar with carbon in many forms, from coal to diamonds, but when a sheet of elemental carbon, a single atom thick, is rolled into a tube, it takes on totally unique and unforeseen properties. For example, an incredibly small shift on the scale of a single atom can change the properties of the tube from conducting to semi-conducting. This makes carbon nanotubes ideal candidates for microelectronic materials.

Pushing or pulling on the tube also changes the electrical properties, making carbon nanotubes ideal for sensors. Other materials exhibit similar unexpected properties at the nanoscale. And I think this is really one of the most important points that we have to recognize when we are looking at nanotechnology. We are not just talking about miniaturization. We are talking about entirely new effects that can be seen on the nanoscale that we don't see elsewhere, and I think that is why I think this is such a vibrant area for research.

Nanotechnology is still in a very early stage of development. The role for federal R&D funding is to provide the fundamental research underpinning upon which future nanoscale technologies will be based.

Nanotechnology research is coordinated in the Federal Government through the National Nanotechnology Initiative, NNI. The NNI is an interagency program that captures relevant federal nanotechnology R&D. Currently, ten agencies participate in the program. The NNI is a critical link between high-risk, novel research concepts and new technologies that can be developed by industry. NNI provides funding for fundamental research at colleges and universities and at our national laboratories.

NNI is creating centers of excellence that bring together diverse populations of scientific domains under one academic umbrella. It is also building a network of central, state-of-the-art user facilities that can be accessed by industry as well as academia.

The Administration's commitment to furthering nanotechnology research and development has never been stronger. Support for NNI is evidenced by significant funding increases for this interagency initiative in each of the President's budget proposals. That trend continues this year with a 10 percent increase over last year's request for nanotechnology, bringing the program's total to $849 million in the President's '04 budget request.

Nanotechnology was also highlighted as a priority research area in the '04 budget guidance memo issued last year to the heads of research agencies by Dr. Marburger and Director Daniels. This year, funding for NNI will support a range of activities, including basic research, more focused efforts directed at answering specific sets of questions, so-called "grand challenges," and building research infrastructures and centers and networks of excellence to support nanotechnology research.

NNI funding also supports mission-oriented research within agencies, research at national laboratories, and research at academic institutions, and other research institutes. A portion of the funding is also dedicated to addressing non-technical research problems in a broader context, including societal implications and workforce training issues.

The research agenda for the agencies participating in the NNI is coordinated by the Nanoscale Science and Engineering Technology Subcommittee, otherwise known as NSET, of the National Science and Technology Council. The NSET Subcommittee is made up of NNI agency representatives, OSTP [Office of Science and Technology Policy], and OMB [Office of Management and Budget]. NSET members meet on a monthly basis to measure progress, set priorities, organize workshops, and plan for the coming year.

In order to provide higher visibility for nanotechnology and to elevate coordination and priority setting, OSTP has proposed reformulating the current NSET as an interagency working group and reconstituting the NSET Committee at a higher level of agency representation.

The National Nanotechnology Coordination Office, NNCO, assists NSET in their activities and serves as the secretariat for the NNI program. The NNCO, which is funded by contributions from participating agencies, carries out objectives established by the NSET members, coordinates and publishes information from workshops, and prepares annual reports on the activities of NNI.

In the past, the Director of the NNCO was a part-time position. Recognizing the key contributions made by the NNCO to the success of this multi-agency effort, OSTP is in the process of hiring a full-time director to run the NNCO.

The Administration appreciates the effort of the Chairman and the other Members of this committee to highlight the importance of nanotechnology through H.R. 766. We look forward to continuing to work with you as the bill moves through the legislative process.

Mr. Chairman, the Administration shares your strong belief in the value of an independent external advisory panel to look over NNI. As such, you will be pleased to know that the President's Council of Advisors on Science and Technology, or PCAST, recently looked—took on this responsibility.

PCAST will review the NNI on an ongoing basis and provide the President with recommendations to improve the program. As an initial step at their March 3, 2003 meeting, PCAST agreed to begin this review with an effort that will assist the NSTC in the development of crisp, compelling, and overarching strategic plan and defining specific "grand challenges" to guide the program.

Mr. Chairman, if there is no objection, I would like to ask that the Nanotechnology Study Work Plan, as approved by PCAST, be included as part of the record.

Chairman BOEHLERT. Without objection, so ordered.

[The information referred to appears in Appendix 2: Additional Material for the Record.]

Mr. RUSSELL. And let me—I see that my five minutes are up, so let me quickly summarize the rest. Essentially, there are a few small issues that I know we can work with you and the Committee's staff on this bill, so I look forward to getting started with that. And I am open to questions on this wonderful set of technological challenges that we face.

[The prepared statement of Mr. Russell follows:]

PREPARED STATEMENT OF RICHARD M. RUSSELL

Mr. Chairman and Members of the Committee, thank you for this opportunity to appear before you today to present the Administration's plans for the National Nanotechnology Initiative (NNI) and the Administration's views on H.R. 766, the *Nanotechnology Research and Development Act of 2003*.

The Administration shares this committee's belief in the importance of federal support for nanotechnology R&D and coordination of the research efforts that are funded. In many ways, I am preaching to the choir and vice versa. Our differences are minor and are mostly reflected in the slightly different paths we use to reach our goals.

Nanotechnology is the ability to engineer at atomic, molecular or supramolecular levels in the length scale of approximately 1 to 100 nanometers—about a thousandth of a millionth of a meter. To provide some perspective, this is approximately 1/100,000 the diameter of the average human hair. Nanoscale science and engineering are not just additional steps towards miniaturization. Nanoscale systems exhibit physical and chemical properties quite different from those found at the micro- and macro-scale. Take carbon, for example. We are familiar with carbon in many forms-coal, diamond, etc. But when a sheet of elemental carbon, a single atom thick, is rolled into a tube, this form of carbon takes on totally unique and unforeseen properties. For example, an incredibly small shift—on the length scale of a single atom—changes the properties of the tube from conducting to semiconducting, making carbon nanotubes (CNTs) an ideal candidate for a microelectronic material. Pushing or pulling on the tube also changes the electrical properties, making CNTs ideal candidates for sensors. Other materials exhibit similarly unexpected properties at the nanoscale.

Commercialization of nanotechnology is expected to lead to new products and applications in materials and manufacturing, electronics, medicine and health care, environment, energy, chemicals, biotechnology, agriculture, information technology, transportation, national security, and other areas. Nanotechnology will likely have a broad and fundamental impact on many sectors of the economy.

New nanotechnology innovations are being made on a regular basis. Just this week it was announced that researchers at the University of Michigan are using nanoprobes to image chemical activity inside living cells. The 20 nm diameter nanoprobes are small enough to fit inside a cell without affecting the cell's normal functions. Sensor molecules inside the nanoprobes emit light when select ions bind to the sensor. This information will help scientists unravel the complicated metabolic processes in living cells.

Scientists from Rice University have attached amino groups to single-walled carbon nanotubes. These amino groups can be used to bond the nanotubes to other polymers, or to form a 'fabric' of nanotubes. This is a crucial step towards manufacturing a new generation of materials that are stronger, lighter, and potentially self-sensing.

Nanotechnology is still at a very early stage of development. The role of federal R&D funding in this area is to provide the fundamental research underpinnings upon which future nanoscale technologies will be based. Numerous challenges must be addressed before the envisioned promise of these technologies can be reached. Overcoming these challenges will require fundamental research to improve our basic understanding in several fields of science and engineering, as well as novel approaches toward synthesis, analysis and manufacturing of nanotechnology-based products. We face a very real challenge developing new instruments that enable accurate, nanoscale-level measurement and manipulation.

These challenges also present opportunities:

- the opportunity to engage in interdisciplinary work, between agencies, that bridge traditional delineations between disciplines;
- the opportunity to reinvigorate chemistry and physics, bringing these disciplines into the mechanistic length scales that underlie the unique properties of nanoscale objects and, not coincidentally, the functioning of biological systems; and
- opportunities to develop new engineering systems and instrumentation that can be used to manipulate and measure properties of nanoscale structures, including biological systems that were, just a short time ago, beyond our means.

As such, nanotechnology is creating a natural domain of interdisciplinary interactions. It is igniting a review of college curricula and creating new educational paradigms. This administration is encouraging these activities through the existing structure of the NNI.

Because of the complexity, cost, and high risk associated with nanotechnology research, the private sector is often unable to assure itself of short-to-medium term returns on R&D investments in this field. Consequently, industry is not likely to undertake the basic research investments necessary to overcome the technical barriers that currently exist. The NNI is a critical link between high-risk, novel research concepts and new technologies that can be developed by industry. This is accomplished by providing funding for fundamental research at colleges and universities as well as at our National laboratories, by creating centers of excellence that bring together diverse populations of scientific domains under one academic umbrella, and by building a network of central user facilities that enable access, by industry as well as academia, to state-of-the-art nanoscale fabrication and analysis facilities. Funding programs are structured to overcome barriers, in both knowledge and facilities, so that America's industries will prosper from our investment in nanotechnology.

The Administration's commitment to furthering nanotechnology research and development has never been stronger. Support for the NNI is evidenced by significant funding increases for this interagency initiative in each of President Bush's proposed budgets. That trend continues this year, with a ten percent increase over last year's request for nanotechnology (to $849 million) in the President's FY 2004 budget. In addition, last year the Director of the Office of Management and Budget and OSTP Director Marburger issued a memo to the heads of executive departments and agencies identifying nanoscale science and technology as one of six interagency research and development priorities.

The National Nanotechnology Initiative

Federal funding for Nanotechnology is coordinated through the NNI. The NNI is an interagency program that encompasses relevant nanotechnology R&D among the participating federal agencies. The federal agencies currently performing nanotechnology research coordinated through the NNI are:

- National Science Foundation
- Department of Defense;
- Department of Energy;
- National Institutes of Health;
- Department of Commerce;
- National Aeronautics and Space Administration;
- Department of Agriculture;
- Environmental Protection Agency;
- Department of Homeland Security; and
- Department of Justice.

Funding for the NNI provides support for a range of activities, which include: basic research, focused efforts directed at answering specific sets of questions of high significance—so-called "Grand Challenges," and building research infrastructure (instrumentation, equipment, facilities) and centers and networks of excellence (larger, centralized facilities intended to provide sites for cooperative and collaborative efforts among distributed networks and groups of researchers at multiple affiliated institutions). Depending on the agency, funding supports mission-oriented research within agencies, research at national laboratories, and research at academic institutions and other research institutes. A portion of the funding is also dedicated to addressing non-technical research problems in a broader context, including societal implications and workforce and training issues.

The research agenda for the ten agencies currently participating in the NNI is coordinated by the Nanoscale Science and Engineering Technology (NSET) Subcommittee of the National Science and Technology Council (NSTC). As you know, the NSTC is a cabinet-level interagency body through which interagency science and technology issues are discussed and coordinated. The NSET subcommittee is staffed by representatives of the participating agencies, OSTP, and OMB. It also includes other federal agencies that do not fund nanotechnology R&D but nevertheless have an interest in these technologies—agencies such as the Food and Drug Administration and the Department of the Treasury. NSET members meet on a monthly basis to measure progress, set priorities, organize workshops, and plan for the coming year.

The current membership of the NSET reflects its origins as an informal working group organized and populated by program officers and researchers within agencies performing or funding nanotechnology R&D. As such, the agency representatives to the NSET have extensive knowledge of and experience with nanoscale R&D. This expertise has been of critical importance to the success of the initiative, providing a necessary link to nanotechnology researchers in industry and academia. However, recognizing that the NNI will increasingly confront policy issues central to its continued success, OSTP has proposed a restructuring of the interagency nanotechnology effort within the NSTC. Under the proposed structure, which was approved by the NSTC's Committee on Technology—to which the current NSET reports—late last year, the current NSET would be reformulated as an interagency working group. In turn, the subcommittee would be reconstituted with membership comprising of higher level agency officials. This new management structure will enable enhanced coordination and priority setting.

The National Nanotechnology Coordination Office (NNCO) assists NSET-participating agencies in their activities, and serves as the secretariat for the NNI. The NNCO, which is funded by contributions from the participating agencies, carries out the objectives established by the NSET members, coordinates and publishes information from workshops sponsored by the NNI, and prepares annual reports on the activities of the NNI. The NNCO also contracts for program reviews to provide feedback on the NNI. It has an annual budget of approximately $1 million. In the past, the Director of the NNCO was a part-time position. Recognizing the key contribution made by the NNCO to the success of a multi-agency effort of the complexity of the NNI, OSTP is in the process of hiring a *full-time* director to run the NNCO.

The Nanotechnology Research and Development Act of 2003

The Administration appreciates the efforts of the Chairman and other members of this committee and others to highlight the importance of nanotechnology science—and to address certain issues through H.R. 766, the *Nanotechnology Research and Development Act of 2003.* We look forward to working with you as the bill moves through the process as our staffs have already begun to discuss some of the key provisions.

In the summer of 2002, the National Research Council (NRC) released the results of their study of the NNI in a report entitled *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative.* The report highlighted the strong leadership of the NNI, praised the degree of interagency collaboration, and lauded the early successes of the research programs.

The report also provided a number of recommendations to further strengthen the NNI. One such recommendation was to create an independent Nanoscience and Nanotechnology Advisory Board to provide advice to the NSET on policy, strategy, management, and other issues. The NRC proposed that the board be composed of "leaders from industry and academia with scientific, technical, social science, or research management credentials." H.R. 766, incorporates this recommendation.

The Administration shares a strong belief in the value of independent external advice regarding the NNI. As such, you will be pleased to know that the President's Council of Advisors on Science and Technology (PCAST), whose members encompass the range of experience and backgrounds articulated by the NRC in their recommendation, recently took on this responsibility. PCAST will review the NNI on an ongoing basis and provide the President with recommendations to improve the program. As an initial step, at their March 3rd 2003 meeting, PCAST agreed to begin this review with an effort that will assist the NSTC in developing a crisp, compelling, overarching strategic plan, and defining specific "Grand Challenges" to guide the program.

PCAST co-chair Floyd Kvamme will lead this effort, which will be undertaken at the full committee level, although separate task forces will form to address particular sets of issues. PCAST will accomplish its work in concert with the NSTC and the resident expertise within the agencies represented on it. In addition, in accordance with a suggestion from this committee, PCAST plans to tap leading researchers in nanotechnology to provide PCAST with technical expertise on the state-of-the-art in nanotechnology—forming a "technical task force" that will augment PCAST's expertise.

PCAST's role in reviewing the NNI fulfills the NRC recommendation to form an external advisory committee. As such, the requirement in Section 5 of H.R. 766, the *Nanotechnology Research and Development Act of 2003,* which mandates the creation of a presidential nanotechnology advisory panel, would duplicate PCAST's efforts and unnecessarily draw resources from the scientific goals of the program. The Administration believes that this provision needs to be stricken from the bill. OSTP will work closely with PCAST to ensure that our mutual goal is met—that is, ensuring that the Nation's investment in nanotechnology research and development realizes its full potential.

The Administration's goals and plans for the NNI program, of which I have provided a brief description today, capture almost every element of the legislation we are discussing. The NNI is a relatively new program, and represents a field that is, in many ways, also quite young. Flexibility—to enable us to adapt the program over time and, for example, on the basis of recommendations from PCAST—will be key to the program's continued success. Of particular importance is the flexibility to perform studies and allocate funds as needed to address new research opportunities and emerging priorities. We also have some concerns with some of the specifics in the bill, such as the exact nature of the triennial review by the National Research Council, some of the particulars regarding the National Nanotechnology Research and Development program, and technical matters to ensure that the interagency committee required by the legislation can function effectively without advisory committee status. I appreciate the Committee's willingness to work with us to address these issues, and look forward to continuing to do so.

Mr. Chairman and Members of the Committee, I hope that this overview has conveyed this Administration's commitment to nanotechnology and the NNI. OSTP is actively working with the NNCO to implement many of the NRC recommendations—recommendations that are reflected in the legislation under consideration today. We believe that our efforts will improve the program substantially and will enhance our nation's investment in nanotechnology.

BIOGRAPHY FOR RICHARD M. RUSSELL

Richard M. Russell, Associate Director with the Office of Science and Technology Policy in the Executive Office of the President, was confirmed by the U.S. Senate in August 2002. As Associate Director he serves as OSTP Director Dr. John Marburger's deputy for technology. Prior to being chosen by the President for his current position, Russell served as OSTP's Chief of Staff. Russell also worked on the Presidential Transition Teams for the Department of Commerce, National Science Foundation and OSTP.

From 1995–2001, Russell worked for the House of Representatives Committee on Science and has a background in technology and environmental policy. The Committee has oversight responsibilities for all federal civilian research and development and authorizing responsibilities for most civilian science programs.

During his time on the Committee, Russell helped draft a wide variety of legislation, including efforts to expand and improve coordination of federal information technology research, improve computer security, and authorize agencies such as the National Institute of Standards and Technology. He also was charged with overseeing the Committee's technology policy, coordinating its oversight agenda, and helping manage the Committee's majority staff.

Russell began his tenure on the Committee as a professional staff member for the Subcommittee on Energy and Environment. He was promoted to Staff Director for the Subcommittee on Technology and finally to Deputy Chief of Staff for the full Science Committee.

Prior to joining the Science Committee, Russell was a professional staff member of the Merchant Marine and Fisheries Subcommittee on Oceanography. The Oceanography Subcommittee had jurisdiction over ocean and environmental research and management.

He also directed the Washington office of the Association of California Water Agencies (ACWA). ACWA is a non-profit association representing 400 public water agencies responsible for delivering 90 percent of California's domestic and agricultural water.

Russell began his career in Washington, D.C. as a research fellow for the Conservation Foundation. He also worked for Congressman Curt Weldon (R–Penn.) and Senator John Seymour (R–Calif.). In 1988 he earned a Bachelor's degree in biology from Yale University.

Chairman BOEHLERT. Thank you very much. And you are right: there are just small differences, and we will work them out. Dr. Theis.

STATEMENT OF DR. THOMAS N. THEIS, DIRECTOR OF PHYSICAL SCIENCES, IBM RESEARCH DIVISION, THOMAS J. WATSON RESEARCH CENTER

Dr. THEIS. Good morning, Chairman Boehlert, Ranking Member Hall, and Members of the Science Committee. I am the Director of Physical Sciences for the IBM Corporation that includes eight main [research] sites around the world. And I have responsibility for IBM's research in the physical sciences. I was also a member of the National Academy of Sciences review of the National Nanotechnology Initiative and participated in the drafting of their report, "Small Wonders, Endless Frontiers."

Thank you for inviting me here today to discuss nanotechnology and H.R. 766. IBM supports increasing nanotechnology coordination and expertise within the Federal Government. We support the vision of adequate funding for nanotechnology research. In particular, we believe that there is a critical need for the Federal Government to support long-term research and to seek the kind of expertise in the scientific community that would guide this research strategy and funding decisions. We think that the *Nanotechnology Research and Development Act of 2003* will be a great help in achieving those objectives.

I am here to say that nanotechnology is a key to the future of information technology. It is the future of information technology hardware. History teaches us that each time we have improved our ability to structure matter, that it has resulted in enormous improvements for the status and condition of humanity.

IBM is pursuing a research effort, a robust research effort in nanotechnology, because that research is resulting right now in better information technology products. The computer that you have in your office contains devices, transistors, the hard disk drive contains a read head—it contains devices that are structured at the atomic scale and devices in which many new dimensions are conveniently measured in nanometers. This is—information technology hardware already involves nanotechnology.

Without further advances in nanotechnology, however, the improvements in speed, cost, energy efficiency of that hardware that we have come—that we have become accustomed to, must slow. And that means that the associated productivity gains and the further development of new applications, which come with cheaper and cheaper hardware, that must also slow.

As Mr. Russell indicated, nanotechnology allows us to characterize and structure new materials with precision at the level of atoms. And you know, this—there are—this has a wide range of impacts across the entire society. One of the simple things is, and he has already alluded to it, carbon nanotubes and other nanostructure materials, hold the promise of being stronger and lighter than conventional materials. And we can all imagine the benefits of having lighter cars and lighter airplanes and maybe even baggage that would survive airport handling.

But the point I want to make here is that strength is only one materials property, and designing materials with atomic precision allows control of all properties of materials, unprecedented control: electronic, magnetic, optical, thermal, any property that we want to enhance. And the reason this ties into information technology is that information technology is not, as Mr. Russell said, just about miniaturization. It is about new invention, new materials, new devices, new structures that are used to process, communicate, and store information. So nanotechnology is at the basis of further—is at the core of any further miniaturization that we will accomplish. And miniaturization has translated into faster, cheaper, more efficient.

The relentless advance of information processing and storage technologies has provided consumers with a wide range of products that do more every year for less: computers, of course, but cameras, cell phones, entertainment systems, and your automobile, which has over 50 microprocessors in it, I believe you would agree, runs better and is more reliable than the one you might have purchased 10 or 15 years ago. The impact on our society has been enormous.

It is not possible to say exactly what entirely new products and services would be supported by these continued advances in information technology hardware. Right now, I can buy a little memory card that goes in a camera or goes in my computer, and it can store many books, hundreds of pictures, and quite a bit of audio information. With the advances that we foresee in nanotechnology, I should be able to buy, and I expect to be able to buy, a card that would store all of the audio that I would ever want to record in my lifetime, all of the pictures I would want to take in my lifetime, and probably anything of interest and any text that I have ever read. I don't know exactly how we would take advantage of that, but I know my children are very, very creative at finding new uses of this technology. And I strongly suspect that they are going to figure out new things to do with it that I can't imagine.

In 2002, the National Academy of Sciences did publish the review of the National Nanotechnology Initiative titled "Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative." I helped write it, and on that basis, I would like to note a few concerns and recommendations of the panel on which I serve.

First, the panel made a series of recommendations toward a shared goal to increase the existing interagency coordination and ensure long-term stability of the federal effort. Nanotechnology is inherently interdisciplinary. The scientific challenges and ultimate benefits cross a variety of agencies. It is very important that we ensure the maximum coordination. The Review Board recommendations on advisory committees, strategic plan setting, long-term funding, multi-agency investments, special funding for interagency collaboration, interdisciplinary culture, all of these recommendations were motivated by this desire to contribute to the coordination and the long-term stability necessary to return the maximum investments from this very considerable investment that the Federal Government is making.

Second, the panel noted the need for expertise to identify and champion research opportunities that do not conveniently fit within any single agency's mission. That is also related to the issue of coordination. The panel recommended the establishment of an independent advisory board to provide advice to the Nanoscale Science Engineering and Technology, the existing NSET Committee. In my view, the exact reporting structure is not important. What we want to emphasize is the need to pull in expertise in nanotechnology to whatever advisory board or committee is set up.

