

NANOTECHNOLOGY: WHERE DOES THE U.S. STAND?

HEARING BEFORE THE SUBCOMMITTEE ON RESEARCH COMMITTEE ON SCIENCE HOUSE OF REPRESENTATIVES ONE HUNDRED NINTH CONGRESS

FIRST SESSION

—————
JUNE 29, 2005
—————

Serial No. 109–21
—————

Printed for the use of the Committee on Science



Available via the World Wide Web: <http://www.house.gov/science>

—————
U.S. GOVERNMENT PRINTING OFFICE

21–950PS

WASHINGTON : 2005

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

COMMITTEE ON SCIENCE

HON. SHERWOOD L. BOEHLERT, New York, *Chairman*

RALPH M. HALL, Texas	BART GORDON, Tennessee
LAMAR S. SMITH, Texas	JERRY F. COSTELLO, Illinois
CURT WELDON, Pennsylvania	EDDIE BERNICE JOHNSON, Texas
DANA ROHRABACHER, California	LYNN C. WOOLSEY, California
KEN CALVERT, California	DARLENE HOOLEY, Oregon
ROSCOE G. BARTLETT, Maryland	MARK UDALL, Colorado
VERNON J. EHLERS, Michigan	DAVID WU, Oregon
GIL GUTKNECHT, Minnesota	MICHAEL M. HONDA, California
FRANK D. LUCAS, Oklahoma	BRAD MILLER, North Carolina
JUDY BIGGERT, Illinois	LINCOLN DAVIS, Tennessee
WAYNE T. GILCHREST, Maryland	RUSS CARNAHAN, Missouri
W. TODD AKIN, Missouri	DANIEL LIPINSKI, Illinois
TIMOTHY V. JOHNSON, Illinois	SHEILA JACKSON LEE, Texas
J. RANDY FORBES, Virginia	BRAD SHERMAN, California
JO BONNER, Alabama	BRIAN BAIRD, Washington
TOM FEENEY, Florida	JIM MATHESON, Utah
BOB INGLIS, South Carolina	JIM COSTA, California
DAVE G. REICHERT, Washington	AL GREEN, Texas
MICHAEL E. SODREL, Indiana	CHARLIE MELANCON, Louisiana
JOHN J.H. "JOE" SCHWARZ, Michigan	DENNIS MOORE, Kansas
MICHAEL T. MCCAUL, Texas	
VACANCY	
VACANCY	

SUBCOMMITTEE ON RESEARCH

BOB INGLIS, South Carolina, *Chairman*

LAMAR S. SMITH, Texas	DARLENE HOOLEY, Oregon
CURT WELDON, Pennsylvania	RUSS CARNAHAN, Missouri
DANA ROHRABACHER, California	DANIEL LIPINSKI, Illinois
GIL GUTKNECHT, Minnesota	BRIAN BAIRD, Washington
FRANK D. LUCAS, Oklahoma	CHARLIE MELANCON, Louisiana
W. TODD AKIN, Missouri	EDDIE BERNICE JOHNSON, Texas
TIMOTHY V. JOHNSON, Illinois	BRAD MILLER, North Carolina
DAVE G. REICHERT, Washington	VACANCY
MICHAEL E. SODREL, Indiana	VACANCY
MICHAEL T. MCCAUL, Texas	VACANCY
VACANCY	
SHERWOOD L. BOEHLERT, New York	BART GORDON, Tennessee

DAN BYERS *Subcommittee Staff Director*
JIM WILSON *Democratic Professional Staff Member*
MELE WILLIAMS *Professional Staff Member/Chairman's Designee*
ELIZABETH GROSSMAN, KARA HAAS *Professional Staff Members*
JAMES HAGUE *Staff Assistant*

CONTENTS

June 29, 2005

Witness List	Page 2
Hearing Charter	3

Opening Statements

Statement by Representative Bob Inglis, Chairman, Subcommittee on Research, Committee on Science, U.S. House of Representatives	14
Written Statement	15
Statement by Representative Darlene Hooley, Ranking Minority Member, Subcommittee on Research, Committee on Science, U.S. House of Representatives	15
Written Statement	16
Prepared Statement by Representative Russ Carnahan, Member, Subcommittee on Research, Committee on Science, U.S. House of Representatives	17
Prepared Statement by Representative Eddie Bernice Johnson, Member, Subcommittee on Research, Committee on Science, U.S. House of Representatives	17

Witnesses:

E. Floyd Kvamme, Co-Chair, President's Council of Advisors on Science and Technology	
Oral Statement	18
Written Statement	20
Biography	27
Matthew M. Nordan, Vice President of Research, Lux Research, Inc.	
Oral Statement	27
Written Statement	29
Biography	37
Financial Disclosure	38
Sean Murdock, Executive Director, Nanobusiness Alliance	
Oral Statement	38
Written Statement	41
Biography	50
Financial Disclosure	51
Jim O'Connor, Vice President, Technology Incubation and Commercialization, Motorola, Inc.	
Oral Statement	51
Written Statement	53
Biography	56
Financial Disclosure	58
Discussion	59

Appendix 1: Answers to Post-Hearing Questions

E. Floyd Kvamme, Co-Chair, President's Council of Advisors on Science and Technology	84
--	----

Appendix 2: Additional Material for the Record

Page

Letter to Robert Inglis from E. Floyd Kvamme, Co-Chair, President's Council of Advisors on Science and Technology, dated July 14, 2005	90
---	----

**NANOTECHNOLOGY: WHERE DOES THE U.S.
STAND?**

WEDNESDAY, JUNE 29, 2005

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

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bob Inglis [Chairman of the Subcommittee] presiding.

**SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES**

Nanotechnology: Where Does the U.S. Stand?

Wednesday, June 29, 2005
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building (WEBCAST)

Witness List

Mr. Floyd Kvamme

Co-Chair
President's Council of Advisors on Science and Technology

Mr. Matthew M. Nordan

Vice President of Research
Lux Research Inc.

Mr. Sean Murdock

Executive Director
NanoBusiness Alliance

Mr. Jim O'Connor

Vice President, Technology Incubation and Commercialization
Motorola, Inc

Section 210 of the Congressional Accountability Act of 1995 applies the rights and protections covered under the Americans with Disabilities Act of 1990 to the United States Congress. Accordingly, the Committee on Science strives to accommodate/meet the needs of those requiring special assistance. If you need special accommodation, please contact the Committee on Science in advance of the scheduled event (3 days requested) at (202) 225-6371 or FAX (202) 225-0891. Should you need Committee materials in alternative formats, please contact the Committee as noted above.

HEARING CHARTER

**SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES**

**Nanotechnology: Where Does
the U.S. Stand?**

WEDNESDAY, JUNE 29, 2005
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, June 29, 2005, the Research Subcommittee of the Committee on Science of the House of Representatives will hold a hearing to examine the findings and recommendations of the recent assessment of the National Nanotechnology Initiative (NNI) by the President's Council of Advisors on Science and Technology (PCAST) and will hear from the nanotechnology community on how U.S. research and business activities in nanotechnology measure up to those of international competitors.

2. Witnesses

Mr. Floyd Kvamme is the Co-Chair of the President's Council of Advisors on Science and Technology and a partner at Kleiner Perkins Caufield & Byers, a high-technology venture capital firm.

Mr. Jim O'Connor is Vice President of Technology Incubation and Commercialization at Motorola, Inc.

Mr. Sean Murdock is the Executive Director of the NanoBusiness Alliance.

Mr. Matthew M. Nordan is the Vice President of Research at Lux Research Inc., a nanotechnology research and advisory firm.

3. Overarching Questions

- What is the position of U.S. research and development and U.S. businesses in nanotechnology relative to that of other countries? What key factors influence U.S. performance in the field, and what trends exist among those factors?
- Which fields of science and engineering present the greatest opportunities for breakthroughs in nanotechnology, and which industries are most likely to be altered by those breakthroughs in both the near-term and the longer-term?
- What are the primary barriers to commercialization of nanotechnology, and how can these barriers be overcome or removed? What is the Federal Government's role in facilitating the commercialization of nanotechnology innovations, and how can the current federal nanotechnology program be strengthened in this area?

4. Brief Overview

- In December 2003, the President signed the *21st Century National Nanotechnology Research and Development Act* (P.L. 108–153), which originated in the Science Committee. This Act provided a statutory framework for the interagency National Nanotechnology Initiative (NNI), authorized appropriations for nanotechnology research and development (R&D) activities through fiscal year 2008 (FY08), and enhanced the coordination and oversight of the program. Funding for the NNI has grown from \$464 million in fiscal year 2001 (FY01) to \$1.1 billion in FY05, and 11 agencies currently have nanotechnology R&D programs.
- In addition to federal investments, State governments and the private sector have become increasingly involved in supporting nanotechnology. In 2004, the private sector in the U.S. invested roughly \$2 billion in nanotechnology re-

search, while State and local governments invested roughly \$400 million. The State and local investment is primarily spent on infrastructure and research at public universities, while the private funding focuses on applied research and development activities at small and large companies, and funding for start-up nanotechnology ventures.

- Other countries are also investing significant funds in nanotechnology research and development. In 2004, governments in Europe, Japan, and elsewhere spent approximately \$2.8 billion in this area, and corporations outside North America spent roughly \$2 billion.
- The *21st Century National Nanotechnology Research and Development Act* required that a National Nanotechnology Advisory Panel (NNAP) biennially report to Congress on trends and developments in nanotechnology science and engineering and on recommendations for improving the NNI. The first such report was released in May 2005 (the executive summary is attached). Its recommendations include strengthening federal-industry and federal-State cooperation on nanotechnology research, infrastructure, and technology transfer, and broadening federal efforts in nanotechnology education and workforce preparation.

5. Background

Overview of Nanotechnology

The National Academy of Sciences describes nanotechnology as the “ability to manipulate and characterize matter at the level of single atoms and small groups of atoms.” An Academy report describes how “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.”¹

Nanotechnology is an enabling technology and, as such, its commercialization does not depend specifically on the creation of new products and new markets. Gains can come from incorporating nanotechnology into existing products, resulting in new and improved versions of these products. Examples could include faster computers, lighter materials for aircraft, less invasive ways to treat cancer, and more efficient ways to store and transport electricity. Some less-revolutionary nanotechnology-enabled products are already on the market, including stain-resistant, wrinkle-free pants, ultraviolet-light blocking sunscreens, and scratch-free coatings for eyeglasses and windows.

In October 2004, Lux Research, a private research firm, released its most recent evaluation of the potential impact of nanotechnology. The analysis found that, in 2004, \$13 billion worth of products in the global marketplace incorporated nanotechnology. The report projected that, by 2014, this figure will rise to \$2.6 trillion—15 percent of manufacturing output in that year. The report also predicts that in 2014, ten million manufacturing jobs worldwide—11 percent of total manufacturing jobs—will involve manufacturing these nanotechnology-enabled products.²

National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) is a multi-agency research and development (R&D) program. The goals of the NNI, which was initiated in 2000, are to maintain a world-class research and development program; to facilitate technology transfer; to develop educational resources, a skilled workforce, and the infrastructure and tools to support the advancement of nanotechnology; and to support responsible development of nanotechnology. Currently, 11 federal agencies have ongoing programs in nanotechnology R&D; funding for those activities is shown in Table 1. Additionally, 11 other agencies, such as the Food and Drug Administration, the U.S. Patent and Trademark Office, and the Department of Transportation, participate in the coordination and planning work associated with the NNI.

¹*Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative*, National Research Council/National Academy of Sciences, 2002.

²Lux Research, “Sizing Nanotechnology’s Value Chain,” October 2004.

Table I. Funding for the National Nanotechnology Initiative (Dollars in Millions)

	FY04 Actual	FY05 Estimated	FY06 Proposed
National Science Foundation	256	338	344
Department of Defense	291	257	230
Department of Energy	202	210	207
National Institutes of Health	106	142	144
National Institute of Standards and Technology	77	75	75
National Aeronautics and Space Administration	47	45	32
Environmental Protection Agency	5	5	5
National Institute for Occupational Safety & Health	0	3	3
U.S. Department of Agriculture	2	3	11
Department of Justice	2	2	2
Department of Homeland Security	1	1	1
Total	989	1081	1054

Source: The National Nanotechnology Initiative—Supplement to the Presidents FY06 Budget Request

In 2003, the Science Committee wrote and held hearings on the *21st Century National Nanotechnology Research and Development Act*, which was signed into law on December 3, 2003. The Act authorizes \$3.7 billion over four years (FY05 to FY08) for five agencies (the National Science Foundation, the Department of Energy, the National Institute of Standards and Technology, the National Aeronautics and Space Administration, and the Environmental Protection Agency). The Act also: adds oversight mechanisms—an interagency committee, annual reports to congress, an advisory committee, and external reviews—to provide for planning, management, and coordination of the program; encourages partnerships between academia and industry; encourages expanded nanotechnology research and education and training programs; and emphasizes the importance of research into societal concerns related to nanotechnology to understand the impact of new products on health and the environment.

National Nanotechnology Advisory Panel Report

The *21st Century National Nanotechnology Research and Development Act* required the establishment or designation of a National Nanotechnology Advisory Panel (NNAP) to assess and provide advice on the NNI. In July 2004, the President designated the existing President's Council of Advisors on Science and Technology to serve as the NNAP. The NNAP's responsibilities include providing input to the administration on trends and developments in nanotechnology and on the conduct and management of the NNI.

The NNAP is required to report to Congress on its activities every two years, and its first report was formally released in May 2005. (The executive summary of this report is included in Appendix A, its content is described below, and the full report is available online.³) The report assesses the U.S. position in nanotechnology relative to the rest of the world, evaluates the quality of current NNI programs and program management, and recommends ways the NNI could be improved.

Benchmarking

The NNAP report finds that U.S. leads the rest of the world in nanotechnology as measured by metrics such as level of spending (both public and private), publications in high-impact journals, and patents. The report also finds, however, that other countries are increasing their efforts and investments in nanotechnology and are closing the gap with the U.S.

Nanotechnology is a relatively new field, and relevant activities in the U.S. and abroad are focused more on research and development than on production and sales. The NNAP observes that, because the relevant markets are still emergent, useful economic indicators, such as market share, are not yet available for the evaluation of the U.S. competitive position. Therefore, the NNAP report considers where the

³The PCAST's report, *National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel*, is available online at http://www.nano.gov/FINAL_PCAST_NANO_REPORT.pdf.

U.S. stands by examining benchmarks such as funding for nanotechnology research and development and numbers of publications and patents.

Reliable data on spending is difficult to gather, as definitions of nanotechnology vary, and investments in the private sector are often not reported. Information gathered by the National Science Foundation demonstrates that funding for nanotechnology around the world has grown significantly over the past decade or so; specifically, while total government investment in nanotechnology research and development was roughly \$430 million in 1997, by 2005 it had climbed to roughly \$4.1 billion—a factor of 10 increase in just eight years. The U.S. traditionally has accounted for just over a quarter of that spending. Japan and the European Union countries collectively each spend roughly the same amount as the U.S.

There is less historical data available for private sector spending on nanotechnology research and development, but current data are gathered. The most recent analysis from Lux Research estimates that corporations worldwide spent \$3.8 billion in this area in 2004, with 46 percent (\$1.7 billion) of that spent by North American companies, 36 percent (\$1.4 billion) by Asian companies, 17 percent (\$650 million) by European companies, and less than one percent by companies from other regions. In addition, venture capital firms invested approximately \$400 million in nanotechnology start-up companies.

Data on spending describe current levels of effort and hence information about future generation of knowledge. Data on publications and patents provide a sense of the level of recent innovations and advances. Analysis of the U.S. share of publications show that, while the U.S. produces the most papers in nanotechnology, both overall and in the most highly-regarded journals, the percent of such papers originating in the U.S. is declining as other countries' contributions grow more rapidly than those from the U.S. Similar trends can be seen in studies of patents awarded.

One of the reasons that the U.S. is the acknowledged leader in nanotechnology is its breadth of investment; research and development activities are ongoing in areas relevant to a wide range of industries (such as materials, energy, electronics, health care, etc.). Most other countries cannot afford to invest as broadly as the U.S. Some of these other countries—particularly in Asia—have chosen to concentrate their investments in particular areas to make strides in a specific sector. For example, Korea and Taiwan are investing heavily in nanoelectronics while Singapore and China are focusing on nanobiotechnology and nanomaterials, respectively.

NNI Management

The NNAP report finds that the NNI is a well managed program. The report notes that the balance of funding among different areas of nanotechnology is appropriate and emphasizes the importance of investment in a diverse array of fields rather than a narrow focus on a just a few “Grand Challenges.” In particular, the NNAP lauds the NNI for advancing the foundational knowledge about control of matter at the nanoscale; creating an interdisciplinary nanotechnology research community and an infrastructure of over 35 nanotechnology research centers, networks, and user facilities; investing in research related to the environment, health, safety, and other societal concerns; establishing nanotechnology education programs; and supporting public outreach.

Recommendations

The NNAP recommends continued strong investment in basic research and notes the importance of recent federal investment in research centers, equipment, and facilities at universities and national laboratories throughout the country (see Appendix B). Such facilities allow both university researchers and small companies to have access to equipment too expensive or unwieldy to be contained in an individual laboratory.

The NNAP also emphasizes the importance of state and industry contributions to the U.S. nanotechnology efforts and recommends that the NNI expand federal-State and federal-industry interactions through workshops and other methods.

The NNAP also recommends that the Federal Government actively use existing government programs such as the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs to enhance technology transfer in nanotechnology. All grant-giving agencies are required by law to have SBIR and STTR programs, and some of them specifically target solicitations toward nanotechnology. However, it is hard to get a clear, up-to-date picture of how much funding is actually provided for nanotechnology-related projects in these programs and on what the demand for SBIR/STTR funding in this area is. The NNAP also recommends that federal agencies be early adopters and purchasers of new nanotechnology-related products in cases where these technologies can help fulfill an agency's mission.

The NNAP also finds that the NNI is making good investments in environmental, health, and safety research, and recommends that the Federal Government continue efforts to coordinate this work with related efforts in industry and at non-profits and with activities conducted in other countries. The NNAP emphasizes the importance of communication with stakeholders and the public regarding research and findings in this area.

Finally, the NNAP emphasizes the importance of education and workforce preparation and recommends that the NNI coordinate with Departments of Education and Labor to improve access to materials and methods being developed for purposes of nanotechnology education and training.

Challenges Ahead

The NNAP notes that successful adoption of nanotechnology-enabled products will require coordination between federal, State, academic, and industrial efforts (including for efficient commercialization of products), training of a suitable high-technology workforce, and development of techniques for the responsible manufacture and use of these products.

Developing a federal strategy to facilitate technology transfer of nanotechnology innovations is a particularly complex challenge because of the wide range of industry sectors that stand to benefit from nanotechnology and the range of time scales at which each sector will realize these benefits. The NNAP report provides examples of various possible nanotechnology applications and when they are expected to reach the product stage (Table 2). The applications cover sectors from information technology and health care to security and energy, and some applications are on the market now, while others are more than 20 years in the future.

Table 2: Areas of Opportunity for Nanotechnology Applications

Time Scale	Nanotechnology Applications
Near-term (1-5 years)	<ul style="list-style-type: none"> - Nanocomposites with greatly improved strength-to-weight ratio, toughness, etc. - Nanomembranes and filters (including for water purification and desalination) - Improved catalysts with one or more orders of magnitude less precious metal - Sensitive, selective, reliable solid-state chemical and biological sensors - Point-of-care medical diagnostic devices - Long-lasting, rechargeable batteries
Mid-term (5-10 years)	<ul style="list-style-type: none"> - Targeted drug therapies - Enhanced medical imaging - High efficiency, cost effective solar cells - Improved fuel cells - Efficient technology for water-to-hydrogen conversion - Carbon sequestration
Long-term (20+ years)	<ul style="list-style-type: none"> - Drug delivery through cell walls - Molecular electronics - All-optical information processing - Neural prosthetics for treating paralysis, blindness, etc. - Conversion of energy from thermal or chemical sources in the environment

Source: Report of the National Nanotechnology Advisory Panel (2005)

As the NNAP report notes, the states are playing an increasing role in nanotechnology. In 2004, State funding for nanotechnology-related projects was \$400 million, or approximately 40 percent of the total federal investment. To date, State funding for nanotechnology has been focused on infrastructure—particularly the construction of new facilities—with some research support being provided in the form of matching funds to public universities that receive federal research dollars. In addition to receiving State support, universities and national laboratories also leverage federal investments through industry contributions of funds or in-kind donations of equipment and expertise. The NNAP report lists 15 examples of nanotechnology infrastructure investments at the State and local levels, and further details on non-federal initiatives can be found in the recent report on a 2003 NNI workshop on regional, State, and local nanotechnology activities.⁴

⁴*Regional, State, and Local Initiatives in Nanotechnology* is the report on a workshop convened on September 30–October 1, 2003 by the Nanoscale Science, Engineering and Technology

Continued

In recent years, the focus has been on the construction of nanotechnology facilities, but as these building projects financed by federal, State, and private funding are completed, the nanotechnology community must consider how best to capitalize on these new resources. Specifically, funding will have to be found for operating expenses, and policies that will attract public and private sector users to these facilities will be needed on topics such as collaboration, intellectual property, and usage fees.

The diversity of industry sectors will be a challenge for developing appropriate education and workforce training programs in nanotechnology. The predicted scale and breadth of research and manufacturing jobs related to nanotechnology will require not only specialized programs but also integration of nanotechnology-related information into general science, technology, engineering, and mathematics education.

Finally, successful integration of nanotechnology into products will require an understanding of the standards and regulations needed to govern responsible manufacturing and use of nanotechnology-enabled products. Under the FY06 budget request, \$82 million (eight percent) of the proposed NNI R&D funding would be spent on research related to the societal implications of nanotechnology. Of this amount, \$38.5 million (four percent of the overall program) would be specifically directed at environmental, health, and safety research, while the remainder is for the study of economic, workforce, educational, ethical, and legal implications. In addition to this funding, relevant work is also ongoing in other NNI focus areas. One example is the development of measurement techniques at the nanoscale which are necessary to set standards that can be used for quality control of nanotechnology products and to manage compliance with safety regulations. Another example is the study of the basic mechanisms of interaction between nanoscale materials and biological systems, which can provide critical information for health care applications as well as safe use practices.

6. Witness Questions

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

Questions for Mr. Floyd Kvamme:

- What is the position of U.S. research and development in nanotechnology relative to that of other countries? What key factors influence U.S. performance in the field, and what trends exist among those factors?
- What fields of science and engineering present the greatest opportunities for breakthroughs in nanotechnology, and what industries are most likely to be affected by those breakthroughs in both the near-term and the longer-term?
- What is the Federal Government's role in facilitating the commercialization of nanotechnology innovations, and how can the current federal nanotechnology program be strengthened in this area?
- What is the workforce outlook for nanotechnology, and how can the Federal Government help ensure there will be enough people with the relevant skills to meet the Nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?

Questions for Mr. Jim O'Connor:

- What is the position of U.S. research and development in nanotechnology relative to that of other countries? What key factors influence U.S. performance in this field?
- What fields of science and engineering present the greatest opportunities for breakthroughs in nanotechnology relevant to Motorola, and what products are most likely to be affected by those breakthroughs in both the near-term and the longer-term?
- What countries and corporations do you perceive to be your closest competitors in nanotechnology science and business? What factors influence Motorola's ability to compete with these groups?
- What is the workforce outlook for nanotechnology, and how does the U.S. position compare to that of other countries? How can the Federal Government help ensure there will be enough people with the relevant skills to meet the

(NSET) Subcommittee, the interagency group that coordinates NNI activities. The report is available online at <http://www.nano.gov/041805Initiatives.pdf>.

Nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?

Questions for Mr. Sean Murdock:

- What is the position of U.S. businesses in nanotechnology relative to that of other countries? What key factors influence U.S. performance in the field, and what trends exist among those factors?
- What investments are other countries making in nanotechnology research, development, and commercialization activities? How do other countries' approaches differ from that of the U.S.?
- What industries are most likely to be affected by breakthroughs in nanotechnology in both the near-term and the longer-term?
- What are typical pathways by which ideas or prototypes of new nanotechnology-related products or processes are successfully developed into commercial applications? What are the primary barriers to these pathways, and how can these barriers be overcome or removed?
- What is the Federal Government's role in facilitating the competitiveness of U.S. industry in nanotechnology, and how can the current federal nanotechnology program be strengthened in this area?

Questions for Mr. Matthew Nordan:

- What is the position of U.S. businesses in nanotechnology relative to that of other countries? What key factors influence U.S. performance in the field, and what trends exist among those factors?
- What investments are other countries making in nanotechnology research, development, and commercialization activities? How do other countries' approaches differ from that of the U.S.?
- What industries are most likely to be affected by breakthroughs in nanotechnology in both the near-term and the longer-term?
- What are typical pathways by which ideas or prototypes of new nanotechnology-related products or processes are successfully developed into commercial applications? What are the primary barriers to these pathways, and how can these barriers be overcome or removed?
- What is the Federal Government's role in facilitating the competitiveness of U.S. industry in nanotechnology, and how can the current federal nanotechnology program be strengthened in this area?

Appendix A

The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel

REPORT TO THE PRESIDENT FROM THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY¹

EXECUTIVE SUMMARY

The President's Fiscal Year (FY) 2004 Budget, released in February 2003, tasked the President's Council of Advisors on Science and Technology (PCAST) with reviewing the National Nanotechnology Initiative (NNI) and making recommendations for strengthening the program. Congress ratified the need for an outside advisory body with its passage of the *21st Century Nanotechnology Research and Development Act of 2003* (the Act), which called for the President to establish or designate a National Nanotechnology Advisory Panel (NNAP). By Executive Order, the President designated PCAST as the NNAP in July 2004. To augment its own expertise in managing large research and development (R&D) programs, PCAST identified a Technical Advisory Group (TAG) comprising about 45 nanotechnology experts representing diverse disciplines and sectors across academia and industry. The TAG is a knowledgeable resource, providing input and feedback with a more technical perspective.

The Act calls upon the NNAP to assess the NNI and to report on its assessments and make recommendations for ways to improve the program at least every two years. This is the first such periodic report provided by PCAST in its role as the NNAP.