Third, the panel recommended that the societal implications of nanoscale science and technology become an integrated—an integral and vital component of the National Nanotechnology Initiative. The broad capabilities of future information technology are easy to forecast, but their implications for society are still very difficult to discern. And yet, society will choose how any given technology is used in the end. And in a democratic society, the basis of that choice should be public discourse about not only the advantages and value of the technology, but also the possible dislocations and problems that may be associated with it. So I urge the Committee to anticipate that there will be societal implications, not every one of them necessarily good and comfortable, for any rapidly advancing technology. We see this across the board. It is not a particular attribute of nanotechnology, so we need to accompany our research effort with efforts to anticipate and manage those implications. And papers that will be published on possible implications will lead to the kind of public discourse that I champion.

Finally, the panel recommended that the National Nanotechnology Initiative support long-term funding in nanoscale science and technology so that that research can achieve its potential and promise. And it is really over—hard to overstate the importance of federal funding for basic research. The simple fact is IBM finds that it is very valuable to participate not just in the development of products, but also in the basic research enterprise. However, that basic research enterprise is so broad and so vast, there are so many opportunities to explore, that no company, not even a company the size of IBM, not even the entire information technology industry, is capable of exploring all of the possibilities.

So in closing, I would like to thank the Committee for the invitation to testify here today. IBM believes nanotechnology has a big place in the future and in the future of society. We urge the Committee to pass legislation—this legislation that will assist in the coordination of the research.

[The prepared statement of Dr. Theis follows:]

Prepared Statement of Thomas N. Theis

Good morning, Chairman Boehlert, Ranking Member Hall, Members of the Science Committee. My name is Thomas Theis and I am the Director of Physical Sciences for the IBM Corporation. The IBM Research Division totals over 3000 people in 8 main sites around the world. I have responsibility for IBM's research in the physical sciences. I also was a member of the National Academy of Sciences review of the National Nanotechnology Initiative and participated in the drafting of their report, *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative.*

Thank you for inviting me here today to discuss nanotechnology and H.R. 766, *Nanotechnology Research and Development Act of 2003*.

IBM supports increasing nanotechnology coordination and expertise within the Federal Government, and providing adequate funding for nanotechnology research. In particular, we believe that there is a critical need for the Federal Government to seek additional external nanotechnology expertise and input to guide its research strategy and funding decisions. The *Nanotechnology Research and Development Act of 2003* will assist in several of these areas.

Nanotechnology is key to the future of information technology. History teaches us that each time man has extended his ability to structure matter, whether it be to shape an ax from rock or a microprocessor from silicon, the benefits are extraordinary and enduring. Nanotech is the next frontier. Research in nanotechnology is driving breakthroughs in *materials* and all the devices that can be built with new and better materials.

IBM is pursuing a robust research effort in nanotechnology because that research is resulting in better information technology products. (The computer in your office already contains devices with some dimensions best measured in nanometers.) I encourage this committee to similarly support nanotechnology and to extend the benefits of nanotechnology across society to a range of industries and endeavors.

Without further advances in nanotechnology, improvements in the speed, cost, and energy efficiency of IT hardware must slow. In turn, the economic growth of the IT industry must slow—along with the associated productivity gains, and the further development of new applications of information technology.

Nanotechnology allows us to characterize and structure new materials with precision at the level of atoms, leading to materials as superior to existing materials as steel was to iron, and iron was to bronze in earlier eras. Nanostructured materials hold the promise of being stronger and lighter than conventional materials. This would have innumerable beneficial impacts from more fuel efficient and safer airplanes and cars, to luggage that can withstand baggage handling at airports! But strength is just one property. Designing materials with atomic precision allows unprecedented control of their electronic, magnetic, optical, and thermal properties—in fact, any property that we want to enhance.

Raw materials constitute an enormous sector of our economy, but the popular imagination is captured by devices—machines that multiply the abilities of body and mind. The history of information technology can be read as a history of miniaturization—of continuous invention of ever smaller versions of the devices that process, store, and communicate information. The story of information processing goes back to mechanical systems such as those used to tabulate the U.S. census a century ago. These were replaced by electromechanical calculators based on relays. Vacuum tubes were used to build the first stored-program computers a half century ago. The transistor quickly replaced the vacuum tube, and in a historical eye-blink, the discrete transistor was displaced by the monolithic silicon integrated circuit. A similar story of new devices and ever-advancing miniaturization can be told for information storage. Through the history of information technology, smaller has consistently translated into faster, cheaper, and more power efficient, supporting the ongoing explosion of new applications of information technology and the growth of the entire industry.

This relentless advance of information processing and storage technologies has provided consumers with a wide range of products that do more every year for less—computers of course, but also cameras, cell phones, entertainment systems, and automobiles that are better in every way than those of ten years ago. The impact on our society, economy and security has been enormous. However, scientists and engineers believe that we will soon reach the practical limit to miniaturization of devices that operate with today's materials and principles. At the same time, we see no fundamental laws preventing the processing and storage of information by new devices operating at the atomic scale. To prepare for this future, IBM's Research Division has been actively pursuing research on new nanostructured materials, nanoscale devices, and the processes to fabricate these materials and devices.

The nano-devices being explored in laboratories around the world do indeed suggest that we still have a way to go on the road to Lilliput. Experimental silicon transistors with a critical dimension, the channel length, as small as six nanometers were fabricated last year. Molecular devices that do away with silicon are being explored for information storage and processing. These may not be ultimately much smaller that the smallest possible silicon transistors, but they may be amenable to fabrication by new chemical-synthetic processes that will dramatically reduce the cost of manufacture of complex IT systems.

It is not possible to say exactly what entirely new products and services will be supported by these continued advances in IT hardware. Right now I can buy a tiny memory card that can hold the text of many books, or hundreds of pictures. With continued advances in nanotechnology, I expect to someday buy a memory card that can hold an audio recording of everything of interest that I have ever heard, the text of everything I have ever read, and all the pictures I have taken in a lifetime. My children will find new and surprising uses for all that information.

Although the economy, particularly the information technology sector, is currently in the doldrums, make no mistake. The rapid pace of technology development is accelerating worldwide. Engineering teams, striving for a competitive edge, are taking greater risks and exploring a bolder range of options. Scientific discoveries that would have languished in the laboratory in years past are being pulled into the product development stream with unprecedented speed. Our country continues to lead the world in information technology, but maintaining this leadership requires continued research investments, particularly in the basic research that feeds this pipeline of innovation. If key scientific advances are made and first exploited outside the U.S., growth will move off-shore.

In 2002, the National Academy of Sciences published the results of a review of the National Nanotechnology Initiative titled, *Small Wonders, Endless Frontiers: A review of the National Nanotechnology Initiative.* I would like to note a few of the concerns and recommendations of the Panel.

First, the Panel made a series of recommendations toward a shared goal—to increase the existing interagency coordination and ensure long-term stability of the federal nanotechnology effort. Nanotechnology is inherently interdisciplinary. The scientific challenges and ultimate benefits cross a variety of agencies, funding programs, and constituencies. Yet, in the absence of coordination, research decisions will be formed primarily from the perspective of a single agency or discipline. In the absence of coordination, an agency's nanotechnology strategy is unlikely to be broad in scope or bold in vision. The Review Board recommendations (on advisory committees, strategic plan setting, long-term funding, multi-agency investments, special funding for interagency collaboration, interdisciplinary culture, etc.) each can contribute to the coordination and stability necessary to return the maximum benefits from nanotechnology research.

Second, the Panel noted the need for expertise to "identify and champion research opportunities that do not conveniently fit within any single agency's mission." To this end, the Panel recommended that the Office of Science and Technology Policy establish an independent advisory board to provide advice to the multi-agency Nanoscale Science, Engineering and Technology (NSET) committee. In my view, the exact reporting structure and composition of this board are not important, as long as the advisory board seeks the advice from "leaders from industry and academia with scientific, technical, social science, or research management credentials." These leaders should have appropriate credentials in the field of nanotechnology. It would be desirable to have some of this expertise reside within the standing membership of the advisory board.

Third, the Panel recommended "that the societal implications of nanoscale science and technology become an integral and vital component of the National Nanotechnology Initiative." To grasp some implications of a mature, imagine a world where information technology is truly ubiquitous and dirt cheap, where even trivial human artifacts contain extraordinary complexity and therefore extraordinary ability to store, process and communicate information. These broad capabilities of future information technology are easy to forecast, but their implications for society are still difficult to discern. That is why we should start to study these issues now. We will not be able to anticipate every societal implication, but the rational study of possible implications, and the publication of research results should enable a healthy public discourse. In the final analysis, society must decide on the appropriate applications of any technology. In a democratic society, such decisions should be made under the light of public discourse I urge the Committee to anticipate the societal implications of a rapidly advancing technology, and accompany our research effort with efforts to anticipate and manage those implications.

Finally, the Panel recommended that the National Nanotechnology Initiative "support long-term funding in nanoscale science and technology so that they can achieve their potential and promise." They further noted that "Truly revolutionary ideas will need sustained funding to achieve results and produce important breakthroughs." It is hard to overstate the importance of federal funding for basic research. Each of the critical breakthroughs in nanotechnology has been based on years of sustained federal funding for researchers. The breakthroughs funded by the Federal Government are the foundation that enables subsequent efforts by the business sector to translate that research into products on the marketplace. Without the Federal Government underwriting the long-term funding, there will be fewer breakthroughs to translate into products and economic prosperity. Simply put, the research opportunities are enormous and there is no way that IBM or the even the entire IT industry can do the job on its own. Furthermore, federally funded university research is the training ground for the scientists and engineers who work in industry and translate basic research results into products.

In closing, I would like to thank the Committee for the invitation to testify here today. IBM believes that nanotechnology has a big place in its future and in the future of society. We urge the Committee to pass legislation that will assist in the coordination of nanotechnology research, incorporation of additional nanotechnology expertise, and long-term and stable funding of nanotechnology.

BIOGRAPHY FOR THOMAS N. THEIS

Dr. Thomas Theis received a B.S. degree in physics from Rensselaer Polytechnic Institute in 1972, and M.S. and Ph.D. degrees from Brown University in 1974 and 1978, respectively. A portion of his Ph.D. research was done at the Technical University of Munich, where he completed a postdoctoral year before joining IBM Research in 1979.

Dr. Theis joined the Department of Semiconductor Science and Technology at the IBM Watson Research Center to study electronic properties of two-dimensional systems. He also collaborated in research on surface enhanced Raman scattering, light emission from tunnel junctions, and conduction in silicon dioxide. The latter work helped to lay the basis for the present understanding of conduction in wide bandgap materials. In 1982 he became manager of a group studying growth and properties of III–V semiconductors. He published extensively on the DX-center, a donor-related defect which limits the digital performance of some III–V transistors.

In 1989 he was named Senior Manager, Semiconductor Physics and Devices. In 1993, he was named Senior Manager, Silicon Science and Technology, where he was responsible for exploratory materials and process integration work bridging between Research and the IBM Microelectronics Division. While in this position, he was the principal author of IBM's successful contract proposal for the DARPA Low Power Electronics Program. This fifteen million dollar, three year, industry-university-SEMATECH joint program significantly advanced silicon-on-insulator materials, devices, and design techniques for low-power, high-performance microelectronics. Also while in this position, Dr. Theis coordinated the transfer of copper interconnection technology from IBM Research to the IBM Microelectronics Division. The replacement of aluminum chip wiring by copper was an industry first, the biggest change in chip wiring technology in thirty years, and involved close collaboration between research, product development, and manufacturing organizations. Dr. Theis assumed his current position, Director, Physical Sciences, in February 1998.

Dr. Theis is a member of the IEEE, the Materials Research Society, and a Fellow of the American Physical Society and currently serves on advisory boards for the American Institute of Physics Corporate Associates, the American Physical Society's Physics Policy Committee, the National Nanofabrication Users network, and the National Research Council's Board on Physics and Astronomy. He served as a Member of the Committee for the Review of the National Nanotechnology Initiative, sponsored by the National Research Council. He has authored or co-authored over 60 scientific and technical publications.

IBM

Thomas J. Watson Research Center
P.O. Box 218
Yorktown, NY 10598

March 14, 2003

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, D.C. 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the U.S. House of Representatives Committee on Science, on March 19th for the hearing entitled *The Nanotechnology Research and Development Act of 2003*. In accordance with the Rules Governing Testimony, this letter serves as formal notice of the Federal funding I currently receive in support of my research.

> I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.
>
> In 2003, approximately 3% of the Physical Sciences Department that I manage, will be funded by various governmental agencies, including DARPA, ARO, NSA, NRO, etc..

Sincerely,

Thomas N. Theis
Director, Physical Sciences

Chairman BOEHLERT. Thank you very much, Dr. Theis. Dr. Roberto.

STATEMENT OF DR. JAMES B. ROBERTO, ASSOCIATE LABORATORY DIRECTOR FOR PHYSICAL SCIENCES, OAK RIDGE NATIONAL LABORATORY

Dr. ROBERTO. Mr. Chairman and Members of the Committee, I am the Associate Laboratory Director for Physical Sciences at Oak Ridge National Laboratory, which is a Department of Energy multi-program lab managed by UT-Battelle, a partnership of the University of Tennessee and Battelle Memorial Institute. It is an honor to appear before the Committee in support of H.R. 766.

At ORNL, I oversee the physical sciences, which include nanoscale science and technology and the development of ORNL's Center for Nanophase Materials Sciences. This is one of DOE's five planned Nanoscale Science Research Centers. The CNMS is a state-of-the-art user facility for nanoscale science and technology. It is located next to the Spallation Neutron Source and builds upon ORNL's strengths in neutron scattering, materials and chemical sciences, and computational science.

I would like to emphasize that the excitement surrounding nanoscale science and technology is real. The recent Nanoscale Science Research Centers Workshop, which was held in Washington, DC, attracted more than 400 scientists from 94 universities, 40 industries, and 15 federal laboratories. It was a pleasure to have Mrs. Biggert join us and give the keynote address at that workshop. In all, more than 2,000 researchers have attended regional and national workshops for the DOE Nanoscale Science Research Centers, excuse me.

Nanoscale science and technology crosscuts the traditional disciplines of materials science, chemistry, physics, biology, computational science, and engineering. It occupies the frontiers of this field, and many of the most important problems in science and technology. The solutions to these problems offer a line of sight to technical advances of enormous impact in materials, information technology, healthcare, and national security. Many see nanotechnology as the basis of the next industrial revolution.

John Marburger describes this revolution as one in which "the notion that everything is made of atoms has a real operational significance". What this means is that we are learning how to use atoms and molecules as building blocks for larger assemblies with more—with new and astounding properties. This has been made possible by extraordinary tools, including synchrotron light sources, neutron sources, electron microscopes, scanning probe microscopes, and high-performance computers. These tools have enabled the atomic-scale characterization, manipulation, and simulation of complex assemblies of atoms and molecules. This is a "bottoms up" view of the world, Mother Nature's world, that embraces breathtaking complexity and seemingly endless possibilities.

So we are at a crossroads in the physical sciences. The boundaries between scientific disciplines are disappearing at the nanoscale. The study of simple, isolated systems is giving way to complex assemblies. We are moving from atomic-scale characterization to atomic-scale control, from miniaturization to self-assembly.

This paradigm shift for the physical sciences rivals other revolutions in science, such as the revolution in biology following the discovery of the molecular structure of DNA.

It is this paradigm shift and the technological impact that will result that underpins H.R. 766. This Act is an important part of the strategy to strengthen the physical sciences in the United States. Other components include the Energy Research, Development, and Commercial Application Act and the Energy Science Research Investment Act. The traceability of advances in the physical sciences to economic growth, new medical technology, energy independence, and enhanced national security are direct. As you know, the President's Council of Advisors on Science and Technology has given high priority to strengthening the physical sciences, including nanoscale science and technology. This priority is reflected in the budget request for the National Nanotechnology Initiative, which increases to 849 million in fiscal year 2004, including 197 for DOE.

Thank you, Mr. Chairman, for your commitment to science and to nanotechnology research and development. H.R. 766 is good for science, and it is good for America. I appreciate the Committee's leadership in this area, and I firmly believe that the future of our nation depends on continued leadership at the scientific and technological frontier, a frontier that includes nanoscale science and technology. Thank you.

[The prepared statement of Dr. Roberto follows:]

PREPARED STATEMENT OF JAMES B. ROBERTO

Mr. Chairman and Members of the Committee:

My name is James Roberto, and I am the Associate Laboratory Director for Physical Sciences at Oak Ridge National Laboratory (ORNL). ORNL is a Department of Energy multi-program laboratory managed by UT–Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute. It is an honor to appear before the Committee in support of the *Nanotechnology Research and Development Act of 2003*.

In my role at ORNL I oversee the physical sciences, including nanoscale science and technology. This includes the development of ORNL's Center for Nanophase Materials Sciences (CNMS), one of DOE's five planned Nanoscale Science Research Centers. The CNMS is a state-of-the-art user facility for nanoscale science and technology. It builds upon ORNL's strengths in neutron scattering (for atomic-scale structure and dynamics), materials and chemical sciences (for synthesis and characterization), and computational science (for simulation and modeling).

The excitement surrounding nanoscale science and technology is real. The recent DOE Nanoscale Science Research Centers Workshop and National Users Meeting in Washington, D.C., attracted more than 400 scientists and engineers from 94 universities, 40 industries, and 15 federal laboratories. More than 2000 researchers have attended regional and national workshops for the DOE Nanoscale Science Research Centers. It is difficult to find a month without a national or international meeting in this field.

Nanoscale science and technology crosscuts the traditional disciplines of materials science, chemistry, physics, biology, computational science, and engineering. It occupies the frontiers of these fields and includes some of the most challenging research problems. The solutions to these problems offer a line-of-sight to technical advances of enormous potential in materials, information technology, health care, and national security. Many see nanotechnology as the basis of the next industrial revolution.

John Marburger, Director of the Office of Science and Technology Policy, describes this revolution as one in which "the notion that everything is made of atoms has a real operational significance." This has been made possible by extraordinary tools such as synchrotron light sources, neutron sources, electron microscopes, scanning probe microscopes, and high-performance computers. These tools have enabled the atomic-scale characterization, manipulation, and simulation of complex assemblies of atoms and molecules. This is a "bottoms up" view of the physical world—Mother Nature's view—that embraces breathtaking complexity and seemingly endless possibilities.

So we are at a crossroads in the physical sciences. The boundaries between scientific disciplines are disappearing at the nanoscale. The study of simple, isolated systems is giving way to complex assemblies. We are moving from atomic-scale characterization to atomic-scale control, from miniaturization to self-assembly. Change is opportunity, and this paradigm shift for the physical sciences rivals other revolutions in science, such as the revolution in biology following the discovery of the molecular structure of DNA.

It is this opportunity, and the technological impact that will result, that underpin the *Nanotechnology Research and Development Act of 2003.* This Act is an important element of the strategy to strengthen the physical sciences in the United States. Other components include the *Energy Research, Development, Demonstration, and Commercial Application Act of 2003* (H.R. 238) and the *Energy and Science Research Investment Act of 2003* (H.R. 34). The traceability of advances in the physical sciences to economic growth, new medical technology, energy independence, and enhanced national security is strong. As you know, the President's Council of Advisors on Science and Technology (PCAST) has given high priority to strengthening the physical sciences, including nanoscale science and technology. This priority is reflected in the budget request for the National Nanotechnology Initiative, which increases to $849M in FY 2004, including $197M for DOE.

I offer the following responses to the specific questions posed by the Committee:

Question 1. Through a workshop and other planning exercises, Oak Ridge National Laboratory (ORNL) has developed a roadmap for its Nanoscale Science, Engineering and Technology research programs, establishing criteria by which staff research proposals are evaluated. ORNL's planning and management activities are analogous to the tasks assigned to the Interagency Committee established in section 3(c) of H.R. 766. In your view, would it be worthwhile to develop a national technology roadmap to guide federal nanotechnology research? To your knowledge, is such an effort underway now?

Answer 1. Through two widely-attended workshops (there has been a lot of interest in these workshops), ORNL developed with the scientific community a set of proposed research focus areas, equipment priorities, and access policies for the CNMS. This input is reflected in the design and research capabilities of the CNMS. This was a very productive exercise, embodying the elements of identifying research grand challenges, improving community cooperation, and enabling interdisciplinary planning that are addressed in the National Academy of Sciences recommendations on the National Nanotechnology Initiative and the provisions of H.R. 766.

A similar roadmapping exercise to guide federal nanotechnology research would be useful. Nanotechnology is here and growing, and the time between discovery and application is shrinking. A coordinated federal program could more effectively leverage the capabilities of the various agencies, establish overarching investment strategies, and inform the research community of technological challenges and needs. One must be careful here. We do not know all the answers. The roadmap will provide focus and accelerate progress in identified directions, but a healthy component of fundamental research must be maintained to underpin the overall nanotechnology effort and provide a broader avenue for innovation.

There are many planning activities under way in nanotechnology at agency, interagency, institutional, professional society, and industry-specific levels. I am not aware of any comprehensive federal nanotechnology roadmapping effort.

Question 2. Likewise, ORNL's Center for Nanophase Materials Sciences, currently under construction, could be a model for the interdisciplinary research centers and advanced technology user facilities authorized in section 3(b). How will the Center foster effective collaboration across academic disciplines, and among government, university, and industry researchers?

Answer 2. The Center for Nanophase Materials Sciences is organized around research focus areas that represent grand challenges in nanoscale science and technology. These focus areas are inherently interdisciplinary and will naturally attract researchers from many disciplines. In addition, an active workshop program will bring together scientists and engineers from a variety of disciplines to assess opportunities in emerging areas of nanoscale science and technology. These workshops, which will be broadly advertised and open, will precipitate the assembly of interdisciplinary teams that will develop user proposals. Finally, the Center will be staffed with scientific and technical user support staff that span materials science, chemistry, physics, biology, computational science, and engineering. These staff and the users will work together in laboratory spaces designed for interdisciplinary research.

Question 3. Some individuals and groups have suggested that nanotechnology developments may raise societal and ethical concerns. Is any part of ORNL's activity devoted to addressing such concerns?

Answer 3. There are legitimate societal and ethical concerns related to technological advances including nanoscale science and technology. While these concerns have been exaggerated in the popular press, all technical progress includes some risk. Public awareness and involvement are essential to dealing with this risk. I am pleased that H.R. 766 includes specific provisions for supporting studies of societal and ethical concerns.

ORNL has a significant outreach program of communication and interaction with the public. This includes public lectures, tours, and secondary school programs, including classroom visits and teacher development. CNMS will be actively engaged in these programs.

Question 4. Are the views of the research community affiliated with ORNL adequately reflected in the research plan for the federal interagency nanotechnology research initiative? Do you believe that there would be value in establishing an external advisory committee for the initiative?