The Administration has identified nanotechnology as one of its top R&D priorities. When FY 2005 concludes later this year, over four billion taxpayer dollars will have been spent since FY 2001 on nanotechnology R&D. In addition, the President's FY 2006 Budget includes over \$1 billion for nanotechnology research across 11 federal agencies. Such a substantial and sustained investment has been largely based on the expectation that advances in understanding and harnessing novel nanoscale properties will generate broad-ranging economic benefits for our nation. As such, the NNAP members believe the President, the Congress, and the American people are seeking answers to four basic questions relative to the federal investment in nanotechnology R&D:

1. **Where Do We Stand?**
2. **Is This Money Well Spent and the Program Well Managed?**
3. **Are We Addressing Societal Concerns and Potential Risks?**
4. **How Can We Do Better?**

Answers to these questions provide the assessments and recommendations called for by the Act. Our conclusions can be summarized as follows:

1. Where Do We Stand?

Today, the United States is the acknowledged leader in nanotechnology R&D. The approximately \$1 billion annual Federal Government funding for nanotechnology R&D is roughly one-quarter of the current global investment by all nations. Total annual U.S. R&D spending (federal, State, and private) now stands at approximately \$3 billion, one-third of the approximately \$9 billion in total worldwide spending by the public and private sectors. In addition, the United States leads in the number of start-up companies based on nanotechnology, and in research output as measured by patents and publications. Our leadership position, however, is under increasing competitive pressure from other nations as they ramp up their own programs.

2. Is This Money Well Spent and the Program Well Managed?

The NNAP members believe strongly that the money the United States is investing in nanotechnology is money very well spent, and that continued robust funding is important for the Nation's long-term economic well-being and national security. Nanotechnology holds tremendous potential for stimulating innovation and thereby enabling or maintaining U.S. leadership in industries that span all sectors. The

¹Released May 2005, full report available online at http://www.nano.gov/FINAL_PCAST_NANO_REPORT.pdf

focus of the NNI on expanding knowledge of nanoscale phenomena and on discovery of nanoscale and nanostructured materials, devices, and systems, along with building an infrastructure to support such studies, has been both appropriate and wise. The NNI has accomplished much already—advancing foundational knowledge, promoting technology transfer for commercial and public benefit, developing an infrastructure of user facilities and instrumentation, and taking steps to address societal concerns—and the economic payoffs over the long-term are likely to be substantial.

The NNI appears well positioned to maintain United States leadership going forward, through both its coordinated interagency approach to planning and implementing the Federal R&D program and its efforts to interact with industry and the public. This approach is outlined clearly in the recently released NNI Strategic Plan, which spells out the goals and priorities for the initiative for the next five to 10 years. The NNAP members believe that this Plan provides an appropriate way to organize and manage the program.

3. Are We Addressing Societal Concerns and Potential Risks?

The societal implications of nanotechnology—including environmental and health effects—must be taken into account simultaneously with the scientific advances being underwritten by the Federal Government. The NNI generally recognizes this, and is moving deliberately to identify, prioritize, and address such concerns.

Environmental, Health, and Safety. The NNAP convened a panel of experts from Government regulatory agencies, academia, and the private sector to discuss the environmental and health effects of nanotechnology. Based on these panel discussions, as well as on information received from the NSET Subcommittee and the TAG, the NNAP members believe that potential risks do exist and that the Government is directing appropriate attention and adequate resources to the research that will ensure the protection of the public and the environment. The NNAP members are particularly pleased that strong communication exists among the agencies that fund nanotechnology research and those responsible for regulatory decision-making.

Education. The future economic prosperity of the United States will depend on a workforce that both is large enough and has the necessary skills to meet the challenges posed by global competition. This will be especially important in enabling the United States to maintain its leadership role in nanotechnology and in the industries that will use it. The NNI has launched a range of education-related programs appropriate for classrooms at all levels and across the country, along with other programs that are aimed at the broader public. While the NNI cannot be expected to solve the Nation's science education problems singlehandedly, the NNAP members believe that these NNI activities can help improve science education and attract more bright young minds into careers in science and engineering.

Other Societal Dimensions. Understanding the impact of a new technology on society is vital to ensuring that development takes place in a responsible manner. In addition to research into societal issues such as the environmental, health, and safety effects of nanotechnology, the NNI's diverse and growing R&D program is exploring other issues such as economic, workforce, and ethical impacts. In addition, communication among the various stakeholders and with the public on these topics is an important element of the program, as indicated by the establishment of an interagency subgroup to address this topic.

4. How Can We Do Better?

The NNAP will monitor progress on the program elements discussed above; in the meantime, the NNAP offers the following recommendations aimed at further strengthening the NNI.

Technology Transfer. The level of interest and investment across many industrial sectors is growing and will likely outpace Government investment in the United States soon, if it hasn't already. The NNI needs to take further steps to communicate and establish links to U.S. industry to further facilitate technology transfer from the lab to the marketplace. The NNAP calls attention to two areas that would augment the existing suite of activities and enhance commercialization of research results.

- **The NNI's outreach to, and coordination with, the States should be increased.** Such efforts would complement those NNI activities already underway with various industrial sectors. The States perform a vital role in fostering economic development through business assistance programs, tax incentives, and other means. In addition, collectively the States are spending substantial amounts in support of nanotechnology R&D and commercializa-

tion. The NNAP members believe that practical application of NNI-funded research results, workforce development, and other national benefits will increase with improved federal-State coordination.

- **The NNI should examine how to improve knowledge management of NNI assets.** This would include assets such as user facilities and instrumentation available to outside researchers, research results, and derivative intellectual property. Through mechanisms such as publicly available and searchable databases, the NNI can—and should—improve infrastructure utilization and the transfer of technology to the private sector.

The NNAP notes that, although ultimate commercialization of nanotechnology is desirable and to be supported, the NNI must remain mindful that its primary focus is on developing an understanding of the novel properties that occur at the nanoscale and the ability to control matter at the atomic and molecular level. While we all want the United States to benefit economically from nanotechnology as quickly as possible, it is critically important that the basic intellectual property surrounding nanotechnology be generated and reside within this country. Those who hold this knowledge will “own” commercialization in the future.

Environmental and Health Implications. The NNI should continue its efforts to understand the possible toxicological effects of nanotechnology and, where harmful human or environmental effects are proven, appropriate regulatory mechanisms should be utilized by the pertinent federal agencies. Nanotechnology products should not be immune from regulation, but such regulation must be rational and based on science, not perceived fears. Although it appears that the public and the environment are adequately protected through existing regulatory authorities, the NNAP encourages the Government regulatory agencies to work together to ensure that any regulatory policies that are developed are based on the best available science and are consistent among the agencies.

The NNAP notes that research on the environmental and health implications of nanomaterials and associated products should be coordinated not only within the Federal Government, but with other nations and groups around the world to ensure that efforts are not duplicated unnecessarily and information is shared widely.

Education/Workforce Preparation. A key to realizing the economic benefits of nanotechnology will be the establishment of an infrastructure capable of educating and training an adequate number of researchers, teachers, and technical workers. To maximize the value of its investment in developing materials and programs for education and worker training, the NNI should establish relationships with the Departments of Education and Labor. While the science agencies such as the National Science Foundation can conduct education research and design excellent programs and materials, ultimately the mission agencies, Education and Labor, must be engaged to disseminate these programs and materials as widely as possible throughout the Nation’s education and training systems.

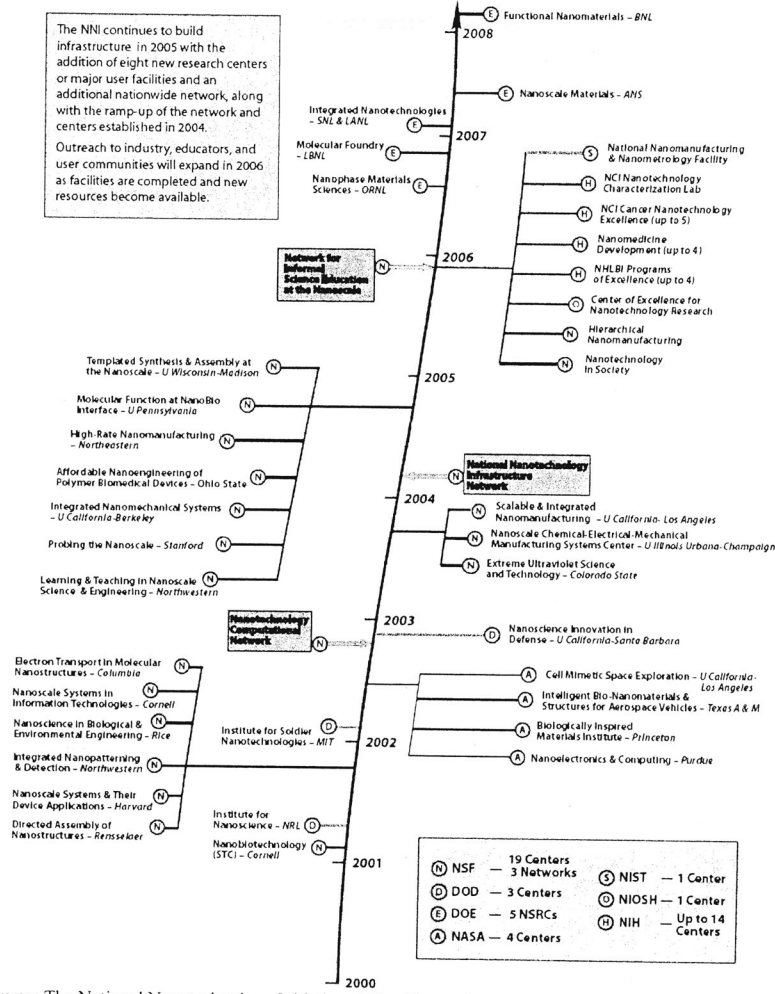
The NNI’s education focus should be on promoting science fundamentals at K–16 levels, while encouraging the development and incorporation of nanotechnology-related material into science and engineering education. To promote mid-career training for professionals, the NNI should partner with and support professional societies and trade associations that have continuing education as a mission.

Societal Implications. The NNI must support research aimed at understanding the societal (including ethical, economic, and legal) implications and must actively work to inform the public about nanotechnology. Now more than ever, those who are developing new scientific knowledge and technologies must be aware of the impact their efforts may have on society.

In summary, the NNAP supports the NNI’s high-level vision and goals, and the investment strategy by which those are to be achieved. Panel members feel that the program can be strengthened by extending its interaction with industry, State and regional economic developers, the Departments of Education and Labor, and internationally, where appropriate. The NNI should also continue to confront the various societal issues in an open, straightforward, and science-based manner.

Appendix B: National Nanotechnology Initiative Centers and User Facilities

NNI Centers and User Facilities



Source: The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel

Chairman INGLIS. The Subcommittee will come to order, and thank you for joining us this morning for a second hearing on nanotechnology. Last month, the Research Subcommittee heard from experts about examples of successful partnerships between government and the private and public sectors, and discussed barriers to future advancement. The witnesses also cited the National Nanotechnology Initiative as a successful program that is helping advance the nanotechnology industry.

Also last month, the President's Council of Advisors on Science and Technology, PCAST, released a report on the state of and the outlook for technology in the U.S. On the whole, the report is very encouraging, and I am glad to see that Mr. Floyd Kvamme, the Co-Chair of PCAST, is one of our witnesses here today. The good news is that the United States still leads the world by most metrics, including funding, patents, and scientific publications. But I find it troubling that other countries are catching up, and not just in funding. I hope we can talk today about ways the U.S. can maintain its status as a world leader in these emerging technologies.

I have said it before. I am not a scientist by background. My minuscule knowledge of nanotechnology, that I guess pun is intended there—is a result of preparing for hearings such as this, and is driven by the realization that this technology will quickly become as commonplace as the Internet. Nanotechnology is already changing the products we use and has the potential to revitalize our manufacturing base. It promises to impact virtually every field, with applications in fields from energy to defense to healthcare to transportation.

Just yesterday, we rolled out the House Hydrogen and Fuel Cell Caucus, with the ultimate goal of leading us to a national hydrogen economy. I am excited to hear that efforts are already underway to use nanotechnology to improve hydrogen production, storage, and fuel cells. The development of this technology is truly amazing, and holds great promise. As many of you know, a hydrogen economy is an issue near and dear to my heart, as is the education of our nation's children in math and science. It is imperative that we encourage and nurture a future generation of scientists to help us maintain our prominence in nanotechnology and in other critically important scientific fields.

That is why today's hearing is so important. As the PCAST report shows, the U.S. is currently ahead of the nanotechnology curve, but other nations continue to invest more and more time, energy, and money in their nanotechnology efforts. If we pause even to glance over our shoulders, we will see them on the horizon, several of whom are already on our heels and pushing to take the lead. This possibility is no small matter. Our last stronghold of competition is innovation, and the United States can not afford to lose the lead on this technology.

Today, I hope our witnesses will address our current nanotechnology position, relative to other countries, from an R&D perspective and from a business perspective, and discuss where our greatest opportunities for breakthroughs are, and what the potential impacts may be in the near-term and in the long-term. Furthermore, we hope to hear what barriers exist to commercializing

nanotechnology, how we could overcome them, and the Federal Government's role in the process.

I look forward to hearing each of your testimonies. At this point, I would recognize Ms. Hooley for an opening statement.

[The prepared statement of Chairman Inglis follows:]

PREPARED STATEMENT OF CHAIRMAN BOB INGLIS

Good morning, and welcome to our second hearing on nanotechnology. Last month, the Research Subcommittee heard from experts about examples of successful partnerships between government and the public and private sectors and discussed barriers to future advancement. They also cited the National Nanotechnology Initiative (NNI) as a successful program that is helping advance the nanotechnology industry.

Also last month, the President's Council of Advisors on Science and Technology (PCAST) released a report on the state of, and outlook for, nanotechnology in the U.S. On the whole, the report is very encouraging, and am I glad to see Mr. Floyd Kvamme, the Co-Chair of PCAST, as one of our witnesses here today. The good news is that the United States still leads the world by most metrics, including funding, patents, and scientific publications. But I find it troubling that other countries are catching up, and not just in funding. I hope we can talk today about ways the U.S. can maintain its status as a world leader in these emerging technologies.

I've said it before: I'm not a scientist by background. My minuscule knowledge of nanotechnology (pun intended) is a result of preparing for hearings such as this, and it is driven by the realization that this technology will quickly become as commonplace as the Internet. Nanotechnology is already changing the products we use and has the potential to revitalize our manufacturing base. It promises to impact virtually every field-with applications in fields from energy to defense to health care to transportation.

Just yesterday, we rolled-out the House Hydrogen and Fuel Cell Caucus, with the ultimate goal of leading us to a national hydrogen economy. I'm excited to hear that efforts are already underway to use nanotechnology to improve hydrogen production, storage and fuel cells. The development of this technology is truly amazing and holds great promise. As many of you know, a hydrogen economy is an issue near to my heart, as is the education of our nation's children in math and science. It is imperative that we encourage and nurture a future generation of scientists to help us maintain our prominence in nanotechnology and in other critically important scientific fields.

This is why today's hearing is so important. As the PCAST report shows, the U.S. is currently ahead of the nanotechnology curve, but other nations continue to invest more and more time, energy and money in their nanotechnology efforts. If we pause even to glance over our shoulders, we will see them on the horizon, several of whom are already on our heels and pushing to take the lead. This possibility is no small matter. Our last stronghold of competition is innovation, and the United States can not afford to lose the lead on this technology.

Today, I hope our witnesses will address our current nanotechnology position relative to other countries, from an R&D perspective and from a business perspective; discuss where our greatest opportunities for breakthroughs are and what the potential impacts may be in the near-term and the long-term. Furthermore, we hope to hear what barriers exist to commercializing nanotechnology, how we can overcome them, and the Federal Government's role in the process.

I look forward to hearing your testimony.

Ms. HOOLEY. Today, the Research Subcommittee concludes its review of the National Nanotechnology Initiative, or NNI, which we began with a hearing on May 18. Just prior to the May 18 hearing, I was astonished to learn the Administration had prevented the appearance of the Co-Chair of the President's Council of Advisors on Science and Technology, to present the Council's Congressionally mandated report on NNI.

Subsequently, the Science Committee ably laid out for the White House our objections to that decision. The decision was reconsidered, and I am happy to say, reversed, and as a result our wit-

nesses this morning include Mr. Floyd Kvamme, who I am extremely pleased to welcome to the hearing.

We will now be able to hear from a key author of the report that provides the initial biennial assessment of NNI. This assessment covers both the content and the management of this important \$1 billion per year R&D initiative.

One aspect of the NNI of great interest to me is how the initiative helps to facilitate the commercialization of nanotechnology. In today's testimony, we will see that Lux Research projects that nanotechnology will impact nearly every category of manufactured goods over the next 10 years, becoming incorporated into 15 percent of global manufacturing output, totaling \$2.6 trillion in 2014. We clearly need to ensure that the United States is a major player in this market, and fares well against strong international competition.

During the Subcommittee's May hearing, we heard about investments underway in the states to advance nanotechnology, and to foster the transition of research results into new products and applications. For example, one of our witnesses, Dr. Cassady, from Oregon State University, described the Oregon Nanoscience and Microtechnologies Institute, better known as ONAMI, which is a collaboration between Oregon's three major research universities, federal research agencies, and the state's thriving high tech sector.

There was a general consensus among the witnesses at the May hearing that the Federal Nanotechnology Funding should include support for applied, pre-competitive research. I will be interested in your views, Mr. Kvamme, and our other panelists, on how we can ensure that the Nation gains the full benefit of the large federal basic research investment being made in nanotechnology. In particular, I would like your suggestions on the kinds of activities that will ensure effective technology transfer to the private sector.

Mr. Chair, I want to thank you for calling this hearing, and I thank all of our witnesses for appearing before the Subcommittee today, and I look forward to our discussion.

[The prepared statement of Ms. Hooley follows:]

PREPARED STATEMENT OF REPRESENTATIVE DARLENE HOOLEY

Mr. Chairman, today the Research Subcommittee concludes its review of the National Nanotechnology Initiative, or the NNI, which we began with a hearing on May 18th. Just prior to the May hearing, I was astonished to learn that the Administration had prevented the appearance of the Co-Chair of the President's Council of Advisors on Science and Technology to present the Council's congressionally mandated report on the NNI.

Subsequently, the Science Committee ably laid out for the White House our objections to that decision. The decision was reconsidered, and I am happy to say, reversed. And as a result, our witnesses this morning include Mr. Floyd Kvamme, who I am extremely pleased to welcome to the hearing. We will now be able to hear from a key author of the report that provides the initial biennial assessment of the NNI. This assessment covers both the content and the management of this important \$1 billion per year R&D initiative.

One aspect of the NNI of great interest to me is how the initiative helps to facilitate the commercialization of nanotechnology. In today's testimony we see that Lux Research projects that nanotechnology will impact nearly every category of manufactured good over the next 10 years, becoming incorporated into 15 percent of global manufacturing output totaling \$2.6 trillion in 2014. We clearly need to ensure that the United States is a major player in this market and fares well against strong international competition.

During the Subcommittee's May hearing, we heard about investments underway in the States to advance nanotechnology and to foster the transition of research results into new products and applications. For example, one of our witnesses, Dr. John M. Cassady from Oregon State University, described the Oregon Nanoscience and Microtechnologies Institute. ONAMI is a collaboration between Oregon's three major research universities, federal research agencies, and the state's thriving high-tech sector.

There was a general consensus among the witness at the May hearing that federal nanotechnology funding should include support for applied, pre-competitive research. I will be interested in the views of Mr. Kvamme and our other panelists today on how we can ensure that the Nation gains the full benefit of the large federal basic research investment being made in nanotechnology. In particular, I would like your suggestions on the kinds of activities that will ensure effective technology transfer to the private sector.

Mr. Chairman, I want to thank you for calling this hearing and thank our witnesses for appearing before the Subcommittee today. I look forward to our discussion.

Chairman INGLIS. Thank you, Ms. Hooley. Other Members, we would be pleased to receive opening statements for the record, if you would like to submit them, so that we can get right to our panel, and let me introduce them.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman and Ms. Ranking Member, thank you for holding this important and very interesting hearing.

I am especially pleased to revisit the role our country has in the nanotechnology field in light of The National Nanotechnology Initiative five-year assessment and recommendations release.

Nanotechnology has the promise of allowing scientists to control matter on every length scale, including materials in the range of one to 100 nanometers. Science is allowing us to control material behavior by altering structures at the level of one billionth of a meter.

The field includes three main categories of promise, materials and manufacturing, information technology and medicine. I am most eager to see what this technology can do for our nation's health and am hopeful that the utilization of nanotechnology will someday positively affect our economy and job market.

Thank you for your willingness to join us, Mr. Kvamme, Mr. O'Connor, Mr. Murdock and Mr. Nordan. I am eager to hear your testimony. Thank you.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

I want to thank Chairman Inglis and Ranking Member Hooley for bringing the issue of nanotechnology before the Subcommittee today. I appreciate their continued leadership on this issue.

Experts believe that nanotechnology could have an impact on our economy and society as significant as the impact of the steam engine, electricity, the Internet, and the computer chip. Researchers and high-tech start-ups have already identified many potential benefits and applications of nanotechnology in health, energy and the environment, information and communications technology, advanced materials, manufacturing, and national security. It is possible that nanotechnology could lead to solar energy that is competitive with fossil fuels.

Medical researchers are already working on using nanotechnology to develop tools for the diagnosis and therapy of cancer. I am proud to say that Texas is playing a leading role in the development of nanotechnology.

Texas is at the center of the impending nanotechnology revolution. Four of the twenty-one Texas universities (Rice University and the Universities of Texas in Austin, Arlington and Dallas) involved with nanotechnology research programs have already developed nanotechnology-specific research centers.

University of Texas Southwestern Medical School in Dallas is the only medical school in the world where four Nobel Laureates are actively involved in research. The center of the world's telecommunications industry is in Richardson, a Dallas suburb, known as Telecom Corridor. The Dallas and Austin regions are focal points

for the semiconductor industry in Texas. More silicon wafers are produced in Texas than in any other U.S. state except California.

I urge my colleagues to continue to pay attention to nanotechnology after this hearing and I hope that the Administration and the Congress can look for ways to build on and strengthen the nanotechnology research. With this committee leadership, we can work in the direction of creating a brighter and more prosperous future for all Americans. I look forward to continue working with my colleagues on both sides of the aisle to ensure the full development of this important initiative.

Chairman INGLIS. Each of you will have five minutes to speak and then we will follow that with a period of questions from the Members here.

Mr. Floyd Kvamme is the Co-Chair of the President's Council of Advisors on Science and Technology, the PCAST organization that I just mentioned. Mr. Matthew Nordan is the Vice President of Research for Lux Research, Inc. Very happy to have you with us. Mr. Sean Murdock is the Executive Director of the NanoBusiness Alliance. Mr. Jim O'Connor is the Vice President of Technology Incubation and Commercialization at Motorola, Inc.

Mr. Kvamme, if you would start us, and we will recognize you for five minutes, and then, we will go down the panel. Thank you.

If you would push that button. Thank you.

Mr. KVAMME. Missed that.

Ms. HOOLEY. We don't have nanotechnology here.

Chairman INGLIS. It is not voice activated.

STATEMENT OF E. FLOYD KVAMME, CO-CHAIR, PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

Mr. KVAMME. My name is Floyd Kvamme, and I am here in my capacity as Co-Chair of the President's Council of Advisors on Science and Technology, or PCAST, which the President designated as the National Nanotechnology Advisory Panel, or NNAP, called for by the legislation that the Science Committee passed and the President signed in late 2003.

In the first periodic—in that report, the approach that the panel took, based on the requirements of the Act, was to ask four basic questions that we felt the President, the Congress, and the American public wanted to hear.

First, where do we stand, or how does our competitive position in nanotechnology R&D stack up relative to other countries? Second, is the NNI money well spent, and the program well managed? Third, are we addressing societal concerns and potential risks? And four, how can we do better, or how can we strengthen the U.S. nanotechnology effort?

During the review process, PCAST convened panels, met with members of the Nanoscale Science Engineering and Technology Subcommittee of the National Science and Technology Council, attended NNI workshops, and consulted individually with researchers across the United States and around the world.

In addition, a particularly valuable resource was our technical advisory group, or TAG—some 45 nanotechnology experts who provided input and feedback from a technical perspective on the various aspects of nanotechnology and the NNI. Because the focus of this hearing is on the U.S. competitiveness in nanotechnology, I will concentrate my remarks on the first of these questions, “where

do we stand?" and on our recommendations for improving the program.

Regarding the other two questions, the NNAP members generally feel that the federal funding for nanotechnology research and development is money very well spent, and that the program is well managed. Likewise, the NNAP concludes that the NNI is taking appropriate steps to understand and address societal concerns and potential risks. For more details about the NNAP's assessment in these areas, please see my written testimony, or the report itself, or I would be happy to answer questions.

So, where do we stand? The metrics that we used to compare the U.S. position in nanotechnology with that of other countries were R&D spending, a measure of input, and percentage of patents and publications, a measure of output. We found, from the data we surveyed, that today, the U.S. is the leader in nanotechnology R&D. The approximately \$1 billion in annual federal funding is roughly one-quarter of the current global investment by all nations. Moreover, many comparisons of international investments do not report total R&D spending; that is, not only federal but also state and private funding. When all public and private funding is considered, the U.S. is funding approximately \$3 billion, or one-third of the nearly \$9 billion in total worldwide spending for what is classified as nanotechnology R&D.

In the United States, states have been particularly active in promoting nanotechnology R&D, investing an estimated \$400 million in 2004 alone. The U.S. also leads in the number of nanotechnology-based startup companies, and in research output, as measured by U.S. patents and publications. However, other countries are aggressively chasing the U.S. leadership position by increasing support for coordinated national programs, and in some cases, by focusing investments in areas of existing national economic strength. For example, many Asian countries are investing heavily in nanoelectronics.

So, how can we do better? The NNAP report makes a number of recommendations. I will mention four here. First, the NNI should increase its outreach to facilitate tech transfer and commercialization. State and regional entities are directing considerable funding toward nanotechnologies. Examples of state nanotechnology initiatives include New York's Albany Nanocenter, the Oregon Nanoscience and Microtechnologies Institute that has just been mentioned, South Carolina's Nanocenter, and others from California, Texas, Pennsylvania, Illinois and many other states, all of which are very active in supporting nanotechnology-based economic development.

While the NNI has begun to reach out to the states, and has begun an organized program of outreach to other, to various industries, more outreach will leverage the federal investment, and complement those NNI activities already underway with various industrial sectors, many of which appear anxious to pull technology developments from the federal research activity.

Second, as mentioned above, we recommend that the NNI continue its efforts to understand the possible toxicological effects of nanotechnology. While it appears that the public and environment are adequately protected through existing regulatory authorities,

the NNAP encourages continued research into possible toxicological effects in the workplace, and urges regulatory agency cooperation to ensure that any policies based on best science, are based on best science, not perceived fears, and are consistent among the agencies. The NNAP also recommends coordinating and sharing environmental health and safety research results internationally, and working with international entities to ensure that efforts are not duplicated and information is shared widely.

Third, in accordance with the Act, the agency group that coordinate the NNI has identified seven program component areas, PCAs, that generally follow the broad categories of foundational research being conducted today. The PCAs represent areas in which ongoing and coordinated investment, across multiple agencies, will be required to support the development of the many anticipated applications of nanotechnology. The NNAP recommends that these PCAs be regularly reexamined and adjusted as necessary to track the developments in nanotechnology R&D. We cannot know where the state of nanotechnology will be 10 years from now, but we can be fairly certain it will be considerably different than what exists today. Flexibilities in these definitions are essential.

Lastly, any look at nanotechnology or technology development in general highlights the need for a more technically trained workforce. A separate, recent PCAST study focused on this subject. Encouraging our young people to pursue technical degrees so that we have a rich mix of technically trained people throughout our society will be a requirement for success in a world increasingly driven by technical advances.

In conclusion, I am personally excited about the continual flow of new discoveries and revolutionary opportunities made possible by nanotechnology R&D, but while all of us would like to see rapid commercialization of nanotechnology research, our panel feels strongly that the NNI must have, as its primary focus, the development of and understanding through research and development of the novel properties that occur at the nanoscale, and the ability to control matter at the atomic and molecular level.

While we all want the U.S. to benefit economically from nanotechnology as quickly as possible, it is critically important that the basic intellectual property surrounding nanotechnology be generated and protected within this country. Those who hold this knowledge and have the workforce to exploit it will own commercialization in the future.

Mr. Chairman, I appreciate the work and support of this committee for nanotechnology R&D, and look forward to continued dialogue with you on this important subject.

[The prepared statement of Mr. Kvamme follows:]

PREPARED STATEMENT OF E. FLOYD KVAMME

Introduction

Mr. Chairman and Members of the Committee, it is a pleasure and an honor for me to testify to you today regarding the National Nanotechnology Initiative (NNI) and general competitive position of United States in nanotechnology. My name is Floyd Kvamme and I am a Partner at Kleiner Perkins Caufield & Byers, a high technology venture capital firm located in Silicon Valley. That is my full time occupation. I was also honored to be asked, and accepted an invitation, by President George W. Bush in 2001 to co-chair his science and technology advisory group, the President's Council of Advisors on Science and Technology (PCAST). The PCAST is

a group of non-government advisors comprising some two dozen senior representatives, appointed by the President, and drawn from industry, education, and research institutions, and other non-governmental organizations. The President's Science Advisor, the Director of the Office of Science and Technology Policy (OSTP) Jack Marburger, co-chairs the PCAST along with me.

Potential of Nanotechnology

"Nanotechnology" touches upon a broad array of disciplines, including chemistry, biology, physics, computational science, and engineering. And like information technology, nanotechnology has the potential to impact virtually every industry, from aerospace and energy to health care and agriculture. Based on the ability to see, measure, and manipulate matter at the scale of atoms and molecules, nanotechnology was born, in many ways, with the advent of atomic force microscopy in the mid-1980s. Today many industries such as those based on semi-conductors and chemicals already are creating products with enhanced performance based on components and materials with nanosized features.

Nanotechnology today reminds me very much of the early days of the semiconductor industry. The new interdisciplinary relationships being forged and the sense of excitement over future possibilities are very reminiscent of that earlier period.

As with semiconductors, future application of nanotechnology based on evolving research could have significant impact throughout the world. Examples where nanotechnology has the potential to vastly improve standards of living in industrialized and developing nations include: medical applications, clean water, and energy. In our report, we highlight some key research in these areas. In medical applications, for example, nanotechnology has made possible the creation of a synthetic bone replacement material that is highly biocompatible and allows bones to heal faster and more completely than the materials that are used today. In the area of energy efficiency, researchers at Sandia Laboratories have demonstrated a light source that mixes different sized "quantum dots" to create high-efficiency white "light emitting diodes" that use about one-tenth as much energy as an incandescent bulb and that could reduce by more than half the amount of electricity used for lighting nationwide. Finally, researchers at Lawrence Livermore National Laboratory are nanoengineering membrane systems that can target and remove contaminants in water, while reducing treatment costs by at least half compared to conventional technologies. Low-cost clean water technologies have obvious application in remediation of contaminated groundwater and treating industrial waste, as well as significant potential to help improve public health in developing nations.

The early recognition of the broad range of useful and powerful nanotechnology applications led to the formal establishment of a National Nanotechnology Initiative (NNI) in Fiscal Year (FY) 2001. Due to its potential to promote innovation and economic benefits, to address the needs of the Federal agencies, as well as to strengthen the position of the United States as a leader in science and technology, the Administration has identified nanotechnology as a top research and development (R&D) priority for the past several years.

History of PCAST's Involvement with Nanotechnology

The history of PCAST's involvement with the NNI extends back to 1999 when the analogous body under the previous Administration supported a proposal for establishing an interagency nanotechnology initiative. In their letter to the President, they included a recommendation that "the progress toward NNI goals be monitored annually by an appropriate external body of experts, such as the National Research Council." In part based on this recommendation, the National Research Council (NRC) was commissioned to do a study of the NNI, which was released in 2002. The first of that study's ten recommendations was that OSTP establish an independent standing nanoscience and nanotechnology advisory board to provide advice to the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee (the interagency body that coordinates the NNI) on policy, strategy, goals, and management.

The President's FY 2004 Budget, released in February 2003, acknowledged the NRC's recommendation for external review, and directed PCAST to conduct an assessment and provide advice regarding the strategic direction of the NNI program. PCAST began this task shortly thereafter.

The 21st Century Nanotechnology Research and Development (R&D) Act

As PCAST was undertaking its review of the NNI, this subcommittee and its Senate counterpart were also in the midst of creating new legislation that would make statutory the activities and organization of the NNI, along with periodic reviews and other aspects of this vital R&D effort. The requirement for an ongoing outside advisory panel was ratified by Congress in the *21st Century Nanotechnology Research and Development Act of 2003* (Public Law 108-153; hereafter referred to as "the

Act”), which called for the President to establish or designate a National Nanotechnology Advisory Panel (NNAP). PCAST’s role was reaffirmed when, in July 2004 by Executive Order, the President formally designated PCAST to fulfill the duties of the NNAP. The order amended the original Executive Order commissioning PCAST, thus establishing that nanotechnology should be included in the formal PCAST charter.

As detailed by Congress in Section 4, the Act calls upon the NNAP to assess the national nanotechnology program in the following areas:

- Trends and developments in nanotechnology
- Progress in implementing the program
- The need to revise the program
- Balance among the component areas of the program, including funding levels
- Whether program component areas, priorities, and technical goals developed by the NSET Subcommittee are helping to maintain U.S. leadership
- Management, coordination, implementation, and activities of the program
- Whether social, ethical, legal, environmental, and workforce concerns are adequately addressed by the program.

The Act requires the NNAP to report on its assessments and to make recommendations for ways to improve the program at least every two years. The first such report provided by PCAST in its role as the NNAP is now complete and was delivered to this subcommittee at the hearing that was held on May 18th. The remainder of my testimony will focus on this report and the observations and recommendations contained therein. Also, because PCAST was designated as the statutorily mandated NNAP, from this point forward in my testimony I will refer to PCAST as the NNAP.

Technical Advisory Group

Before getting into the specifics of the report, I’d like to highlight a resource that our panel relied on during the course of the review in order to augment the NNAP’s expertise in managing large R&D programs with more specific nanotechnology technical expertise. Early in our review, the NNAP identified a Technical Advisory Group (TAG) comprising approximately 45 nanotechnology experts who represent diverse disciplines and sectors across academia and industry. The TAG is a knowledgeable resource, providing input and feedback with a more technical perspective. The NNAP called upon its TAG on several occasions for broader expert opinions on various topics. Two particular areas where the TAG was very helpful were in reviewing and providing feedback on the NNI Strategic Plan and in helping to illuminate and rationalize for the NNAP some of the key opportunities in nanotechnology research over the short-, medium- and long-term. Input from the TAG has been considered and is represented in the report you have before you today.

NNAP Report

The approach we took during our first assessment of the NNI was to ask some basic questions that encompass the requirements of the Act and that we perceived to be the most pressing questions the President, the Congress and the American public wanted answers to. These were:

- **Where do we stand?** In other words, how does our competitive position in nanotechnology R&D stack up relative to other countries?
- **Is this money well spent and the program well managed?** This encompasses the general request for an external assessment of the NNI.
- **Are we addressing societal concerns and potential risks?** Responding to specific Congressional and public concerns, are we paying close enough attention to environmental, health and safety risks and other societal issues?
- **How can we do better?** What does the NNAP recommend that will help the U.S. strengthen its nanotechnology effort?

I will summarize our assessment and recommendations, and recommend to the committee our full report for a more thorough review of these issues.

Where do we stand?

In attempting to compare the strength of the U.S. nanotechnology effort internationally, the NNAP reviewed a number of metrics that our members felt were appropriate for assessing the competitive position of the U.S. in this new technology area where research and technology discoveries in many cases have yet to reach the

marketplace. We looked at available data for levels of international R&D investment by governments (including Federal, regional, State, and local), as well as private corporations and venture capital firms. We also surveyed data on patent and publication trends to assess commercial interest and strength of research findings among various countries that are active in nanotechnology.

The data surveyed indicate that, today, the United States is the leader in nanotechnology R&D. The approximately \$1 billion annual Federal Government funding for nanotechnology R&D is roughly one-quarter of the current global investment by all nations. Total annual U.S. R&D spending—including federal, State, and private funding—now stands at approximately \$3 billion, one-third of the approximately \$9 billion in total worldwide spending by the public and private sectors. It is noteworthy that State, local and regional governments have been particularly active in promoting nanotechnology development, investing \$400 million in 2004 according to one estimate.¹ In addition, the United States leads in the number of start-up companies based on nanotechnology, and in research output as measured by patents and publications.

However, the data also show that other countries are aggressively chasing this leadership position, both in terms of ramping up coordinated national programs—many of which are modeled directly on the NNI—as well as in focusing investments to areas of existing national economic strength. For example, many of the Asian countries are investing heavily in nanoelectronics. Further, the U.S. lead in publications and patents appears to be slipping. Increased international activity is resulting in increased competitive pressure from other nations and, in the opinion of the NNAP, an increased urgency that the U.S. continues its focus on nanotechnology R&D excellence.

Is this money well spent and the program well managed?

Chapter 2 of the report provides an assessment of the NNI program and its accomplishments. The NNAP also evaluated the Administration's recently released Strategic Plan and the mechanisms in place to manage the program. The NNAP concludes that the money the United States is investing in nanotechnology is money very well spent, and that continued robust funding is important for the Nation's long-term economic well-being and national security.

Nanotechnology holds tremendous potential for stimulating innovation and thereby enabling or maintaining U.S. leadership in industries that span all sectors. The NNAP concludes that the strategic focus of the NNI on expanding knowledge of nanoscale phenomena and on discovery of nanoscale and nanostructured materials, devices, and systems, along with building an infrastructure to support such studies, has been both appropriate and wise. The NNI has accomplished much already—advancing foundational knowledge, promoting technology transfer for commercial and public benefit, developing an infrastructure of user facilities and instrumentation, and taking steps to address societal concerns—and we believe the economic pay-offs over the long-term should be substantial.

The NNAP commends the NNI in particular for making the long-term commitment to nanotechnology R&D through the establishment of a geographically distributed suite of centers of excellence and broadly available user facilities. Largely university-based, the centers provide education of skilled scientists and engineers as well as serving as focal points of multi-disciplinary R&D and, hopefully, new economic opportunities that are geographically dispersed. User facilities, such as the five Department of Energy Nanoscale Science Research Centers, provide access for all researchers to state-of-the-art equipment and expertise for advanced nanotechnology R&D. Staff at the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory in Tennessee—the first of the DOE centers to become fully operational—are currently installing equipment and hiring additional researchers.

At this time, the NNI appears well positioned to maintain United States leadership going forward, through both its coordinated interagency approach to planning and implementing the Federal R&D program and its efforts to interact with industry and the public. This approach is clearly outlined in the recently released NNI Strategic Plan, which spells out the goals and priorities for the initiative for the next five to 10 years. The NNAP surveyed the TAG to augment our review of this Plan, and we believe it provides an appropriate way to organize and manage the program, and that the goals and priorities outlined in the Plan are likewise appropriate.

¹ Lux Research, Inc. 2005. *Statement of Findings: Benchmarking U.S. States in Nanotech*. New York: Lux Research, Inc.

There are a number of cautionary notes and minor recommendations contained in our report, which I will detail in a few minutes when I discuss how we can do better, and I would be happy to answer any other questions on items I may not have covered in my testimony. However, overall I think I can safely say that the NNAP endorses current funding and management of the NNI and believes the strategic direction of the program is sound at this point.

Are we addressing societal concerns and potential risks?

The NNAP believes that the societal implications of nanotechnology—including environmental and health effects—must be taken into account simultaneously with the scientific advances being underwritten by the Federal Government. In its review, the Panel found that the NNI does recognize this, and is moving deliberately to identify, prioritize, and address these concerns. The NNI and NNCO are more organized on this front than when the PCAST first began its review of the NNI two years ago. Because, as many members of the Congress and this committee have rightly pointed out, addressing risks and societal concerns is so important, the NNAP placed special emphasis on this topic, and will continue to do so.

In order to gain insight into environmental, health, and safety issues around nanotechnology, the NNAP convened a panel of experts from Government regulatory agencies, academia, and the private sector. Based on this panel discussion, as well as on information received from the NSET Subcommittee and its TAG, the NNAP believes that potential risks do exist and that the Government is directing appropriate attention and adequate resources to the research that will ensure the protection of the public and the environment. The NNAP is particularly pleased that strong communication exists among the agencies that fund nanotechnology research and those responsible for regulatory decision-making. The pertinent government agencies are devoting more attention and resources toward these issues than most people may realize.

In addition to research into issues related to environmental, health, and safety effects of nanotechnology, the NNI's diverse and growing R&D program is exploring other societal issues such as economic, workforce, and ethical impacts. The NNAP believes that understanding the impact of a new technology on society is vital to ensuring that development takes place in a responsible manner. The NNAP is pleased with the level of discourse on societal issues and believes these efforts should continue.

In addition, communication with the various stakeholders, including the public, on these topics is an important element of the program. Therefore, we were pleased that the interagency group managing the NNI established a new subgroup to address the topic of public engagement.

One societal issue that I would say has engendered the most lingering concern for the NNAP during this review is one which also affects the broader science and technology enterprise and about which PCAST has previously studied and reported. That is, the health of science education in the U.S. and the projected shortage of a qualified science and technology workforce. The future economic prosperity of the United States will depend on a workforce that both is large enough and has the necessary skills to meet the challenges being posed by global competition. This will be especially important in allowing the United States to maintain its leadership role in nanotechnology and the industries that will use nanotechnology. The NNI has launched a range of education-related programs appropriate for classrooms at all levels and across the country, along with other programs that are aimed at the broader public. While the NNI cannot be expected to solve the Nation's science education problems single-handedly, the NNAP believes that NNI activities can help improve science education and attract more bright young minds into careers in science and engineering. The issue of science education in the U.S. is one about which the PCAST feels strongly, and I would direct you to our previous report, *"Sustaining the Nation's Innovation Ecosystem: Maintaining the Strength of Our Science and Engineering Capabilities"* for more information and for our views on this issue generally.

How can we do better?

This chapter of our report presents NNAP recommendations for how we feel the NNI program can be strengthened and improved. I will describe briefly the areas in which our recommendations are principally focused, and would be happy to answer questions about these and any of the other recommendations in our report.

Technology Transfer: The issue of facilitating the transfer of technology from government labs or universities into the marketplace is a subject that I know this committee has been interested in and which generates a significant amount of discussion. In the case of nanotechnology, the level of interest and investment across

many industrial sectors is growing and will likely outpace Government investment in the United States soon, if it hasn't already. In our report, the NNAP recognizes and applauds current efforts to promote technology transfer, such as ongoing dialogues between the NNI and various industries and recent efforts by research agencies to direct Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) contracts toward nanotechnology projects. However, the NNAP also believes there are additional steps the NNI should take to further communicate with and establish links to U.S. industry in order to facilitate technology transfer from the lab to the marketplace.

The NNAP calls out two particular areas that could augment the existing suite of activities and enhance commercialization of research results. The first of these is increasing NNI's outreach to the States, which, as previously noted, are directing considerable funding toward nanotechnology projects. The NNAP believes that greater federal-State interaction can leverage the investments and competencies of both. States, in particular, have a strong interest in and capacity for stimulating economic development and commercial activity.

A notable example of State activity is Albany NanoTech, home to five R&D centers and the College of Nanoscale Sciences and Engineering at the State University of New York (SUNY) Albany. As you heard in testimony by Mr. Michael Fancher at the May 18th hearing that you convened, Albany NanoTech has attracted over \$1 billion in private investment and has over 100 partnerships with other universities, federal labs, and industry. Programs in nanoelectronics have led to close relationships with major electronics firms such as IBM, ASML, Tokyo Electron and International Sematech.

Oregon is another state that has developed a nanotechnology initiative and committed state funds to support infrastructure development for Oregon's Nanoscience and Microtechnologies Institute. The University of South Carolina has invested in the creation of the USC NanoCenter to serve as a focal point for the University's nanotechnology research, to foster multi-disciplinary research and education efforts, and to promote economic development. South Carolina's NanoCenter has developed a special emphasis on creating dialogue concerning the societal and ethical implications of nanotechnology. These are a few examples of specific state and regional activities. Obviously, there are others, including states like California, Texas and Illinois, all of which are very active in supporting technology clusters to spur economic development.

The NNI has begun to reach out and understand what the states are doing, as evidenced in workshop on Regional, State, and Local Nanotechnology Initiatives held in late 2003. The NNAP encourages more outreach to the States to help leverage the federal investment. Such efforts would complement those NNI activities already underway with various industrial sectors. The NNAP believes the States perform a vital role in fostering economic development through business assistance programs, tax incentives, and other means. The NNAP believes that practical application of NNI-funded research results, workforce development, and other national benefits will increase with improved federal-State coordination.

A second, related effort is the development of improved knowledge management of NNI assets. Funding for the NNI to date has resulted in a vast network of assets that should, through proper management, be available to outside researchers and other private interests. The NNAP recommends the NNI focus on improving access to its knowledge assets—including user facilities and instrumentation available to outside researchers, research results, and derivative intellectual property. Through mechanisms such as publicly available and searchable databases, the NNI can—and should—improve infrastructure utilization and the transfer of technology to the private sector.

While the NNAP agrees that ultimate commercialization of nanotechnology is desirable and to be supported, I do want to emphasize that the Panel feels strongly that the NNI must remain mindful of its *primary* focus toward developing an understanding, through research and development, of the novel properties that occur at the nanoscale and the ability to control matter at the atomic and molecular level. While we all want the United States to benefit economically from nanotechnology as quickly as possible, it is critically important that the basic intellectual property surrounding nanotechnology be generated and reside within this country. Those who hold this knowledge and who have a workforce prepared to exploit it will “own” commercialization in the future.

Environmental and Health Implications: Picking up on the issues raised in Chapter 3, the NNAP recommends the NNI continue its efforts to understand the possible toxicological effects of nanotechnology and, where harmful human or environmental effects are proven, that the pertinent federal agencies should promptly regulate accordingly. Nanotechnology products should not be immune from regulation,

but such regulation must be based on science and rationality, not perceived fears and irrationality. Judging on where we are today with existing research and regulation, it appears that the public and the environment are adequately protected through existing regulatory authorities. However, the NNAP encourages continued research into possible toxicological effects—particularly in the workplace—and urges Government regulatory agencies to work together to ensure that any regulatory policies that are developed are based on the best available science and are consistent among the agencies. The NNAP recommends coordinating and sharing environmental, health and safety research results internationally to ensure that that efforts are not duplicated unnecessarily and information is shared widely. The NNAP will continue to monitor the development of these issues very closely.

Program Component Area Flexibility: In accordance with the Act, the interagency group that coordinates the NNI has identified seven Program Component Areas (PCAs) that generally follow the broad categories of foundational research being conducted today. The PCAs represent areas in which ongoing and coordinated investment across multiple agencies will be required to support development of the many anticipated applications of nanotechnology. The NNAP recommends that these PCAs be regularly re-examined and adjusted as necessary to track the developments in the nanotechnology R&D field. Today's PCAs should not be viewed as set in stone, and today's organizational choices cannot be allowed to continue indefinitely and thereby to drive the future progression of the program. We cannot know where the state of nanotechnology will be 10 years from now, but we can be fairly certain it will be considerably different than exists today.

Education/Workforce Preparation: A key to realizing the economic benefits of nanotechnology will be the establishment of an infrastructure capable of educating and training an adequate number of researchers, teachers, and technical workers. To maximize the value of its investment in developing materials and programs for education and worker training, the NNAP felt that better relationships should be established between the NNI and the Departments of Education and Labor. While the science agencies such as the National Science Foundation (NSF) can conduct education research and design excellent programs and materials, ultimately the mission agencies, Education and Labor, must be engaged to disseminate these programs and materials as widely as possible throughout the Nation's education and training systems. The NNAP also felt that the NNI's education focus should be on promoting science fundamentals at K–16 levels, while encouraging the development and incorporation of nanotechnology-related material into science and engineering education. To promote mid-career training for professionals, the NNAP recommends that the NNI partner with and support professional societies and trade associations that have continuing education as a mission.

Other Societal Implications: The NNAP strongly supports continued NNI funding for research aimed at understanding the societal implications of nanotechnology, including ethical, economic, and legal aspects. The NNAP members believe the NNI also must work to inform the public about nanotechnology and seek to understand and address public concerns about this emerging area of technology development. Now more than ever, those who are developing new scientific knowledge and technologies must be aware of the impact their efforts may have on society. Nanotechnology, like biotechnology, has the potential to require individuals, corporations, and governments to make decisions that have ethical, legal, and other societal implications. The NNI must actively engage scholars who represent disciplines that might not have been previously engaged in nanotechnology-related research to address these issues. Moreover, these efforts should be integrated with conventional scientific and engineering research programs so that the people who develop nanotechnology are more fully aware of the societal implications of their work. While the NNAP generally felt that the NNI through its National Nanotechnology Coordination Office (NNCO) has done a good job initiating public outreach and is working to facilitate stakeholder discourse on these subjects, we would encourage continued attention to societal issues into the future.

Other Recommendations/NNAP Report Schedule: Beyond the issues I have highlighted, the NNAP report generally endorses the NNI and recommends continued robust funding to help maintain U.S. leadership. We also suggest increased coordination with other interagency groups and more involvement by agencies not participating in NNI at a level appropriate to their mission, most notably DHS. Finally, there are a few administrative items, such as a recommendation that the NNAP report schedule be adjusted to more adequately complement NNI strategic plan reporting activities. These recommendations and others are more fully described in the report, and I would be happy to respond to any follow-up questions you have.

Conclusion

In conclusion, speaking as a member of the NNAP who has been very closely involved in studying and monitoring developments in nanotechnology over the past several years, and as an early participant in the semiconductor research industry, I am personally excited about the continual flow of new discoveries and truly revolutionary opportunities made possible by nanotechnology R&D. I believe the NNAP report echoes this enthusiasm and conveys our general support for continuing down the path of robust funding and support for the NNI in order to maintain the U.S. competitive edge in this emerging area. I particularly appreciate the work of this committee and the support in Congress generally for nanotechnology R&D, and I look forward to continued dialogue with you on this important research endeavor.

BIOGRAPHY FOR E. FLOYD KVAMME

Since March 1984, Floyd Kvamme has been a Partner at Kleiner Perkins Caufield & Byers, a high technology venture capital firm. He is responsible for the development of high technology companies from early start-up to publicly traded phase.

Floyd Kvamme currently serves on the boards of Brio Technology, Gemfire, Harmonic, National Semiconductor, Photon Dynamics, Power Integrations, and Silicon Genesis.

Mr. Kvamme is Chairman of Empower America, a Washington based issue advocacy organization. He serves on the boards of the Markkula Center for Applied Ethics Advisory Board at Santa Clara University and the National Venture Capital Association (NVCA) and on the Executive Committee of The Technology Network. In 1998, Kvamme served as Chairman of the Electronic Commerce Advisory Council for the State of California.

On the political front, Mr. Kvamme served on the High Tech Advisory Committee and on the National Finance Committee of the Bush for President Campaign. Previously, he served on the Finance Committee of the Fong for Senate Campaign.

Floyd Kvamme was one of five members of the team that began at National Semiconductor in 1967, serving as its General Manager of Semiconductor Operations and building it into a billion-dollar company. He served as President of the National Advanced Systems subsidiary, which designed, manufactured and marketed large computer systems.

In 1982 he became Executive Vice President of Sales and Marketing for Apple Computer. While at Apple, his responsibilities included worldwide sales, marketing, distribution and support.

He holds two degrees in Engineering; a BS in Electrical Engineering from the University of California at Berkeley (1959) and an MSE specializing in Semiconductor Electronics from Syracuse University (1962).

Chairman INGLIS. Thank you, Mr. Kvamme. Mr. Nordan.

STATEMENT OF MATTHEW M. NORDAN, VICE PRESIDENT OF RESEARCH, LUX RESEARCH, INC.

Mr. NORDAN. And there we go. Good morning, Chairman Inglis, Ranking Member Hooley, and Members of the Committee. Thank you for inviting me to testify today. My company, Lux Research, advises corporations, investors, startups, and public sector institutions on exploiting nanotechnology for competitive advantage. I lead the research team.

Now, let us start with the good news. The U.S. leads the world in nanotechnology today. Last year, \$4.6 billion of government spending went into nanotech R&D worldwide. \$1.6 billion was in the U.S., far exceeding second place Japan at \$1 billion flat. Sixty-nine percent of nanotech patents issued by the USPTO are assigned to U.S. based entities, versus only 56 percent for patents overall, so we have a lead there. Last year, \$3.8 billion in corporate R&D went into nanotechnology. Of that, \$1.7 billion came from U.S. based companies like GE and GM, again far exceeding second place Japan at \$1.1 billion. Finally, 24 percent of scientific articles on nanoscience and nanotechnology have emerged from the U.S.,

with China and Japan next, at 13 percent and 11 percent respectively.

However, our lead is tenuous. The rest of the world is catching up. We are falling behind in government investment. At purchasing power parity, Taiwan, Japan, and South Korea all exceed us on a per capita basis. Taiwan's \$9.40 per head at PPP last year was nearly twice our \$5.42. We are threatened by industrial policies abroad that do what the U.S. will not, namely put universities and corporations together to dominate specific, near-term applications. To return to Taiwan, 60 percent of the funds in its \$640 million nanotechnology initiative are devoted to working directly with corporations to achieve leadership in specific product categories.