Answer 4. I believe that the views of the nanoscale science and technology community affiliated with ORNL are generally reflected in the research plan for the federal nanotechnology research initiative. However, as the initiative develops, continued review and oversight of federal nanotechnology programs by PCAST would be useful in providing overall guidance for the initiative, providing high-level feedback on programs and research directions, and providing visible and independent assessment of national policy and opportunities.

Thank you, Mr. Chairman, for your commitment to science and nanotechnology research and development. The scientific community appreciates the Committee's leadership in this area and firmly believes that the future of our nation depends on continued leadership in science and technology.

BIOGRAPHY FOR JAMES B. ROBERTO

Jim Roberto is Associate Laboratory Director for Physical Sciences at Oak Ridge National Laboratory. As Associate Laboratory Director, he is responsible for ORNL's research portfolio in materials science, condensed matter physics, chemistry, and nuclear physics. This includes the Chemical Sciences, Condensed Matter Sciences, Metals and Ceramics, Physics, and Research Reactors divisions; the High Flux Isotope Reactor; the Center for Nanophase Materials Sciences; and scientific user facilities in neutron scattering, heavy ion nuclear physics, and materials microanalysis (more than 600 staff and $180M in annual expenditures).

Roberto joined ORNL in 1974 following completion of a Ph.D. in applied physics from Cornell University. Prior to his present appointment he served as director of ORNL's Solid State Division from 1990 to 1999. His research interests have included x-ray and neutron scattering, ion-solid interactions, and materials for fusion reactors. He is a former President of the Materials Research Society and Chair of the Division of Materials Physics of the American Physical Society. He has served on three National Research Council committees, most recently as Vice-Chair of the NRC study on Condensed-Matter and Materials Physics, and is a fellow of the American Association for the Advancement of Science.

Chairman BOEHLERT. Thank you very much, Dr. Roberto. And let me thank you for providing specific responses to specific questions posed to you, which is in your testimony, which I commend to the attention of my colleagues. Thank you for that. Dr. Batt.

STATEMENT OF DR. CARL A. BATT, CO-DIRECTOR OF THE NANOBIOTECHNOLOGY CENTER, CORNELL UNIVERSITY

Dr. BATT. It is rare that an academic has such a rarefied audience, and it is also rare that I only have five minutes to talk about a whole field. So if you will, I will quickly go through a series of images, which I hope will sort of portray what nanotechnology is all about and the excitement of the Nanobiotechnology Center, which is a National Science Foundation supported science and technology center.

So let me, first of all, treat you all like I would my students, and those include not only undergraduates and graduate students at Cornell, but also kids in elementary programs, middle schools, and high schools. I try to see them all.

Chairman BOEHLERT. That is at the right level.

[Slide]

Dr. BATT. So I will pose a question here, and the question is: How many angels can dance on the head of a pin? And the answer is, of course, one, as you will see in the image over on your left. The real question is: How small can we make the head of a pin, but more importantly, how small can we make the tip of a pin? And the image over on the right is an atomic force microscope, which is basically like a microscope. It feels along the surfaces, and we can make these tips as narrow as a single molecule. Back in 1959, Richard Feynman prophetically sort of laid out nanotechnology as we know it by suggesting the notion that why couldn't we write the Encyclopedia Britannica on the head of a pin? An IBM—my colleagues at IBM, about 10 or 12 years ago, actually showed that you could really write out IBM, which was one of the most brilliant sort of advertising schemes that I have ever thought of. And so we can write the Encyclopedia Britannica on the head of a pin. There is no issue related to that.

So let's again continue our education lesson. When we talk about nanotechnology and we talk about nanometer scale, we are talking about molecular scale. We go from the width of a hair, which is about 100 microns, about what we can see, except when we get a little bit older and we need some glasses, down to around two nanometers. So it is two nanometers across the helix of DNA.

So really what we do at the Nanobiotechnology Center is, really, we are trying to build innovative tools to study biology at the nanometer scale. Most biology really occurs at the nanometer scale, but we have yet to really discover all of the interesting tools that we need to study this phenomena at that scale, and that is what our Nanobiotechnology Center is all about.

The Center is composed of six institutions, Cornell being the lead institution, and we are very grateful to the National Science Foundation for their investment in our Center. We are joined by Princeton University, Clark Atlanta, Howard, Oregon Health and Sciences Center, and Wadsworth Center, which is in the New York State Department of Health.

So let me just spend a few minutes telling you about what we are doing now and what totally exciting things that are going on in nanotechnology. Basically, the human genome is done. We have finished that, and although it lays out a blueprint for what is the basis for human beings, as we know it, we really are only beginning to scratch the surfaces.

[Slide]

On the right hand side, is an image of a machine that is used to sequence DNA. It took about 300 of these machines about a year to sequence one genome. If we are going to ever advance genomics into the realm of sort of modern medicine and be able to have sort of healthcare directed toward genomics, we are going to have to improve that. My colleagues Paul McEuen and Harold Craighead, and this was the cover of Science a few weeks ago, have developed a new technology for sequencing DNA. They are sequencing single molecules of DNA, which allows us to do this process in a massively parallel type of fashion, which really allows us to then look at instrumentation for sequencing DNA at, really, the nanometer scale.

Some other colleagues of mine, Bob Austin, who is at Princeton University, and Lois Pollack, who is at Cornell, are studying the fundamental issues of how proteins fold. Again, we understand the complete genome. We understand all of the DNA sequences, but what we don't understand is how these sequences actually fold up into proteins. And they are studying this fundamental phenomenon by taking single molecules of proteins and watching how they fold, watching how they fold in a microsecond time scale.

My own group at Cornell is looking at what we call biofabrication. We want to take all of these chip people and actually put them out of business by making structures biologically, by producing various types of structures.

[Slide]

And what you see there, that NBTC [Nanobiotechnology Center] image, is actually about the width of a hair. And we have grown these sort of structures onto the surface of silicon using enzymes and various types of components.

And then finally, we are not unaware of the fact that we need to take this technology and reduce it to something that is relevant to things like homeland security. And so my group is working on basically hand-held sensors that we believe in the next few years will be able to detect a wide variety of food-born pathogens, biowarfare agents, and other sorts of medical pathogens that might be important in the future. And I have—and at some point you might want to come and see, we have these little chips here, which are basically chips to actually purify DNA and then do the amplification all on the chip. And we see, in the next five years, these being very affordable hand-held sensors.

So what is the road to success? The road to success in the Center is basically looking at interdisciplinary efforts. We try to ask fundamentally important biological questions. We try to ask how cells respond, what—how does DNA sort of function. But we are also trying to do, in collaboration with engineers and physicists, develop innovative tools.

We are very grateful to the National Science Foundation for their long-term investment, but there are issues to be addressed. University departments are like little kingdoms. They are basically built to function primarily in the education area, and when we start looking at research opportunities that sort of cross over these areas, we have significant challenges. Independent investigators, the term used in academia is "herding cats." If you can imagine how hard that is to do, that is how hard it is to sort of get different faculties to sort of agree on a single research focus. We need to sort of understand how we can evolve departmental structures and how eventually the flow of what we call indirect cost really benefits all.

And there are solutions. Certainly, our Center is a solution. We bring to the problem a variety of different departments throughout Cornell University as well as a number of other institutions. We recognize contributions that individuals make. And what is really needed is investment in infrastructure. We are one of the hubs of the National Nanofabrication Users Network, a wonderful system, a wonderful toolbox where we can go out and perform nanotechnology.

So what is not nano? The book came out, I bought it, hard cover, 30 bucks, and let me just tell you, that is not what nano is.

[Slide]

The images you see at the left and the right are cartoons. They are nothing more than an artist's imagination. They are not what nanotechnology is all about. The book in and of itself has really no technical base that I could understand. I am a microbiologist. It was kind of interesting reading. I am looking forward to the movie. Maybe it will make sense then. What is nanotechnology to me and what is important in terms of addressing societal and ethical issues is sort of portrayed on this next set of images.

[Slide]

As I said, I spend about a third of my time out in schools talking to little kids. They are the future of science and engineering in this country. We have programs that we run not only at—around the Ithaca area, but we also go up to the Onondaga Nation School, a very charming community of Native Americans about an hour away. We go up to Shea Middle School up in Syracuse. This is the future of science in America. These are the sort of people—these are the sort of opportunities that academic scientists need to embrace and need to really understand their role in sort of communicating to this audience.

[Slide]

The group of pictures over in the lower right hand side are my students. They are very much committed to this era. They are very much interdisciplinary. I am amazed at how much they know, and I try to pretend that I really understand all of it, so I thank you very much.

[The prepared statement of Dr. Batt follows:]

PREPARED STATEMENT OF CARL A. BATT

Let me first thank you for the invitation to offer my testimony on H.R. 766, *Nanotechnology Research and Development Act of 2003.* It is a privilege to speak not just on behalf of my own group, but the Nanobiotechnology Center and moreover the scientists and engineers who are engaged in a grand adventure. To start the discussion, I would pose the age old question, *how many angels can dance on the head of a pin?* While this vexing question has been the fodder of philosophers and theologians, a practical answer eludes us. Two confounding factors: how small are angels and how small can we make the head of a pin. In medieval times, angels were believed to be the smallest possible physical object. A more approachable challenge came in 1959 with the question from Richard Feynman "Why cannot we write the entire 24 volumes of the *Encyclopedia Britannica* on the head of a pin?" [1] The challenge of moving around single atoms has been met, the issue of making it prac-

[1] Feynman, R.P. (1959) (http://nano.xerox.com/nanotech/feynman.html)

tical remains.[2] We can now for all practical purposes write the *Encyclopedia Britannica* on the head of a pin. But what should come of these technological feats, what is nanotechnology?

Through nanotechnology we seek to control single molecules at the atomic level and through those processes create novel materials as well as new devices. Nanotechnology as practiced by scientists and engineers in the academic sector is not just an exercise in fancy science, it will have a significant impact on industry and society as a whole. It will provide novel medical therapies, help to survey and protect the environment, make unique materials that have enhanced properties and lead to a new generation of manufacturing capabilities that will simply revolutionize and revitalize American industry.

The impact that nanotechnology is currently having on new and existing industries is significant, but the potential for the future is enormous. It is estimated that nanotechnology will have a one-trillion dollar impact on the global economy in the next decade. Existing industries including those not typically characterized as 'high tech' will see their product lines and the way they manufacture them influenced by our growing knowledge in nanotechnology. Moreover, aspects of nanotechnology will help to drive small companies whose products are developed for niche markets including sensors, bio and chemical analytical devices and boutique chemical and ingredients. These technologies are not likely to require the multi-billion dollar investments that 'chip' manufacturers must face. Therefore progress will be even more rapid as the relative risk from investing in nanotechnology will be lower. Nevertheless significant investment in research and development is needed especially in the academic sector.

Nanotechnology will lead a renaissance in manufacturing in more rural areas abandoned by traditional manufacturing over the past 50 years. It has the potential for reviving communities that used to be the home of skilled laborers who contributed to the last industrial revolution. While 'traditional' chip based manufacturing has contributed to economic growth in a select number of regional areas, nanotechnology and especially its applications to the interface with biology will have a more wide-spread geographic impact. As a resident of upstate New York, I look forward to nanotechnology being an economic driver in a community that has seen most of the manufacturing jobs lost over the past 50 years. I live in a small town, Groton, New York that used to be the home of Smith Corona. At one point it employed over a thousand people in my town but those jobs left as the utility of the typewriter dwindled.

How does the Cornell Nanobiotechnology Center advance nanotechnology research and development compared to what the University could accomplish on its own?

Support from the National Science Foundation through our designation as a Science and Technology Center is clearly the driving force behind our research and development efforts at the Nanobiotechnology Center. *Our center has one mission: to build innovative tools to study biology at the nanometer scale.* Cornell University is the lead institution in the Nanobiotechnology Center and our partners include Wadsworth Center (NYS Department of Health), Princeton University, Oregon Health and Sciences University, Howard University and Clark Atlanta University.

The field of nanobiotechnology, as created with the establishment of our center in 2000, would not exist in its current incarnation were it not for the collective efforts of the center's faculty and the commitment of the NSF. Most of today's most challenging problems in science and engineering are complex and they will not be solved by single investigators working within the borders of their own chosen fields. Problems as far ranging as curing cancer to building the next-generation of sensors to help safeguard our homelands, could not be successfully addressed without support similar in size and scope to the investment made by the NSF in our center. That investment over the anticipated 10 years of our center's life will total approximately $40M. While that is substantial compared to individual investigator awards (by an order of magnitude), the support per investigator within the Nanobiotechnology Center is not extraordinary, nevertheless the center concept works and value is added through a 'center' type of mechanism. What is extraordinary is the nature of the center and the commitment that we have to act as an interdisciplinary team pooling our collective skills in fields including life sciences, engineering, physics and chemistry. Not an obligation borne out of mandate, but a commitment that arises from the notion that no individual and no single discipline can bring all of the skills that are required for these complex endeavors. The center

[2] Eigler, D.M., Schweizer, E.K. *Nature* 344:524–526 (1990). (http://www.almaden.ibm.com/vis/stm/atomo.html)

will cease to be a Science and Technology Center at the end of 2009, the obliged 10-year sunset of all NSF supported Science and Technology Centers. What we hope to leave as a legacy is a unique collection of innovative tools to study biology at the nanometer scale, a fledgling knowledge of how biological molecules behave in the nanospace and a talented group of young people. My colleagues Paul McEuen, Harold Craighead and I are extending Paul's efforts to create single molecule transistors[3] to develop sensors that are sensitive enough to detect a single piece of DNA. We see applications in environmental protection, food safety and homeland security for these sensors and envision how a network of these sensors can form a web that would survey large areas alerting us to potential hazards. Others at the Nanobiotechnology Center including Lois Pollack and Robert Austin (Princeton) are creating devices[4] to understand how proteins fold, a fundamental process that will unlock the mysteries of the genome by informing us how to translate the vast databases of DNA sequences into functional elements.

The challenges of addressing the development of new scientific disciplines in a university setting are significant but Cornell does it better than most. The University is just a physical entity that hopefully fosters the faculty, students and staff to excel. Fortunately if you are at a university like Cornell, which is rich in a tradition that nurtures interdisciplinary research and whose departments, schools and colleges cover a wide range of areas from food science to physics (not to mention the humanities), you have all of the resources that you could ever hope to muster. Nevertheless there needs to be some glue, some incentive. The Nanobiotechnology Center with the support of the NSF provides that incentive, as it encourages faculty to nucleate and explore complex problems that can only be addressed by developing and exploiting unique tools. Support is primarily used to provide stipends and salaries for graduate students and postdoctoral associates. They are truly the bright young minds that bring their enthusiasm to bear on these biological problems. So in effect the center has many products, not just the fruits of our scientific discoveries but also the students and postdoctoral associates that are supported and trained by the center. These students and postdoctoral associates are the next-generation of scientists and engineers who are equipped with a unique set of skills honed by the interdisciplinary nature of their research. My students approach scientific questions in a much different fashion than traditionally trained students, acquiring, then applying a wide range of skills far more diverse and more versatile than I garnered as a graduate student. Graduate training, at its core, is focused on engaging a student's mind and providing them with challenging questions. It is not much different than when I was a graduate student, but the current set of questions and the potential routes to answer those questions are much more robust for students engaged in the center's programs. For example students in my laboratory are actively engaged in what we call biofabrication, using biological systems much the same way that you would use tools and processes from the microelectronics industry to build computer chips. We, on the other hand, instead of using x-rays and harsh chemicals, use biological molecules and 'grow' our components with tools isolated from cells. We hope over the coming years to marry the biological machinery with more traditional forms of fabrication to develop unique materials and then structures that have properties virtually unknown in the natural or manmade world. These might be replacement parts for damaged cellular components or new devices that can survey the environment for pollutants well before we recognize the impact of these pollutants on our health. We look to biofabrication as being an environmentally friendly form of fabrication that will complement the existing silicon processing methods that are well entrenched in the industry.

Does the center actively foster collaboration across academic disciplines, for example?

The research projects supported by the Nanobiotechnology Center are expected to be interdisciplinary, and in fact, it would be virtually impossible for us to make progress if we worked in isolation apart from our colleagues in other disciplines. The challenges are simply too complex and for the faculty our training was for the most part focused narrowly in a single discipline. When you survey the goals of the various research projects you discover that even those biological questions which appear simple are vastly complex. We also seek unique solutions for fabrication at the nanometer scale using biology to inform us. You can look at something as simple as a diatom and realize that within its limited genome is the blueprint for creating

[3] Park J., Pasupathy A.N., Goldsmith J.I., Chang C., Yaish Y., Petta J.R., Rinkoski M., Sethna J.P., Abruna H.D., McEuen P.L., Ralph D.C. (2002) *Nature* 417:722–725

[4] Pollack, L., Tate, M.W., Finnefrock, A.C., Kalidas, C., Trotter, S., Darnton, N.C., Lurio, L., Austin. R.H., Batt, C.A., Gruner, S.M., and Mochrie, S.G. (2001) *Phys Rev Lett* 86:4962–4965

three-dimensional structures in silicon that would be the envy of any engineer. But our main focus is on exploring problems in biology at the nanometer scale. For example, a number of projects seek to explore the question: how molecules behave in the nanospace? Through nanotechnology we seek to have an unprecedented and highly precise means to understand and control molecules. To assemble them and to rearrange them in a manner that yields unique properties. Molecules behave quite differently when they are constrained and yet most models to explain, for example, how various molecules regulate the controlled growth of cells (or the uncontrolled as in the case of cancer) do not account for the complexity of these situations. So to address the question, the center fosters interactions between biologists who understand the nature of the molecules and the engineers who can build tools to study these molecules. Left alone biologists would not attempt to build tools to study molecules at the nanometer scale, while engineers would not have an appreciation of the complexity of biological molecules let alone the systems in which they are found.

Cornell University is fortunate to have four NSF supported centers that have a focus or at least a concentration in nanotechnology. These include my own Nanobiotechnology Center, the Cornell Center for Materials Research, the Center for Nanoscale Systems and a splendid facility, the Cornell Nanofabrication Facility that is our beloved 'tool box' where we create these nanodevices. There are faculty that are members of more than one of these centers and we collectively form a very strong foundation in nanotechnology. We come from different departments and from different colleges scattered throughout Cornell University. We come together not just because of the funding but because of the intellectual community that exists within these different centers.

For faculty, working across disciplines is a matter of communication. We speak different languages and exist in different cultures. We approach problems differently. Physicists work in a world dominated by large analytical instruments many of which are custom built and years are invested in their creation. Biologists are much more likely to seek out existing technology because their science involves generating data that can be compared to data generated using similar instrumentation. But moreover we differ in the way we approach experimentation and the questions that we are seeking to answer. Our students are hybrids able to conceive, create and use innovative tools and seek answers to important biological questions. Our job as faculty is to facilitate and encourage this interaction. In my experience once it gets started, those students that are motivated and forward thinking, get engaged and will move the effort along.

How does your center interface with the private sector? Do you host any collaborative university-industry nanotechnology research and, if the answer is yes, does the existence of the center make those collaborations easier?

In 2001, I was fortunate to be the project leader for an effort that was selected by New York State, through the New York State Office of Science, Technology and Academic Research (NYSTAR) for support. Over two years, $2.8M was pledged to the Alliance for Nanomedical Technologies. The Alliance had one simple goal: to bring together academia and the private-sector to develop the next generation of nanomedical devices. In establishing this research and development center, we sought industrial input from the beginning. Too often academic institutions invent, publish and then look to find a champion for its technology. Too often then the specifications of the technology arising from a scientific discovery made in academia do not match the needs of the private-sector. Too often then the investment in retrofitting technology developed in academia for the private-sector is greater than the return. Academia is a grand incubator from which emerges scientific discovery and that process should remain unfettered. Nevertheless the Alliance set forth, in developing its research goals, to be inclusive of the private-sector and within one year we had 28 affiliates who brought their business plans and technology targets to the table and engaged our academic scientists in serious discussions. From those discussions, a series of research projects were formulated which were driven by the rigorous academic questions offered by the faculty balanced with the future needs of the industry. For example, Alliance supported researchers are looking at arrhythmia in cardiac cells while also designing the next generation in wireless cardiac monitoring all guided by specifications articulated by our private-sector affiliates. Similarly, Alliance supported research will yield a new class of hand-held sensors that are capable of precise identification of bacteria. This technology will have multiple uses in insuring food safety and well as homeland security.

The linkage between the university and the private-sector is absolutely critical. Having been engaged in one form or another of technology development for over 20 years, I believe that success is dependent upon the technology having a practical impact on the lives of people. Making scientific discoveries, publishing papers, going to meetings to exchange ideas with my colleagues is only part of the process. Seeing technology reach a point where it is available is also important. And the university is typically awful about bringing technology to a point where it is commercially viable. The Alliance for Nanomedical Technologies is attempting to bridge that gap and simplify the hand off from the university to the private-sector. Not everyone in academia is happy about this linkage, many feeling that it will compromise their 'academic freedom.' To paraphrase the words of Lloyd Old, a friend and the Chief Executive of the Ludwig Institute for Cancer Research (with whom we have a partnership to develop therapeutic agents for cancer research) scientific discoveries by the academic community in and of themselves, are admirable but it remains a great challenge to insure that they are *useful.* While linkages with industry are only one way that research discoveries can achieve a degree of usefulness, certainly seeing research reach some stage of application is important especially as we articulate its value to the general public.

Some individuals and groups have suggested that nanotechnology developments may raise societal and ethical concerns. Is any part of your center's activity devoted to addressing such concerns?

New technology will always raise the concerns of the public especially when we, the scientific community do not take the time and have the patience to articulate the field. What falls into the void that we create by remaining cloistered in our laboratories, are pundits and pseudoscientists whose mission is to, at best, tantalize, at worse, to strike fear. It makes great novels, and it makes even better movies but the threshold into science fiction is murky. Nanotechnology will not as a technology spawn a new threat to society. History shows that most of the dangers to society that result from the misuse of technology arises not from state-of-the-art technology but more mundane technology in the hands of opportunists. We have in the last twenty years alone seen horrific acts carried out by individuals and groups with some fairly unsophisticated technology.