Even when measured by patents at our own USPTO, we lag other countries in some of the most promising and near-term fields. Of 70 patents for carbon nanotube field emission displays, 22 are assigned to South Korean entities, and 20 to Japanese ones, versus only 12 for the U.S. We have overestimated our lead. Scientists in countries with a less rich history of science and technology are not lagging when it comes to nanotech. On the contrary, they are studying our publications, being educated in our universities, and outfitting their labs with equipment from U.S. firms. China spent \$130 million U.S. on nanotech last year. At purchasing power parity, that was \$611 million, 38 percent of what we spend. The Iranian nanotechnology initiative was ordered by none other than President Mohammad Khatami.

U.S. patents are at risk in countries that do not strongly enforce intellectual property laws. There is a class of nanomaterials called metal oxide nanoparticles. They are used in everything from high SPF sunscreens to rocket fuels. Now, I recently met with several manufacturers in this field at a conference. First, I spoke with U.S. based firms, like Nanotechnologies, Inc., NanoGram, and NanoPhase, all of whom have invested great amounts of money to develop exclusive patented processes for making these nanoparticles. Then, I spoke with a marketing manager from a Chinese competitor, and he was full of detailed, quantitative information about his company's products, until I asked what his production process was, aiming to see if his company might be infringing on the patents of one of the U.S. based firms. He professed that the question had never come up.

What can the U.S. do to maintain and, moreover, extend leadership in nanotechnology? I see five key actions. First, the U.S. must grow federal funding for nanotechnology research. Nanotech is a horizontal enabler most similar to assembly line manufacturing or to electricity that will impact virtually every manufactured good. It is as critical for us to lead in this field now as it was to lead in packet switched networks decades ago, far before the Internet stimulated economic development.

Second, we must eliminate regulatory uncertainty surrounding environmental, health, and safety issues in nanotechnology. There are no firm guidelines from the EPA or OSHA today about how those agencies plan to regulate nanomaterials, and as a result, large corporations are beginning to hold back investment, for fear that the ground will shift underneath them.

Third, we must attract U.S. students to the physical sciences, but as well, we must retain the foreign students that we import. Nobel laureate Richard Smalley has observed that on current trends, by 2010, 90 percent of physical scientists worldwide will be Asian nationals, 60 percent will be practicing in Asia. The U.S. should strengthen science education in K-12, reconsider the effect of visa tightening on the inflow of foreign science and technology students, and develop economic incentives to retain those researchers when they study here. Quite frankly, we risk becoming a drive-through educational institution for other countries' students.

Fourth, we must create financial incentives aligned with desirable applications. Such programs can be coordinated through existing agencies. They require no incremental bureaucracy. Consider NASA's \$11 million project with Rice University to develop extremely low loss power cables based on carbon nanotubes.

And finally, we must be sensible about export controls in nanotechnology, which could choke commercialization. Export controls in this field, per se, are a dead end. The field is too broad to implement them. Such action would be like trying to impose controls on assembly line manufacturing techniques and equipment. Instead, we believe the U.S. should identify specific nanotech applications with military significance, like nanoparticulate explosives, and impose sensible controls on them within existing frameworks.

I appreciate your inviting me here to speak. I think nanotechnology is critical to our nation's future, and I am pleased to answer any questions.

[Statement of Mr. Nordan follows:]

PREPARED STATEMENT OF MATTHEW M. NORDAN

The U.S. leads the world in nanotechnology today, but its position is tenuous. To maintain global leadership, U.S. policy-makers must grow federal funding for nanotech research; eliminate regulatory uncertainty surrounding environmental, health, and safety issues; and do a better job of retaining foreign Ph.D. students. In addition, the U.S. must create financial incentives aligned with desirable applications and approach export controls sensibly.

The U.S. Leads the World in Nanotechnology Today

Nanotechnology is the purposeful engineering of matter at scales of less than 100 nanometers (nm) to achieve size-dependent properties and functions. Nanotech innovations occupy a value chain starting with nanomaterials like carbon nanotubes and dendrimers, followed by intermediate products like memory chips and drug delivery carriers built with nanomaterials, and ending with enhanced final goods like mobile phones and cancer therapies (see Figure 1). Lux Research projects that new, emerging nanotechnology applications will affect nearly every type of manufactured good over the next ten years, becoming incorporated into 15 percent of global manufacturing output totaling \$2.6 trillion in 2014 (see Figures 2 and 3).¹

Multiple Metrics Testify to the Position of the U.S.

Massive investment is going into nanotech—\$8.6 billion combined in government spending, corporate R&D, and venture capital worldwide in 2004, up 10 percent from 2003 (see Figure 4-1).² By most measures, the U.S. leads in nanotechnology today, including:

- Absolute public sector spending. Of the \$4.6 billion spent by governments on nanotechnology R&D last year, the U.S. led in absolute terms with nearly \$1.6 billion; runner-up Japan spent less than two-thirds as much at \$1.0 billion (see Figure 4-2).³

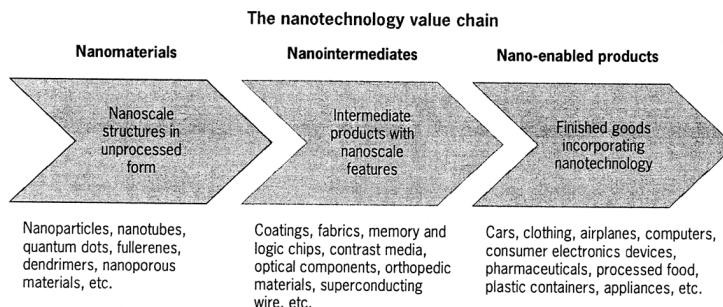
¹ Source: October 2004 Lux Research report, "Sizing Nanotechnology's Value Chain."

² Source: 2004 Lux Research reference study, "The Nanotech Report 2004."

³ Source: 2004 Lux Research reference study, "The Nanotech Report 2004."

- Patents issued. U.S. leadership in patent activity in general is amplified when it comes to nanotechnology. While 56 percent of total issued patents at the U.S. Patent and Trademark Office are assigned to U.S.-based entities, 69 percent of nanotech patents are.⁴

Fig. 1: Nanotech Adds Value across Industry Value Chains in Three Stages



Source: October 2004 Lux Research report "Sizing Nanotechnology's Value Chain"

- Corporate R&D spending. We conservatively estimate that corporations worldwide spent \$3.8 billion on nanotechnology R&D in 2004; of this, \$1.7 billion was spent by corporations based in the U.S., far more than in any other country (see Figure 4-3).⁵
- Scientific publications. Of a representative sample of 109,728 articles published in peer-reviewed journals about nanoscience and nanotechnology through June 2005, 24 percent were authored by U.S.-based scientists—exceeding second-place China (at 13 percent) and third-place Japan (at 11 percent) by a wide margin (see Figure 4-4).⁶

Deeply Embedded Sociocultural Values Drive U.S. Leadership

The U.S. owes its leadership position in nanotechnology to wise decisions, made by both governments and private sector entities like venture capital investors, about how science and technology innovations should be commercialized. These decisions, in turn, stem from deeply embedded sociocultural values—for example, that successful risk-taking innovators should capture large rewards, and that short-term failure is a step toward long-term success. The U.S. benefits from:

- World-class universities that create grist for the commercialization mill. Universities provide an effective vehicle for transferring cutting-edge technology from the lab to the manufacturing floor.⁷ The U.S. serves as a model for the world in this regard, for both high technology in general and nanotech in particular. U.S. investment in knowledge as a percentage of GDP totaled 6.8 percent in 2000, topping the league tables of the first-world OECD countries.⁸ The Bayh-Dole Act of 1980 gave universities powerful financial incentives to transfer innovation into commercial entities, and corporations working in nanotech eagerly tap these resources: 85 percent of corporations active in nanotech R&D interviewed by Lux Research in Q4 2004 have university collaborations.⁹

⁴Source: USPTO searches as of June 22, 2005. For more information on nanotechnology and patents, see the March 2005 Lux Research report, "The Nanotech Intellectual Property Landscape."

⁵Source: 2004 Lux Research reference study, "The Nanotech Report 2004."

⁶To identify these articles, we used the Science Citation Index with a search string of "(quantum dot OR nanopartic* OR nanotub* OR fullerene* OR nanomaterials* OR nanofib* OR nanotech* OR nanocryst* OR nanocomposit* OR nanohorn*)."

⁷It should be noted that national labs such as Oak Ridge and Sandia also serve as wellsprings for innovation that can be commercialized down the road.

⁸Source: OECD Factbook 2005.

⁹Source: December 2004 Lux Research report, "The CEO's Nanotechnology Playbook."

Fig. 2: Product Categories Will Incorporate Emerging Nanotechnology at Different Rates

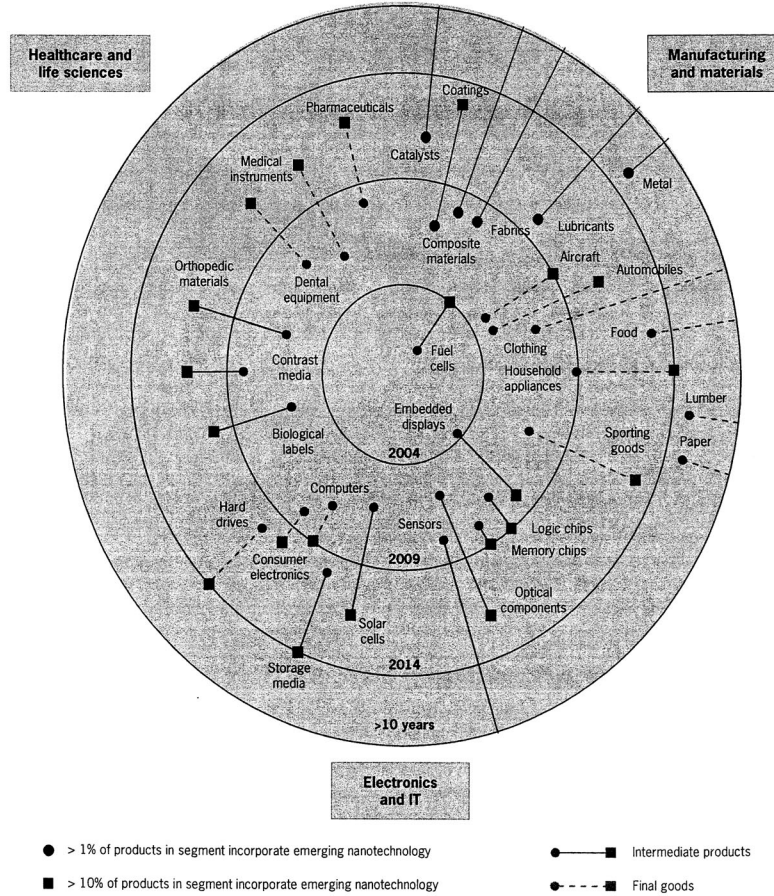
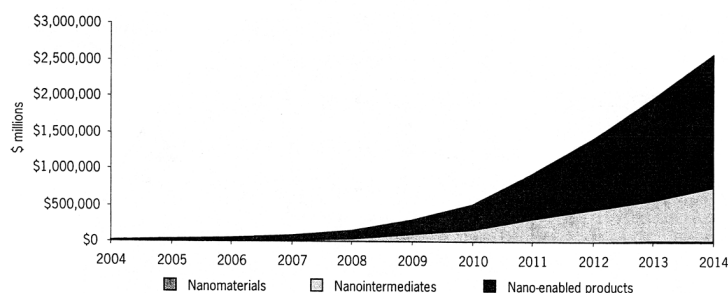


Fig. 3: Global Sales of Products Incorporating Emerging Nanotechnology, by Value Chain Stage, 2004 to 2014



Source: October 2004 Lux Research report "Sizing Nanotechnology's Value Chain"

- A culture of entrepreneurship that thrives on constructive failure. In the U.S., leaving a comfortable corporate job to launch a start-up company is widely considered a positive career move. In other first-world countries, it may either be viewed as foolish or be nearly impossible to accomplish. Hotbeds like Massachusetts's Route 128, California's Silicon Valley, and Texas's greater Austin area team with the combination of innovative thinkers, technical talent, and experienced management needed to forge a successful start-up. It's no surprise that, of approximately 1,200 nanotech start-ups active in 2004, half were located in the U.S.¹⁰
- World-leading availability of risk capital. Although corporations do an effective job of incubating incremental nanotechnology applications that complement their existing products, disruptive nanotechnology applications overwhelmingly arise from start-up companies such as Aspen Aerogels, Nanospectra Biosciences, and Nantero. Venture capital is the lifeblood of these small firms, and the U.S. claims 56% of venture capital deployed in start-ups globally.¹¹

The Dominant U.S. Position in Nanotechnology Lies at Risk

Despite the U.S.'s strong position in nanotechnology, other countries—from the usual suspects like Japan and South Korea to surprises like Australia and Israel—challenge its dominance. Witness:

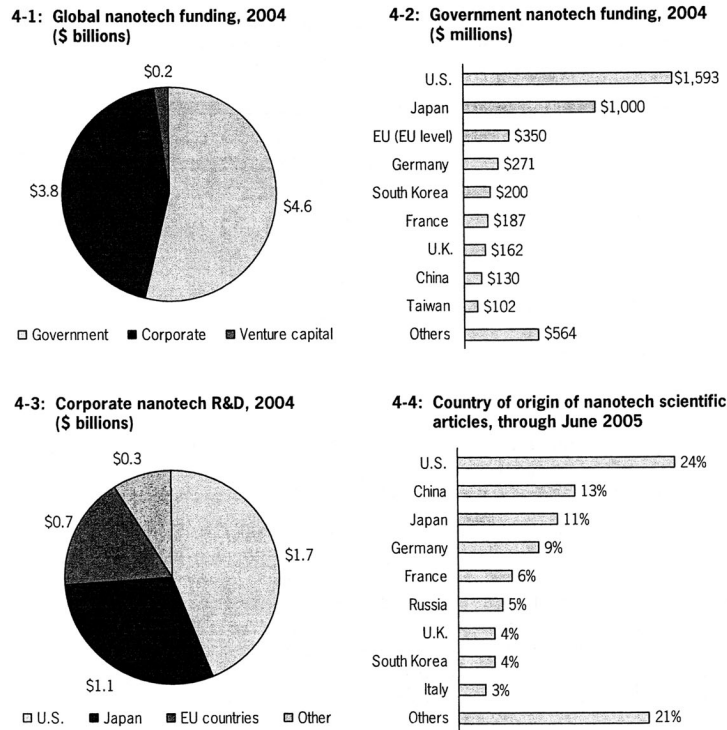
- **U.S. loss of spending leadership on a relative basis.** Although the U.S. puts more government funding to work on nanotech research than any other country on an *absolute* basis, it has already fallen behind Asian competitors on a *relative* basis. This trend becomes even more apparent when spending levels are corrected for purchasing-power parity, reflecting the difference in what a dollar buys from one country to the next. On this basis, the U.S. invested \$5.42 per capita in government spending on nanotechnology last year, exceeded by South Korea at \$5.62, Japan at \$6.30, and Taiwan at \$9.40—nearly twice the level of the U.S. (see Figure 5-1).¹²

¹⁰ Source: 2004 Lux Research reference study, "The Nanotech Report 2004."

¹¹ Source: Lux Research analysis based on Thomson Venture Economics and IMD World Competitiveness Yearbook 2004.

¹² Source: Published spending allocations and Lux Research analysis.

Fig. 4: The U.S. Leads the World in Nanotechnology Today



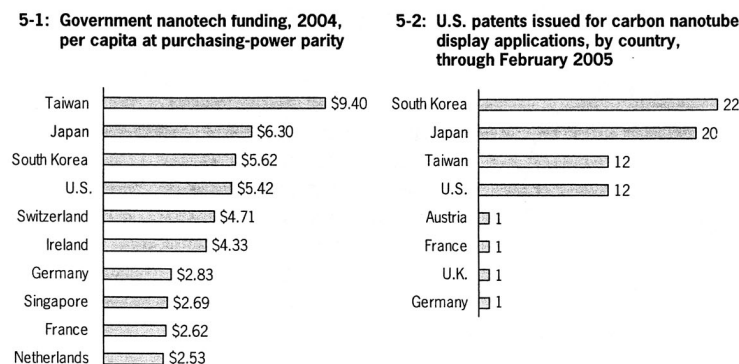
Source: 2004 Lux Research reference study "The Nanotech Report 2004," Science Citation Index search (see endnote 6)

- Industrial policy abroad aimed at dominating specific product segments.** U.S. industrial policy eschews direct government/industry collaboration for leadership in specific applications. In Europe and Asia, many governments pursue the strategies that the U.S. avoids, giving foreign competitors a leg up on their U.S. rivals. For example, of the \$640 million allocated to Taiwan's Nanoscience and Nanotechnology Initiative over five years, 60 percent is earmarked for "strategic industry applications" developed collaboratively between government institutions and industrial champions.¹³ Two of Taiwan's top nanotechnology applications are magnetoresistive RAM, which U.S. companies Freescale Semiconductor, IBM, and NVE have been developing for more than a decade, and carbon nanotube field emission displays, which U.S.-based electronics giant Motorola, small-cap company Nano-Proprietary, and start-up cDream are working on.¹⁴

¹³ Source: "The Strategy and Experiences to Industrializing Nanotechnology in Taiwan," presentation delivered at SEMI NanoForum 2004, November 15, 2004, by Tsung-Tsan Su, Ph.D., General Director, Nanotechnology Research Center, Industrial Technology Research Institute, Taiwan.

¹⁴ Such initiatives do not exist only in Asia. In Europe, the NanoCMOS project aims to reach the 45-nm semiconductor process node in 2005, well ahead of the International Technology Roadmap for Semiconductors targets. It received 24 million in initial funding from the European Commission and is being executed by a consortium anchored by semiconductor heavyweights Infineon (Germany), Philips (the Netherlands), and STMicroelectronics (France).

Fig. 5: The Dominant U.S. Position in Nanotechnology Lies at Risk

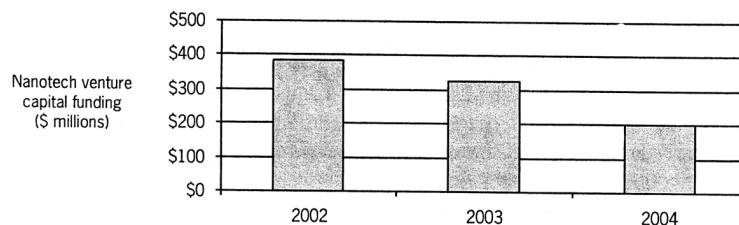


Source: Published spending allocations and Lux Research analysis; U.S. Patent and Trademark Office searches

- Leadership of high-volume, near-term applications on foreign shores.** In many specific, promising application domains, researchers in other countries have begun to outpace the U.S. in developing intellectual property—even when measured by patents issued within the U.S. patent system. Consider carbon nanotubes in displays, where the wonder materials have been proposed for a new type of large, flat-panel monitor that could outperform LCD and plasma at lower cost and energy consumption. Of 70 patents for carbon nanotube display applications issued by the U.S. Patent and Trademark Office through February 2005, only 17 percent were issued to entities based in the U.S. compared with 29 percent in Japan and 31 percent in South Korea (see Figure 5–2).
- Innovative efforts in unexpected places.** Scientists in countries with a less rich history of science and technology innovation are not lagging when it comes to nanotech. On the contrary, they are studying U.S. scientific publications, being educated in U.S. universities, and orienting their initial capital investments toward the instrumentation needed for nanotechnology research, without having to maintain technology infrastructures and skill sets that were cutting-edge 20 years ago. The result: impressive efforts in countries not known for scientific leadership. The \$130 million in estimated government spending on nanotech last year in China equaled \$611 million at purchasing-power parity, or 38 percent of U.S. expenditure; in addition, China recently launched a world-leading effort to set standards for nanomaterials.¹⁵ Further, some countries that the U.S. considers to represent strategic threats have thriving nanotech programs; the Iranian NanoTechnology Initiative was ordered by none other than President Mohammed Khatami.¹⁶

¹⁵Source: Lux Research analysis.

¹⁶Source: “Revolutionary Nanotechnology,” *Hamshahri* (Iranian daily newspaper), No. 3651, page 10, March 3, 2005. Accessed via [http://www.netiran.com/?fn=artd\(3434\)](http://www.netiran.com/?fn=artd(3434)).

Fig. 6: Venture Capital Funding Invested in Nanotech Start-Ups, 2002 to 2004

Source: 2004 Lux Research reference study "The Nanotech Report 2004"

- Lack of concern with violating intellectual property (IP) protection.** Companies exploiting nanotechnology depend on international property protection to defend their freedom to operate. Yet in many foreign countries, lax enforcement of intellectual property means that rivals appear to ignore patents in practice. In the crowded field of metal oxide nanoparticles, with applications in everything from sunscreens to rocket fuels, 74 companies compete globally, eight of which are in China. The U.S.- and European-based companies—like NanoGram, Nanophase, and Nanotechnologies Inc.,—depend on proprietary, patented production processes for their differentiation and financial valuations. But the Chinese manufacturers stress their ability to deliver identical products at prices 15 percent to 20 percent cheaper—and generally refuse to name their production processes, raising suspicion that they are using Westerners' patent filings like recipe books. With lax Chinese IP enforcement and no way to infer a manufacturing process from the nanoparticles that result, U.S. nanoparticle firms have limited means to compete.

Entrepreneurs Face Steep Hurdles on the Path from University Lab to Successful Start-Up

For the U.S. to remain highly competitive, it must help start-ups overcome:

- Funding gaps.** The widespread perception that nanotechnology start-ups have more venture capital than they can reasonably deploy is dead wrong. In fact, venture funding for nanotechnology start-ups declined from \$385 million in 2002 to \$200 million in 2004, and accounted for only two percent of nanotechnology R&D funding that year; cautious VCs burned by the Internet bubble hesitate to commit more cash until they see substantial exits (see Figure 6).¹⁷ To encourage entrepreneurs to bring nanotech innovations out of university laboratories and into the commercial arena, government funding through vehicles like Small Business Innovation Research (SBIR) grants and the National Institute of Science and Technology's Advanced Technology Program (ATP) is an absolute necessity.
- Human resource gaps.** The U.S. is not generating enough Science and Engineering Master's degree and Ph.D. holders to maintain leadership in nanotechnology. Tighter controls on student visas since the September 11 attacks have reduced the inflow of Ph.D. students to the United States in favor of Western Europe, and as economies in China, India, and South Korea develop, foreign scientists are less likely to remain in the U.S. for their careers than they were a decade ago. Nobel Laureate Richard Smalley from Rice University has noted that at current rates, by 2010, 90 percent of all physical scientists will be Asian and 50 percent of them will be practicing in Asia.
- Manufacturability gaps.** Nanotechnology start-ups must cross a much ballyhooed "valley of death" to obtain the risk capital funding required to move the business forward. Yet they also must cross another, related, valley between small-scale benchtop production volumes and the pilot-scale production required to win commercial contracts. Our contacts with nanotechnology

¹⁷Source: 2004 Lux Research reference study, "The Nanotech Report 2004."

researchers indicate that the Nanoscale Science Research Centers scattered throughout the U.S. assist with basic research only (not scale-up), are ill-used, and do not help bridge this gap. As a result, many start-ups spend redundant millions to build the same manufacturing pilot plants that they end up using perhaps 10 percent of the time; dedicated, shared manufacturing facilities devoted to technology incubation would help bridge this gap more cost-effectively.

The U.S. Government Must Take Concerted Action to Maintain Leadership

We recommend that the U.S. Government:

- **Grow federal funding for nanotechnology research.** To maintain leadership, the U.S. National Nanotechnology Initiative (NNI) must be funded at or beyond current budget request levels. It should not be assumed that U.S. states will pick up any slack should federal spending ebb: Although U.S. states spent \$432 million last year, complementing approximately \$1.15 billion at the federal level, most of this money went to initial purchases of equipment and construction of facilities, not to funding ongoing research activity by Ph.D. and postdoctoral students. This state spending essentially represents one-time capital expenditure unlikely to be sustained.
- **Eliminate uncertainty surrounding environmental, health, and safety (EHS) issues.** Nanoparticles present new EHS issues; not enough fundamental toxicity research has been done on nanoparticles to decisively determine what hazards they may pose to workers, the public, and the environment—or how such hazards may be mitigated. We believe fundamental research on nanoparticle toxicity can realistically be performed only under a government aegis; to perform it, the U.S. Government must at least double the small sums currently allocated at the federal level for nanotech EHS research, which totaled only 3.7 percent of the 2006 NNI request (see Figure 7).¹⁸

Beyond fundamental research, agencies like the Environmental Protection Agency have not yet established firm guidelines for how new nanoparticles will be treated under existing, or potentially new, regulatory schemes. While this unwillingness to rush to judgment before all the facts are in is well intentioned, it has perverse effects: Based on our contact with individuals driving nanotech initiatives at America's largest corporations, it's clear to us that ambiguity surrounding EHS regulation of nanoparticles is hampering commercialization—firms do not want to play a game whose rules may change at any time. To move forward, the EPA, the FDA, and NIOSH must issue clear guidance to industry on how they plan to approach nanoparticles.

- **Attract U.S. students to science and engineering and retain foreign ones.** As with many science and technology fields, funding and development incentives for nanotechnology research will amount to nothing without a steady stream of advanced science and engineering degree holders entering the workforce. The U.S. should strengthen programs designed to inspire students with wonder for the physical sciences in K–12 education, reconsider the effect of visa tightening on the inflow of foreign science and technology graduate students, and develop economic incentives for foreign science and technology graduates to remain in the United States rather than repatriate, taking with them the skills they acquired in the U.S.

¹⁸Source: May 2005 Lux Research report, "A Prudent Approach to Nanotech Environmental, Health, and Safety Risks."

Fig. 7: U.S. Government Spending on Nanotech EHS Research Is Insufficient

Organization/initiative/program	Total nanotech spending (\$ millions)	Nanotech EHS spending (\$ millions)	Total budget (\$ millions)
National Nanotechnology Initiative (FY2006 projection)	\$1,100	\$38.4	\$1,100
National Science Foundation (funding awarded to date)	\$345	\$8.3	\$5,500
Environmental Protection Agency (program announced November 12, 2004)	\$4	\$4	\$7,600
National Toxicology Program (currently earmarked for nanomaterial toxicology studies)	\$0.5	\$0.5	\$183

Source: May 2005 Lux Research report "A Prudent Approach to Nanotech Environmental, Health, and Safety Risks"

- **Create financial incentives aligned with desirable applications.** We believe U.S. economic development policy is right not to fund specific solutions to broad technology problems. However, the U.S. would be well served by government programs that provide funds to nanotechnology researchers, giving them incentives to develop applications with well-defined *ends*, without specifying particular technology *means*. Such programs can be coordinated through existing agencies and require no incremental bureaucracy.

Consider NASA's \$11 million project with Rice University to develop extremely low-loss power cables based on carbon nanotubes: Such cables could enable a national power grid, shuttling electricity from locations of sustainable resources to areas of high demand without losing it on the way. The National Renewable Energy Laboratory estimates that solar cells covering a 100-by 100-mile area in Nevada could meet the U.S.'s entire energy needs, but without low-loss power cables the electricity could never reach demand hubs like Chicago and New York.¹⁹

- **Employ export controls sensibly, without choking nanotech commercialization.** Export controls for products incorporating nanotechnology have become a hot topic inside the Beltway; individuals representing multiple organizations across branches of government have independently sought Lux Research's advice on this issue. We believe that export controls for "nanotechnology" per se are a dead end. The field is too broad; such action would be like trying to impose export controls on assembly-line manufacturing techniques and the equipment used to implement them—impossible to carry out rationally. Instead, we believe the U.S. should identify relevant nanotechnology *applications* (e.g., radiation-hardened solar cells, high-frequency beam-steerable antennas, nanoparticulate propellants and explosives) and impose sensible export controls on them within existing frameworks rather than introducing new ones.

BIOGRAPHY FOR MATTHEW M. NORDAN

Matthew Nordan heads Lux's research organization. Under Matthew's leadership, the Lux Research analyst team has become a globally recognized authority on the business and economic impact of nanotechnology. Lux Research serves as an indispensable advisor to corporations, start-ups, financial institutions, and governments seeking to exploit nanotechnology for competitive advantage.

Matthew has counseled decision-makers on emerging technologies for a decade. Prior to Lux Research, Matthew held a variety of senior management positions at emerging technology advisor Forrester Research, where he most recently headed the firm's North American consulting line of business. Earlier, Matthew lived for four years in the Netherlands growing Forrester's operations in Europe, where he launched and led research practices in retail, mobile commerce, and telecommunications.

Matthew has been invited by news outlets including CNN and CNBC to comment on emerging technology markets and has been widely cited in publications such as

¹⁹Source: John A. Turner, "A Realizable Renewable Energy Future," *Science*, Vol. 285, Issue 5428, pp. 687–689, July 30, 1999.

The Wall Street Journal and *The Economist*. He has delivered advice to clients and been an invited speaker at conferences in North America, Europe, Southeast Asia, Japan, Australia, and South Africa. Beyond the corporate sphere, Matthew has participated in developing public-sector technology strategy for organizations including the World Economic Forum, the European IT Observatory, and the Dutch transportation ministry.

Matthew is a summa cum laude graduate of Yale University, where he conducted cognitive neuroscience research on the neural pathways mediating emotion and memory.

June 24, 2005

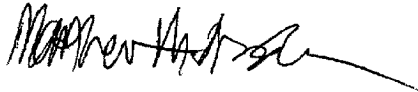
The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on June 29th for the hearing entitled "*Nanotechnology: Where Does the U.S. Stand?*" In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding I currently receive related to the hearing topic.

I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two preceding fiscal years.

Sincerely,



Matthew M. Nordan
Vice President of Research
Lux Research, Inc.

Chairman INGLIS. Thank you, Mr. Nordan. Mr. Murdock.

**STATEMENT OF SEAN MURDOCK, EXECUTIVE DIRECTOR,
NANOBUSINESS ALLIANCE**

Mr. MURDOCK. We are all going to make that mistake. Good morning. I would like to thank you, Mr. Chairman, Ranking Member Hooley, and the Members of the Research Subcommittee of the Committee on Science for the opportunity to testify on this critically strategic question.

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the premier nanotechnology policy and commercialization advocacy group in the United States. Our members span multiple stakeholder groups, from startups surviving on angel funding and SBIR fund-

ing, to Fortune 500 companies with multimillion dollar commitments to nanotechnology R&D, to academic research institutions and public-private partnerships working to derive economic development, benefit, and growth through nanotechnology. This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of business success, economic growth, and quality-of-life improvements in the 21st Century. The Alliance provides a collective voice and vehicle for efforts to advance the benefits of nanotechnology across our economy and our society.

With that perspective in mind, I would like to share with you my thoughts on the United States' competitive position in the commercialization of nanotechnology. To briefly synthesize, the U.S. is leading the world today, but our lead is far from secure. We face stiff and accelerating competition and we need to take action to ensure leadership.

Nanotechnology will have tremendous impact on virtually every sector of our economy. Near-term applications include scratch resistant coatings, stain resistant textiles, high performance tennis rackets and golf clubs, computer memory and storage, flat panel displays, drug delivery systems, chemical and biological sensors, and dramatically more sensitive and selective diagnostics to name a few applications. Given this breadth, it is clear that nanotechnology will be the engine of innovation for the next 50 years, and we must be at the forefront of this revolution.

Furthermore, nanotechnology's implication for homeland security, defense, cleaning the environment and developing renewable, sustainable sources of energy make its development strategic as well as economic for the United States. For these reasons, we as a nation and as the last superpower cannot afford to hold anything less than a commanding position of leadership in the commercialization of nanotechnology.

While the knowledge development that we refer to in nanoscience R&D create value for the U.S. and society as a whole, it is through the commercialization of nanotechnology into new processes and products that businesses will create jobs, and that this nation will see a return on its investment. On this dimension, the United States is performing quite well. According to our database, of all companies involved with nanotechnology, a little over 50 percent are in the United States.

That is the good. The bad news is while we lead in the number of nanotech startups, the so-called valley of death, the period between a company's formation and its achieving significant cash flow, is particularly acute for nanotechnology, and is constraining the growth of the sector. Most nanotechnology innovations require significant investment and platform development before any revenues can be generated because they are based upon fundamental scientific breakthroughs and basic research at universities and federal labs.

Burned by the dot-com bubble, and needing to raise internal rates of return in order to raise the next fund, venture capitalists have been shying away from investments in these kind of platform technologies that have longer-term commercialization processes and unclear market economics. According to data from *Small*

Times Media, we continue to generate about 30 to 40 venture backed startups a year, and I am sure that there are many, many others that are being formed that fall beneath the radar screen because they lack the capital to get noticed. However, the growth of this group has been stagnant over the past several years, as venture capital funding for nanotech has remained relatively flat at about an average of a little more than \$200 million. To put that in perspective, the investment over the past seven years by VCs has been about the equivalent of the investment of the Federal Government in 2004.

Leading Fortune 500 companies also have nanotechnology initiatives and funding for R&D, but many have scaled back their early stage research and development in response to stock market pressures for near-term profitability and the reduction of cost. The commitment to early stage R&D at GE, IBM and the likes of Motorola is the exception and not the rule. Many companies plan to innovate through acquisition. Relying upon startups to develop and commercialize innovations further expands the valley of death since companies are looking for startups to have developed their technologies far enough to ease integration. It also means that more than ever, startups represent the product pipeline for large corporations and their successful formation is key not only to creating new prosperity, but continuing our existing prosperity.

Until the VC cycle changes again, and stock markets allow companies to adopt longer horizons, we have a substantial and growing valley of death. Since the market is not prepared to take on this risk, the government needs to help bridge this gulf. Specifically, the government must fully and effectively use the SBIR and other programs at its disposal to enhance commercialization activity.

Many member companies speak of the myth of SBIR Phase III grants. The Phase I innovations proved out in Phase II are supposed to be brought into use in the sponsoring agency. While SBIR grants in and of themselves are quite valuable for those attempting to commercialize nanotech innovations, purchases to meet agency needs would generate a sustainable source of revenues, provide customer validation, and accelerate the learning curve through production. Furthermore, this would ensure that our agencies, particularly defense and homeland security, would remain ahead of the world in terms of nanotech integration capability.

We need to create new nanotech innovation ecosystems to form particularly between U.S. startups and incumbents. If we are to retain our jobs in existing companies and industries, then we will need to integrate the innovations of nanotech startups into these sectors rapidly. Without incentives to form domestic partnerships, the value from our nation's investment may be disproportionately captured by foreign companies with patient capital who partner with cash-strapped U.S. startups.

However much the government can do directly, in the end the greatest leverage will be achieved by creating greater incentives for the private sector to invest and aggressively participate in the commercialization process. To that end, we should investigate establishing a permanent R&D tax credit, and potentially creating new vehicles, like the R&D limited partnerships, that were instrumental in the formation of commercialization capital for biotech.

These will unlock not only more of the potential of nanotech, but all technology-driven industries.

Thank you, Mr. Chairman. I would be happy to answer any questions you may have.

[The prepared statement of Mr. Murdock follows:]

PREPARED STATEMENT OF SEAN MURDOCK

I would like to thank you, Mr. Chairman, Ranking Member Hooley, and Members of the House Research Subcommittee of the Committee on Science for the opportunity to testify on this critically strategic question.

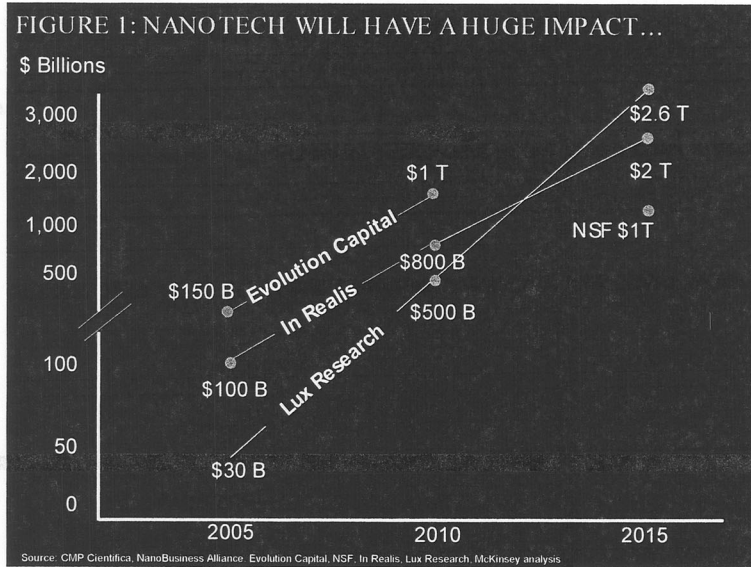
My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the premier nanotechnology policy and commercialization advocacy group in the United States. NanoBusiness Alliance members span multiple stakeholder groups and traditional industrial sectors, including newly formed start-ups surviving on angel funding or SBIR grants, Fortune 500 companies with multi-million dollar commitments to nanotechnology R&D, academic research institutions, and public-private partnerships working to derive economic development and growth through nanotechnology. This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of business success, economic growth and quality-of-life improvements in the 21st century. The Alliance provides a collective voice and a vehicle for efforts to advance the benefits of nanotechnology across our economy and society.

With that perspective in mind, I would like to share with you my thoughts on the United States' competitive position in both the research and commercialization of nanotechnology. The U.S. is leading the world in nanoscience today, but our lead is narrow and we face stiff and accelerating competition. Action, both in terms of spending and policy, is required at the federal, State, and local levels to assure that we maintain this lead.

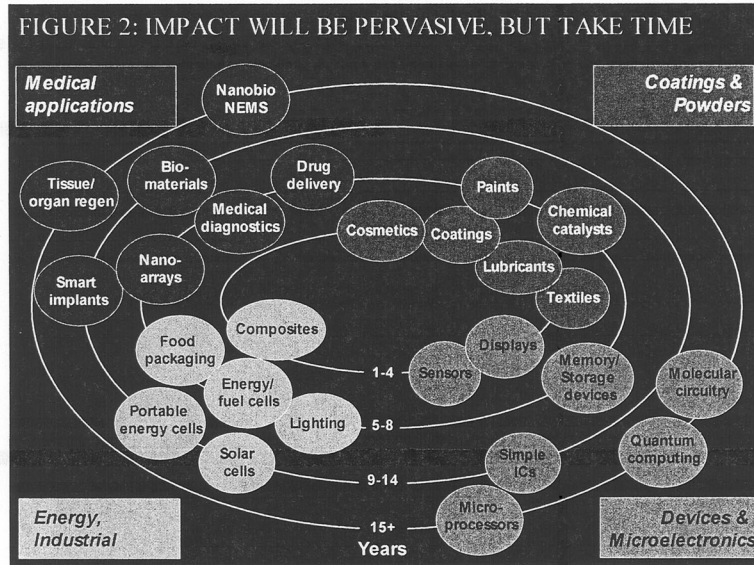
Since this subcommittee has relatively strong familiarity with nanotechnology and the *21st Century Nanotechnology Research & Development Act*, I only need to give some highlights of the potential of nanotechnology and why it is so important. It is my belief and the belief of every member of the Alliance that nanotechnology will have a tremendous impact on virtually every sector of the global economy, a belief that is reflected in the diversity of our membership. In some industries, such as data storage, companies without a nanotechnology strategy already cannot compete. This will become pervasive in all industry sectors that produce goods rather than services. Furthermore, I believe that nanotechnology is not just a tremendous economic driver, but that its implications for homeland security, defense, cleaning the environment, and developing renewable, sustainable energy sources should make its development a key strategic as well as economic goal for the U.S. For these reasons, we as a nation and as the last superpower cannot afford to hold anything less than a commanding leadership position in the commercialization of nanotechnology.

Investing in nanotechnology could also bring other benefits, beyond the creation of jobs, bolstering of the economy, and strategic leadership. Investing in commercialization allows us to reinvest in nanoscience education, research, and development, forging a virtuous circle that will ensure our children enjoy the same improvement in quality of life that we have. Nanotechnology's potential to provide solutions to the grand challenges of today could provide a rallying point and inspire interest comparable to the race to overtake Sputnik in the 50's and 60's, still one of the greatest periods of innovation in American history.

The stakes are incredibly high. The NSF has estimated that the global impact of nanotechnology enabled products and services will be \$1 trillion by 2015. Many considered this estimate to be quite lofty when it was made in 2000 with the launch of the National Nanotechnology Initiative. However, more recent estimates for the global impact of nanotechnology enabled goods are even larger than the NSF's. In Realis, a consulting group, has predicted that nanotech will impact up to \$2 trillion of global economic output, while Evolution Capital, an investment bank, estimates that the market will reach \$1 trillion five years earlier in 2010. Finally, in perhaps the most rigorous study to date, Lux Research, a nanotechnology analyst group, has estimated that nanotech will impact \$2.6 trillion in global economic output by 2015 (see Figure 1).



While these estimates are mind-numbingly large, a brief mention of some prospective applications and estimated time to market helps to make them more tangible and more credible. Simple and passive applications of nanotechnology including nanoparticles, coatings, catalysts, and nanocomposites are already on the market, while more revolutionary applications, including the first generation of nanotechnology-enabled pharmaceuticals, bulk nanomaterials, sensors, and many more are beyond the research stage and well into the product pipeline. In addition to developing revolutionary products, nanotechnology will radically change the cost-structures of many industries, making non-nano alternatives simply non-competitive (see Figure 2).



On the strategic side, nanotechnology will enable dramatic enhancements in military and homeland security capabilities. Start-ups are working on new protective armor, chem/bio suits, and chem/bio sensors, as well as a variety of technologies such as quantum computing and encryption which have enormous dual-use applications.

Given the potential of nanotechnology and the evidence of traction toward realizing that potential, it is increasingly clear that nanotechnology will be a game changing technology. Economists estimate that technology innovation in the U.S. (transistors, integrated circuits, recombinant DNA, etc.) generated half of the economic growth over the past fifty years. Nanotechnology is likely to be the engine of innovation for the next fifty years, and we must be at the forefront of this innovation.

That is the importance of nanotechnology as a national goal, but it does not answer the question of where the country currently stands with respect to other nanotechnology leaders such as China, Japan, and the E.U., the other global leaders in nanotech. Fortunately, at the current time, the U.S. is clearly in a leadership position, evidenced by its strength in investment, scientific publications, and patents. This should not be taken for granted—key innovations have been developed in the E.U. (such as the electron microscope, the instrument that helped enable all nanotech research) and Japan (such as the discovery of the nanotube, the most versatile and powerful nanomaterial yet developed).

FIGURE 3: THE U.S. CURRENTLY LEADS THE WORLD IN GOVERNMENT R&D INVESTMENT, WITH A LITTLE OVER 25% OF THE TOTAL

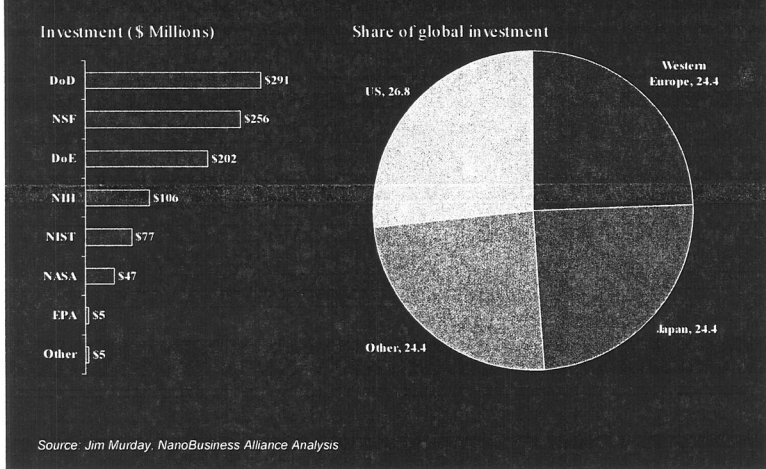
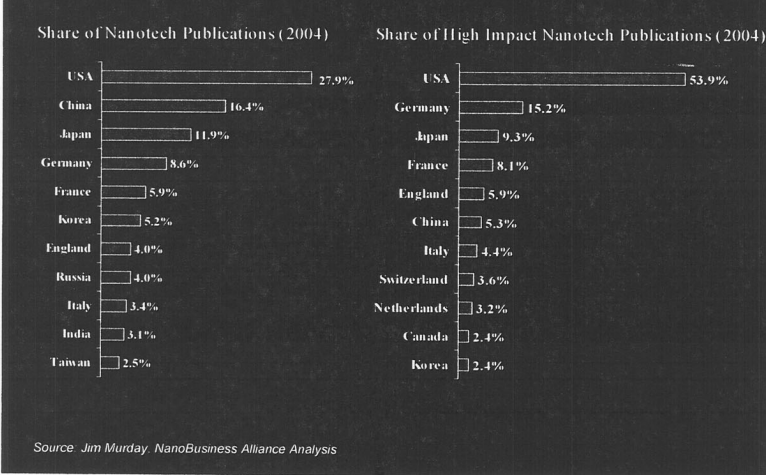
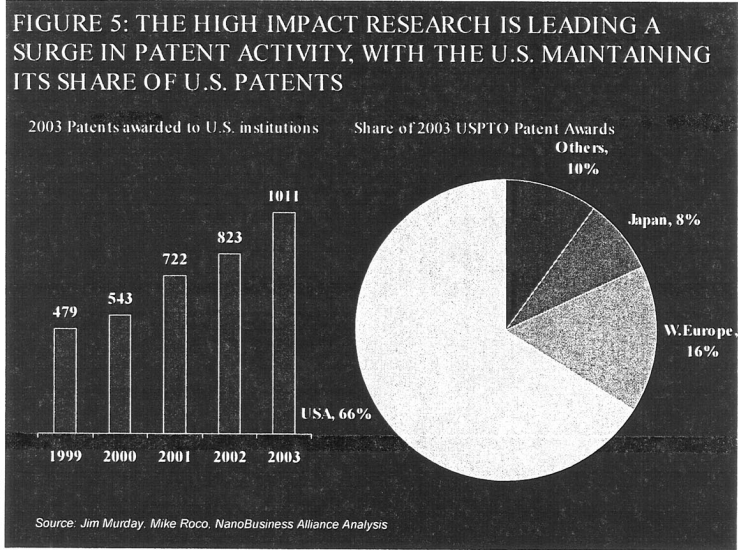
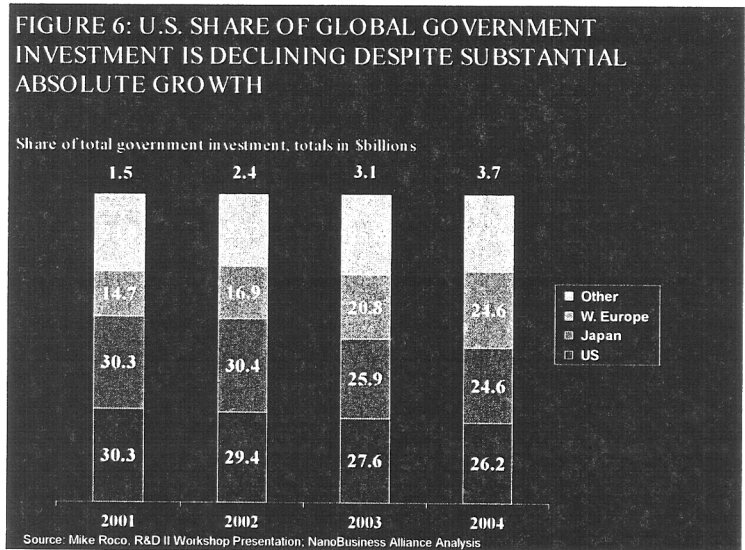


FIGURE 4: THE U.S. PUBLISHES MORE THAN ANY OTHER COUNTRY AND HAS A DISPROPORTIONATE SHARE OF HIGH IMPACT PAPERS

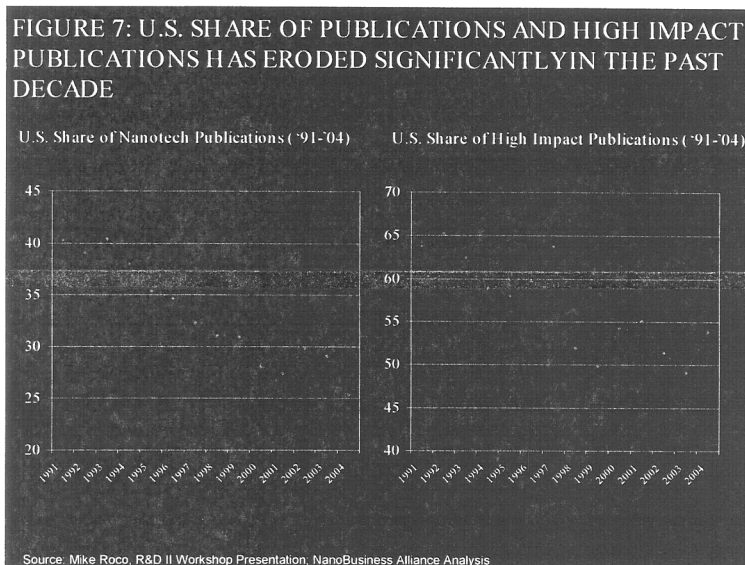




Ironically, the challenges to U.S. domination of nanotechnology are in part a result of our early support of nanotechnology. The formal launch of the NNI in 2000 brought the potential of nanotechnology into the world consciousness and initiated a race for global leadership. As a result, the U.S. share of global government expenditures has dropped since 2001, despite the absolute commitment more than doubling in the same time period from \$465MM to \$960MM (see Figure 6).



Not surprisingly, the growth in foreign investment in nanotechnology R&D has helped other nations to gain ground in the development of new knowledge, innovations and the production of human capital (see Figure 7).

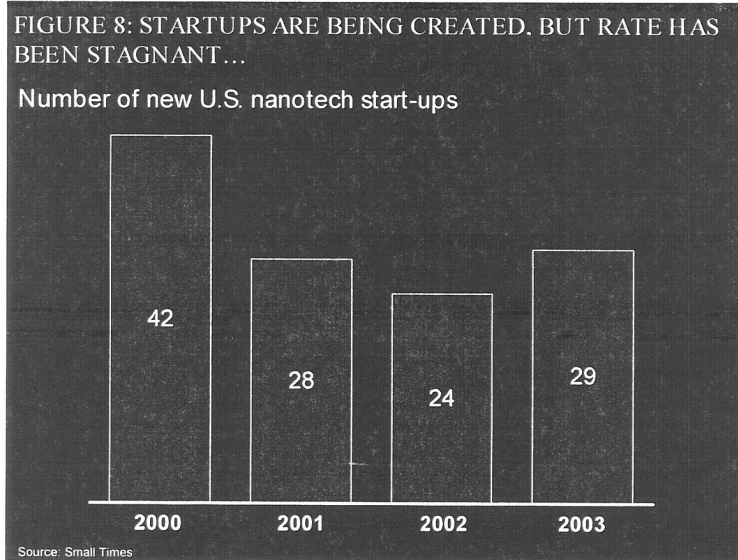


Of particular competitive concern is China. *The Scientist*, an American academic journal, said that from January to August 2004 China had presented 3,621 research papers on nanotechnology, more than any other country, as tabulated by the Scientific Citation Index. According to the article, China published 14 percent more papers than the United States in that time period. Furthermore, China currently has more than 3,000 researchers who are engaged in related programs and has had series of innovative achievements according to the Director of China's National Center for Nanoscience and Technology and the Vice President of the Chinese Academy of Sciences.

While knowledge development and nanoscience R&D create value, it is through the commercialization of nanotechnology into new processes and products that businesses will create jobs and nations will see a return on their investments.

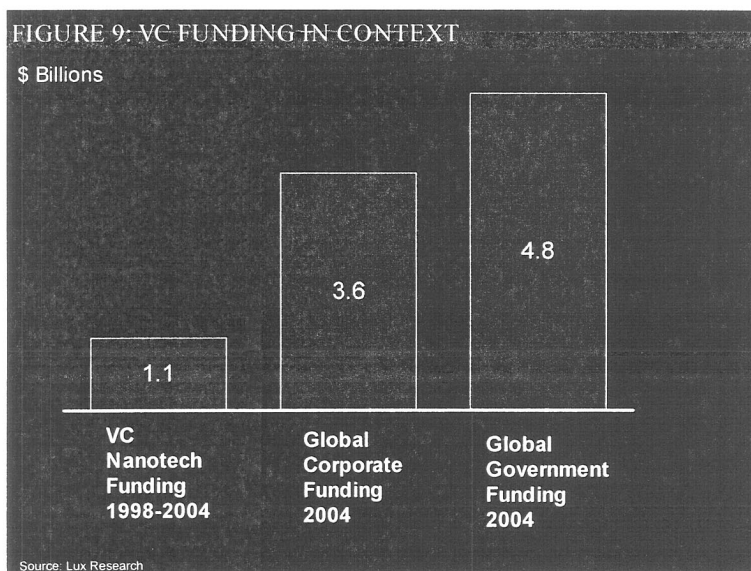
According to the NanoBusiness Alliance's proprietary database on all companies involved with nanotechnology worldwide, a little over 50 percent of the companies are in the United States (613 of 1,175). However, if one is to believe the announcements made at the ChinaNano2005 trade expo that China has almost 800 companies involved with nanotechnology and a recent EU report claiming that Europe has 500, the share would appear to be significantly lower. Unfortunately, it is notoriously difficult to track commercial developments in nanotechnology, so we cannot be precisely sure.