There are certainly ethical concerns with any new technology that must be considered. The prospects of a run away technology as described in Michael Crichton's book *Prey* would be a sad outcome, but the current state-of-the-art in nanotechnology in no way enables that outcome. The technology as described in this fictional account is not even close to reality. No enabling technology exists or is on the horizon that could account for the fanciful creatures described there. In fact I was, as a microbiologist disappointed by the lack of even a single technically feasible anchor in the book. Yet it received lots of press coverage and through a variety of media especially the Internet, fanciful predictions of doom proliferated. Unfortunately, the barrier between scientific reality and science fiction is only as high as the imagination of a talented cartoonist. Pictures abound on the internet of nanobots and other imaginary things and we at the Nanobiotechnology Center spend a good deal of time engaged in reality checks for students and the general public. Even some of my colleagues lean over the line at times seduced by the publicity and the potential that this notoriety brings in terms of funding and other opportunities. Yet the practical reality, self-assembling, autonomous machines smaller than a bacterium that can scurry about like little fleas are still just the product of an artist's imagination. One practical problem that is yet to be solved is powering these devices. In most cases the battery to run any mechanical device far exceeds the device itself.

There are real dangers in the world and those that concern us now are fifty year old technologies, lethal in the hands of individuals and organizations that would choose to use them.

So how best to meet the societal concerns of nanotechnology? My colleague, Anna Waldron (who directs our education effort at the Nanobiotechnology Center) and I have elected to focus our attention on the next generation of potential scientists and engineers. This is not a theoretical exercise carried out in the ivy covered walls of Cornell University, but a practical experiment in classrooms in towns and villages that surround our campus. We are engaging the young men and especially the young woman, who in increasing numbers, do not look at science as an educational opportunity let alone a career for them. *They do not see themselves as scientists* and that is a significant barrier that we seek to overcome. We work in concert with their teachers recognizing that this partnership will only work if we understand their world. With more and more mandated curricula, we need to fit into their needs rather than offering content that has no relevance to the rest of their educational experience. We operate three middle school science clubs for girls addressing the challenge of encouraging young women to consider careers in science. We also host two afterschool science clubs for underrepresented minorities at the Onondaga Nation School and Shea Middle School (Syracuse, NY) exercising our belief that these young students have all the potential in the world. We offer events for the general public and every summer we engage more than 3,000 people at the Great New York State Fair with the wonders of the Nanoworld. In about one month we will have the grand opening for a traveling museum exhibit, *It's a NanoWorld,*[5] that has been developed with our collaborators from the Sciencenter and Painted Universe in Ithaca, which we estimate will reach more than one million people during its tour around the United States.

In helping educate and more importantly inspire these young students, we hope to raise the general awareness of the public at large as to what nanotechnology is all about. That this technology and in general most technology has a very positive impact on our lives. We have coined this effort *Main Street Science* and over the next five years hope to take the scientific discoveries of our center and others and translate them into practical and approachable concepts for students and the general public. At Main Street Science we will harness the energy of our undergraduates and graduate students to develop hands-on activities giving them a practical experience in community science. What scientific discoveries do we hope to share with young students? For example few students even through high school understand what the term 'nano' means in its fullest context. They understand that a nanosecond is pretty fast but they don't comprehend that a hummingbird beats its wings about 100–200 times per second. That is virtually imperceptible to the human eye and is faster than the flickering of a fluorescent light bulb. Never the less computers operate about a million times faster. They know that a nanometer is pretty small, but they do not realize that the distance between atoms is on the order of a nanometer. So for younger children, we consider it a challenge for them to comprehend simply what a billion is and expose them to the concept using thousands of little plastic Lego blocks. We engage kids and have them hopefully begin to believe that science is a good thing and learning about science can be exciting. Regardless of whether these kids go on to get their Ph.D. in nanotechnology it is important to have them believe that they can do it.

A more scientifically literate public is one sure route to ameliorate the fears that seem to accompany many scientific revolutions. History is replete with examples of where new scientific discoveries were met with public challenges and only after a significant back lash, did we the scientific community come out of our laboratories and seek to engage the public. The NSF to their credit has put engagement as one of the important criterion for their supported research programs.

> *Are the views of the academic research community adequately reflected in the research plan for the federal interagency nanotechnology research initiative? Do you believe that there would be value in establishing an external advisory committee for the initiative?*

Clearly any researcher focused on nanotechnology would find merit in the research plan for the interagency nanotechnology research initiative as outlined in H.R. 766. I have watched with a great deal of satisfaction and pride the efforts of the National Science Foundation in their development of the current array of centers and other programs. It is precisely these types of external stimuli that help drive innovation at the university. Investments by the NSF are welcome and more would be appreciated. The benefit from investing in technology is magnified well beyond the academic community and is an economic driver for new and existing industries. The number of new startups whose business plan includes nanotechnology is growing exponentially.

An external advisory committee would have a daunting task in lending guidance to a national nanotechnology initiative. Nanotechnology is a very complex field whose definition has yet to be fully formulated and embraced by everyone in the scientific community. Purists look at nanotechnology as including only those efforts that impact at the nanometer scale. I take a more broader view cognizant of the appeal that the term 'nano' has especially when it comes to engaging young scientists. I like the definition in H.R. 766 "at the atomic and molecular scale." Certainly an advisory committee charged with insuring that the scientific community moves forward is important. Too often academics look at research in their chosen field and funding for it as an entitlement. The never-ending battle cry that more research is needed is something that I believe needs to be continuously reassessed. Scientists in academia have two important functions, to engage in scientific discovery and to provide educational opportunities for students of all ages. Nanotechnology represents one field that will have a dramatic impact on our nation

[5] www.itsananoworld.org

and its citizens. Moving forward in a bold and progressive fashion is important and certainly guidance from highly regarded and respected scientists in the field would be an useful component.

In summary, this bill represents a significant investment but one that will stimulate a new era in, not only science but technology. Nanotechnology will be the basis for vast improvements in materials, sensors, electronics and will impact a number of fields including the life sciences. It will stimulate scientists in a diverse array of disciplines to think beyond their current set of tools and the potential is enormous. We will see nanotechnology impact existing industries but also drive the development of new industries launching new start-up firms that take the best of American entrepreneurship and couple that to discoveries in academia. Investment in nanotechnology through the a mechanism as outlined in H.R. 766 will help enormously.

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EDUCATION:

October 1981 - Ph.D. Rutgers University, Department of Food Science
October 1979 - M.S. Rutgers University, Department of Food Science
December 1975 - B.S. Kansas State University, Microbiology

PROFESSIONAL EXPERIENCE:

1999-present	**Director**, *Cornell University/Ludwig Institute for Cancer Research Partnership* Cornell University
1999-present	**Co-Director**, *Nanobiotechnology Center* Cornell University
2001-present	**Project Leader**, *Alliance for Nanomedical Technologies* Cornell University
1998-present	**Professor**, *Department of Food Science* Cornell University
1996-2001	**Director**, *Laboratory for Molecular Typing* Cornell University
1991-1998	**Associate Professor**, *Department of Food Science* Cornell University
1985-1991	**Assistant Professor**, *Department of Food Science* Cornell University
1984-1985	**Research Scientist**, *Department of Applied Biological Sciences* Massachusetts Institute of Technology
1982-1984	**Postdoctoral Research Associate,** *Department of Nutrition and Food Science* Massachusetts Institute of Technology

PROFESSIONAL ACTIVITIES:

Membership-	ASM, AAAS, IAMFES
2001-	**Editorial Board**, Protein Expression and Purification
2001-	**Editorial Board,** Journal of Food Science
1987-2000	**Chief-Editor**, Food Microbiology
1996-1999	**Editor**, Encyclopedia of Food Microbiology
1987-1992	**Editorial Board**, Food Biotechnology
1987-1991	**Consultant** USAID -NIAB, Faisalabad, Pakistan
1988-1989	**Chairman**, Central New York IFT

AWARDS:

1988- Yoplait Institute Research Award
1990- Samuel Cate Prescott Award (Institute of Food Technologists)
1997-Teaching Excellence Award (Department of Food Science)
2000-Liberty Hyde Bailey Professor (College of Agriculture and Life Sciences)

ACTIVITIES:

University committees

Undergraduate Honors Program, CALS-1990-1991
NIH Biotechnology Training Program Grant Executive Committee 1990-1995
Life Safety, Food Science Department, 1992-present
Planning, A Food Science Department committee that serves to advise the department chairperson, 1993-present
Scientific Administrative Board Cornell Biotechnology Program, Center for Advanced Technology, 1993-1996.
Graduate Admissions-Graduate Field of Food Science and Technology, 1993-1995.
The Future of the Geneva Food Science and Technology Department CALS committee initiated at the request of Dean David Call to help chart the future of the Food Science and Technology Department at the Agricultural Experiment Station in Geneva. 1995
Graduate Admissions-Graduate Field of Microbiology, 1996-present.
Laboratory for Molecular Typing. Founder and managing director. A facility associated with Biotechnology Institute BioResource Center dedicated to providing genetic typing of bacteria. 1995-2000
Nanotechnology: Frontiers in Biology, Chairman. A workshop sponsored by NSF, National Nanofabrication Users Network and the Cornell Nanofabrication Facility November 20-21, 1996.
Nanofabrication Committee. A committee initiated at the request of Dean John Hopcroft to advise him on future directions for the College of Engineering in nanotechnology. December 1, 1996-1997
Office of Economic Development. A university committee whose mission is to foster economic development in the community. 1997-1999
Stocking Hall Renovation Committee, 1997-1999
Cornell University Genomics Taskforce. A university committee to explore our future directions in genomics. 1998-present
Executive Committee Nanobiotechnology Center -Advisory committee to Nanobiotechnology Center. 2000- present
Life Sciences Building Committee A university committee to design a new building which will be the cornerstone for genomics at Cornell University. 2000- present
Life Sciences Advisory Council A Provost-appointed committee to provide guidance to the Provost in the area of Cornell's investment in the Life Sciences. 2000- present

Outside committees

Board of Directors- Ithaca Montessori School. 1998-present; President 1999-present, Interim Director, summer 1999
Business Innovation Center. A Tompkins County-Cornell joint venture in business assistance. 1998-2001
Advisory Board-Department of the Army, Research and Technology Directorate. 2000-
Bacteriology Advisory Board. American Type Culture Collection 2000-

Assignments

Scientific Advisory Committee-University of Minnesota-Symposium on Application of Biotechnology in the Food Processing Industry. October 8, 1984. St. Paul, MN.
Biotechnology: Microbial principles and processes for fuels, chemicals and biologicals Lecturer-Summer course Massachusetts Institute of Technology, Cambridge, MA. 1984-1994.
Zone supervisor-Environmental Health, Radioisotopes, Stocking Hall 1987-present
Safety Issues of Transgenic Plants Invited-Rapporteur, Boyce Thompson Institute, Cornell University, Ithaca, NY, May 1-2, 1989
Second Symposium on the Genetic Engineering of Animals Organizing committee-, Cornell University, July 25-28, 1989

Safety of foods of animal origin: Charting the course Invited Participant. College of Veterinary Medicine, Texas A&M University, College Station, TX June 25-28, 1991 (see Acuff, G.R., Albanese, R.A., Batt, C.A. et al. [1991]).

NSF panel member-NSF ERC review team September 29, 1999.

NIH panel member-SBIR Infectious Diseases and Microbiology IRG March 16-17, 2000. November 13-14, 2000

PUBLICATIONS

Peer reviewed publications:

1. Batt, C. and Solberg, M. (1982) Asexual developmental markers in an aflatoxigenic strain of *Aspergillus parasiticus*. Can. J. Microbiol 28:1206-1209.
2. Batt, C. and Solberg, M. (1983) Effect of volatile components of carrot seed oil in growth and aflatoxin production by *Aspergillus parasiticus*. J. Food Sci. 48:762-764.
3. Batt, C. and Solberg, M. (1985) Association of lactase activity with conidiation in an aflatoxigenic strain of *Aspergillus parasiticus*. FEMS Letters 27:277-280.
4. Batt, C.A., Claps, M.C., Bodis, M.S., Jamas, S. and Sinskey, A.J. (1985) Analysis of xylose operon regulation by Mud-lac fusion: Trans effect of plasmid coded xylose operon. Can. J. Microbiol. 31:930-933.
5. Batt, C.A., Carvallo, S., Easson, D.D., Akedo, M. and Sinskey, A.J. (1985) Evidence for a xylose metabolic pathway in *Saccharomyces cerevisiae*. Biotechnol. Bioeng. 28:549-543.
6. Batt, C.A., Shanabruch, W. and Sinskey, A.J. (1985) Expression of pAm□1 tetracycline resistance in *Corynebacterium glutamicum*: Segregation of antibiotic resistance due to intramolecular recombination. Biotech. Lett. 7:717-722.
7. Batt, C.A., Novak, S.R., O'Neill, E.O., Ko, J. and Sinskey, A.J. (1986) Hyperexpression of *Escherichia coli* xylose isomerase. Biotechnol. Prog. 2:140-144.
8. Jamieson, A.C., Vandeyar, M.A., Kang, Y.C., Kinsella, J.E. and Batt, C.A. (1987) Cloning and nucleotide sequence of the bovine β-lactoglobulin gene. Gene 61: 85-88.
9. Chow, J.J., Batt, C.A. and Sinskey, A.J. (1988) Characterization of *Lactobacillus bulgaricus* bacteriophage ch2. Appl. Environ. Microbiol. 54: 1138-42.
10. Hahm, Y.T. and Batt, C.A. (1988) Genetic transformation of an $argB^{-}$ strain of *Aspergillus oryzae*. Appl. Environ. Microbiol. 54, 1610-1611.
11. Vandeyar, M.A., Weiner, M.P., Hutton, C.J. and Batt, C.A. (1988) A simple and rapid method for the selection of oligonucleotide-directed mutants. Gene 65, 129-133.
12. Kim, S.G. and Batt, C.A. (1988) Heterologous expression of the *Escherichia coli* β-galactosidase gene in *Streptococcus lactis* by translational fusion. Food Microbiol. 5, 59-73
13. Wong, D.W.S., Yee, L.N.H. and Batt, C.A. (1989) Thermal inducible expression of xylose isomerase and its performance in a hollow fiber bioreactor. J. Ind. Microbiol. 4, 1-5.
14. Wong, D.W.S., Batt, C.A. and Kinsella, J.E. (1990) Purification and characterization of rat liver transglutaminase. Inter. J. Biochem. 22, 53-59.
15. Batt, C.A., Jamieson, A.J. and Vandeyar, M.A. (1990) Identification of essential histidine residues in the active site of the *Escherichia coli* xylose (glucose) isomerase. Proc. Natl. Acad. Sci. USA 87, 618-622
16. Batt, C.A. (1990) A simple procedure for the *in vitro* selection of oligonucleotide primed site-directed mutations. DNA Prot. Eng. Tech. 2, 48-50.
17. Batt, C.A., Rabson, L.D., Wong, D.W.S. and Kinsella, J.E. (1990) Expression of recombinant bovine β-lactoglobulin in *Escherichia coli*. Agr. Biol. Chem. 54, 949-955.
18. Silva, M, Wong, D.W.S. and Batt, C.A. (1990) Cloning and sequencing of the genomic bovine β-lactoglobulin gene. Nucl. Acid. Res. 18, 3051.
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20. Batt, C.A., Webb, J., Oren, P. and Flick, P. (1990) An improved method for oligonucleotide mediated site-directed mutagenesis. Biotechniques 9, 555-556.

21. Kim, J.H. and Batt, C.A. (1991) Molecular characterization of a *Lactococcus lactis* bacteriophage F4-1. Food Microbiol. 8, 15-26.
22. Kim, J.H. and Batt, C.A. (1991) Nucleotide sequence and deletion analysis of a gene coding for a structural protein of *Lactococcus lactis* bacteriophage F4-1. Food Microbiol. 8, 27-32.
23. Kim, S.G. and Batt, C.A. (1991) Identification of a nucleotide sequence conserved in *Lactococcus lactis* bacteriophages. Gene 98, 95-100.
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25. Wong, D.W.S., Batt, C.A. and Kinsella, J.E. (1991) Expression of the transglutaminase gene in *Escherichia coli*. Inter. J. Biochem. 23, 947-953.
26. Chung, D.K., Kim, J.H. and Batt, C.A. (1991) Molecular cloning and nucleotide sequence of the major capsid protein of *Lactococcus lactis* ssp. *cremoris* bacteriophage F4-1. Gene 101, 121-125.
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30. Winters, D.A. and Batt, C.A. (1991) Irreversible denaturation of *Lactobacillus bulgaricus* b-galactosidase. Milchwissenschaft **46**, 753-757.
31. Bor, Y-C., Moraes, C., Lee, S-P., Crosby, W., Sinskey, A.J. and Batt, C.A. (1992) Cloning and nucleotide sequence of the *Lactobacillus brevis* xylose isomerase. Gene **114**, 127-131
32. Kim, J.K., Kim, S.G., Chung, D.K., Bor Y.C. and Batt, C.A. (1992) Use of antisense mRNA to engineer a bacteriophage resistant lactic acid starter culture. J. Ind. Microbiol **10**, 71-78.
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Patent applications:

Assay for microorganisms by polymerase chain reaction coupled ligase chain reaction. U.S. Patent Application filed October 27, 1993. U.S. Pat. Appl. No. 08/145,067

Cloning of the HTLV-I receptor. U.S. Patent Application filed. U.S. Pat. Appl. No. 08/242,679

Chairman BOEHLERT. Thank you very much, Dr. Batt. Mr. Marty.

STATEMENT OF MR. ALAN MARTY, EXECUTIVE-IN-RESIDENCE, JP MORGAN PARTNERS

Mr. MARTY. Mr. Chairman, Members of the Committee, I thank you for allowing me the opportunity to testify before you on behalf of the Nanobusiness Alliance and its member organization.

We are witnessing the dawn of a new era in science, industry, and quality of life. More quickly than anyone could have imagined even just a few years ago when the NNI was announced, nanotechnology is entering the marketplace. And my testimony will be focused on that marketplace transition more than on the science specifically and indeed changing our lives.

My own firm, JP Morgan Partners, believes that nanotechnology advances will impact many of the sectors where we already invest, including biotechnology, energy, communications, and semiconductors. Over the past few years, we have provided venture capital to five nanotechnology companies in diverse market applications like textiles, drug discovery, electronics, and flat panel displays. Last quarter, JPMP led a $30 million C round of funding in Optiva, which was one of the largest nanotechnology funding rounds for all VCs in 2002. We are continuing to diligently investigate private equity funding opportunities in nanotechnology and feel that it is a promising area for commercial growth.

The NSF conservatively predicts a $1 trillion global market for nanotechnology in little over a decade. In order to ensure that nanotechnology hits its potential, we must proceed aggressively, learning from lessons of the past, and create a dialogue with the public today so that everyone understands and prepares for the transformative effects of nanotechnology in the future. This starts with the passage of the *Nanotechnology Research and Development Act of 2003.*

The Act is a visionary piece of legislation. It has the strong support of the Nanobusiness Alliance and its member organizations: some 250 start-ups, corporations, universities, economic development groups, and investment firms from across the United States.

With a plethora of products in the market, and more on the way, it is no longer prudent to view nanotechnology as just a science. While basic research efforts must be protected and enhanced, as they are the linchpins of this new industrial revolution, our focus must be widened to include commercialization and a global race in the field of nanobusiness. We must look to find ways to take basic research and advance it toward commercialization. We must—we are—we need funding solutions for technical problems, such as packaging and integration of nanotechnology. Further, we need funding solutions to scaling problems, such as process reproducibility and process quality.

In the effort to commercialize nanotechnology, private equity can play an important role. Over 60 U.S. venture capital firms and numerous corporate venturing operations have invested in nanotechnology related start-ups. But many promising entrepreneurs and interesting technologies will not be funded by private equity sources, because they can not bridge the gap from the laboratory to the marketplace.

Venture firms must place funds in a manner that will bring competitive returns to our limited partners. Usually this means that a start-up must make reasonable progress in commercialization issues before a venture firm can reasonably invest. Unfortunately, this is often where federal funding has been lacking. The result is that many businesses that could drive future commercial growth for our country never get their ideas out of the laboratory.

Foreign governments, on the other hand, are very focused on bridging the gap from the laboratory to the marketplace, and here is a recent example. Two weeks ago, Japan held a nanotech event that demonstrated products that were already in the market or were about to be introduced to the market. 25,000 attendees showed up over three days at the convention center. Some 18 countries had booths at the show. What was particularly telling was that all of the country booths were sponsored by government economic development groups, except the United States, which was science and academic backed. Also telling was that most commercialized technology demonstrated at the show was derived from U.S. developed intellectual property, only it was Japanese, German, and Korean companies that were commercializing these technologies and advancing them beyond basic research.

But while the proposed increases to the NNI are indeed solid and significant, especially in these turbulent economic times, we must remain aware of the fact that other nations are challenging us and are willing to match and, in some cases, exceed us in spending and effort.

In closing, the Nano Alliance—excuse me, the Nanobusiness Alliance sees the Act's ability to strengthen the structure of the NNI as being vitally important. Second, we support the Act's call for the development of some sort of outside advisory board, though we feel this group must include not just researchers, but business people, local government officials, economic development experts, and ethicists. Third, we support the Act's call for further examination and tracking of international funding, development, and competition. Fourth, we support the Act's efforts to further address the social and environmental impacts of the science, but we would caution, as mentioned by Dr. Batt, that this effort be focused on real science, not well-read science fiction. And fifth, we back the Act's efforts to encourage nanoscience through additional grants and the establishment of interdisciplinary Nanotechnology Research Centers.

Again, I would like to thank the Chairman, Congressman Hall, and the Committee for this opportunity to address them.

[The prepared statement of Mr. Marty follows:]

PREPARED STATEMENT OF ALAN MARTY

Introduction

Mr. Chairman, Congressman Hall, Members of the Committee, I thank you for allowing me the opportunity to testify before you on the topic of the *Nanotechnology Research and Development Act of 2003*—on behalf of the NanoBusiness Alliance and its member organizations.

We are witnessing the dawn of a new era in science, industry and quality of life. More quickly than anyone could have imagined even just a few years ago when the

National Nanotechnology Initiative (NNI) was announced, nanotechnology is entering the marketplace and indeed changing our lives.

Today's nanotech industry might be compared to the computer industry of the 1960s, before the integrated circuit, or the biotech industry of the 1970s. A variety of nanomaterials including enhanced polymers, coatings, and fillers, are already available, producing revenues, and profits. America's store shelves have sunscreens, tennis rackets, and cell phones with nanotechnology elements bettering them. Carbon nanotube flatscreens, advanced military sensors and other electronic products will be in the market within 18 months. And advanced nanotech medical advances will be imminently impacting lives as they proceed through human trials—targeted drug delivery and cancer tagging procedures.

My own firm, JP Morgan Partners, believes that nanotechnology advances will impact many of the sectors where we already invest, including biotechnology, energy, communications and semiconductors. Over the past few years, we have provided venture capital to five nanotechnology companies in diverse market applications like textiles, drug discovery, electronics and flat panel displays. Last quarter, JPMP led a $30 million C round of funding in Optiva, which was one of the largest nanotechnology funding rounds for all VC's in 2002. We are continuing to diligently investigate private equity funding opportunities in nanotechnology and feel it is a promising area for commercial growth.