However, the rate of formation of new nanotech start-ups over the past several years has been relatively stagnant (see Figure 8).

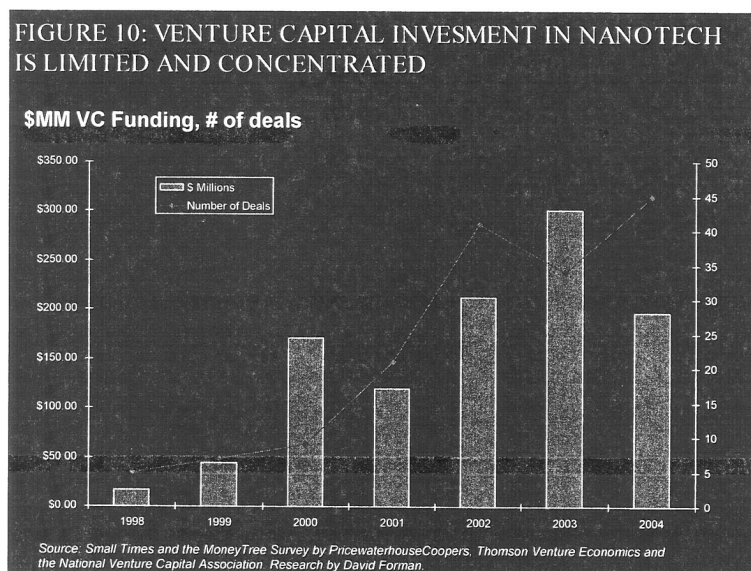


This is, perhaps, one of the most disconcerting indicators for nanotechnology in the U.S. The entrepreneurial culture and deployment of risk capital, especially venture capital, toward early stage technology companies has been a key source of competitive advantage for the United States. This historic advantage appears to be at risk.

Although we lead in the number of nanotechnology startups, these startups need risk capital to bring these nanotechnology innovations to market. The so called “valley of death,” the period between a company’s formation and its achieving significant cash flow, is particularly acute for nanotechnology. Most nanotech innovations require significant investment and “platform” development before any revenues can be generated because they are based upon fundamental breakthroughs in basic research at universities and federal labs. Burned by the dot com bubble and needing to raise IRR’s in order to raise the next fund, VC’s have been shying away from “platform” technologies without near-term commercialization processes and end market economics. In fact, the total VC financing over the past seven years is approximately the same as the U.S. Government investment in 2004 (see Figure 9).



Furthermore, the investment to date has been highly concentrated in a few, mature nanotech companies.



Highlighting this trend, almost all of the venture capital that went to nanotech companies in the first quarter of 2005 was placed into four companies, NanoTex (\$33MM), Nanomix (\$17MM), Nantero (\$17MM), and NanoOpto (\$12MM).

While leading Fortune 500 companies have nanotechnology initiatives and some funding for R&D, most have scaled back their early stage research and development in response to stock market pressure for near-term profitability and reducing costs. Many companies plan to “innovate through acquisition,” relying upon start-ups to develop and commercialize innovations. This further expands the “valley of death” since companies are looking for startups to have developed their technologies far enough for ease of integration. It also means that more than ever start-ups represent the product pipeline for large corporations, and that their successful formation is key not only to creating new prosperity, but continuing our existing prosperity.

Until the VC cycle changes again and the stock markets allow companies to adopt longer time horizons, we have a substantial and growing “valley of death.” Since the market is not prepared to take on this risk, the government needs to develop programs to bridge this gulf.

Given the current landscape, there are a few key initiatives that the Federal Government can take to revitalize nanotechnology commercialization here and bolster our global lead.

The federal investment in infrastructure and user facilities is part of the solution. These facilities, in theory, provide access to critical and expensive equipment, and reduce the capital intensity of nanotech commercialization activity. However, many nanotech start-ups lack the process knowledge and internal capabilities to make effective use of these investments. The government must also ensure sufficient operating funds to provide services and train the start-ups, or the assets will be underutilized and the investment will not generate the return we expect.

The U.S. Government must be the “gold standard” as the most hospitable climate for commercializing nanotech innovations. We must lead in the development of new nanotech knowledge and research infrastructure. As such, our share of worldwide government investment should be at least on par with our share of global GDP.

We should establish goal-oriented research programs to address our grand challenges. While much fundamental research remains to be done, we should endeavor to do it to the extent possible within the context of its potential uses. The National Cancer Institute’s Centers for Cancer Nanotechnology Excellence (CCNEs) provide a model for this. To quote the recent solicitation, “The CCNEs will be a national resource that will integrate nanotechnology development into basic and applied cancer research to facilitate the rapid application of this science in the clinic. This initiative will catalyze targeted discovery and development efforts that offer the greatest opportunity for advances in the near- and medium-terms and will lower the barriers for those advances to be translated to the private sector for commercial development.” The NCI has established clear objectives without constraining how to get achieve them, and thus the creativity of the scientists pursuing the research. This model should be emulated and extended in other agencies and strategic investment areas.

Next, the government must fully and effectively utilize the SBIR and ATP programs to enhance commercialization activity. Many member companies speak of the “myth” of the SBIR Phase III—the phase where innovations proved out in Phase II are supposed to be brought into use in the sponsoring agency. While the SBIR grants in and of themselves are quite valuable to those attempting to commercialize nanotech innovations, purchases to meet agency needs would generate a sustainable source of revenues and provide customer validation. Furthermore, this would ensure that our agencies, particularly Defense and Homeland Security, remain ahead of the world in terms of nanotech integration capabilities.

The ATP program, although controversial, provides one of the only sources of capital (and thus incentives) for new nanotech innovation ecosystems to form, particularly between U.S. startups and incumbents. If we are to retain jobs in our existing companies and industries, then we will need to integrate the innovations of nanotech start-ups into these sectors rapidly. Without incentives to form domestic partnerships, the value from our nation’s investment may be disproportionately captured by foreign companies and governments with patient capital who partner with cash strapped U.S. startups.

However much the government can do directly, in the end, the greatest leverage will be achieved by creating stronger incentives for the private sector to invest and aggressively participate in the commercialization process. To that end, we should investigate establishing a permanent R&D tax credit and possibly create new vehicles like the R&D Limited Partnerships that were instrumental in biotech capital formation. These will unlock not only more of the potential of nanotech, but of all technology-driven industries.

In closing, all technological progress depends first and foremost upon human capital. We must adopt an integrated human capital strategy spanning multiple time

horizons. In the near-term, we must encourage the best and brightest to come to the U.S., help build out our knowledge base, and transform nanotech inventions to innovations that touch our daily lives. This will mean streamlining immigration requirements for “knowledge” and highly skilled workers so that we not only attract but retain these workers as citizens. In the medium-term, we must greatly strengthen our job training programs. In the longer-term, we must dramatically strengthen the science and technology education system, the ultimate investment in our commercial future.

BIOGRAPHY FOR SEAN MURDOCK

Prior to becoming the Executive Director of the NanoBusiness Alliance, he was the Executive Director and a founding board member of AtomWorks, an initiative formed to foster nanotechnology in Illinois and more broadly throughout the Midwest.

Sean has established himself as a leading thinker in the areas of nanotechnology commercialization and economic development. He has delivered keynote speeches on the commercialization of nanotechnology at several nanotechnology conferences, and served as Co-Chair for the Commercialization Focused NanoCommerce 2003 Conference and Trade Show. Sean has been quoted extensively on the subject in many leading publications including *Fortune*, *The Economist*, the *Chicago Tribune*, the *Chicago Sun-Times*, and *Small Times*.

Sean has been very active in nanotechnology trade and economic development issues. He helped to organize and execute the first Nanotechnology Trade Mission to Europe in conjunction with the NanoBusiness Alliance and the U.S. Department of Commerce. He has also been engaged with senior officials of the U.S. Department of Commerce’s Technology Administration on the potential impact of export control issues on nanotechnology development and commercialization.

Prior to founding AtomWorks and serving as the Executive Director of the NanoBusiness Alliance, Sean had more than seven years experience in management consulting, most recently as Engagement Manager at McKinsey & Company. Sean served a variety of Fortune 500 companies, focusing primarily upon the industrial and chemicals sectors. While there, he developed some of the firm’s early perspective on the business opportunities created by the nanotech revolution, publishing the first two internal documents on the subject.

Sean received his Master’s in Business Administration and Master’s in Engineering Management from Northwestern University. He holds a BA in Economics from the University of Notre Dame.

6/28/05

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the Committee on Science of the U.S. House of Representatives on May 12th for the hearing entitled "The Future of Computer Science Research in the U.S.." In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding I currently receive related to the hearing topic. I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two preceding fiscal years.

Sincerely,



Sean J Murdock
Executive Director
NanoBusiness Alliance

Chairman INGLIS. Thank you, Mr. Murdock. Mr. O'Connor.

STATEMENT OF JIM O'CONNOR, VICE PRESIDENT, TECHNOLOGY INCUBATION AND COMMERCIALIZATION, MOTOROLA, INC.

Mr. O'CONNOR. Chairman Inglis, Ranking Member Hooley, and Members of the Subcommittee, fellow panelists, good morning. I want to thank you for inviting me to share Motorola's thoughts on where the United States stands competitively and innovatively when it comes to the subject of nanoscience and nanotechnologies.

As the Vice President for Technology Commercialization at one of America's largest preeminent technology companies, I am honored to represent Motorola's 24,000 research scientists and engineers before this distinguished panel that time and again stands up and fights for the complex, fast moving technology world and the ever-growing high tech industry.

Today, as we consider the recent report by the President's Council of Advisors on Science and Technology on the National Nanotechnology Initiative at Five Years, I will use it to give you a snapshot of where we stand in relation to our global competitors. I also want to provide you some insights on how Motorola is trailblazing the nanotechnology frontier with breakthrough sciences and commercial applications.

While the National Nanotechnology Initiative is a relatively young concept, those of us in the research and development community know the basic science for its foundation, and have been around for many years. As the PCAST Report states, 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 lastly, to areas of national interest such as homeland security.

And because of the strong commitment from the Congress and those in the Administration who understand these societal benefits, the U.S. has surged to the forefront of nanotechnology research and development, ahead of Europe, ahead of Asia, ahead of all other competing nations around the globe.

Generally speaking, this rise to prominence has been through good old American collaboration. Thanks to public-private partnerships between Federal and State governments, business and academia, our nanotechnology position has become quite strong. For instance, Motorola today can leverage research performed in a number of our nation's esteemed universities, such as U.C. Berkeley on better nanotubes and nanowires, Harvard on fabricating nonvolatile electronic memory using nanotubes, and lastly, Stanford on two particular projects, one to use synthesis technology for biological and chemical sensors and field emission devices, and the other, to build up a portfolio of nanodots, nanotubes, and nanowires for more enhanced electronics.

And while Motorola is still a few weeks away from officially announcing it, I am proud to inform this distinguished panel that this summer, Motorola is launching the Center for Interdisciplinary Research on Nanotechnology with Arizona State University. This strong partnership between university and industry will promote nanotechnology, education, research, and commercialization. ASU will advance the state of the art in nanotechnology for communications, while Motorola will use basic and applied technologies to develop useful and innovative products and services for American consumers, better mobile devices, equipment, and high frequency applications.

But the private sector partnering with academia could not do it alone. We are grateful for federal support through grants as well as research and development tax credits. To further illustrate the high tech industry's importance to our economy in terms of research, sales, and exports, America is at the vanguard in the number of startup companies based on nanotechnology, as some of the panelists have spoken. We also lead the world in research output.

To fully understand the zeal to get a competitive edge in the global market, let us look at Asia. While some of these Far East nations may not be spending as much money as the U.S. is today, they are being very strategic by choosing to concentrate their investments in particular areas in order to make significant strides sooner in a specific sector. For example, Korea and Taiwan are investing heavily in nanoelectronics, while Singapore and China are focusing nanobiotechnology and nanomaterials respectively.

Mr. Chairman, you may be wondering why is a continued federal commitment to nanotech so important? Let me answer it this way.

Nanotechnology research holds tremendous potential for stimulating innovation, and its revolutionary applications will enable the U.S. to maintain our global leadership in industries that span many sectors. That is as long as our public policies don't ease off the pedal of momentum or slam on the brakes of critical funding or R&D tax initiatives altogether. And don't worry. The private sector will not abandon this effort either. We are in it for the long haul in a partnership atmosphere.

For instance, in addition to Motorola's efforts, IBM, Intel, DuPont, and NEC have kicked off major nanotechnology efforts. These breakthroughs make life simpler, safer, and more enjoyable. And remember, we are simply on the cusp of much, much more to come, new advances, and more challenges.

However, there are bumps in the road ahead. You have probably seen reports on the shortage of Americans skilled in science and technology. The U.S. is slipping behind our competitors, Asia in particular, in undergraduate and graduate training. At Motorola, we have found that every day we go into the marketplace searching for highly skilled workers, demand far outpaces supply, and this challenge seems to get worse as each month passes. It further illustrates another important component to the global competition in the high tech industry. We are no longer competing against Europe and Asia in developing better products, but also in trying to lure and secure basic workforce needs.

Simply put, we must have a well educated talent pool to survive. Therefore, Motorola strongly supports the PCAST Report recommendation that the NNI establish relationships with the Department of Education and Labor to develop education and training systems, to improve the Nation's technical proficiency in the STEM fields of science, technology, engineering, and math.

Life-changing dreams are becoming a reality in our nation's nanotechnology labs. We must press forward in a coordinated, collaborative fashion between Federal and State governments, businesses in the private sector and our academic institutions. We must go full speed ahead on the nanotechnology express lane, to boost our economy and our citizens' quality of life.

Thank you for listening. I will be happy to take any questions.
[The prepared statement of Mr. O'Connor follows:]

PREPARED STATEMENT OF JIM O'CONNOR

Chairman Inglis, Ranking Member Hooley, our homestate Illinois Congressmen Johnson and Lipinski, and Members of the Subcommittee, good morning. I want to thank you for inviting me to share Motorola's thoughts on where the United States stands competitively and innovatively when it comes to the subject of nanoscience and nanotechnologies.

As the Vice President for IP Incubation & Commercialization at America's largest cell phone manufacturer, I am honored to represent Motorola's 24,000 research scientists and engineers before this distinguished panel that time and again stands up and fights for the complex, fast-moving technology world and the ever-growing high-tech industry.

Today, as we consider the recent report by the President's Council of Advisors on Science and Technology (PCAST) on *The National Nanotechnology Initiative at Five Years*, I will use it to give you a snapshot of where we stand in relation to our global competitors. I also want to provide you some insights on how Motorola is trailblazing the nanotechnology frontier with breakthrough sciences and commercial applications.

While the National Nanotechnology Initiative (NNI) is a relatively young concept, those of us in the research and development community know the basic science for

its foundation has been around for years. As the PCAST Report states: 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.”*

And because of a strong commitment from the Congress and those in the Administration who understand these societal benefits, the U.S. has surged to the forefront of nanotechnology research and development—ahead of Europe, ahead of Asia, ahead of all other competing nations around the globe.

Generally speaking, this rise to prominence has been through good old American collaboration. Thanks to public-private partnerships between Federal and State governments, business and academia, our nanotechnology position has become strong. For instance, Motorola can leverage research performed in a number of our nation’s esteemed universities, such as:

- U.C. Berkeley on better Nano-Tubes and Nano-Wires;
- Harvard on fabricating nonvolatile electronic memory using Nano-Tubes; and,
- Stanford on two projects: one to use synthesis technology for biological and chemical sensors and field emission devices; the other to build up a portfolio of Nano-Dots, Nano-Tubes and Nano-Wires for more enhanced electronics.

And while Motorola is still a few weeks away from officially announcing it, I am proud to inform this distinguished panel that this summer Motorola is launching the Center for Interdisciplinary Research on Nanotechnology with Arizona State University. This strong partnership between university and industry will promote nanotechnology education, research and commercialization. ASU will advance the “state of the art” in nanotechnology for communications, while Motorola will use basic and applied technologies to develop useful and innovative products and services for American consumers—better mobile devices, equipment and high frequency applications.

But, the private-sector partnering with academia could not do it alone. We are grateful for federal support through grants as well as research and development tax credits.

The PCAST Report states: the U.S. Government this year will spend just over \$1 billion on Nano R&D. To put this in perspective, \$1 billion is roughly one-quarter of the current global investment by all nations. And when you combine federal, State and private U.S. dollars, our overall investment jumps to \$3 billion, or one-third of the estimated \$9 billion in total worldwide spending by the public and private sectors combined on Nano R&D.

To further illustrate the high-tech industry’s importance to our economy in terms of jobs, research, sales, and exports, America is at the vanguard in the number of start-up companies based on nanotechnology. We also lead the world in research output as measured by patents and publications—as you can imagine, this number-one position is very important to Motorola today and will continue to be important for our competitive growth in the future.

For example, Motorola is near commercialization on the first of its kind 5-inch color video flatscreen using Carbon Nanotube technology. This Nano Emissive Display technology, which provides much brighter and thinner flat panel displays, is now available for licensing. Motorola expects this breakthrough technique could create larger flat panel displays with superior quality, longer lifetimes and lower costs to consumers than current products in the competitive video display market.

While that’s the good news, the PCAST Report highlights there are some pressing challenges that threaten our leadership position in the global economy. Specifically, the relative lead the U.S. currently holds is in jeopardy because the rest of the world is catching up in a variety of measurements. In government funding, for example, the rate of increase in the European Union and Asia is higher than that of the U.S. This should be a wake-up call for American researchers and policy-makers alike.

For instance, the EU announced this month the adoption of a Nanosciences/Nanotechnology Action Plan for Europe for 2005-2009. Their plan proposes measures to be taken at the national and European level to strengthen research and develop useful products and services so that Europe can maintain its competitive edge in the global economy.

In the EU, much work is being leveraged through consortia efforts which promote partnering between companies and universities. And, Japan has had over 20 years of commitment to nanotechnology through funding of broad and focused national programs. Furthermore, China now has over twice as many engineers working in

nanotechnology than the U.S. does because it's been identified there, as a "government initiative."

To fully understand the zeal to get a competitive edge in the global market, let's look at Asia in general. While some of these Far East nations may not be spending as much money as the U.S. is today, they are being very strategic by choosing to concentrate their investments in particular areas in order to make significant strides sooner in a specific sector. For example, Korea and Taiwan are investing heavily in Nano-Electronics while Singapore and China are focusing on Nano-Bio-technology and Nano-Materials respectively.

Mr. Chairman, you may be wondering:

- Why is a continued federal commitment to nanotech so important?
- Why should the American taxpayer invest so much in the global race over nano R&D?
- And maybe most importantly, what are the actual benefits of nanotechnology to American consumers?

Let me answer this way: nanotechnology research holds tremendous potential for stimulating innovation. Its revolutionary applications will enable the U.S. to maintain our global leadership in industries that span all sectors. That's as long as our public policies don't ease off the pedal of momentum or slam on the brakes on critical funding or R&D tax initiatives altogether. And don't worry, the private sector will not abandon this effort either—we're in it for the long haul.

For instance, a few large multinational companies such as IBM, Intel, DuPont and NEC have kicked off major nanotechnology efforts. My company, Motorola, continues to rebuild, retool, and consolidate our nanotechnology programs. In addition, as I mentioned earlier, the number of nano start-ups in the U.S. has increased significantly due to heavy private sector venture capital investing.

However, I want to be candid. One of the biggest challenges before research scientists and engineers—those not necessarily known for their communication skills—is being able to relate to the American people what's actually going on in nanotech labs.

This morning, I'd like to give it a shot by using a very popular Motorola product—the mobile phone.

When Motorola launched the 1st cell phone, do you remember how bulky and cumbersome it used to be?

Well, thanks to cutting-edge research utilizing nanotechnology principles at Motorola labs, tomorrow your mobile phone can have better optics, better acoustics, and better displays, more efficient batteries, and overall enriched electronics in a very small form factor.

Specifically, Nano-Composites can make today's cell phones structurally stronger, but physically smaller and lighter. Nano-Displays are larger, brighter and cost less due to embedded carbon nanotubes, and Nano-Power can give this light-weight phone higher capacity power sources for storage and conversion.

Let me be as clear as possible: if the Internet improved our quality of life via the Information Superhighway, then nanotechnology should be considered the Express Lane for future technological breakthroughs to make our lives simpler, safer, smarter and more enjoyable. And please remember, we are simply on the cusp of much, much more to come—new advances and more challenges.

For instance, understanding the societal implications of nanotechnology—including ethical, economic, and legal issues—will still need to be confronted and addressed in the future, and the NNI must work harder and more consistently to better educate our fellow citizens about the wonders of nanotechnology.

And talking about education, there have been many recent reports on the shortage of American workers skilled in science and technology. The U.S. is slipping behind our competitors—Asia in particular—in undergraduate and graduate training.

At Motorola, we have found that everyday we go into the marketplace searching for highly skilled workers, demand far outpaces supply, and this challenge seems to get worse as each month passes. It further illustrates another important component to the global competition we're witnessing in the high-tech industry. No longer is this just about a company's business demand to develop better products against Europe and Asia, but about American companies increasingly under pressure to compete against our rivals when trying to secure our basic workforce needs. Simply put, we must have a well-educated talent pool to survive.

Therefore, Motorola supports the PCAST Report's recommendation that the NNI establish relationships with the Departments of Education and Labor to develop education and training systems to improve the Nation's technical proficiency in

areas related to science, technology, engineering and math—better known as the STEM fields.

In addition, immigration policies have to be set to allow, at least in the near-term, U.S. trained graduates from foreign countries to stay and work here and in the longer-term, a steady influx of new foreign students to come to the U.S. for their education.

On top of much-needed talent to work inside our labs, Motorola also believes there's a need for external funds to boost the physical infrastructure to foster and maintain long-term research. I'd suggest this be a combination of direct funding and R&D tax credits to the nanotechnology labs.

As far as innovation and patenting are concerned, Motorola believes corporate investment in nanotech is very product focused. The scope of research must be longer-term. In fact, long-term funding could actually enhance the speed and number of patents that are awarded and help ensure that America retains its global leadership position.

And our competitive edge isn't just about what the Federal or State government should be doing. We, as an industry, must look inside our own operations and see how we can do better. For instance, Motorola needs to take further steps to communicate with and establish links to further facilitate technology transfer from the lab to the marketplace.

As I close, the commercialization of nanotechnology does not necessarily depend upon the creation of new products—such as stain-resistant, wrinkle-free pants, or even new, emerging markets—like those more superior flat-panel displays using Carbon Nanotubes being developed by Motorola researchers as we speak.

Gains can come from incorporating nanotechnology into existing products, resulting in new and improved versions of these products. Just imagine: faster computers, lighter materials for aircraft, less invasive ways to treat cancer, and more efficient ways to store and transport electricity.

Life-changing dreams are becoming reality in our nation's nanotechnology labs. We must press forward in a coordinated, collaborative fashion between Federal and State governments, businesses in the private sector, and our academic institutions. Simply put, we must go full speed ahead on the Nanotechnology Express Lane to boost our economy and our citizens' quality of life.

Thank you for listening. I will be happy to take any questions.

BIOGRAPHY FOR JIM O'CONNOR

Jim O'Connor is Vice President of Technology Incubation and Commercialization at Motorola. In this role, Jim's operational responsibilities include working closely with a global team of 4,600 technologists, prioritizing technology programs, creating value from intellectual property, guiding creative research from innovation through early-stage commercialization, and influencing standards and roadmaps. Previous to this role, Jim was Managing Director and co-founder of Motorola Ventures, the corporate venture capital investment arm of Motorola, Inc. This role included active review of investments and management of the global minority equity opportunities strategic to Motorola's core and emerging businesses. During this time, Jim oversaw the creation of investment operations in Silicon Valley, Europe, Israel and China. He led Motorola's investment into 4th Pass, Mesh Networks, Foundstone, Xtreme Spectrum and Bitfone.

He co-founded Motorola Ventures in September 1999 following a year of service in the U.S. Government as a White House Fellow appointed by President William Jefferson Clinton. He was chosen by and served his assignment through Treasury Secretaries Robert Rubin and Larry Summers. During his time at the Treasury Department, he was responsible for coordinating strategies on domestic financial policy, electronic commerce and community development policy. Prior to his public service, Jim worked as a Management Consultant with the global management consultancy A.T. Kearney out of Chicago where he focused on strategic and operational issues with Fortune 100 companies. Jim received his BA and JD from Georgetown University where he lettered in crew and football and was named an East Coast Athletic Conference (ECAC) All-Star and GTE Academic All-American. He received his MBA from the J.L. Kellogg Graduate School of Management where he received the Dean's Award for Outstanding Achievement.

Jim was named a Henry Crown Leadership Fellow by the Aspen Institute in 2004, a United States-Japan Leadership fellow in 2000 and a Leadership Greater Chicago Fellow in 2000. Jim remains active in the local Chicago community as Co-Chair of the Chicagoland Entrepreneurial Center, which is a national model for public-private partnerships that are established to assist entrepreneurs. He is a Board Member of the Chicagoland Chamber of Commerce. Jim is also the founder of Kellogg

Corps, a non-profit entrepreneurial program at the Northwestern J.L. Kellogg Graduate School of Management whose mission is to bring management expertise to non-profit organizations in developing countries. In addition, Jim is an Advisory Board Member of the J.L. Kellogg Graduate School of Management. He serves as an Advisory Board Member of the NanoBusiness Alliance, the preeminent nanotechnology public policy organization in the United States. He founded the Field Associates, the Field Museum's young professional Board, as well as the Lyric Opera Auxiliary Board, the Lyric Opera's young professional Board. Jim also serves on the Board for the Children's Home & Aid Society, the Chicago Cities in Schools Program (CCIS) as well as the Big Shoulders Board for the Archdiocese of Chicago's inner-city school fund. He was awarded the Motorola CEO Award for Volunteerism in 2002. He was awarded the Motorola CEO Award for Outstanding Achievement in 2004. He is a member of the American Bar Association, the Economic Club of Chicago and Executive Club of Chicago.

Jim lives in Wilmette, Illinois with his wife, Julie, and their twin sons.

Jim O'Connor

Vice President & Director
Early Stage Accelerator

June 23, 2005

The Honorable Bob Inglis
Chairman, Research Subcommittee
Committee on Science
B-374 Rayburn Office Building
Washington, DC 20515

Dear Congressman Inglis:

Thank you for the invitation to testify before the Research Subcommittee of the Committee on Science of the U.S. House of Representatives on June 29th for the hearing entitled "*Nanotechnology: Where Does the U.S. Stand?*" In accordance with the Rules Governing Testimony, this letter serves as formal notice of the federal funding Motorola currently receives related to the hearing topic.

- \$600,000.00, N66001-01-1-8964, DASRPA, FY2001-FY2004
- \$377,782.00, N66001-02-C-8011, DAPRA, FY2002-FY2005
- \$677,941.00, 70NANB4H3012, NIST, FY2004-FY2005
- \$5,572.00, 70NANB4H3028, NIST, FY2004-FY2005

Sincerely,



Jim O'Connor
Vice President

JJOC/mij

DISCUSSION

Chairman INGLIS. Thank you, Mr. O'Connor. I will recognize myself for a first round of questions here.

Over the last several weeks, I have noticed several articles about environmental issues associated with nanotechnology. Maybe they were there before, and maybe it is just because of the last hearing that I started noticing them. But Mr. Nordan, you mentioned the regulatory uncertainty about environmental regulation in the area of nanotechnology. What do you think is driving those stories? I mean, are there real concerns out there about the environmental impacts of these, or is that mostly a health and safety issue, as in workers exposed to materials. Comment on that, if you would.

Mr. NORDAN. Well, it is a complex topic. It doesn't easily reduce to a sentence or two, I am afraid. My firm just published a report on this particular topic, that we will be glad to make available to the Committee.

The first cut that you have to make is between real risks and perceptual risks, which are equally important. So, on one hand, there are real risks of manufactured nanoparticles, nanotubes, metal oxide nanoparticles, fullerenes, dendrimers. All of the building blocks of nanotechnology may have adverse effects, adverse effects in high volumes to manufacturers in an assembly line, who might have the opportunity to encounter large quantities of them in an aerosol in the air, for example, adverse effects to consumers at use, or adverse effects on the environment that may take a long time to rear their heads. There is a strong belief, and you can demonstrate that the multiwall nanotube composites that are already used in cars, for example, today, are in a situation such that the nanotubes can't get out of their composite matrix, but does that sustain in a landfill for 20, 30, 50 years? The answer is we don't know right now.

So, on one hand, there are real risks that companies working in this field are treating assiduously—DuPont is a good example—where David Warheit, among others, has been a leader in conducting EHS research on the real risks of nanoparticles. On the other hand, there are perceptual threats, which are often written off by participants in the field of nanotechnology as not terribly important, but if you look at the genetically modified food experience in Western Europe, you can see that the belief that there might be a threat, even when none actually exists, can choke commercialization just as real risks do. In fact, in many cases, those threats can appear earlier, and have a broader magnitude of impact, than real risks, as we have encountered with materials like asbestos, have.

To this end, there are a couple of actions that I feel are relevant at a government level. One of them is to conduct more and broader research into the real risks of nanoparticles. It is probably a fallacy to assume that the private sector will pick up all of the slack here. When it comes to specific applications, like carbon nanotubes in displays, or in composite matrices, it is absolutely reasonable to expect that the DuPonts and GEs and Dows of the world have a vested interest in their commitment to shareholders to minimize risk, such that that application level research will be done. When it comes to fundamental research on the particles themselves, irre-

spective of any specific application, it is probably off the mark to believe that that research will be conducted by the private sector. Funding here is insufficient today. If you look at the budget request for the NNI for Fiscal Year 2006, only 3.7 percent of funding is earmarked for EHS concerns. We believe that number needs to be two to four times higher than it is today.

Secondly, there is an issue about reducing regulatory uncertainty, and you have to think about this from a risk reduction standpoint. Let us say that you or I are a business manager at, I don't know, what would a good example be, DuPont? You are looking at introducing a new insulating material that involves nanoparticles, right? And you sit down with your government relations head, and start talking about what the risks are here, and you ask well, what are the applicable regimes under the EPA? Is this a new substance that has to be registered under the Toxic Substances Control Act? Is it going to be considered an existent substance that is not going to have a lengthy approval process? And the regulator looks at you and says I don't know. They haven't really decided yet. Now, the lack of action here is not ill-intentioned by any means. The folks at these agencies are looking at nanotechnology, and they don't want to introduce firm regulations before all the facts are in from research.

That said, we believe that action is required at this point, because corporations are now looking at these opportunities, and are putting them off for a year or two or three or five, until at least an indication of how a regulatory framework will be developed is in. Action is required here in order not to stall commercialization.

Chairman INGLIS. Mr. Kvamme, any thoughts on that subject from you, as well as this other thing, the environmental issue, I have seen rising up. The other thing I have seen in some media accounts since our last hearing—I don't think it is associated with last hearing, but it sort of, I have noticed it since, is a little bit of push back about now, we get a lot of hype on this subject, and that is not going to change the world.

Mr. KVAMME. Well, as has already been mentioned, we actually spent quite a bit of time on the environmental aspects of this, and I had the pleasure of being in some of the NSET meetings on this as well, and I am very pleased with the role, for example, EPA among others, NIOSH, et cetera, are taking in those roundtables that are essentially monthly meetings.

The concern that we came up with was really workplace related, as I mentioned in my testimony. That is because of the raw particles are really available there, and frankly, it is not a lot different in my view, than what we had in the early days of the semiconductor business, when we were working with the same, you know, arsene gases, and et cetera, that are not good for folks. And so, we had to do controls in our workplace. Once that material was installed in the silicon, once those nanotubes are installed in a tennis ball or something like that, we are far less concerned, because of the technology involved there.

So, I would totally agree that continued study of this is necessary, because materials, the way I like to think about it is, think about a Tinkertoy set, where you are putting molecules together, and think about the fact that it is a different material if the peg

goes into one different slot in that round circle. Tinkertoys probably age me, or show my age, anyway. Those of you that remember Tinkertoys, okay. It is a different material, and you could say that that means that carbon can be thousands of materials, really, and we have to be sensitive of that, particularly in that construction phase. So, on the environmental thing, like I say, I think it is mostly workforce-related, at least as far as we have a concern. We will continue to look at that.

Chairman INGLIS. All right. Speaking of being sensitive, I need to be sensitive to the clock up here, and recognize Ms. Hooley, but perhaps, others might want to take a crack at that, as later questions, as you see the opportunity, about whether this, whether nanotechnology can change the world, as I think everybody up here is assuming it can, and you are assuming it can, and how we would answer people who say the other, that it is much ado about nothing. I am not sure they say that, but they have been sort of poohing some of the advances that could happen. So, perhaps, as we go along, you might want to address that.

Ms. Hooley.

Ms. HOOLEY. Thank you. Thank all of you for testifying.

Do any of you have any experience with the Advanced Technology Program, and do you believe it is valuable and deserving of our continued support? Anyone to comment on that? Advanced Technology Program? Anyone?

Okay. I am going to go the next—oh, good. Mr. Murdock.

Mr. MURDOCK. I will say that while I don't personally have experience with the Advanced Technology Program, there are many nanotech companies who ultimately have utilized the Advanced Technology Program, from Luna Innovations in Texas, and Spectra Biosciences, also in Texas, to name a few, and I think all would say that it has been incredibly helpful for them in maturing the technology, and in specific cases, in forming partnerships with large companies, who will ultimately be the channel, if you will, to market, to commercialize these innovations.

Ms. HOOLEY. Okay. Mr. Kvamme, and excuse me for butchering your name many times today, your report discusses the federal role in commercialization of nanotechnology, and specifically mentions the Small Business Innovation Research and Small Business Technology Transfer Programs as sources of funding for critical early stages of technology development. Why is the report silent on the Advanced Technology Program? Any reason for that?

Mr. KVAMME. Our emphasis on the commercialization aspect, as you saw in the report, was utilizing the state economic development agencies that exist in every single state. We had the pleasure of meeting with a number of state representatives, and feel that that is an area where there is a considerable amount of interest in economic development. Your state of Oregon, for example—

Ms. HOOLEY. Right.

Mr. KVAMME.—is very, very active in this area, and we felt that that close to home area for tech transfer was a more valuable resource to getting to commercial application of products than anything else we were able to see. In fact, it is larger than the SBIR, STTR programs. In fact, on its impact in the nano area that, at least as far as we could see from our study.

Ms. HOOLEY. A question for all of you, and I know a couple of you mentioned it, talking about how do we make sure that we have the scientists in this country to work in this kind of technology? What is your question of what we do to interest our young people from majoring or taking advantage of science and math courses that are offered to them in high school, college, and so forth?

Mr. KVAMME. If I could begin on that, I—

Ms. HOOLEY. You may.

Mr. KVAMME.—would be very happy, because you have just hit my hot button. It is the area that concerns me most at all.

Ms. HOOLEY. It should concern all of us, yeah.

Mr. KVAMME. And we issued a report on that subject, a workforce report, some several months ago, and made a number of recommendations. I think some of the most important things is to stop looking at engineering, for example, as a trade school. People who graduate with an engineering degree have learned how to do problem solving, analysis. They shouldn't be considered only aimed at engineering careers any more than French majors should be aimed at becoming Frenchmen. There is no connect there at all. An engineering degree—

Ms. HOOLEY. I have never heard that before.

Mr. KVAMME. But an engineering degree is a valuable degree, and we must make sure that people who want to be in problem solving areas, whether they want to go into public policy, or any other field, can gain a lot of insight into that by utilizing a technical degree. So, we have to change that perception that there aren't jobs for these people. I will remind you of the G.I. Bill. Nobody questions today whether the G.I. Bill was a good idea. At the time, however, remember how controversial it was. I wasn't exactly around then, but I was alive.

Ms. HOOLEY. Right.

Mr. KVAMME. But, you know, I will quote the President of the University of Chicago at that time. "What are we going to get? Educated hobos?" to use a very negative term of the day. Because he didn't believe that an advancement in technology would benefit all of society. We have to remove that notion that we don't need more engineers, we don't need more scientists, and it is prevalent. Believe me, it is prevalent. It has to be removed.

Secondarily, I think it is unfortunate, but the facts are, a science education is tough.

Ms. HOOLEY. It is.

Mr. KVAMME. And it is harder than a lot of other things. When kids go away to school, we don't have a problem with matriculating freshmen at the Bachelor's level. We have a problem that they drop out and go into other fields, because it is hard. I think we have to incentivize them. I was, frankly, very disappointed when Approps, in the last few days, dismissed a program that we had recommended, that I was with Secretary Spellings yesterday morning on this subject, had asked for an initial program to help fund scientific study by Bachelor's degree students.

I think it is important that we understand that it is tough, and if you want to call it bribery, call it bribery, but keep youngsters in there, because they are interested in it, but it is hard. What incentives can we offer for them? We have a number of recommenda-

tions in our report. I would be happy to supply copies of that report also, but it is an area of great concern to us. I think it is our largest area of concern, because we are entrepreneurial in this country. We just need more bodies to handle the entrepreneurial nature across our economy.

Ms. HOOLEY. Anyone else want to talk about that?

Mr. NORDAN. To add to that point from the other end of the educational spectrum, I know this is probably not something that is welcome by the Committee to hear, but this essentially comes down to money, all right.

If you are a Ph.D. student, and you have just completed a doctoral degree, and you are now looking at doing a postdoc, and doing an assistant professorship at a university, and moving upward, the amount of money that you will make doing that is an order of magnitude less than you will achieve by taking that same degree, and working for a Wall Street firm, or a management consultancy, or something else, applying your scientific knowledge not to scientific development, but in a professional services context.

If the mechanisms through which we fund postdoctoral degrees and assistant professorships within state universities gave a better cost/benefit ratio on the value of time for these individuals, you would see more of them working to apply the degrees in scientific context, rather than in other ones.

Ms. HOOLEY. Okay.

Mr. MURDOCK. There is also another lever. I am sure this committee often hears of, you know, the Sputnik generation, and the race. And we need a clear, compelling, cohesive vision for how science and technology can change the world around us in meaningful ways. And that will motivate people, the individuals going through the educational system, to do that.

That is one of the reasons that we believe, you know, translational, goal-oriented research should also be in the mix. If you make the National Cancer Institute's Center for Cancer Nanotechnology Excellence, they are looking at trying to take nanotechnology and bring it to bear as rapidly as possible, not to eliminate cancer, because that is not quite feasible, but to minimize the pain and suffering associated with cancer, and they have set a specific target of 15 years from now. It is that kind of program and activity that people can relate to that will motivate them to be part of the solution. And part of this is, as Matthew said, motivation. There are financial levers to motivation, and there are values-oriented levers to motivation. We need to pull on both.

Mr. O'CONNOR. One last comment on that. At Motorola, we take that very seriously. We have 24,000 scientists, and we feel we have to make a committed amount of dedicated time to this with children. I will give you a couple statistics. In China, for example, 45 percent of the degrees are engineering, whereas in the U.S., it is five percent.

Ms. HOOLEY. Forty-five percent?

Mr. O'CONNOR. That is correct. And that is not uncommon to see that in some of our international partners. Another statistic that is of interest is there is a group called the International Science Engineering Fair, in which there are 600,000 U.S. students that

participate. There are six million students in China that participate.

So, I think there has to be a concerted effort across the public and private sector to address this issue, and different nonprofit organizations and large companies need to make a dedicated commitment, if we really want to get to that supply of our top talent, to do what we need to do, to get to the next generation of technology.

Ms. HOOLEY. Thank you.

Chairman INGLIS. Thank you, Ms. Hooley. Mr. McCaul, recognized for five minutes for questions.

Mr. MCCAUL. Thank you, Mr. Chairman. I thank you for putting this hearing together. I thank the witnesses. I wanted to follow up on the university-industry partnership issue. I represent the Research and Development Center, the UT system, it is called the J.J. Pickle Center. He was a former Chair of the Science Committee. Unfortunately, he recently passed away. I was at his funeral.

But I wanted to follow up on that. I know, Mr. Murdock, you had had some experience with the University of Texas. Mr. O'Connor's comment was interesting. This partnership won't do it alone, and I am interested in your comments on that. In getting the tour of the Center, it was very impressive, in terms of the research and development going on at the university, and the exchange of information and partnering with the high tech, which is very prevalent in the Austin area, in my district. A lot of the funding actually was at the Pickle Center, to make the semiconductor wafers, and the industry got a lot of the benefit out of that, and I would like you to comment on the pros and cons of how can we strengthen the partnership, what are the problems associated with the partnership? And lastly, I would say the majority of students that I saw working at the Center were over here on student visas, predominantly from Asian countries, and more disturbing is what I was essentially told that most of them would not stay, we would not have their talent after they graduated. They would essentially return back to their countries, and you know, we have this investment, in terms of training, that we give to them, and yet, we lose that talent when they return back to their country. So, if you could, if you wouldn't mind addressing maybe those two issues.

Mr. MURDOCK. To respond, I am not overly familiar with the specific university-industry partnership that you are referring to, but having said that, we do rely extensively, in the United States on foreign students right now for postdoctoral positions and they do a lot of great research, help us build our knowledgebase, develop the innovations, in fact, of our patent applications. And we are training them.

The issue of students' visas on foreign immigration is very important. In the near-term, we need to have an influx of human capital from around the globe. The United States should be the place where the best and brightest from around the world come to do research and commercialize their activity. I think that is a very positive thing.

The risk of doing that is that we don't cultivate enough of our own talent, and so we need to be cognizant of that, and you know, as we have talked about, increase the supply of trained scientists and engineers from the lower grades, all the way up while doing

that. So, these need to be pulled simultaneously. And then, we need to take steps to ensure, and to create incentives, as Matthew said, to ensure that we retain the talent here. When we lose the talent, it is a net loss. But it is important to manage across all phases simultaneously.

Mr. O'CONNOR. Yes, I would like to comment on the UT partnership, because I am familiar with it. It is a great program. In fact, a couple of years ago, I got involved in that program via a small company called Molecular Imprints, which is a nanoimprint lithography company. A man by the name of Norm Schumaker. And a good example of some of the context of partnership and why it makes a difference in this commercialization chasm of death that they talk about and how we can get through it, is this small company came out of UT, needed some venture funding, and through our venture arm, we actually formed a partnership, through venture capital and a commercial agreement, to help get them to the next stage. So, you had a good example of innovation within a university, a small startup in venture funding, and a large company working a collaborative agreement to bring this company's technology to bear. So, we think that is a great example of the kind of partnerships that are achievable, and the types of things that we are looking more often to do.

Mr. MCCAUL. Thank you. Any other comments on that? Mr. Nordan.

Mr. NORDAN. I would just underscore the fact that the issue is retention. If the takeaway that you get from today's discussion is we need to plow resources into inspiring students with wonder for science and technology in K-12, that is absolutely right. It will be absolutely ineffectual for years. In the near-term, the lever that is open to us to pull is being able to retain foreign students that are already studying on our shores, but are no longer staying here. If you look at the course of American Ph.D.s, right. In the first half of this century, we educated a lot of American Ph.D. and postdoctoral students who, in rare cases, would go and practice abroad. In the second half of the 20th century, we then imported a large number of students, but were highly effective at being able to keep them here, which is a reason that our university staffs and the R&D staff of companies like Motorola are so diverse, and we gain from that diversity.

The problem is that as economic fortunes have improved in India, China, South Korea, et cetera, the cost/benefit tradeoff of remaining in the U.S., cut off from cultural links and cultural support, versus returning home, is no longer as stark as it once was, and we are losing these students. What can those incentives be? Well, they are fairly broad-based. There is a lever that we have to pull in visas. There is a lever that we have to pull in improving the lot of what a postdoctoral situation, or an early university professorship would be, in terms of financial remuneration in the United States. There are probably other levers that I am not aware of, but in the short-term, the lever we have to pull is retention, and the long-term lever we have to pull is education of our students domestically.

Mr. MCCAUL. I agree with that, and my time has expired. Thank you, Mr. Chairman.

Chairman INGLIS. Thank you, Mr. McCaul. Ms. Johnson.

Ms. JOHNSON. Thank you very much. I am pleased to follow Mr. McCaul, because I think that some of the things that we have done on this committee might lend a little bit of insight.

About six or seven years ago, with Congresswoman Connie Morella, we sponsored a bill to try to get the attention of young people, and interest them in science and technology, and it was focused, at the time, on women and minorities, only to find that it was not just women and minorities we need to attract, because the figure for Anglo males going into engineering was just dropping like a lead balloon. And so, we now know that 80 percent of the scientists, researchers in this country are not American-born, and we do need to give great attention to that.

The University of Texas Southwestern Medical School is in my district, and I work closely with them on this kind of research, as well as University of Texas at Dallas and the system where we hope to become a leader, just as we led the way in the Dallas area for the chip. And I think that this technology, the nanotechnology, is going to be in that category. I think for healthcare delivery, a number of things, this is the research we need to focus on. It is like the steam engine when it came about, or the Internet when it came about. It is going to make that kind of impact on our economy, so it is important that we do invest money in this research.

And we are falling behind other countries in research dollars. We used to be leaders. Now we are behind. But it was out of this type of research that brought us to where we are now. This is the research that caused us to have the economy we had in the '90s. It came from this area. So, I cannot be more passionate about how much we need the leadership in this area, and hope that all of us can influence young people to go, and it does start in K-12, because we know that at the sixth grade, they start dilly dallying to something else.

We have tried to determine what causes that. We rank number 18 in the world in the science and math, and we should not be, in a leading country. But we cannot get it without the support that we need. And so, could you take that back to the White House?

Mr. KVAMME. I would be very happy to, and in fact, you might be pleased to know that what you just said would almost sound like you were a fly on the wall at a meeting I had with Secretary Spellings yesterday morning, because we talked about this exact idea, and the fact that you folks here in the Congress have approved that billion dollar math and science program, how do we push that? You know, we were reviewing, and our committee is reviewing a very interesting study out of UCLA on 1,546 colleges and universities in this country, and what is motivating kids to take the major that they are. It is very, very telling. It is also very interesting as to who studies engineering.

Many, many of the students that go into engineering happen to be from families that are first time college people. They are coming from—I am an example of that. My folks are immigrants. My dad was a carpenter. My mother was a domestic worker. And—but I am finding that, even in the current generation, that is still true. How do we make sure that those families understand that an engineering degree is a good idea? So, we are working on that. We are

looking at where is the market for this, and hopefully, we will be able to come up with some concrete proposals. We already have them in our existing workforce report, but it is a very, very high priority at the PCAST.

Ms. JOHNSON. One of the ways we can do it is through partnerships. I carried legislation on that area. Texas Instruments is our star company for involving themselves in our education system in Dallas. What we find is that when students can relate this to everyday life, and understand how it relates to the research, and what brings on the technology and the advancement and what have you, the more they appreciate doing it. Now, Texas Instruments funds a lot of this for the Dallas Independent School District, and I have no objection to it. But we, as a nation, cannot afford not to invest more in this area. We are losing our edge, our competitive edge.

Mr. KVAMME. At the risk of taking the time, let me just agree with you, but let me also help you think this through. Think about it, a hundred years ago, a kid walking down Main Street saw every potential job they could have in their life.

I defy you to walk down the streets of Silicon Valley—area—and know what is going on behind those buildings. It is not possible. We have hidden from our kids. I will tell you a personal story. When I was running National Semiconductor, we had 9,000 people in my operations. We decided, for reasons that are obscure, to have our company picnic at the plant, instead of going to a distant site. Usually, about 1,000, 1,500 people showed up. 24,000 people came. The police were irate. Why did they come? Kids wanted to know what their folks did for a living. They wanted to see their workplace. They wanted to. It taught me a real lesson about opening up. We have to understand that we have to bring our children into the workplace. We have to make sure the insurance companies don't bar that, because they try to. They don't like kids running around this instrumentation, but it is critical that we do that.

I knew what my dad did. He built buildings. He built houses. Our kids don't know what their parents do. It has an impact on family values. It has an impact on everything. Open up. In East Palo Alto, I suggested that those young kids, they wanted to go visit companies that I was involved in. I said no, no. Get them to go to Johnny's mom's company. Get them to go to Billy's dad's company. And go visit that, and open it up so that they can see, they can relate to work in the environment. Again, I feel so strongly about this, I am sorry.

Ms. JOHNSON. Well, my time is up. But I feel equally as strongly, and I am very happy to meet you. I might become a worrywart.

Mr. O'CONNOR. Yes, if I may, I share your passion on this as well, and I think—to answer one of your questions earlier about how to make this real. I think that is one of the problems with nanotechnology is that it is somewhat of an esoteric concept to people. So, when you talk about it, they may not get it. And that is why we firmly believe we have to do more in the communities to do different things, and we are working with public schools in different areas. And one good example of it that we like to show, is if you look at the cell phone, from you know, 10, 15 years ago, and you actually feel that it is really quite remarkable, and then you

compare it to what you have today. This is just the start of the kind of technology evolution that nanotechnology is going to allow. The miniaturization, the better displays, the printed electronics and transistors inside, to allow shrinkage.

And people get it when they start to see these things, and when you talk about displays and having carbon nanotubes and nanoemissive displays that actually allow you to see a basketball or a baseball more clearly going across the screen, at a much lower cost than what is currently available, it comes to life for people, and it is quite real. So, I think those types of examples make a difference in getting this type of technology understood by people.

Chairman INGLIS. I should not have thrown away that big phone recently. I should have kept it—

Mr. O'CONNOR. That is right.

Chairman INGLIS.—and used it as a prop. Mr. Kvamme, that was a very interesting point about openness. That is very interesting. Mr. Sodrel.

Mr. SODREL. Thank you, Mr. Chairman. A lot of good comments and challenges, and I guess, I want to take the final step. Let us assume that we get all of our students motivated and inspired to pursue science. We, in fact, produce more scientists and engineers. We invest more in research and development. We develop public and private partnerships, and we provide salaries that attract and keep good folks. So, now, we are in the ideal world.

As you pointed out early on, I think most of you made the point that other countries are working hard to catch up. In some cases, catch up means stealing technology and research from our country. China, for example, has shown little respect for intellectual property or patent rights, and a real enthusiasm for industrial espionage, or whatever term you want to use. So, my question is, how do we maintain any real lead in nanotech when any breakthrough in research can be transmitted to our world competitors at the speed of the Internet?

Mr. NORDAN. If I can take a first shot at that one. It is just like the Red Queen in Alice in Wonderland. It is not an issue of being in one place before someone else. It is always being one step ahead, being able to run faster. There is an evolutionary arms race to think about.

The fact is, if you look at what was mentioned earlier, revitalizing the U.S. manufacturing base through nanotechnology, there is certainly pilot scale manufacturing and certainly manufacturing where specific skills are required, generally low volume, that will be incentivized by nanotechnology. But if you look at fields of nanomaterials today, the manufacturing train has already left the station.

Where the U.S.' economic opportunity is here is in coming up with the ideas that may be implemented in manufacturing plants on other shores. To give you an example, in the category of fullerenes, it is a kind of nanomaterial, think of a soccer ball, where the intersections between the stitching are carbon atoms, and the stitching is bonds, right? There is a company that is a joint venture of Mitsubishi Corp. and Mitsubishi Electric in Japan, called Frontier Carbon. They built a plant capable of manufacturing 40 tons of fullerenes a year. Do you know what world de-

mand for fullerenes was last year? About one and a half tons. It is unlikely that you are going to find U.S. based companies investing that far ahead of demand in order to attain manufacturing dominance, but what is not known is that at that plant, the manufacturing process they use to make the fullerenes is not home-grown. It is licensed from a company spun out of MIT called Nano-C, that has an innovative process using two dimensional flames to create fullerenes at very high quality and high purity, right.

The way that the U.S. can maintain its edge in this regard is not by trying to go toe-to-toe against competencies, be they be in low labor tasks, or tax advantages for capital investment in manufacturing facilities, et cetera, that we are unlikely to catch up in, compared with other countries that have more runway to go down, in terms of economic development based on nanotechnology. It is to have an unremitting, relentless flow of novel ideas that take time and keep us continually two, three, five years ahead of what other countries can attain.

We cannot prevent research being done that goes into a startup company being transmitted in some way, be it through a patent process, et cetera, to a country that perhaps does not have the respect for intellectual property rights that Western European and U.S. nations hold. That is going to happen. The achievement that we can drive toward is to always be ahead, and always be first to market with those novel ideas. And through that, I think we will attain economic rewards. After that, there are a million tiny things that can be done that will have an impact. Working through organizations like the World Trade Organization, to encourage stronger IP enforcement in countries like these. Being able to have win-win partnerships involving joint development, which countries like—companies like Motorola are good at doing, that give strategic incentives, as well as economic ones or legal ones, to these countries to expect—to respect intellectual property laws.