As production of nano-products becomes easier, faster and cheaper, every market sector will begin to feel their impact. The NSF conservatively predicts a $1 trillion global market for nanotechnology in little over a decade.

In order to ensure these types of numbers; in order to ensure that nanotechnology hits its potential; in order to ensure that the U.S. remains the leader in nanoscience and nanobusiness; we must proceed aggressively—learning from the lessons of the past—and create a dialog with the public today so that everyone understands and prepares for the transformative effects of nanotechnology in the future. This starts with the passage of the *Nanotechnology Research and Development Act of 2003.*

The Act is a visionary piece of legislation. It has the strong support of the NanoBusiness Alliance and the Alliance member organizations—some 250 start-ups, corporations, universities, economic development groups and investment firms from across America. By all accounts this is a vital and timely bill that builds on the fine work of the NNI and will assist America's long-term scientific and economic competitiveness in the nanotech field.

NanoScience to NanoBusiness

Nanotechnology is becoming nanobusiness faster than anyone imagined. A big reason for this has been the ripple effect from the NNI's groundbreaking work and how it has sparked the imagination of researchers, entrepreneurs, executives, and people from across the world. The foresight of Presidents Clinton and Bush, the efforts of Mike Roco, Jim Murday, Phil Bond and others has been the trigger for a new age of industry.

With a plethora of products in the market and more on the way, it is no longer prudent to view nanotechnology as just a science. While basic research efforts must be protected and enhanced as they are the lynchpin of this new industrial revolution, our focus must be widened to include commercialization and a global race in the field of nanobusiness. We must look to find ways to take basic research and advance it towards commercialization. We need funding solutions for technical problems such as packaging and integration of nanotechnology. Further, we need funding solutions to scaling problems such as process reproducibility, product quality and product cost. We must find a way to use nanotechnology to give taxpayers a return on their investment, develop the economy and create good high paying jobs. The *Nanotechnology Research and Development Act of 2003* lays the foundation for this.

Corporations

Just five years ago only a few corporate visionaries—IBM, HP, TI among them—were undertaking any research and development in the nanosciences. Today you would find that most manufacturing companies of the Fortune 500 have some nanotechnology effort—GM, GE, Siemens, Intel, NEC, ChevronTexaco, Mitsubishi, Hitachi and Dow have launched significant nanotech efforts—in R&D, investment and product development.

Start-Ups

Unlike the Dot-com era, nanotech start ups are built on physical, chemical and biological science. They have real technology. Real assets. And more often than not, they are founded by researchers from universities, government and corporate laboratories.

More than half the world nanotech start-ups are in the U.S. And while it is difficult to pin an exact number on how many there are, it is safe to say that over one thousand are currently in operation or in the incubation stage in the U.S., up from approximately one hundred just three years ago. Although these start-ups are driven by enthusiastic entrepreneurs and usually have valuable technology, most of these small companies will fade away due to lack of expertise or funding necessary to bring them to product commercialization.

Private Equity Funding

Over sixty U.S. venture capital firms, in addition to numerous corporate venturing operations, have invested in nanotech-related companies. Because the formal definition of nanotechnology is quite malleable, it is difficult to measure the total private equity investment level, but Venture One tracked almost $500 million in nanotech funding to start-ups in 2002.

Many promising entrepreneurs and interesting technologies will not be funded by private equity sources because they cannot bridge the gap from the laboratory to the marketplace. Venture firms like JP Morgan Partners must place funds in a manner that will bring competitive returns to our limited partners. Usually, this means that a start-up must make reasonable progress in process reproducibility, product quality and product cost before a venture firm can reasonably invest. Unfortunately, this is often where federal funding has been lacking. The result is that many businesses that could drive the future commercial growth for our country never get their ideas out of the laboratory.

Regional Development

Ultimately, regional development efforts—the creation of technology clusters (Nanotech Valleys if you will)—will fuel the explosive growth of the nanotechnology industry. Localized development efforts are already underway from Virginia to Texas to California.

In February alone, Massachusetts, Michigan, New Jersey, and Connecticut announced the formation of statewide nanotechnology initiatives, initiatives that begin to bring together businesses, universities, investors and government agencies. This has been the fulfillment of much of the Johnny Appleseed-like efforts of the NanoBusiness Alliance that started at its inception.

The Alliance launched a "Nanotech Hubs Initiative" last year to jump start regional technology cluster development. It has been overwhelmed with interest in starting these efforts. Though it has launched efforts in six regions—as well as affiliates in the EU and Canada—the Alliance has been inundated with calls from 38 states and 27 countries to help develop this capacity. These states and regions are already looking to nanotechnology to ignite economic development.

Regions are looking to grasp the size of the market, its dynamics, its best practices, how to improve tech transfer efforts and how to leverage other nanotech initiatives. In some cases the Alliance has the answer. In many it does not. This is a consequence of the nanotech field's growth outpacing original projects.

Foreign Competition

Nanotechnology is emerging as a truly global technology. Unlike many past waves of technological development, nanotechnology is not dominated by the United States. In several areas of nanotechnology the U.S. is being outpaced by foreign competition. Japan, EU, Russia, Korea, and China are all significant players in the field of nanotechnology.

A recent report from the Journal of Japanese Trade & Industry notes that the Japanese government views the successful development of nanotechnology as the key to "restoration of the Japanese economy." In an editorial to the *Jerusalem Post* just last week titled "NANOTECHNOLOGY HOLDS A KEY TO ISRAEL'S FUTURE," Shimon Peres made a similar case. They are not alone. Funding has grown at unprecedented rates across the globe over the last three years as nations try to outpace the U.S.

Two weeks ago Japan held a nanotech event that demonstrated products that were already in the market or were about to be introduced to market. 25,000 attendees showed up over 3 days at the convention center. Some 18 countries had booths at the show. What was particularly telling was that all the country booths were sponsored by government economic development groups except the U.S.—which was science and academic backed. Also telling was that most commoditized technology demonstrated at the show was derived from U.S. developed intellectual property—only it was Japanese, German and Korean companies that were commercializing these technologies and advancing them beyond basic research.

China spends about $300–400 million on nanotechnology a year—yet in adjusted value that is a huge amount. The European NanoBusiness Association has made the claim that nanotech is "the EU's to lose" and says that they outspend the United States 2 to 1. Japan's numbers are almost directly in line with our NNI and from a per capita level the Swiss and even the Australians are spending more than the U.S.

So while the proposed increases to the NNI are indeed solid and significant—especially in these turbulent economic times, we must remain aware of the fact that other nations are challenging us and are willing to match and in some cases exceed us in spending and effort. It is important that we focus on this and spend money wisely and create a solid partnership between government, industry and the U.S. university system to ensure that effort and performance are maximized so that we can indeed win this next industrial revolution.

Summary of Challenges in the NanoBusiness World

Many nanotech companies have emerged from the basic research cycle and are addressing commercialization issues such as packaging, integration and scaling. Except for the ATP program, no government programs properly address this vital timeframe in the cycle of research and business. This time period is one that competing nations in Asia and the EU are particularly attuned to addressing and are providing a life line to many U.S. start-ups, which sends growth and profits abroad.

Another area of concern for nanotech start ups is the current state of U.S. intellectual property. The Patent Office is in desperate need of training programs to ensure its examiners understand nanotechnology and its multi-disciplinary nature.

In addition, the current state of technology transfer is lacking by any measure. The technology transfer process from government and academic labs to the marketplace is very difficult. Bayh-Dole is a well written piece of legislation, but its implementation at America's universities is stalling the transfer process.

And while the NNI and overall government nanotech efforts have been a great source of coordination and basic research funding for many, these nanotech grants remain among the most competitive in the government.

Also, education, as well as workforce training and development are beginning to become issues among the nanotech community. In order to be the industry of tomorrow nanotechnology companies need the workforce of tomorrow—well trained researchers and staff.

Lastly, while the futuristic nanotechnology scenario described by Michael Crichton is thankfully science fiction, real researchers in the lab still have many questions on nanotechnology's health, environmental and societal effects. These concerns are leading to hesitation. They have also left room for activists with bad intent to fill the information void with fear. Nanotechnology is too important to the future of the American people to let this happen. We need more information and a coordinated effort to educate and dialog with the public on nanotechnology and its potential.

Close

In closing, nanotechnology the science is indeed now rapidly becoming nanotechnology the business. As a nation we have been very fortunate to have the visionary support—from both sides of the aisle—in developing and maintaining the NNI. However, we are now at a cross roads where we must expand its reach from the laboratory to the board room. While maintaining the development of basic research as a priority, we must expand our sights to cultivate the nanotechnology industry and usher in a new Industrial Revolution. Again, that is why the *Nanotechnology Research and Development Act of 2003* is so important.

1. We see the Act's ability to strengthen the structure of the NNI as being vitally important—increasing the long-term stability and growth of our nation's nanotechnology efforts.
2. The Act makes the development of the nanotechnology sector a major government focus. We especially support the Act's call for the development of some sort of outside advisory board—though we feel this group must include not just researchers, but business people, local government officials, economic development experts and ethicists.
3. To ensure America's long-term leadership in nanoscience and nanobusiness, we also strongly support the Act's call for further examination and tracking of international funding, development and competition.
4. We strongly support the Act's efforts to further address the social and environmental impacts of the science, but we would caution that this effort be focused on real science, not well read science fiction.
5. And, we back the Act's efforts to encourage nanoscience through additional grants, and the establishment of interdisciplinary nanotechnology research

centers. This will lead to more innovation and further development of the nanotech economy.

Long-term, the Alliance would like to see Congress continue its focus on nanotechnology developing programs—and expanding existing programs—for commercializing nanotechnology development.

1. Develop real numbers and benchmarks for the size and projected growth of the nanotechnology field and its economic effects.
2. Create programs to develop the nanotechnology workforce of tomorrow from Ph.D. level through K–12. We must find ways to incentivize American children to pursue the sciences in general—but especially nanoscience.
3. Ensure that the USPTO is properly educated and equipped to evaluate and approve nanotechnology patents. And make sure that there is global patent fairness. We cannot allow other nations to use patent approval as a weapon to slow down and steal our basic research.
4. Develop programs that promote and nurture regional nanotechnology cluster development.
5. Develop programs to improve the state of tech transfer at government labs and academic institutions which will improve the commercialization of emerging technologies.
6. Involve the U.S. public more in the dialog educating them and listening to their views on this paradigm shifting technology.

Again, I would like to thank the Chairman, Congressman Hall and the Committee for this opportunity to address them.

ALAN MARTY
Executive-in-Residence
JP Morgan Partners
50 California Street, Suite 2940
San Francisco, CA 94111

INDUSTRY EXPERIENCE:

2002-now **JP Morgan Partners,** San Francisco, CA
Executive in Residence, Nanotechnology. Leads nanotechnology investment effort for JPMP.

1989-2001 **Hewlett-Packard Company/Agilent Technologies**, Palo Alto, CA
General Manager, Microdisplay Products Operation. Addressed display applications in the mobile communications and consumer electronics markets.

General Manager, Integrated Circuit Business Division. Directed HP's worldwide IC business. Addressed semiconductor applications including computer microprocessors, computer peripherals, storage, communications and high speed measurement.

Worldwide Manufacturing Manager, Integrated Circuit Business Division.

R&D Director, Integrated Circuit Business Division.

1988-1989 **United States Government**, Washington, D.C.
White House Fellow and Special Assistant to the Secretary of Defense. Served under the Honorable Frank Carlucci and the Honorable Richard Cheney.

1984-1988 **Applied Materials, Inc.**, Dallas, TX

Summer 1983 **McKinsey & Company**, Chicago, IL

1979-1982 **Caterpillar Tractor Company**, Peoria, IL

1978 **Silliman University**, Dumaguete City, Philippines
Associate Professor.

EDUCATION:

1982-1984 **Stanford Graduate School of Business**
MBA degree.

1982-1984 **Stanford Graduate School of Education**
Masters degree in Administration and Policy Analysis.

1975-1978 **Iowa State University**
BS in Materials Science Engineering.

ADDITIONAL INFORMATION:
Holds two issued patents in optical systems.

March 17, 2003

The Honorable Sherwood L. Boehlert
Chairman, Committee on Science
2320 Rayburn House Office Building
U.S. House of Representatives
Washington, D.C. 20515-6301

Dear Mr. Chairman:

Thank you for your invitation to testify before the Committee on Science on March 19, 2003. I am sending this letter to comply with Rule 1 of the Rules Governing Testimony before the Committee.

As an individual I have not received any federal funding which directly supports the subject matter on which I am testifying, federal nanotechnology programs and the Nanotechnology Research and Development Act of 2003 (H.R. 766). I am not aware of any such funding directly received by J.P. Morgan Partners or any of its affiliates. Several of the portfolio companies in which J.P. Morgan Partners is an investor have received such funding:

Nanosys, Inc.	approximately $1 million	through 2002
Surface Logix, Inc.	approximately $5 million	2002
Illumina, Inc.	approximately $9 million	through 2002
Nextec Applications, Inc.	$ 69,874	1999

I look forward to appearing before your committee on March 19.

Sincerely yours,

Alan Marty
Executive in Residence
J.P. Morgan Partners, LLC

DISCUSSION

Chairman BOEHLERT. Thank you very much. Let me ask our non-government witnesses—well, let me ask all of you, where are we vis-á-vis the competition? Are we playing catch-up? Are we ahead, but being challenged as never before? How would you assess where we are, and what are other governments doing to support nanotechnology R&D? Dr. Theis?

Dr. THEIS. Well, certainly, we see other governments willing to fund this kind of research and development at a level that is comparable to the U.S. National Nanotechnology Initiative. I do personally believe that the United States has a bit of a secret weapon in our venture capital community and our entrepreneurial spirit that we are willing to focus and—in a way, and take chances and accelerate certain science, the development of that science into products. And that is a system that should be encouraged. And it is a system that can't function without government funding of basic research, which——

Chairman BOEHLERT. Dr. Roberto, yeah, what do you—how do you see things?

Dr. ROBERTO. I think we are in a very tough fight. I think that we have an edge right now, but I think the kind of investments that we are talking about in H.R. 766 and the kind of priority you are addressing this with is essential to staying ahead.

Chairman BOEHLERT. Dr. Batt.

Dr. BATT. I think you have to define, you know, which particular field we are looking at. I think if you are talking about sort of the grinded out kind of miniaturization sort of stuff, yeah, I would say that we are not necessarily as competitive as we should be. I would argue in our particular field, nanobiotechnology, where we are trying to marriage two distinct fields, we are way ahead of the game. We seem to have, in the United States, this ability to sort of collaborate across disciplines that is really kind of unique and almost indifferent to the university structure.

Chairman BOEHLERT. Mr. Marty, talking about venture capital.

Mr. MARTY. Well, let me talk about governments first, just a couple numbers, and these numbers have a big error band on them, because they are—none of the governments do a particularly good job at defining exactly what is nanotechnology and what it isn't. But Japan, in '03, is looking to spend a billion dollars of government money in nanotechnology. The European Union, greater than one billion in '03. South Korea, 145 million in '02. And a lot of this is focused not on basic research, but on the commercialization process. So I think most people would feel comfortable that the U.S. has a good lead, maybe not as strong a lead as we have had in past scientific endeavors, but I think we have got a good lead in basic science.

I think the challenge for us is can we commercialize this so that we can get the economic benefit, the jobs benefit out of this nanotechnology revolution.

Chairman BOEHLERT. So you are comforted by the Administration's Initiative and the response from the Congress on a bipartisan basis?

Mr. MARTY. I am absolutely comforted by it, and I think it is very fundamental.

Chairman BOEHLERT. Thank you. Mr. Russell, do you want to respond to that?

Mr. RUSSELL. Yeah, I think the summary is a good one. I think that this is clearly an area that there is a tremendous interest across the globe in terms of research. I think we still are in the leadership position, and I also think that it is an area that we are going to continue to have to fund aggressively.

Chairman BOEHLERT. Mr. Marty, what about the commercialization part of the equation, ATP [Advanced Technology Program], for example?

Mr. MARTY. Well, ATP has been, you know, challenged here in Washington, DC by many folks. I do think that ATP has a unique role to play in commercialization. I mean, there are a lot of start-ups, and that is where I spend my life, the world of start-ups, who have a basic technology that they have been able to prove once or maybe a dozen times in the laboratory. But unfortunately, I have—you know, as I look at hundreds of deals, I am not able to invest in any of those start-ups. And that is generally true for all venture capital players, because there is no—we have no intuition that they will have an ability to produce that product at any sort of volume, at any sort of an appropriate cost structure.

And the ATP, actually, is one of the unique funding mechanisms that allows those kinds of start-ups to get funding that can move them a little bit further down the path. And by showing some reasonable progress, all of a sudden, the venture funds become available to these companies. But without showing some reasonable progress in that area, they, frankly, die and go away.

Chairman BOEHLERT. Well, that is the very purpose of ATP, as I see it. We don't need another agency to provide money for what the private sector is willing to provide money for.

Mr. MARTY. That is right.

Chairman BOEHLERT. We have got to be the investors. Dr. Batt, I—you ought to take your show on the road, because you can excite a lot of people, and you bring it down to everyday real terms that people can understand. And I will tell you one way to get a lot of people excited about this is not so much through the technology, but the opportunities it presents for America outside of our urban centers to develop new industries, new job opportunities. That is a wonderful presentation you have.

Dr. BATT. Well, thank you. I mean, one of the things that we look at, and I started about five years ago a small company in Ithaca basically to sort of bridge the academic sort of commercial gap that I saw there. And I think it is very important for us to sort of recognize the fact that this—these sorts of industries will not be the giant chip manufacturers. These are going to be small industries, and as you are well aware in upstate New York, we would like to see a little bit more of these sort of high-tech jobs come back there and be able to sort of rejuvenate that area.

Chairman BOEHLERT. Thank you very much. Cornell is leading the way in that regard. Mr. Hall.

Mr. HALL. Mr. Chairman, Mr. Marty is—the Advanced Technology Program has been controversial since its inception, has it not?

Mr. MARTY. It has.

Mr. HALL. And is not——

Mr. MARTY. Not in the industry. I think it has been controversial, you know, in Washington. I think in industry, it has been——

Mr. HALL. I think——

Mr. MARTY [continuing]. Appreciated.

Mr. HALL [continuing]. It is heading into doing away with it.

Mr. MARTY. Right.

Mr. HALL. And I think you probably have a problem with that. And I might ask Mr. Russell, though, in all fairness, what emphasis should the National Nanotechnology Initiative base on the transition of research results to commercial developments and to bridge the gap between basic research and commercialization? What is your position? Or do you have a position opposite to what Mr. Marty has?

Mr. RUSSELL. Well, two separate issues I think here. One is in terms of sort of the emphasis of NNI currently and over time. Clearly, one of the things that has been emphasized by NNI is basic research. And I suspect that that will continue into the future. That being said, if you look at some of the specific programs that are—that fall under NNI, including the centers, for example, that DOE is structuring, there clearly is a specific outreach effort to the commercial sector through user facilities again, for example, at both DOE and NSF. NSF has actually started those centers up.

In addition, I think when you start talking about technology transfer, that is a major issue and consideration not just for nanotechnology, but I think across the entire federal research effort. It is something that we are taking very seriously and something we are working hard on. An example, the PCAST, which is now beginning to review NNI, has just released an interim report on how we can improve our mechanisms for technology transfer. They are going to continue to do that review. They are sort of uniquely qualified to look at that issue, in part because they are made up of both university presidents and heads of major companies.

And so I think the issue of how we transfer technology is an important one. It is embedded in the NNI program. There are parts of the NNI program that are specifically oriented toward interfacing with not just academia, but also industry. But I also think that the primary focus, at least currently for NNI, is going to be basic research.

Mr. HALL. Mr. Marty, your company thinks nanotechnology advances are going to impact a lot of the sectors where we already invest—and that seems to be something that you could really—including biotechnology, energy, communications, and semiconductors, in your opening speech.

Mr. MARTY. Right.

Mr. HALL. What is your position on Mr. Russell's—I mean, I think you to be wonderful, and you all are—all of you obviously have two brains. And you can get around any questions that we ask, but it would be wonderful in this, which is a wonderful thrust, one of the greatest. And I really recognize the Chairman and the other Members who introduced this legislation. It is really one of the finest, the most pure. It makes you feel clean when you are a part of it, this thrust. How can you two continue to work together, because we want to be successful in this? We want to be first. We don't want to be third.

Mr. MARTY. Well, first of all, I do feel strongly that, as I said in my remarks, that nanotechnology will impact some of the most basic industries in our country. And so the ability to move forward with not only basic research, but also commercialize it, is going to impact the semiconductor industry. You know, it is a $136 billion industry. It is growing at 10 percent. It will not continue in at the pace it has been continuing if we do not have the advances in nanotechnology. It is just fundamental.

The same is going to be true for the flat panel display industry, an industry that the United States would like to take a larger share of. It is a $25 billion industry. We have got some very interesting basic research and basic intellectual property that has been established here in the United States. If we are not able to find a way to commercialize that and bridge the gap to commercialization, then my expectation is that that $25 billion industry, which is currently growing at 28 percent, will continue to be dominated by countries outside of the United States.

So for me, the challenge for us is to take what we have as fundamentally strong and compelling intellectual property in the nanotechnology area and find a way to move that into, you know, the industrial complex that we have within the United States to create jobs and opportunity.

Mr. HALL. My time is up, and I thank you. I yield back.

Mr. SMITH OF MICHIGAN [presiding]. Well, with the prerogative of the Chair, I hope when we are talking about "commercialization," we are talking about commercialization in the United States. And when we are talking about "taking the lead," we are talking about taking the lead in adding to not only health and our capacity to improve research, but also the United States' economy. And with that, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much. I note that the legislation is suggesting about a 10 percent increase in our spending level for this research. And of course, the panel has unanimously forced this increase in spending levels, considering that this is the technology of the future, etcetera. Maybe you could tell us where we should decrease the spending of research in order—what is the technology of the past that we need to defund in order to come up with this money?

Mr. RUSSELL. Well, first let me be clear about my statement. And I think in my written testimony it is clear. I have been—I discussed the President's '04 budget, which included a 10 percent increase. I think in that budget you will find that we did, indeed, weigh pros and cons and, as current discussion that you have heard indicates, there are some programs that did not receive as much funding as other programs. We think nanotechnology is one that——

Mr. ROHRABACHER. You are being nebulous about that. You might mention a few.

Mr. RUSSELL. For example, the—a program that we were just discussing, the ATP program, did not receive significant amounts of funding in the President's budget, and again, NNI and other priority basic research programs did receive substantial increases. And I think that priority setting is crucial in any budget exercise. And so we believe that nanotechnology research is a priority. It is one of the few priorities that we specifically outlined to the heads of all of the various research agencies when the Director of OMB, Mitch Daniels, and the head of OSTP, Dr. Marburger, sent out their memo last summer indicating what the priorities are. So——

Mr. ROHRABACHER. Anybody else want to take a shot at knocking somebody else off his horse in order to get onto the horse? I would have to say that in my 14 years in Congress, I have always been able to find people who have something to advocate spending more money on, but I have never been able to find even those people willing to advocate spending less money on something else. And until the scientific community gets its act together and is able to do that, it is not going to be taken as seriously as they would be. People who come up here to testify should be able to very easily say, "This research is no longer as worthwhile. This research is, and that is why we are advocating we spend it there."

About some of the other things that we have heard today, is this—are we going to be able to write an encyclopedia on the head of a pin? Is that—are we going to be able to—with—take information something on the size of the head of a pin and retrieve it?

Dr. THEIS. I would say beyond a shadow of a doubt. In fact, the problem, of course, is not writing it, it is retrieving it. But I think——

Mr. ROHRABACHER. Right.

Dr. THEIS [continuing]. That the exploratory research in laboratories around the world certainly indicates that that will happen, that and quite a bit more.

Mr. ROHRABACHER. Okay. But that hasn't happened yet, right? We haven't——

Dr. THEIS. Not—certainly not as a practical product.

Mr. ROHRABACHER. All right. So this trillion dollars a year, and I think as Mr. Marty has suggested, a trillion dollars, within 10 years, we are going to have a billion-dollar—this is going to be a trillion-dollar business?

Dr. THEIS. Well, you know, I would like to continue with that.

Mr. ROHRABACHER. Sure.

Dr. THEIS. We—Mr. Russell and I did try and make the point that this is about new materials. I don't know the exact science of the material sector of the economy, but it is certainly hundreds of billions of dollars. And there are—there will be very few new materials developed and brought into the marketplace in the future that are not nanostructured materials. In other words, all new materials in the future, all improved materials will be nanostructured materials. So that is an enormous sector of the economy by itself. To get to the trillion dollars, I think you also have to include the—you know, the information technology hardware, which I alluded to, which is already a nanotechnology. It is not a mature nanotechnology, but it is already a nanotechnology. So those are realistic kinds of numbers.

Mr. ROHRABACHER. Are we going to have clothing that you don't have to wash as much because it won't get as dirty?

Dr. THEIS. Well, that is a—that sounds trivial, and I may——

Mr. ROHRABACHER. No, it is not trivial.

Dr. THEIS. I don't know. But you know, there are—those things are happening right now. There are nanoparticles being incorporated into fibers for clothing for exactly those applications. There are nanoparticles in paints, in cosmetics, in all sorts of mundane, everyday things, but this—I—you know, those are obviously not the spectacular applications of material science, and they are not the spectacular application——

Mr. ROHRABACHER. But you do remember the man in the white suit?

Dr. THEIS. Yes.

Mr. ROHRABACHER. For those who don't—haven't seen that film, I would recommend it. It is kind of an interesting film. But thank you very much. Your remarks have been enlightening.

Mr. SMITH OF MICHIGAN. And the new man in the white suit, the suit stays white. Mr. Miller.

Mr. MILLER. Thank you. For the last 21 years I have been married, my dirty clothes simply appear clean and folded in my chest of drawers, and up here in Washington, I find the only way they become clean is if I go down to the coin-operated laundry in my building. So having clothes that stay cleaner is very attractive to me. It is not trivial at all.

I did want to follow up on the questions that Mr. Hall asked earlier. Mr. Marty, Senator Allen testified earlier that we were well behind in nanotechnology, behind other industrialized countries, or even some that were not so industrialized. He had listed Japan, Korea, the European Union, China, I don't think he mentioned Israel, but I have read or heard elsewhere that Israel is also probably ahead of us in nanotechnology. Do you agree that we are behind them in nanotechnology?

Mr. MARTY. It is very hard to measure.

Mr. MILLER. Um-hum.

Mr. MARTY. And so as you read in literature, and as I talk to people, I get a variety of different opinions. My own opinion is that we are being outspent by Japan. We are being outspent by the European Union right now. And on a per capita basis, we are being outspent by a lot of people: Singapore, Korea, etcetera.

But I also believe that we fundamentally have some structures in the United States that give us some advantage and that make it—make this a very attractive place for not only developing technology with our university labs and our universities, but also commercializing technology. So I think the future is yet to be written. To me, an important thing to realize is that we are not as far ahead as we have been in past scientific endeavors. And so I think it is a closer race. And if we don't keep our minds focused on some of the issues of commercialization, we may find it is a race that we are yet to lose.

Mr. MILLER. When you say those other nations are outspending us, are you—are they outspending us in basic research or in commercialization efforts?

Mr. MARTY. You know, I wish I could give you a good answer. I think—I have not been able to find literature that is compelling to answer that question. I think it is very fuzzy. And to the extent that somebody within the Federal Government, as envisioned in this bill, could give us better visibility as to who is spending real money on what, I think that would actually be significant value added.

Mr. MILLER. In—Mr. Marty, in both your written testimony, I think you also mentioned in your oral testimony, that JP Morgan Partners have invested in five nanotechnology companies in textiles, drug discoveries, electronics, flat panel. How much have you invested and what do you—is your expected rate of return on that over the next five or 10 years?

Mr. MARTY. Well, the first four that we invested in were small investments. We were still trying to understand what nanotechnology was. We did make, as I mentioned in my notes, we did lead a $30 million round just last November in a company called Optiva. So given that we are an $8 billion fund, our investments in nanotechnology to date are, you know, less than $40 million. So it is a pretty over the last, you know, four years or so. So it is actually a pretty small amount of our investment. And I think this makes a very important point, which is that we invest not because it is nanotechnology and not because it is the future of, you know, economic development for the country. We invest for return. And generally what we find, if we take nanotechnology investments and we compare them against investments in, you know, movie theaters or pharmaceutical companies or, you know, oil drilling or something like that, and we look at all of those different possibilities, the nanotechnology often is too risky. It is not sufficiently commercialized yet for us to be able to make a good, wise investment.

And so that is okay. That is what venture capital is about, but I think it points to the issue of making sure that we can, in fact, engage the venture capital community in commercializing this technology. And that means we need to bring it along a little bit more.

Mr. MILLER. Had the ATP program, the Advanced Technology Program, in any way, helped take those products from basic research to commercialization? Had they done anything in packaging, integration, scaling to prepare those—make the transition?

Mr. MARTY. There are certainly good examples where ATP has been helpful. I am sure there are also examples where ATP has been ineffective. And so I am not trying to say exactly how the legislation ought to be written. But I am advocating, having spent a lot of time in other countries in the commercial world, I do believe that the United States needs to continue to look for ways that we can help small companies to make progress toward commercialization, because otherwise, those companies will seek funding outside of the United States.

Dr. BATT. If I may chime in for a second, just sort of looking at the academic section of the investment there, I think we are still the envy of the world. I think the investments that are made by, for example, the National Science Foundation to academic science, are—there are countries looking to model what we are doing here.

I think where the gap exists is simply taking that basic research, taking that knowledge and then sort of converting that into something that is commercializable. And that is where you see a significant investment in countries like Japan and Korea and in the EU.

But I think as far as the bringing together of academic scientists to sort of cross disciplines, I know that our particular center has been approached many, many times to sort of ask us a question: "How do we do that?" And I still think that the creativity in the academic sector is still there. It is still a very powerful resource and worthy of investment.

Mr. SMITH OF MICHIGAN. As Chairman of the Research Subcommittee, we have held hearings on nanotechnology. And of course, outside of medical, NSF is the largest basic research effort in nano, as you know, Mr. Batt. And at $221 million, we—NSF represents about 30 percent of the total NNI budget. But in NSF, with our basic research and our requirements for publication, and I am moving back into commercialization again, I mean, we might lead the world in terms of our basic research, but I guess a couple concerns, one is making sure that the American taxpayers paying for that effort get some of the rewards. And so the technology transfer in this area that allows the economy in the United States to benefit has got to be one effort.

And the other thing that I have been—that seems to be apparent is other countries are coming to Cornell and looking at our basic research and trying to utilize that basic research, add to theirs that isn't always as available as ours, to win the war in commercialization. So maybe start with you, Dr. Batt, in your general comments, since you are the only one, I guess, here that is conducting the—some of the NSF money in the area.

Dr. BATT. Yeah, I mean, it is a great concern, because you know, we try to be as global as we can in terms of one where our students come from, and also trying to then, as I do to sort of maximize the pool of students of U.S. citizens that come into our educational system. And we try to sort of encourage those sort of linkages with the private sector. The problem in academia is largely that when we continue to operate in sort of isolation, we build this widget, and then we go out and try to sell it. And then we realize that that linkage should have been made well before we really formulated all of our research plans. And that is—a lot of what we try to do is just sort of bring the private sector, not serving their needs exclusively, but understanding what their needs are all about, so that the transfer of that technology into the private sector is a relatively smooth transition. We still have a lot to learn. You know, academia sort of built this educational institution. And it is probably only within the last, you know, 30 or 40 years we began to realize that it is, as you well articulate, that we can't simply operate in a vacuum, that our resources come from the taxpayers of the United States. And we need to sort of give back to them something that is really tangible, not a publication in Science.

Mr. SMITH OF MICHIGAN. All right. Let us take it from there with Mr. Theis and let Mr. Marty maybe in turn. So you know, this is a Science Committee, but as Mr. Rohrabacher points out, other countries can—are allowed to consider their investments in the new machinery, the new investments—and depreciate it on their tax bill the year that they purchase it. We have to let the inflation sort of eat up some of our investment. So it seems to me like not only do we need NNI for the research, we need some of an effort within Congress to look at the different aspects to help make sure that we commercialize it and take advantage of it here. And I am talking about the depreciation schedule that tends to—inflation eats up the value of that depreciation. But in terms of the commercialization, Mr. Theis, then you, Mr. Marty.

Dr. THEIS. Well, I can't comment on what changes in the tax laws or the accounting principles would help that effort. But I distinguished between companies like IBM that are large and established and are defending established markets and need to incorporate a continuing stream of incremental improvements and advances in the established technologies. And I think large companies, established companies in the United States, at least in information technology, are doing a good job of that. And we will go to the national labs, and we will go to the universities. And we develop the university relationships. Different companies do it differently, but we all have strong mechanisms in place to make sure that we are looking at what is going on and collaborating and moving this stuff out of——

Mr. SMITH OF MICHIGAN. Is there any way that you can think of that we can encourage the private sector to be part of that basic research investment? Any way we can have a win-win? Mr. Marty, you go ahead.

Dr. BATT. I don't have a specific recommendation.

Mr. MARTY. I have one specific one, which I would envision that the whole panel here would be supportive of. I mean, the U.S. Patent Office is challenged right now in the nanotechnology area just because nano—I mean, we are all challenged in the nanotechnology area. So that is not a reflection particularly on the Office, but nanotechnology is moving very quickly. It is very broad, and it is very interdisciplinary, which means it is challenging to get your hands around the science as well as what the commercial ramifications are. To the extent that we are able to have faster patent movement, more clear patent movement, that allows the private sector to have something to invest in even before the commercial product is, you know, within two years. And so I would say one of the things that we could make sure that we follow-up on as a National Nanotechnology Initiative, is to assure that our patent office is the very best in the world when it comes to handling patents in the nanotechnology——

Mr. SMITH OF MICHIGAN. Give me Mr. Russell and Mr. Roberto just very quickly. Do we—is there some kind of an effort that should satisfy us that we are looking at the research that countries like Japan and Germany or whoever that are leading or challenging us in this area, do we know the kind of research results that they have achieved? Or is that difficult with the organizations?

Mr. RUSSELL. Two quick things. One, first getting back to your first question. There actually is one thing in the tax code that I think would be helpful, which is making the tax credit permanent, something the Administration supports and something that I know a lot of the Members of this committee——

Mr. SMITH OF MICHIGAN. Yeah, but you know, you can play so many games with it that it is tough. But I would like to encourage more basic research credit, actually. But go ahead.

Mr. RUSSELL. Yes. The second thing is, on the patent issue, that is also an important issue. And actually, the Patent and Trademark Office has put forward a plan that is intended to reformulate how it does business and hopefully will speed the process. And that really is something that hopefully will be helpful.

In terms of looking at what is happening overseas, one of the big complicating features there is even just the definition of nano. And I think you will find this with all of the numbers that you see. Nano can be defined as everything, because everything, obviously, is built on atoms. And so yes, it is followed. We do look at it. There are some good studies, but a lot of the numbers aren't apples to apples. And you have to keep that in mind.

Mr. SMITH OF MICHIGAN. Just a comment, Mr. Roberto.

Dr. ROBERTO. Through the scientific community, we have a very good interaction internationally, and I think we have a good idea of what is going out there in basic science—going on out there in basic science.

Mr. SMITH OF MICHIGAN. Do you have a good idea of what is going on in military research complex?

Dr. ROBERTO. It would depend on whether that was classified or not, and probably not.

Mr. SMITH OF MICHIGAN. Probably not. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. And I really do appreciate the testimony of our experts up here. A couple of words that I have heard that sort of takes off some thinking is I believe Dr. Batt had something about vacuum. And I think that nature hates a vacuum, so it is going to be filled by something. And so I really appreciated your approach and instruct that you focus on what nanoscale technology is all about. And we talk about youngsters. And I think that that is where we have to really start mainly because in the past when we talk about technology, we have always—the big battle was about H1B Visas. If we do it right now and do it correctly now, we can grow our own. But I don't think that we have to be concerned about foreign competition or people coming from other countries. Because they add a flavor and insight that we don't have in this country that we found that, at least in Silicon Valley, that the great amount of technology came from folks who came overseas and stayed and created jobs. So I am not fearful of that, either.

What I am concerned about is we talked about having people at the table, presidents of universities and things like that. My question to the group is who is not at the table now that should be, because what I want to be able to do is anticipate unintended consequences? The only way you are going to do that is have folks like yourselves from different backgrounds ask the question, "What if?" And I think the new one that came up for me today that I haven't thought about were problems that could be barriers in terms of the patent office. And you know, how do we make that efficient? How do we make it fair so that there is access to some sort of economic benefit to the research and the creativity we have both in the private sector and the university?

And I guess my other question would be, we need to find ways to make new ideas more public so that those folks who are not in that circle can also think why not this, so that we can expand this whole mindset even further? And you are right, I believe nanoscale is ubiquitous, and there isn't anywhere that it wouldn't be applicable. So I am very curious of—to hear the reaction of the panel.

Mr. MARTY. I really appreciate your comments, Congressman Honda. I do think that the engine of nanotechnology is the scientific community. There is no doubt about it. But in order to actually move the whole train forward, and in particular with respect to this bill, when we talk about, you know, who is going to be the outside advisory board that is going to talk about nanotechnology. As I suggested in my comments, I really think we need heavy research, no doubt about that. But we also need some business people, some local government officials, because a lot of this can be handled, you know, with regional sorts of initiatives, economic development experts and ethicists, I think, having that whole community. When you ask who are the people at the table, I think these are the kinds of people you should consider having at the table in order to round out nanotechnology.

Dr. BATT. Back about two years ago with support from the state of New York, we established what we call the Alliance for Nanomedical Technologies. And when I set up my advisory panel, I did just that. We brought in, you know, representatives from the private sector at the beginning, so that we, again, were not this sort of pure academic institution that was going to sort of develop these things and then go out and shop them. What we found was that there were significant issues, but they could be addressed in terms of intellectual property, in terms of who owned the technology, what did the people who came to the table first get as an advantage. And what they got as an advantage was a first look at the technology that was coming out of this research effort.

We didn't really bring in the—sort of the societal ethical issues, because I think what is not at the table right now and what is missing in a lot of this is really just the general public. I mean, the general public has no idea. We are developing exhibits for the science center in Ithaca. We ask kids, like, "What is nano?" And they have no idea. It is probably not until maybe high school where people understand what that scale is. And yet when you look at the general public, they are terrified of things they can't see. You know, you sort—you know, you see it in terms of bacteria and biowarfare agents. And now nanotechnology is even worse, because it is something that a bunch of guys in spooky suits are making some place in the deserts in New Mexico. It is not happening, but those are the kind of things that you get.

And that is why I think what we are trying to do in terms of going out to the general public and just simply talking to them, which is very hard for academics to do. I mean, we are terrified talking to normal people. But it is something that we have to do. We have to show them that we are kind of like normal people. We just, you know, sort of sit in a lab all day, but more or less, we are kind of just like the rest of them.

Mr. HONDA. I—thank you for that response, but I think that you are correct. And that is why I think the advisory group is important so that we start addressing some of these questions that—and the best example I can think of is stem cell research, where all kinds of things come up in people's minds where it bridges or sometimes becomes a barrier, you know, in our beliefs and our value systems. And if we do it right at the beginning, we can avoid a lot of that fear and really start working with youngsters. Because when you go from the vacuum tube and the size of computers back in the 50's, when I was going to high school, to today, you would have never convinced anybody that that was possible. And yet, we are past the Dick Tracy era now. And I think that it can be wild and fun, but I don't want it to be scary for folks. And we can really control this kind of——

Chairman BOEHLERT. Thank you very much. The gentleman's time has expired. Mrs. Biggert.

Mrs. BIGGERT. Thank you, Mr. Chairman. Just briefly, Mr. Marty, you mentioned in your testimony that at the group of the various countries that were together with their products, so to speak, that so many of what they had presented was based on our intellectual property. Did you mean that we had given that to them or was this something that had become available by other means?

Mr. MARTY. No, I only reflected that a lot of this basic research had been initiated here. I was not meaning to reflect anything illegal. It is just within the world of basic science, if things aren't patented, I mean, information flows pretty broadly. So——

Mrs. BIGGERT. I just wanted to clarify that that it is—having been in China recently and seen a lot of our goods over there that were questionable. My question then for the panel is how will the flat—or what I might call inadequate or disparate funding levels for research in the physical sciences adversely—will this adversely affect our ability to realize the promise of nanotechnology? Whoever would like to answer this——

Mr. MARTY. Well, it certainly has an effect. I would say that one of the good things about the NNI is that it has resulted in some increases in funding for the physical sciences. And it has resulted in a significant shift of resources from areas that are a little less exciting and less interesting to this area, which is very exciting and interesting. So it has had a desirable effect.

Of course, the history, as I believe you know, is that funding in the physical sciences has been flat as a fraction of—or actually trending downward for a very—as a fraction of total funding for quite a long time. And it is certainly not something we want to continue, because if you look at all of the basic science that supports, you know, silicon microelectronics, our existing information technology, that basic science was done in the 1930's and the 1940's. And so there is this long lead time between doing the basic research and getting the tremendous economic benefits that we know flow from basic research. So we need to make the investments now for the next 20 years.

Mrs. BIGGERT. Well, what we have seen is with NIH. We have doubled the funding in five years for that with NSF. The same as that we are proceeding to do that, so that it seems to me that we are, you know, losing parity with the physical sciences to keep up with those other two.

Mr. MARTY. Well, I could amplify that by saying that there is a tremendous role for the physical sciences to play in health science and in life sciences. And that is all the instrumentation and all of the mechanisms by which the studies of biology, the human body, and so forth are done and by—and the instruments, which support medicine. And that does come from the physical sciences. So we don't want to get this—and in fact, NIH has now, because they have a good funding situation, they have directed some of that funding in the direction of instrumentation, and some of it is in the direction of nanotechnology. So some of that funding is going into the overall thrust.

Mrs. BIGGERT. Thank you. Mr. Russell.

Mr. RUSSELL. Yeah. No, on those two points, I think that they are being made well. Two things. One is with respect to NNI, one of the strengths of the program is that it is an interagency program that captures not just the leading physical science funders, such as NSF, but also NIH, also DOD. As a matter of fact, one of the recommendations of the NRC report is to actually have NIH even participate more in the program. And that is something that we are very supportive of. And so I think it is a great model of how we can take a basic science and rope in all of the relevant agencies, because as was pointed out, NIH relies on the physical sciences. And actually, it also funds the physical sciences, if you look over time. I think the last time I looked at it, about a billion dollars of NIH's money was going to chemistry and physics-related research. But I think clearly that NNI is a great example, and I think that is one of the reasons why it not only has so much support, it is also receiving substantial increases in budget.

Mrs. BIGGERT. And we are talking about so much—well, really for nanotechnology to flourish, we are going to need new skills in this field and in engineering. And are we going to have the next generation of scientists and engineers to be educated and trained in this field? Probably Dr. Batt or Dr. Theis.

Dr. THEIS. Well, let me just say that it is my hope. I mean, you know, science, as a profession, is not looked at very favorably by the vast majority of young people. They don't understand what we do. They don't understand what the benefits are. They can turn on cable TV and see basketball players and all of these rock stars and all of this other stuff. I am not advocating a cable channel devoted to science, because I don't think that is appropriate. But I think we have to sort of have these kids understand that there are exciting opportunities there and hopefully give them that sort of peek of what it is all about in a very sort of fun way.

Everything we do is fun. That is what we try to go out there and convince these kids that it is kind of fun. And yes, there is some hard work behind that, but it is not just hard work, that there are really some interesting things.

To go back to what you were talking about as far as, you know, the sort of physical sciences, one of the things that we discovered that—in developing the center is that the really intriguing questions in science are in biology. And yet the really intriguing tools to answer those probably lie in the physical sciences. And it is only in—probably in the last couple of years that the physical sciences have developed enough instrumentation to really probe these very complex biological questions. And how you sort of bring those groups together is a very interesting problem.

Chairman BOEHLERT. The gentlelady's time has expired. Mr. Bell.

Mr. BELL. Thank you, Mr. Chairman. First, I would like to thank all of you for your presentations here today. I would agree with those who believe that nanotechnology is the present as well as the future, and it is extraordinarily important in my district. Dr. Batt, you probably know that we have an NSF-funded nanotechnology center in my district, Rice University, that is working very hard, so I certainly realize the invaluable work that folks, such as yourselves, are doing. And I also appreciate Dr. Russell including in his statement the cutting edge work of Dr. Richard Smalley, who I have had a chance to visit with here recently. And for those of you who don't know, Dr. Smalley is the Rice Nobel Laureate, who, for those with a less scientific background, is also known as "the Buckey Ball guy."

And I—we have—Dr. Batt, you pointed out what—in your presentation, what nanotechnology is not, but I guess what is also sort of fascinating about it that it is so many things. And whether medicine, engineering, computing, it can have a huge impact on all of those areas, but one area we really haven't touched on very much here today is energy. And you know, when Dr. Smalley gives talks about this subject, he talks about how nanotechnology could really change the world in which we live when it comes to energy. And I am curious as to whether you all think this legislation takes into account the importance of nanotechnology's energy applications. And Dr. Batt, I will just start with you.

Dr. BATT. Well, first of all, I am well aware of the program at Rice. They do a lot of things very, very well. And Smalley there, is a pioneer. There is absolutely no doubt. And I am really surprised how small Rice really is as a university. It is really not large, and yet they have made a very large impact in a very small field.

As far as energy is concerned, we look at energy in two forms. One is that there are a lot of interest in how do you power these devices. You know, we can sort of look at these and design these very small-scale things that move, and yet when it comes to them powering these things, it is an intangible problem. A colleague of mine, Amit Lal at Cornell University, is developing very, very small batteries that take advantage of the properties of radioactive material. And these are very low-level energy radioactive materials, and he is actually developing batteries that are on the size scale of the types of devices that we are trying to develop.

The only area that is really intriguing is biological energy. Obviously, we are full of billions of cells that all fuel themselves and all have energy, and yet we don't walk around with 50-pound batteries on our backs that, integrated into biological systems, is really not only a system to sort of utilize energy, but also to generate them. And yet we understand a little bit about that, but again, we don't understand it as a fundamental basis. And we don't understand how we then take that fundamental knowledge in biology and really convert that into something which we can practically harness in terms of developing these sort of nanoscopic materials.

Dr. ROBERTO. I would like to add that looking more broadly at energy, there are tremendous impacts of nanoscience that—you can think of fuel cell materials. You can think of catalysis for the hydrogen economy or for other applications. That is a $30 billion or more industry. You can talk about advances in using photosynthesis. You can talk about high-temperature materials, and there are a number of applications where you can improve the properties of materials and make them perform better at the high temperatures that you need to get energy efficiency, also lightweight materials for vehicles. And so there are tremendous opportunities that we see in energy and energy independence that can come from nanoscience.

Mr. BELL. Does anyone else have any thoughts on how the legislation addresses the energy application? Mr. Russell.

Mr. RUSSELL. Yeah, I was going to say I had the pleasure, actually, of participating with Dr. Smalley on a panel that briefed PCAST before it took on the assignment of looking at nanotechnology and the NNI program. And actually, PCAST has set up one of the three areas it is going to look at. It is actually segmenting itself into three sort of task forces. One of them is energy and environment. And that is going to be co-chaired by Charles Vest. And so as this relates to the advisory functions that are recommended by the legislation, I think that is going to be an important component. It is one of the reasons why we are so gung ho on having PCAST perform those advisory functions is because they, I think, have targeted the right issues, and energy is one of them.

Mr. BELL. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you, Mr. Bell. We are going to have the folks from Rice up in our early April hearing, so we very much look forward to that. Dr. Gingrey.

Dr. GINGREY. Thank you, Mr. Chairman. Not to be outdone by my colleague, the gentleman from Texas, I would like to put in a plug for the outstanding work that is being done at my Alma Mater, the Georgia Institute of Technology in regard to nanotechnology as well.

I wanted to ask—I am going to direct this question, Dr. Batt, to you and also to Mr. Marty. In light of the recent bill that we passed in the House banning human cloning for both reproductive—reproduction and research, some individuals in groups have suggested that nanotechnology developments may raise societal and ethical concerns. Is any part of your center's activity at Cornell devoted to addressing such concerns? And then I will ask Mr. Marty the same question in regard to your investment choices.

Dr. BATT. To—as I said, we haven't addressed that issue sort of head-on. We get a lot of interest from people who I would argue on the fringes of their knowledge of nanotechnology. I was interviewed by a high school student who basically asked the question, "Was nanotechnology going to lead to the demise of civilization as we know it?" And I said, "No, it is not." Until we sort of really sort of broaden the sort of education base of the general public, then the arguments are simply between sort of academic scientists on one end and sort of the—what I again would call the fringe element at the other end. And that is really not a very productive discussion at this point in time, because it sort of argues what their knowledge of nanotechnology is, which is the sort of black helicopter sort of floating through your bloodstream and sort of changing your personality versus what we know to be as the very core fundamental limitations and what we can do right now. And what lies in between is sometimes not a very productive discussion, because I will try to tell them that I can't imagine why you would want to do that. And they will say, well, because of these unknown elements out there that really want to promote that. What is lying in between is the general public that we have to sort of really embrace and begin to have them understand what is nanotechnology, what are things they can't see, what is this area all about, how is this going to benefit me at a really very early stage.

I mean, the classic error that was made was with, as we now know as being in error, with genetically modified organisms. The industries that were involved in it really didn't think it was important for them to sort of articulate what they were doing to the general public. Then what happens is there is this backlash, and now you have to sort of go back, deal with the backlash, and then deal with what is people's fundamental misconceptions about what is going on.

So we, as a center, haven't really done that probably as much as we should, but largely because those discussions tend to be very, again, on two ends of the spectrum without the great middle being involved in that. And the great middle is really what we try to do, which is to educate the general public as to what nanotechnology is all about.

Dr. GINGREY. And Mr. Marty.

Mr. MARTY. Yeah. Great comments. You know, as VC investors, you know, I guess speaking for myself in particular, I mean, what we try to do is understand, you know, what is—if you can paint a scenario that says, "This is possible that this could happen," then you think about it. And you think about what the ramifications are, both as an investment—investor and as a citizen. And so for a lot of the things that we work on and everything we have invested in to date, you know, textiles and displays and, you know, computers, I mean, there is really no ethical ramifications that we can even come up with. Now as we—as you look down the road and we hear about some of the scenarios that, you know, I labeled kind of well-read fiction, my challenge with dealing with those intellectually is I can not come up with a scenario where that can become real. And so I kind of don't spend much time thinking about those things, although I get those comments from people: "Well, aren't you worried about this? Aren't you worried about that?" Unless I can scientifically come up with a scenario where that could, in fact, become reality, I really don't know how to deal with it. I don't know how to think about that scenario.

So I do think it is important in this bill that we continue anything that is new is going to have some impact on society. And it is going to have some impact—you know, we want to have society kind of involved in the conversation, and we want to be thinking about these things proactively. But most of what has hit the press and most of the ethical things that have kind of come to me to date, I haven't been able to paint a scenario where they can scientifically become real. So they have not gotten my mind share to date.

Dr. GINGREY. There is so much misinformation out there on the Internet, as you all know. And of course, I think the educational program, Dr. Batt, that you are taking on the road, is exactly the way to approach it so that knowledge is understanding of this technology. Thank you.

Chairman BOEHLERT. Thank you very much. And I want to thank all of our witnesses for being resources for the Committee. We really appreciate you sharing your time and your thoughts and your expertise with us. We are working together in common cause for something that is very important to our future. So thank you very much. Now we may have some additional questions that we would submit in writing, and we would ask, if we do that, that you try to be timely in your response to give us the benefit of your thinking. Thank you so much. The meeting is adjourned.

[Whereupon, at 11:56 a.m., the Committee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard M. Russell, Associate Director for Technology, Office of Science and Technology Policy

Question submitted by Chairman Sherwood Boehlert

Q1. You mention in your testimony that the Department of Homeland Security (DHS) is part of the interagency nanotechnology initiative. Can you tell us how much of the DHS budget is being devoted to that and what the nature of DHS participation will be?

A1. The President's FY 2004 Budget identified $2 million for nanotechnology efforts at the Department of Homeland Security (DHS). These efforts represent ongoing investments within the Transportation Security Administration for technologies to assist in explosives detection and other advanced transportation security systems.

Questions submitted by Ranking Member Ralph M. Hall

Q1. The National Research Council committee that reviewed the National Nanotechnology Initiative criticized the initiative for too little information sharing among the agencies during program planning and execution and for a lack of willingness by the participating agencies to co-fund large research programs. What is your response to these criticisms? Since OSTP has broad responsibility for coordinating the major interagency research initiatives, how do you intend to address these findings of the NRC committee?

A1. OSTP is keenly interested in ensuring that the NNI represents a highly coordinated interagency activity. Towards this end, OSTP has initiated activities aimed at increasing the degree of coordination between the agencies that participate in the program. These include a principals-level meeting convened by OSTP Director John Marburger, which has resulted in an increased commitment to significant interagency coordination between the Department of Energy's (DOE'S) Office of Science, the National Science Foundation (NSF), and the National Institutes of Health (NIH). In addition, the restructuring of the current National Science and Technology Council's Nanoscale Science, Engineering, and Technology (NSET) subcommittee into an interagency working group, with a reconstituted subcommittee made up of higher level agency officials, will enable enhanced coordination and priority setting. Similarly, the role of the National Nanotechnology Coordination Office (NNCO), which assists NSET-participating agencies in their activities and serves as the secretariat for the NNI, has been strengthened by the hiring of a full-time director to run that office. All of these efforts are aimed at increasing the extent of interagency coordination within the NNI.

In addition, the NRC committee's report, in addressing the issue of interdisciplinary, cross-agency research, suggested the creation of a nanotechnology advisory panel that "would be capable of identifying research opportunities that do not fit within any single agency's mission," and "should be composed of leaders from a broad representation of industry and academia. . .leaders with scientific, technical, social science, or research management credentials relevant to advances in nanoscale science and technology." The President's Council of Advisors on Science and Technology (PCAST), whose members encompass this range of experience and backgrounds, has begun a review of the NNI and, in particular, will help identify new Grand Challenges that will help guide the program. Issues related to interagency coordination surfaced at PCAST's March 3 meeting, at which the nanotechnology review was discussed, and are likely to be an area of further examination.

Q2. The budget justification for the President's FY 2004 budget request for the National Nanotechnology Initiative states, "This research could lead to. . .accelerated biotechnical applications in medicine, health care, and agriculture." Similarly, the National Research Council committee that reviewed the National Nanotechnology Initiative suggests that the impact of nanotechnology on medicine and health care will be great and that, consequently, NIH should be a major player in the initiative. Yet, despite all the promise of nanotechnology for applications related to disease diagnosis and drug delivery, NIH is proposing to allocate only $70 million to the $850 million nanotechnology initiative out of the agency's $28 billion FY 2004 budget request. Can you explain why NIH has such relatively little interest and commitment to the initiative, particularly in light of the tasking memo from OMB and OSTP to the agencies that identified *nanoscale science and technology as one of the highest R&D priorities of the Administration?*

A2. NIH's commitment to biomedical research and development at the nanoscale, and to related interagency collaboration, is very strong. In fact, NIH's investment in nanotechnology research has tripled over the last four years, and NIH Director Elias Zerhouni stated in a recent letter to members of the Senate, "I have made nanoscale biomedical research at the NIH a personal priority, my staff have included the area in our 'roadmapping' efforts to plan future research directions, and we plan to proactively pursue opportunities in nanoscale biomedical research in support of our mission and national health care priorities."

NIH's organization comprises 27 institutes, each of which administers its own research and grant programs based on its unique mission, presents challenges for funding research in a multidisciplinary field such as nanotechnology. To address these challenges, NIH has created a mechanism for dealing with cross-cutting issues, the Bioengineering Consortium (BECON), which consists of senior-level representatives from all of the NIH institutes, centers, and divisions plus representatives of other federal agencies concerned with biomedical research and development. BECON is able to facilitate requests for and reviews of grant proposals for research areas that cut across different institutes at NIH. BECON recently issued a Program Announcement specifically aimed at enhancing nanoscience and nanotechnology research approaches that have the potential to make valuable contributions to biology and medicine. In addition, NIH started the Bioengineering Nanotechnology Initiative to partner with the small business community.

NIH's most recent call for projects, "Nanoscience and Nanotechnology in Biology and Medicine" is targeted at high risk, high impact exploratory and developmental projects based upon nanotechnology. Recent solicitations from several institutes have focused on using nanotechnology to develop improved imaging contrast agents for the diagnosis of disease, systems for targeted drug delivery and tissue replacement, tools for studying the basic functioning of living cells and their constituent proteins, and completely novel ways to sequence DNA.

NIH representatives, through the Nanoscale Science and Engineering Technology (NSET) interagency working group, are preparing a workshop aimed at identifying future research directions for nano-biotechnology. This workshop will communicate the concepts and recent discoveries from the physical science and engineering communities to members of the biomedical community, identifying key areas for the formation of new interdisciplinary research partnerships.

Q3. What portion of the proposed FY 2004 funding for the National Nanotechnology Initiative will be directed to instrumentation development, and will the responsibility for such activities be across several agencies or concentrated at DOE?

A3. Research and development of instrumentation and metrology form one of the nine grand challenges currently identified by the NSET. Roughly three percent of the FY 2003 request was allocated to instrumentation and metrology, with the bulk of the research effort focused at NIST. The investment in scientific instruments and tools will increase in FY 2004 and expand to several agencies, including NSF, the Department of Defense, and DOE. In addition, NIH also funds the development of new tools to measure various cellular and sub-cellular functions.

Q4. Does the National Nanotechnology Initiative place sufficient emphasis on the transition of research results to commercial developments? You noted in your testimony that the initiative is "a critical link between high-risk, novel research concepts and new technologies that can be developed by industry." Please describe how the initiative provides this linkage and explain what kinds of mechanisms under federally sponsor research programs are appropriate for encouraging and supporting technology transfer to industry?

A4. Issues of technology transfer are not unique to nanotechnology. Ensuring that research and development activities funded by the Federal Government are effectively transferred to the private sector is an issue that is relevant to virtually all areas of science and technology. Recognizing this, PCAST recently completed a study on technology transfer. Their report is currently in the final stages of preparation and will be released shortly.

The NNI continues to invest in the construction of central user facilities that serve as a nexus for innovation and outreach. Over the past five years NSF has developed a National Nanofabrication Users Network (NNUN), which provides centralized user facilities for academia, industry and national laboratories. These centers provide nanofabrication and characterization facilities for a fee much smaller than the cost of developing and maintaining unique facilities. To complement and expand the user center network, DOE is constructing five new centralized facilities associated with particular DOE Laboratories. The DOE centers will also offer peer-reviewed access to fabrication, testing and characterization facilities, and will do so at no charge to users doing non-proprietary research. These user facilities allow companies to experiment with high-risk, high-payoff nanotechnologies without the burden of sometimes significant capital investments and will foster industrial collaborations with academic and national laboratory researchers.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Alan Marty, Executive-in-Residence, JP Morgan Partners

Questions submitted by Representative Ralph M. Hall

Q1. You cited the Bayh-Dole Act in your testimony as being a well-written piece of legislation, but indicate that its implementation is stalling the technology transfer process. Could you give us some examples of what you mean, and suggest how we could improve the implementation process?

A1. The Bayh-Dole Act is a well written piece of legislation. Unfortunately its implementation has been lacking. The *Harvard Business Review* noted that more than $1 trillion annually is wasted in patent assets—when one considers both corporate and university operations. An entire pillar of the economy goes wasted every year.

According to the Association of University Technology Managers, North American universities last year spent approximately $29.5 billion on research which resulted in approximately 13,032 new invention disclosures. Approximately 75 percent of these new technologies go unlicensed. Of the more than 3,000 universities actively involved in tech transfer less than 10 make a profit. That is a painful statistic indeed.

While universities can argue that their impact on the economy through research is a well trained workforce, this is still no excuse for the lack of commercialization. The NanoBusiness Alliance from speaking to numerous corporate and university members have found a range of problems.

1. The Home Run: Most universities make the majority of their income from a single transferred patent, hence they are always trying to find the next big one instead of managing and effectively marketing a layered portfolio. Also this quest for a home run creates a great deal of fear—fear of not negotiating a high enough percentage of a transfer deal that will lead to scrutiny later. Hence they often transfer nothing for fear of being called to the mat for cutting a bad deal.
2. Business Dynamics: Universities for all of our calls to act more like a business do have some reasonable restraints on acting like a corporation. Businesses fail to notice this and hence negotiate as if they are dealing with someone in the same industry. Hence there is a failure to communicate the business dynamics properly.
3. Limitations on Collaboration: Many U.S. government grants to universities provide no benefit for corporations to collaborate with universities in terms of tech transfer creating a disincentive to work with U.S. schools.
4. Marketing Budgets: Universities fail to understand they need to aggressively market their technology portfolios. The U.S. government labs have been far more aggressive at attending trade shows, providing information on their websites and in helping their researchers and staff understand business dynamics.
5. Skill Set: University employees are often not equipped or incentivized to be entrepreneurial and fundamentally don't understand the dynamics of business. Many schools would be better served contracting out managing their efforts to private firms.

This failing must be corrected soon. I have heard one leading U.S. corporation note they would rather work with the less expensive and easier to negotiate schools in China, India, Russia, and EU than U.S. schools.

To improve the system what is needed is not so much a major rewriting of Bayh-Dole, but a framework for more successfully implementing it and a network to share best practices. In addition:

We need to ensure labs have the resources and motivations to prioritize tech transfer. Despite mission statements that tout tech transfer as a priority, many labs fail to direct resources—either capital or people with industry expertise or both—to fund effective collaborative efforts.

We need to better understand the impact of licensing activity on University research. Bayh-Dole has clearly had enormous benefits for our universities, facilitating commercialization of innovations and encouraging partnership outside the ivy towers. It has helped research universities emerge as real drivers of regional economic growth. We need to better understand the impact of increased university emphasis on licensing opportunities—on the mix of basic and applied research, on dissemination and sharing of knowledge, and on industries' willingness to partner with universities.

We need to train and create entrepreneurial and business savvy professors, graduate students and tech transfer staff and provide a system to rate and incentivize their performance.

Q2. You called in your testimony for development of the real numbers and benchmarks for the size and projected growth of the nanotechnology field and its economic benefits. What would be some of the difficulties to developing these benchmarks and who should be responsible for this carrying out of this work?

A2. Real Numbers: The greatest difficulty in developing real numbers for the nanotech field has much to do with the size and scope of the field.

Nanotechnology will have an effect on nearly every industry in much the same way that the internal combustion engine, harnessed electricity and the transistor did on existing industries. Determining the value of "nano" developments prove incredibly difficult and accurately arriving at numbers is indeed the stuff of leading economists.

Current estimates on the size of today's nanotech field range from $1 billion to $350 billion depending on the criteria.

Long-term estimates of industry size as developed by NSF ($1 trillion market in 13 years) are not based on accepted economic methodology. Industry leaders—mostly the R&D professionals of companies—were polled and the numbers were simply added up at the end. It could be correct, but it would have more to do with luck than science.

Not having simple numbers and agreed upon criteria make it difficult to gauge growth and performance. It also makes the ability to judge competitive threats and the value of investments abroad all the more difficult. Before starting studies on using nanotech as a means of economic development or putting in place surveys on sector growth or gauging foreign competition, we need accepted and agreed upon numbers and baselines.

The Department of Commerce Office of Technology Policy would likely be the most capable office at developing accurate and timely numbers, drawing on the resources of industry and the other agencies involved in the NNI.

Appendix 2:

Additional Material for the Record

PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

NANOTECHNOLOGY WORK PLAN

MARCH 3, 2003

PCAST's nanotechnology efforts will be conducted at the full committee level as an ongoing, long-term activity. Task forces will be formed as needed to investigate particular topic areas.

Initial Primary Objectives

PCAST will conduct a comprehensive review of the federal nanotechnology effort including the extent to which it successfully links to the needs of the private sector, its importance to economic competitiveness, and what results can fairly be expected (short-term and long-term). The Administration's management objectives, as well as the National Research Council's (NRC's) recommendations, suggest two primary objectives for PCAST to achieve. While additional goals and objectives exist and PCAST will address other NRC concerns over time, PCAST can initially assist in:

1. Developing a compelling set of *"Grand Challenges"* to focus the research effort on key scientific/technological challenges (including a review of the NNI program's existing grand challenges); and
2. Developing a crisp, compelling overarching *Strategic Plan* to set the general direction of the Federal Government program and to guide the development of detailed research plans.

In order to achieve these objectives, PCAST will work with the National Science and Technology Council's (NSTC's) Nanoscale Science, Engineering and Technology INSET) Subcommittee, as well as the National Nanotechnology Coordination Office.

Initial PCAST Task Forces

PCAST will initially form three Task Forces among its members to explore particular topic areas:

Materials/Electronics/Photonics	*Energy/Environment*	*Medical/Bio/Social*
Wayne Clough – Chair	Charles Vest – Co-Chair	Bernadine Healy – Co-Chair
Gordon Moore	Steve Papermaster – Co-Chair	Charles Artnzen – Co-Chair
Steve Burke	Bobbie Kilberg	Kathy Behrens – Co-Chair
Kenneth Nwabueze	Norm Augustine	Ralph Gomory
Luis Proenza	Walter Massey	Marye Anne Fox
Raul Fernandez	Martha Gilliland	
Bob Herbold		
Erich Bloch		

Technical Expertise

PCAST will form a "Technical Task Force" of outside (non-government) technical experts to assist PCAST in its review of the NNI program. The Technical Task Force will be comprised of scientists who are on the forefront of the various fields of nanotechnology research. The types of expertise represented might include: materials science; bio/life sciences; energy; electronics/photonics; and molecular motors.

Additional Outreach

PCAST will also outreach and consult with Congress, interested businesses, scientists, institutions (e.g., universities), trade associations, state and local government representatives, and other parties with an interest or relevant experience (such as the Director of the National Coordination Office for the NSTC's Networking and Information Technology R&D program).

Additional Topics

After addressing the two primary objectives listed above, and in addition to its ongoing review of the federal nanotechnology effort, PCAST will explore a wide variety of topics relating to nanotechnology and its potential benefits to the American public and the U.S. economy. Such topics may include the identification of metrics for measuring progress (and applying these metrics to continually assess program progress); social and ethical considerations of nanotechnology; technology transfer issues and mechanisms; and comparisons of the U.S. program with international programs (in terms of both effort and results).

Initial Timelines

- *Late Summer 2003*—Primary Objectives—a set of recommendations on Grand Challenges and Strategic Goals to inform the formation of the FY 2005 budget for NNI (not budgetary levels but how the money is spent).
- *Early 2004*—NNI Program Review—a presentation from NNI on its FY 2005 budget and the achievement of the recommended objectives.
- *Summer 2004*—Report on Metrics, and decide on new topic area(s).
- When warranted, issue additional recommendations and follow-up reports.

Order Code RS20589
Updated March 12, 2003

CRS Report for Congress

Manipulating Molecules: The National Nanotechnology Initiative

Michael E. Davey
Specialist in Science and Technology
Resources, Science, and Industry Division

Summary

The Bush Administration has requested $849 million for nanotechnology research for FY2004, a 9.7% increase over FY2003. **(See Table on page 3.)** Nanotechnology is a newly emerging field of science where scientists and engineers are beginning to manipulate matter at the molecular and atomic level in order to obtain materials and systems with significantly improved properties. Ten nanometers is equal to one-ten thousandths the diameter of a human hair. Proponents of this technology argue that nanotechnology will lead to a new industrial revolution in the 21st century. Scientists note that nanotechnology is still in its infancy, with large scale practical applications 10 to 30 years away. Congressional concerns center around coordination and priority setting for the NNI, whether the President's Council of Advisors on Science and Technology (PCAST) or an independent non-governmental experts should be used to conduct outside periodic reviews of the NNI , challenges associated with interdisciplinary research, and potential environmental and health concerns associated with the deployment of nanotechnologies. This report will be updated as events warrant.

Introduction

For FY2004, the Bush Administration has designated the National Nanotechnology Initiative (NNI) as a multi-agency research initiative. As indicated in the **table on page 3**, the Administration is requesting $849 million for the NNI, a 9.7% increase over the FY2003 estimated funding level of $774 million. If Congress approves this requested increase, funding for the NNI will have doubled since FY2001. Nanotechnology is the creation and utilization of materials, devices, and systems with novel properties and functions through the control of matter atom by atom, or molecule by molecule. Such control takes place on a scale of a fraction of a nanometer to tens of nanometers. Ten nanometers is equal to one-ten thousandths the diameter of a human hair.

Academic and industry scientists working in this field contend that research in nanoscience will lead to revolutionary breakthroughs in such areas as medicine, manufacturing, materials, construction, computing, and telecommunications. For example, *Science* magazine designated scientists' and engineers' ability to build the first set of molecular-scale circuits as the scientific breakthrough of 2001. The magazine noted that when such circuits are wired to computer chip architectures this will result in incredible computing power in tiny machines.[1] Many scientists contend that breakthroughs in nanotechnology (or nanoscience as some researchers refer to it) will eventually lead to molecules replacing silicon on computer chips which in turn could result in computers that are billions of times faster than today's most sophisticated computers. Researchers are also studying ways to treat neurological disorders by developing silicon capsules that include nanopore screening membranes (18-25 nanometers wide) that allow the desired molecules to flow in and out while blocking the patient's antibodies from attacking the treated area. While both private sector and federally sponsored research in nanoscience has led to encouraging breakthroughs in the last couple of years, nanotechnology is still in its infancy. Most scientists contend that practical applications of this newly emerging science, such as the ones described above, could be 10 to 30 years away.

Nanotechnology and the Federal Role

All natural materials and systems establish their fundamental properties at the atomic and molecular scale. Consequently, the ability to control matter at those levels provides the means for tailoring the fundamental properties, phenomena, and processes exactly at the scale where the basic properties are determined. According to the Administration, in FY2004 the NNI will continue to focus on fundamental research in the following areas: 1) Research to enable efficient nanoscale manufacturing, and novel instrument for nanoscale measurements; 2) Nano-biological systems for medical advancements and new products; 3) Innovative nanotechnology solutions for detection or and protection from biological-chemical-radiological-explosive agents; 4) the education and training of a new of a new generation of workers for future industries; and 5) Partnerships and other policies to enhance industrial participation in the nanotechnology revolution.[2]

Once the NNI was established in 2000, the Nanoscale Science and Engineering and Technology (NSET) also was established as a subcommittee of the National Science and Technology Council's (NSTC) Committee on Technology. NSET serves as the coordinating body of the NNI with membership composed of representatives from the different departments and agencies participating in the initiative, as well as a representative from the Office of Science and Technology Policy. The NNI is built around five funding themes distributed among the agencies currently participating in the NNI. The agencies include the National Science Foundation (NSF), the Departments of Defense (DOD), Energy (DOE), Homeland Security (HLS), Agriculture (USDA), Justice (DOJ), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), The National Institute of Standards and Technology (NIST), within the Department of Commerce, and the Environmental Protection Agency (EPA).

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[1] *Molecules Get Wired*, Science Vol. 294, December 21, 2001. P. 2442-43.

[2] Fiscal Year 2004, Analytical Perspectives, Budget of the U. S. Government, p.177-78.

In October of 2000, the NSTC approved NSET's request to establish the National Nanotechnology Coordinating Office (NNCO). Besides being responsible for the day-to-day management of the NNI, the NNCO will assist the NSET committee with identifying funding priorities, establishing budgets, and evaluating current NNI activities. Below is a brief summary of the five major cross-cutting NNI themes with *estimated* funding levels for FY2003 as well as the proposed increases for each theme in FY2004.[3]

1. Fundamental Nanoscience and Engineering Research. *($248 million +$22 million)* Long term basic research is essential to establishing a fundamental knowledge of nanoscale phenomena. Research activities will focus on fundamental understanding and synthesis of nanometer-size building blocks with potential breakthroughs in areas such as materials and manufacturing, nanoelectronics, medicine and healthcare, environment and energy, chemical and pharmaceuticals industries, biotechnology and agriculture, computation and information technology, and national security. One of the fundamental challenges facing researchers is to try to control and manipulate matter at the ultimate frontier where, for example, as you move from 1 to 100 nanometers, the texture of atomic and molecular matter can suddenly change from soft, to hard, to brittle, and back to soft again without explanation.

Table 1. Estimated Funding for Nanotechnology FY2004

$ millions

	FY2001 Enacted	FY2002 Enacted	FY2003 Estimate	FY2004 Request
NNI Total	**422**	**697**	**774**	**849**
NSF	150	204	221	249
DOD	110	224	243	222
DOE	88	89	133	197
HHS (NIH)	39	59	65	70
NASA	20	35	33	31
DOC (NIST)	10	77	69	62
EPA	5	6	6	5
Dept. HLS. (TSA) [a]	0	2	2	2
USDA	0	0	1	10
Dept. of Justice	0	1	1	1

a. Transportation Security Administration

2. Grand Challenges. *($279 million + $24 million)* The second theme includes support for interdisciplinary research and education teams, including centers and networks, that work on major long-term objectives. In the area of efficient energy conservation and storage one of the challenges is to understand how deliberate tailoring of materials at the nanoscale can lead to novel and enhanced functionalities of relevance

[3] For more details of the FY2003 NNI themes, see *National Nanotechnology Initiative, The Initiative and Its Implementation Plan,* Detailed Technical Report Associated with the Supplemental Report to the President's FY2003 Budget, June 2002, p. 46-86.

in energy conversion, storage and conservation. Another long term challenge is to develop tools for modeling and simulating the broad range of manufacturing processes involving nanostructures thus allowing the processes to be better understood and optimized. Developing bio-nanosensor devices for biological threat detection is another nanotechnology opportunity that could foster efficient and rapid biochemical detection and mitigation in situ for chemical bio-warfare.

3. Centers and Networks of Excellence. *($124 million + $14 million)* To date, 15 centers of excellence (6 NSF, 4 DOE, 4 NASA, 1 DOD) have been established through the NNI. The primary objective of the centers is to enable research activities that cannot be conducted through the traditional mode of single investigator, small groups, or with current research infrastructure. Further, each center is expected to establish partnerships with industry, national laboratories, and other sectors, including state supported nanoscience activities. The research activities of the centers are expected to enhance multidisciplinary research activities among government, universities and industry performers, which in turn, are expected to create a vertical integration arrangement that includes activities from basic research to the actual development of specific nanotechnology devices and applications.

4. The Creation of Research Infrastructure. *($108 million + $12 million)* The fourth theme supports the creation of a research infrastructure for metrology, instrumentation, modeling and simulation, and facilities. Most of the R&D instrumentation and facilities will be made available to users not only from the institution that operates the facility but also from other institutions including industry and government. The ultimate objective is the development of research instrumentation and facilities so that new innovations can be rapidly commercialized by U.S. industry. According to NSET, if the need for instrumentation and the ability to transition from knowledge-driven to product-driven efforts are not addressed satisfactorily, the United States will not remain internationally competitive in this field.

5. Ethical, Legal, and Social Implications. *($16million,+$3 million)* In concert with the initiative's university based research activities, this effort is designed to provide effective education and training of skilled workers in the multidisciplinary perspective necessary for rapid progress in nanotechnology. Researchers will also examine the potential social, economic, ethical, legal, and workforce implications of nanotechnology. In March of 2001, the NSET released a report on the Societal Implications of Nanoscience and Nanotechnology. Based on the proceedings of a two day workshop, the report states that support for research on the potential social, economic, and ethical implications must be a high priority for the NNI. According to the report, such efforts should help to reduce or dispel some of the unfounded fears that often accompany dramatic advances in science and engineering.[4]

Congressional Issues

Coordination and Priority Setting for the NNI. In June of 2002, the National Research Council (NRC) released a report entitled *Small Wonders, Endless Frontier, A*

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[4] For more details on this report, and other Federal nanotechnology related documents sce, [http//www.nano.gov]

Review of the National Nanotechnolgy Initiative. As part of its study the NRC was asked to examine such issues as the balance of the NNI R&D portfolio, the effectiveness of interagency coordination, and to identify important areas of future investments. As the first of ten major recommendations contained in the report, the NRC suggested that OSTP establish the National Nanotechnolgy Advisory Board (NNAB) which among other things could work with NSET agencies to reach beyond their individual research missions in order to identify "cross cutting research opportunities with the greatest potential payoff and the broadest impact."[5] The NRC panel was composed of representatives from industry, small business, and academia with scientific, engineering and social science backgrounds. The NRC report indicated that the NNAB could also address other NNI concerns, such as nano research infrastructure needs, technology transfer efforts, and the extent to which NSET R&D priorities reflect an awareness of private sector and international nanotechnology R&D activities. In response to the NRC recommendation, the President's Council of Advisors on Science and Technology (PCAST) has initiated a review of the NNI that will focus on three separate areas of inquiry. They include; 1.) medical, biological and social implications; 2.) materials and electronics; and 3.) energy and the environment. According to Dr. John Marberger, the Director of the Office of Science and Technology Policy, this initial PCAST study should be completed by late summer 2003, to aid with the development of NNI FY2005 budget priorities.

House and Senate NNI Legislation. Both the House (H.R. 766, Representatives Boehlert and Honda) and Senate (S. 189, Senators Wyden and Allen) have introduced legislation that would establish the NNI in law, noting that the major interagency initiative is a top priority for the Administration's FY2004 non-medical, civilian scientific and technology R&D. The House bill provides recommended authorization levels from FY2004-FY2006 for NSF, DOE, EPA, DOE, and NIST. The Senate bill contains recommended FY2004 authorization levels for all the civilian agencies participating in the NNI. The House and Senate bills contain provisions that would maintain multi-agency coordinating mechanisms, such as the NSET, as well the NNCO which is responsible for coordinating the daily activities of the NNI, and serving as a point of reference for responding to federal, state, and private sector inquiries related to the NNI. In response to the NRC report calling for an independent outside review of the NNI, the House and Senate bills call for the President to establish an independent advisory committee consisting of non-federal members, including representatives from academia and industry, as well as individuals who possess expertise regarding the ethical, legal, and social implications related to the development and deployment of nanotechnology. According to a House committee staffer, some Members of Congress are not convinced that PCAST possesses the time or the breadth of scientific and technological knowledge, related to nanotechnology, to conduct a comprehensive in-depth analysis of the NNI. Finally, both bills call for the National Academy Sciences to conduct periodic reviews of the NNI.

The Challenge of Interdisciplinary Research. In testimony before the Senate Commerce Subcommittee on Science, Technology and Space, R. Stanley Williams, from Hewlett-Packard, testified that nanoscience is a field where hundreds of years of advancements in the fields of biology, physics, and chemistry have come together in just

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[5] *Small Wonders, Endless Frontiers, A Review of the National Nanotechnology Initiative,* National Research Council, National Academy Press, Washington D. C., 2002, p. 20.

the past decade. According to Williams, now that all three fields have come together "each has realized that it can learn much from the others, so that the field of nanoscience has transcended traditional academic boundaries."[6] Nevertheless, while the NRC report also recognizes the pivotal role that interdisciplinary scientific discovery will play in the advancement of nanoscience and nanotechnology, the report notes that most of the Nation's education and research enterprise is not producing researchers who are capable of engaging in research that crosses disciplinary boundaries. In addition, the report notes that the overall academic value system regarding scientific quality "continues to discourage interdisciplinary research, with negative consequences for tenure, promotion, and the awarding of research grants."[7] The 21st Century Nanotechnology Research and Development Act (S.189), contains a provision that would establish Interdisciplinary Research Centers, funded in the range of from $3-5 million per year, for the next 5 years. According to S. 189, the goal is to establish geographically diverse centers, including at least one center in a State participating in NSF's Experimental Program to Stimulate Competitive Research (EPSCoR). Such centers could play a key role in developing a cadre of scientist and engineers trained in interdisciplinary studies to push the frontiers on nanoscience.

Nanotechnology Environmental and Health Concerns. Despite the great promise surrounding nanotechnology, questions have been raised regarding potential environmental and health concerns associated with the development and use of nanoscale materials. While nanotechnology may have the ability to make the environment cleaner, scientists acknowledge that manufacturing and use of nanomaterials could also present unique environmental concerns since these materials represent new types of matter. Dr. Mark Wisner, a researcher at the Center for Biological, and Environmental Nanotechnology (CBEN) at Rice University, has raised concerns about potential environmental effects when carbon nanotubes end up in the environment. As part of its NNI activities, the EPA is sponsoring research that will examine possible environmental concerns associated with the manufacturing and use of nano materials. Regarding health concerns, Dr. Vikki Colvin, a colleague of Dr. Wisner at CBEN, has reported that nanomaterials can insinuate themselves into cells which Colvin claims is unusual for most inorganic materials. She contends that we do not know what these new materials will do at the cellular level. While she believes that nanomaterials will interact with biology in ways that larger materials cannot, Dr. Wisner also noted that accumulation of materials in the liver of laboratory animals demonstrates that nanoparticles can accumulate within organisms. Wisner contends if we know nanomaterial can be taken up by cells, then there is an entry point for nanomaterial into the food chain. He suggested researchers should examine whether nanoparticles absorbed into bacteria enhance the ability to "piggyback"their way into the bacteria and cause damage to cellular structures.[8]

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[6] Stanley Williams, HP Fellow, Testimony before the Commerce Committee, Subcommittee on Science, Technology and Space, September 17, 2002., page 2.

[7] Op. Cit. *Small Wonders, Endless Frontiers*, p. 30.

[8] Smalltimes, *Nano Litterbugs? Expert See Potential Pollution Problems,* March/April, 2002

108TH CONGRESS
1ST SESSION

H. R. 766

To provide for a National Nanotechnology Research and Development Program, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 13, 2003

Mr. BOEHLERT (for himself, Mr. HONDA, Mr. EHLERS, Mr. HALL, Mr. SMITH of Michigan, Mr. GORDON, Mrs. BIGGERT, Ms. EDDIE BERNICE JOHNSON of Texas, Mr. BARTLETT of Maryland, Ms. LOFGREN, Mr. GUTKNECHT, and Mr. BISHOP of New York) introduced the following bill; which was referred to the Committee on Science

A BILL

To provide for a National Nanotechnology Research and Development Program, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Nanotechnology Research and Development Act of 2003".

SEC. 2. DEFINITIONS.

In this Act—

(1) the term "advanced technology user facility" means a nanotechnology research and development facility supported, in whole or in part, by Federal funds that is open to all United States researchers on a competitive, merit-reviewed basis;

(2) the term "Advisory Committee" means the advisory committee established under section 5;

(3) the term "Director" means the Director of the Office of Science and Technology Policy;

(4) the term "Interagency Committee" means the interagency committee established under section 3(c);

(5) the term "nanotechnology" means science and engineering aimed at creating materials, devices, and systems at the atomic and molecular level;

(6) the term "Program" means the National Nanotechnology Research and Development Program described in section 3; and

(7) the term "program component area" means a major subject area established under section 3(c)(2) under which is grouped related individual projects and activities carried out under the Program.

SEC. 3. NATIONAL NANOTECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM.

(a) IN GENERAL.—The President shall implement a National Nanotechnology Research and Development Program to promote Federal nanotechnology research, development, demonstration, education, technology transfer, and commercial application activities as necessary to ensure continued United States leadership in nanotechnology research and development and to ensure effective coordination of nanotechnology research and development across Federal agencies and across scientific and engineering disciplines.

(b) PROGRAM ACTIVITIES.—The activities of the Program shall be designed to—

(1) provide sustained support for nanotechnology research and development through—

(A) grants to individual investigators and interdisciplinary teams of investigators; and

(B) establishment of interdisciplinary research centers and advanced technology user facilities;

(2) ensure that solicitation and evaluation of proposals under the Program encourage interdisciplinary research;

(3) expand education and training of undergraduate and graduate students in interdisciplinary nanotechnology science and engineering;

(4) accelerate the commercial application of nanotechnology innovations in the private sector; and

(5) ensure that societal and ethical concerns will be addressed as the technology is developed by—

(A) establishing a research program to identify societal and ethical concerns related to nanotechnology, and ensuring that the results of such research are widely disseminated; and

(B) integrating, insofar as possible, research on societal and ethical concerns with nanotechnology research and development.

(c) INTERAGENCY COMMITTEE.—The President shall establish or designate an interagency committee on nanotechnology research and development, chaired by the Director, which shall include representatives from the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, the National Institute of Standards and Technology, the Environmental Protection Agency, and any other agency that the President may designate. The Interagency Committee, which shall also include a representative from the Office of Management and Budget, shall oversee the planning, management, and coordination of the Program. The Interagency Committee shall—

(1) establish goals and priorities for the Program;

(2) establish program component areas, with specific priorities and technical goals, that reflect the goals and priorities established for the Program;

(3) develop, within 6 months after the date of enactment of this Act, and update annually, a strategic plan to meet the goals and priorities established under paragraph (1) and to guide the activities of the program component areas established under paragraph (2);

(4) consult with academic, State, industry, and other appropriate groups conducting research on and using nanotechnology, and the Advisory Committee; and

(5) propose a coordinated interagency budget for the Program that will ensure the maintenance of a balanced nanotechnology research portfolio and ensure that each agency and each program component area is allocated the level of funding required to meet the goals and priorities established for the Program.

SEC. 4. ANNUAL REPORT.

The Director shall prepare an annual report, to be submitted to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate at the time of the President's budget request to Congress, that includes—

(1) the Program budget, for the current fiscal year, for each agency that participates in the Program and for each program component area;

(2) the proposed Program budget, for the next fiscal year, for each agency that participates in the Program and for each program component area;

(3) an analysis of the progress made toward achieving the goals and priorities established for the Program; and

(4) an analysis of the extent to which the Program has incorporated the recommendations of the Advisory Committee.

SEC. 5. ADVISORY COMMITTEE.

(a) IN GENERAL.—The President shall establish an advisory committee on nanotechnology consisting of non-Federal members, including representatives of research and academic institutions and industry, who are qualified to provide advice and information on nanotechnology research, development, demonstration, education, technology transfer, commercial application, and societal and ethical concerns. The recommendations of the Advisory Committee shall be considered by Federal agencies in implementing the Program.

(b) ASSESSMENT.—The Advisory Committee shall assess—

(1) trends and developments in nanotechnology science and engineering;

(2) progress made in implementing the Program;

(3) the need to revise the Program;

(4) the balance among the components of the Program, including funding levels for the program component areas;

(5) whether the program component areas, priorities, and technical goals developed by the Interagency Committee are helping to maintain United States leadership in nanotechnology;

(6) the management, coordination, implementation, and activities of the Program; and

(7) whether societal and ethical concerns are adequately addressed by the Program.

(c) REPORTS.—The Advisory Committee shall report not less frequently than once every 2 fiscal years to the President and to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate on its findings of the assessment carried out under subsection (b), its recommendations for ways to improve the Program, and the concerns assessed under subsection (b)(7). The first report shall be due within 1 year after the date of enactment of this Act.

(d) FEDERAL ADVISORY COMMITTEE ACT APPLICATION.—Section 14 of the Federal Advisory Committee Act shall not apply to the Advisory Committee.

SEC. 6. NATIONAL NANOTECHNOLOGY COORDINATION OFFICE.

The President shall establish a National Nanotechnology Coordination Office, with full-time staff, which shall—

(1) provide technical and administrative support to the Interagency Committee and the Advisory Committee;

(2) serve as a point of contact on Federal nanotechnology activities for government organizations, academia, industry, professional societies, and others to exchange technical and programmatic information; and

(3) conduct public outreach, including dissemination of findings and recommendations of the Interagency Committee and the Advisory Committee, as appropriate.

SEC. 7. AUTHORIZATION OF APPROPRIATIONS.

(a) NATIONAL SCIENCE FOUNDATION.—There are authorized to be appropriated to the National Science Foundation for carrying out this Act—

(1) $350,000,000 for fiscal year 2004;
(2) $385,000,000 for fiscal year 2005; and
(3) $424,000,000 for fiscal year 2006.

(b) DEPARTMENT OF ENERGY.—There are authorized to be appropriated to the Secretary of Energy for carrying out this Act—

(1) $197,000,000 for fiscal year 2004;
(2) $217,000,000 for fiscal year 2005; and
(3) $239,000,000 for fiscal year 2006.

(c) NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.—There are authorized to be appropriated to the National Aeronautics and Space Administration for carrying out this Act—

(1) $31,000,000 for fiscal year 2004;
(2) $34,000,000 for fiscal year 2005; and
(3) $37,000,000 for fiscal year 2006.

(d) NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY.—There are authorized to be appropriated to the National Institute of Standards and Technology for carrying out this Act—

(1) $62,000,000 for fiscal year 2004;
(2) $68,000,000 for fiscal year 2005; and
(3) $75,000,000 for fiscal year 2006.

(e) ENVIRONMENTAL PROTECTION AGENCY.—There are authorized to be appropriated to the Environmental Protection Agency for carrying out this Act—

(1) $5,000,000 for fiscal year 2004;
(2) $5,500,000 for fiscal year 2005; and
(3) $6,000,000 for fiscal year 2006.

SEC. 8. EXTERNAL REVIEW OF THE NATIONAL NANOTECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM.

Not later than 6 months after the date of enactment of this Act, the Director shall enter into an agreement with the National Academy of Sciences to conduct periodic reviews of the Program. The reviews shall be conducted once every 3 years during the 10-year period following the enactment of this Act. The reviews shall include—

(1) an evaluation of the technical achievements of the Program;

(2) recommendations for changes in the Program;

(3) an evaluation of the relative position of the United States with respect to other nations in nanotechnology research and development;

(4) an evaluation of the Program's success in transferring technology to the private sector;

(5) an evaluation of whether the Program has been successful in fostering interdisciplinary research and development; and

(6) an evaluation of the extent to which the Program has adequately considered societal and ethical concerns.

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