But ultimately, the number one lever that we have to pull here is by always being first and always being ahead.

Mr. KVAMME. I actually disagree with Matt on that, so maybe, I ought to make a comment.

Mr. SODREL. Okay.

Mr. KVAMME. And have fun. The reason that you put a semiconductor plant today in China has nothing to do with labor rates. It has to do with return on capital employed. When you look at a semiconductor plant, 93 percent of the cost is related to capital. About six percent is labor. When they give you a situation in a plant that is going to last 10 years, zero tax for the first five years, and half tax for the next five years, in our manufacturing report, we reported that for a \$3 billion investment, it costs, just because of cost of capital, \$1.3 billion more for that plant in the United States as it is in Europe—as it is in China. It has nothing to do with labor rates, and the public doesn't understand that at all. It is a capital issue.

So, as we talk about nanotechnology, unfortunately, the manufacturing plants are going to be expensive. So, who is going to give you the best opportunity for return on your capital? If you get hit with 35 percent off the top here, and four percent someplace else, it makes a dramatic difference. You do not put those high value

plants overseas for four percent of your cost structure. You just don't do it. When I sit in board meetings, the reason we go overseas is tax benefit, okay? I realize that is not the purview of this committee, but that is the reason.

Now, by the way, the Indian situation is different. India is looking more at more labor-intensive things, and what I call the slope-and-intercept problem, you know. It is the same thing in so many industries. It takes \$800 million to make a drug. The drug manufacturing costs are zero, almost, per pill, but who is going to pay the \$800 million? Who is going to pay the \$3 billion back? Who is going to pay for the software back, the development cost, that intercept? If you think about it in a chart, you have this enormous startup cost, so I think that is a big issue.

On the patent point, I think that is also a point that you make, and we do have a tool there that has been effectively used in the past, and sometimes, folks are reluctant to use it. It is called closing them off at the borders. We can't forget the fact that we are a huge market. Now, obviously, international markets are growing, and there, I would agree with Matt, but as far as serving the U.S. market with products that are ripped off from us, we have a tool, if we enforce it. We are not very good, sometimes, at enforcing it. I have good experiences, and I have had ugly experiences on that front. But that is a tool we have to protect our markets that I think we ought to utilize.

Mr. NORDAN. Just to keep the discussion going, do you think it is realistic that tax rates like the ones you have described in China could ever be approached in the U.S. at any scale?

Mr. KVAMME. These are the folks that make those decisions.

Mr. SODREL. Okay.

That is music to my ears. I was sworn in in January, and I often tell people I spent my career in real life, with balance sheets and profit/loss statements, and so you are speaking my language now. We certainly need to have you come back and testify before one of the other committees, when we get into tax simplification.

Thank you, Mr. Chairman. I am sure my time has expired.

Chairman INGLIS. Mr. Murdock, did you want to add something to that?

Mr. MURDOCK. Yes, if I could. I also would like to reinforce the need to, obviously, enforce the intellectual property laws, that it will be, in fact, critical to maintaining U.S. leadership. Furthermore, I am not prepared to cede, if you will, manufacturing of nanotechnology-enabled products here in the United States. I believe that we need to endeavor to be more than just IP companies. If you look at the total value associated with any product, most of the value tends to accrue to those that are closest to the customer; that in fact, make it. And while IP may have higher margins, you know, ultimately, there is a big value pool out there, and we need to ensure that we are taking steps to capture the value.

Furthermore, IP is not the only source of intellectual capital, if you will. There is know-how, and that is the reason for the importance of manufacturing. Ultimately, when we move from the knowledge or the proof-of-principle into making the stuff, we develop process knowledge. That process knowledge helps us to refine and improve both the quality of the product and the throughput, if you

will. And it increases the value of the labor. It increases the marginal productivity of the labor. That is what enables us to pay high wages and keep jobs here.

So, while we need to be realistic and understand that this is a global economy, we also need to take steps to do what we can to ensure that we do commercialize and manufacture the set of technologies that we can here.

Chairman INGLIS. Thank you. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman, and this discussion has been interesting, and being someone who wants to keep jumping in at each juncture, I sat on my tongue, and I just, you know, listened. And we have gone all over the board, Mr. Chairman, on technology and let me see if I can pose a couple of questions.

From education to investment, I think the gentlemen are correct that we are not doing quite enough, in terms of education and the research that was done at UCLA, I suspect that the population was a pretty narrow population at UCLA. And I suspect a lot of them had black hair, too, in the engineering department. But I think that there is something to be learned from that, in that there are a lot of things that we need to be doing in our society, in terms of education, and taking what we learned from that research, apply it to our country.

I don't think that this country has been disciplined enough, and—to apply what we have learned in all spectrums of our society, like Kansas or Appalachia, where families need this kind of education, and need this kind of rigor and expectation. It is not about Asia being better or Asia having more. It is just that Asia had decided to something, and India had decided to do something, and this country just needs to decide what they are going to do with their education and invest it in this country.

Whether it is Appalachia, Southern states, the valleys of California, we just need to stop, and invest in our own education, take the best practices, and expect it of our own children. That is the problem. The reason why people are coming over to this country from other places is because the graduate programs and the companies that work together, they have a freedom, and there is a lot less control, if you will, in what they do and how they think.

And I suspect that a lot of the people who work in our companies in Silicon Valley not only come from India and China. If you look at a lot of startups, they come from Europe, they come from the UK, everywhere. So, it is a magnet for the intellectual curiosity people that want to participate in this country.

In terms of the PCAST report on government roles in research and development and commercialization, bridging the gap, if you will, I think the report went all over the place, but did not say specifically what the role is. They pushed it off onto states and private companies, which is being done, because the Feds refuse to do it. And in the report, it talked about SBIR and STTR, and there is a role there. Certainly, there is a role there, because they get a percentage of income from other projects, and put it in there, and then they use that money. But when you reduce the amount of money in each of these programs, they get less money, and then we zeroed out ATP, I believe.

And I guess, to the gentlemen, I would like to know, just how strongly do you feel about the role of government in helping companies bridge this valley of death, in terms of our competitiveness—you said it once, but I would like to hear it again, in strong terms. And then have this sent to the President, the Administration, because the Committee here, the full Committee, was asked not to move forward on programs like ATP. We didn't, and so, you know, our job is to propose and authorize and then it is the Administration's job to figure out whether they are going to back it up or not, but in this democratic society, we are the ones that are supposed to listen to you, and translate that into programs, and I have a bill, called the Nanomanufacturing Investment, H.R. 1491, which addresses specifically bridging the valley of death, and I would like to hear what your reactions are to that bill, and how that can be improved, and whether it should be supported by this Administration, as the previous bill that we signed, the Nanotech bill, that Mr. Kvamme and PCAST had supported also. I think that is the next piece that needs to be signed, so that we can make sure that we move forward in areas that you are all concerned about. That and education, I think, are intertwined, and then, moving forward with educating our members of our communities, and bringing them along, so that there is no perceived fear, that there is knowledge. That is important, and I think that that is part and parcel of education, and part and parcel of the bill that we are looking at, so that more and more people will be exposed to this thing we call nanoscale activities, because it is a brand new enabling activity, that will just change the complexion of this world. I wonder whether you have any reactions to what I said. I have rambled a bit, but I think you get the gist of my comments.

Mr. O'CONNOR. If I may. I appreciate your comments, Congressman. I couldn't agree more. To be emphatic, from the private sector perspective, we truly feel the government needs to take a strong hand in developing this technology. It is part of an overall partnership. Large companies like Motorola, small startups, nonprofit organizations, venture capitalists, and the government. It has to be an emphatic focus across the board.

And when you travel abroad, you see this. You go to places like China and Korea, where there is a strong partnership between the government and the private sector in developing these technologies. We can't sit by the wayside. We have to move this forward. So, from a private sector perspective, we feel we are not doing enough. We have to do more, and it has to be really on a consortium partnership level.

Mr. HONDA. And is it the nature of nanoscale activities, one of the reasons why we have to shift federal paradigms in order to be able to justify going into this activity?

Mr. MURDOCK. I think the meta-theme, if you will, of the role of government, is to create a conducive commercialization climate, to help create an ecosystem where this can be done. And there is no one silver bullet. It is going to take many things moving in parallel to accomplish that. Actually, you referred earlier to the regulatory climate, and export controls, so obviously maintaining our investment in the generation of knowledge through nanoscience R&D in the 21st Century—doing more through the SBIR programs, and po-

tentially, making them longer and bigger, like NIH has done, if you look at that as best practice to help get over the transaction costs of going through the grant program. Leveraging fast track, you know, there has been talk in the SBIR as to whether venture capital funded companies should be able to receive grants. You know, ultimately, we need to do as much as we can to encourage capital formation associated with the—rather than discourage. So, we believe that, you know, venture capital companies ought to be included. As I said, Phase III, I think the government can play an incredibly important role in acquiring and integrating nanotech innovations into its agency needs and missions rapidly, and to design with intent to do that on a go forward basis, and then, ultimately, creating incentives for the private sector to form long-term commercialization-oriented capital. The stock market, we all know, drives companies to short-term performance. We ought to think about how to create new vehicles to enable the set of folks who are longer-term in their thinking and have more patient capital to deploy that to help grow the sector.

Mr. NORDAN. To add to that, I absolutely agree with my fellow panelists that there is an important and key role for the Federal Government in bridging the chasm of death that we have talked about.

The only point of caution I would add is that if you look at the history of industrial policy, it is littered with examples where state agencies encouraged the development of a specific technology solution to a problem to their peril, right.

The government of France, for example, put a great deal of money into specifically minicomputers right at the time that personal computers were beginning to usurp them, and that was a bad choice. What I would encourage is not activity focused on specific technology solutions, but on solving broad problems. The National Cancer Initiative's nanotechnology effort is a great example, where there are broad goals to come up with noninvasive therapies, for example, or targeted agents, but no specification to use specifically gold nanoshells or dendrimers, or another technology platform. This is a place where we can make some wiser decisions than perhaps some of our international competitors have. If you look at Taiwan, which I mentioned beforehand and works very closely with specific corporations on specific solutions, one of the solutions they are backing is magnetoresistive memory, right, which is one of several forms of nanoenabled memory that could be much more dense, much lower power, and nonvolatile. But it is probably a bad choice. That technology solution could lose in the marketplace to nanotube-based memory, or memory based on organic porphyrin molecules. A wiser choice might be to create incentives, and ATP may be one incentive structure, to solve the problem without subsidizing or incentivizing a specific solution.

Mr. MURDOCK. I was going to follow up briefly and say that meta-theme, if you will, goal-oriented research centers, translational research centers focused on very clear, well established societal problems like cancer are one way that we can simultaneously, again, captivate the imagination of our youth, and get people drawn in, and make very specific progress toward these goals, and it provides a forum, if you will, for industry to effectively

engage, rather than trying to sift through everything, and figure out where the relevant research that is taking place in cancer therapy.

Mr. HONDA. Mr. Chair, if I may just ask you to look at the bill, and wordsmith in ways that it would encapsulate what it is that you just mentioned.

Mr. KVAMME. Well, I was just going to add, you know, I am sure one of the difficult jobs you have where you sit, is dividing the pie. You know, where do you spend the money? I mean, it has got to be a very difficult job. We have that in management every day. I would put education at the top of the list. I would put programs, you know, again, we made some recommendations along those lines, programs to encourage STEM graduation at the top of the list.

The second thing I would do is I would return, if I could, to the spirit of the '60s in federal procurement. The Federal Government was a more risk-taking buyer in the days of Apollo. I sold parts into the Apollo computer, and it was fun. MIT was doing the design. I got to sit in the capsule in 1963. It was exciting stuff. The Federal Government has become a very, very cautious buyer. They should be—they are 20 percent of the economy. Is 20 percent of the business that the other gentlemen have talked about in the nano area being bought by the Federal Government today? I seriously doubt it. They are a much, much more conservative buyer, and at the end of the day, what you need is customers, in any business. It is kind of fundamental.

As far as the government as an investor, it is not hard to invest in good ideas. It is very hard to say no when the good idea isn't panning out real well. I think the big problem with a lot of government programs is they keep funding things that ought to have been shot. In the venture business, we all have closed-end funds, and you get, unfortunately, to say no when things haven't worked out, because we are in the risk business. It is a shame it is called venture capital. It ought to be called risk capital. Because it is a risky business. And what I have found, therefore, is that government investment is best done in things like facilities. There is a finite number of dollars involved in building a facility. In backing a corporate enterprise, you need oversight that I think is beyond the scope that is conceivable by government, because they—you just can't say no appropriately, and those would be my comments, Mr. Representative, and my representative, for a good while, by the way.

Mr. MURDOCK. If I could pick up quickly on Floyd's comment on facilities. The investment in facilities and infrastructure is incredibly important, and I think the 21st Century Nanotech R&D Act has done a phenomenal job that way, specifically—I am from Chicago and the DOE, Argonne Center for Nanoscale Materials there is going to be incredibly important to the—I think that drives down, if you will, the capital intensity of commercializing nanotechnology, which is an incredibly important part of the solution, so that startups don't have to acquire all that capital.

In order to effectively use it, though, it is incredibly important that we have, if you will, the operating funds as well, because the startups do not have, necessarily have the process know-how, or

the skills, to make effective use of to get the return on that investment in facilities and infrastructure, we need to match it with operating funds to provide services and get the utilization from the startup community.

Chairman INGLIS. Thanks. Mr. Akin.

Mr. AKIN. Thank you, Mr. Chairman. This could be a question for any of the witnesses. What is the role, I think you just made reference, of venture capital in bringing the products of nanotechnology research to the market? Do you think there is enough venture capital investment available to nanotechnology companies, and why? And then, what factors most influence venture capital investment choices in nanotechnology?

Mr. KVAMME. Okay. I guess I am a venture capitalist, so I have to take a first shot at that. Actually, venture capital availability right now, in total is pretty good. I think we may have, you know, we got into a mode that was kind of, during the bubble, it was kind of nutso, but if you take a look at the professional venture capital business, it has grown through the, you know, and if you eliminate the bubble, we are back on the curve that you would have projected from the early '90s, so the total amount of venture capital that is being deployed, and looks like it is being somewhat effectively deployed in the \$20 billion a year range right now.

Now, obviously, that covers an extraordinarily wide range of kinds of opportunities, nanotech being only one of many. And I would say that, you know, and this is corresponding with what some of the others have already said. Some firms are more interested in this area, and others are not. There is one problem that we faced on the Committee that you should all be aware of. Some things are hard to call nanotech, because they seem to meet the requirements, but this requirement that the processes be different or not conceivable from the larger scale is touchy. So, I am, for example, involved with a company in layer transfer of silicon, very, very fine layers of silicon. We don't call that a nanotech investment. I think some might, but you know, right now, the level is relatively low.

I think there is an adequate amount of venture capital. Venture capital is measured by one metric and one metric alone by the investors. It is called internal rate of return, which means you not only have to make hits, you have to make hits that hit quickly, and sometimes, nanotech is not viewed that way, as biotech wasn't in the early '80s.

Mr. NORDAN. To give a bit more global perspective on the same question. Right now, venture capital is notable in nanotechnology by its absence, not its presence. Last year, by our math, about \$8.6 billion globally went into nanotech R&D. Of that, \$4.6 billion was government, \$3.8 corporate R&D, and this tiny slice, about two percent, \$200 million of venture capital. That number has declined in the course of the last three years, from \$385 million in 2002 to \$200 million in the last year. And is also highly, highly concentrated in a very small number of companies.

We count about 1,200 nanotech startups globally. Of those, as of the middle of last year, only 109 had ever received a dime of institutional venture capital. Of those, only 10 had done two rounds, and that money was, then, even further concentrated in very spe-

cific sectors, about 40 percent in health care and life sciences, mostly drug delivery, about 40 percent in electronics and IT, mostly novel forms of computer memory, about one-sixth in materials, and then a tiny slice of five percent in tools.

That number, over all of those years, is equivalent to maybe around 1.4 to 1.7 percent of total VC dollars deployed. Now, the reasons for this are good reasons. As Floyd mentioned beforehand, there was a dramatic efflux of venture capital money during the bubble. As a result, venture capitalists are much more cautious. There are some other, more human factors reasons as well. Venture capital firms tend to be dominated by former successful entrepreneurs who invest in companies that they know well. Because of that, they tend to be staffed with folks who know electronics and who know life sciences very well, but often don't have experience in materials, and find it more difficult to be able to do due diligence on a materials investment. That means that it is less likely that a nanotech startup with a materials play is going to find a willing audience within a venture capital company.

Now, what can be done at the federal level in order to influence this? The levers are not terribly strong. I think that the meta-theme that Sean has mentioned beforehand about having goal-directed research would create a form of validation, right, for venture capitalists, that there is something here. There is a story here that is bigger than this one company. The issue of permitting SBIR grants to be allocated to venture backed companies is another lever that can be pulled.

Mr. O'CONNOR. Yeah, I think, picking up on one of Floyd's comments, I think what it is important to understand is——

Mr. AKIN. Could I interrupt just a second.

Mr. O'CONNOR. Yes. Sure.

Mr. AKIN. I want to make sure I am understanding what you are saying. In answer to the question, what factors most influence venture capital choices, I think I heard your response is particularly the specific area of application. There are certain favored areas, such as you said medicine particularly, and that is part of what is driving it.

Mr. NORDAN. Well, I would turn this back to Floyd, but in observation of these companies, the human resources, the knowledge that they have tends to be in those domains, in life sciences and electronics, typically not in materials. That drives selection. But the overarching factor, as Floyd mentioned, IRR is the metric that matters. IRR comes down to risk, and nanotechnology investments are viewed as more risky, because to date, there is not a strong track record of exit. In an early period, right, you do not have the pot of gold at the end of the rainbow to go on. You have the rainbow itself, and you are going to assume there is something at the end. There are companies that have gone public, and done IPOs based on nanotechnology. They have not strongly identified themselves with nanotech. Inacon, which went out last year, was pitched as a life sciences company, for example.

Mr. AKIN. Thank you. I am sorry. I didn't mean to interrupt you.

Mr. O'CONNOR. Not a problem. Just to pick up on those thoughts. I think what is important to understand in this field is it is a longer cycle of commercialization than most. If you compare

nanotechnology to enterprise software, for example, it is not even comparable. It is a generally six to seven year cycle. In our case, on some of our commercialization of carbon nanotubes, it has been 15 years since early '90s, when we worked on this, and have roughly 150 patents. So, it is not something that happens overnight, and because of that, to answer your question, you get into the risk/reward scenario. Many VCs will be reluctant to get into it. I think, similar to what Mr. Nordan was saying, they may not know this area, and then, lastly, the whole concept of how do you exit? I think big companies will start looking at opportunities to potentially buy, but I don't think you have seen the IPO opportunities peak up as much, which is what is going to motivate a venture capitalist to get liquidity.

Mr. AKIN. Thank you very much. I guess I was looking at it partly from the numbers of how much. You had almost been cut in half in three years, how much venture capital would come in. I was trying to figure out what is driving some of that.

Mr. MURDOCK. Well, one point to raise on that, that number is rising this year. Obviously, the jury is still out, but in one week of this year, I believe the second week of March, \$66 million, equivalent to a third of the entire investment last year, went into three companies, Nantero, Nano-Tex, and Nanomix. The reason for this is that the bets that were placed in nanotechnology, the initial bets on startups, were made in 2001 and 2002, and a large number of bets that were relatively small bets at a time, right, were made. Many of those companies are gone now, but those that are surviving are now doing series C and D rounds, further on, which tend to be bigger rounds of investment than the As and Bs that start companies, and as a result, seeing companies like the ones that I have mentioned reach a later part of their lifecycle, they are attracting more funding. That is causing money that has been deployed to raise.

Our estimate, based on year to date, is probably we are looking at around \$350 million, similar to the levels of 2002 in the course of this year.

Mr. AKIN. Thank you, Chairman.

Chairman INGLIS. Mr. Sherman.

Mr. SHERMAN. Thank you, Mr. Chairman. Thanks for allowing me to participate in these hearings, even though, as a Member of the Full Committee, I am not a Member of this subcommittee.

It was interesting to hear the conversation about the industrial policy nature of what we are doing. I certainly agree with Mr. Kvamme that education is important. That wouldn't even be thought of as industrial policy. I know the comment is made well, China is using government money to subsidize this area. But keep in mind, let us say you are a Chinese entrepreneur. You get government money. You develop technology and then you decide to move to Switzerland for tax reasons, or you decide to move the jobs to India for cheaper labor. You would be sent to a reeducation camp. Now, that is one way to work industrial policy. I have yet to see how the U.S. . . . I mean education, obviously, the benefit is to the student, and the student is staying here. But I have yet to see how, short of reeducation camps, we could work out something with business entrepreneurs so that these benefits—these are high-

ly risky. It is not enough to say well, you invest a billion dollars, and look, you got 10,000 jobs. Because you are probably going to lose the billion dollars. You take that kind of risk and it hits, we should have a million jobs. Well, maybe not. Maybe it is a heads, we lose, tails, India wins or Switzerland wins, depending upon whether it is tax policy or cheap labor that drives things.

But I want to shift to something completely different, an issue that I have bored my colleagues on this committee with for a while. And that is the issue of enhancing human intelligence or developing artificial intelligence. Now, the National Nanotechnology Initiative has provided funds, and I am pleased to see that roughly four percent of that money is going towards looking at some of the concerns that people have about nanotechnology, health and environment, the toxicity of some nanoparticles. And that is all well and good, but the statute that we passed—and this is really a question as to whether any of us serving on an authorizing committee are just wasting our time—we know the appropriators are there every year to make sure that what they put in the statute is adhered to, and if not, then, you don't get the money for the next year. But there are those who think that those of us on authorizing committees are wasting our time. And the statute makes it clear that program activities are to include the potential, studying the potential use of nanotechnology, or the societal impacts of the potential use of nanotechnology in enhancing human intelligence, and developing artificial intelligence which exceeds human capacity. Later, in Section 5, those two matters are to be reported on back to Congress, and I wonder if Mr. Kvamme could tell us what the Administration is doing to carry out that part of the mandate of the bill.

Mr. KVAMME. Well, we tried to look at that, and because clearly, I think the general sense of our counsel, at least, was that we are not interested in, what was that famous book, *Prey*. You know, we are not interested in creating *Prey* animals. As a matter of fact, we were somewhat concerned that that—

Mr. SHERMAN. Yes, but the language I was able to get in the statute had nothing to do with *Prey*.

Mr. KVAMME. I understand that. Yeah.

Mr. SHERMAN. And—

Mr. KVAMME. The enhancing aspect is what I am getting at. As you will see in our report, we actually have an example, though, of things that hopefully will work better to enhance medical improvements, the screw that we talk about, for use in medical applications, that is more capable of becoming, or being like bone material, we think is an important contribution.

Mr. SHERMAN. If I can interrupt, because I have got one more question.

Mr. KVAMME. And maybe I am on the wrong track.

Mr. SHERMAN. Okay. The law says look at the societal impact—

Mr. KVAMME. Yeah.

Mr. SHERMAN.—of creating a half-human, half-enhanced technologically, chip-enhanced human brain, and a new species that may or may not consider itself human. Your response is we are developing a new screw that might be used in brain surgery.

Mr. KVAMME. Yeah.

Mr. SHERMAN. You are supposed to be looking at the societal problems, and you are looking at the technological capacity.

Mr. KVAMME. I guess it somewhat depends upon your definition of the word enhanced, okay?

Mr. SHERMAN. Well, but the statute is you are supposed to look at the societal problems—

Mr. KVAMME. Yeah.

Mr. SHERMAN.—caused by—

Mr. KVAMME. Yeah.

Mr. SHERMAN.—levels of intelligence beyond those of anyone in this room, with the possible exception of the chairman. And your response is we don't want to study the societal problems of doing it. We want to study how to do it.

Mr. KVAMME. I don't intend that to be my response.

Mr. SHERMAN. Okay. Then what has been funded to look at the potential societal and ethical implications of developing new, intelligent species?

Mr. KVAMME. Well, there are a number of studies that you are probably aware of that—and workshops in that particular area—one of them hasn't taken place yet. This summer, NSF has a workshop relative to that, a Center for Society, and in our study, we spent a full day on these types of matters. We did not see, and maybe we should have looked more deeply, we did not see that at this point in time, the societal applications, such as creating half-humans, to use your example, were going on. We are trying—

Mr. SHERMAN. Well, it is obvious it is not going on now.

Mr. KVAMME. Yeah.

Mr. SHERMAN. These sections were not designed to become operative only a year before it was technologically possible. For a species to decide whether it wants to go out of business should take more than a year, and you would think that a statute that says look at a societal problem should not mean well, don't do anything as long as the technology is more than a year away. Again, I think you are illustrating the point that those of us on our authorizing committees are not really in a position, in writing statutes, to actually affect Administration policy.

Mr. KVAMME. That is very possibly true.

Mr. SHERMAN. Then, you want our support, you want our authorization, you will ignore those provisions of the statute we put in—

Mr. KVAMME. No, no, no, no, no. I did not say that, sir.

Mr. SHERMAN. Well, you just said it is quite possibly true that those of us on authorizing committees, even when successful in getting our language into authorizing bills, will find that our provisions will be ignored, cannot be enforced through the appropriations process. That was the theory I started off with.

Mr. KVAMME. You are, unfortunately, putting words in my mouth that are not accurate, sir. The answer I am trying to give you is the following. I am saying that we have looked at that. We interpreted that statute in a way that apparently you do not interpret it. We ought to get clarification on your interpretation.

Mr. SHERMAN. Well, I wrote it, so maybe you should. Thank you.

Mr. KVAMME. Thank you.

Chairman INGLIS. Perhaps, if you want to add any comments on that in writing, we are happy to receive them.

Mr. SHERMAN. Fine.

Chairman INGLIS. We are going to go with another brief round of questions, three minutes. We are going to reset the clock for three minutes. We are actually going to stick to the clock this time. We were rather generous in the last time, but Ms. Hooley had some questions, and I had one quick question for Mr. Kvamme.

Very interesting discussion you were having about siting of sophisticated plants, and the incentives, relative to being in China, let us say, as opposed to being in the United States. If you were sitting up here, and trying to figure out, devise strategies on how to keep a manufacturing base here in the U.S., besides the education component, which we have discussed this morning, what else would you advise us to do, to make it so that that decision that you were talking about earlier would come the other way, and you would site one of those very sophisticated nanotechnology plants in the U.S., rather than in China?

Mr. KVAMME. Tax policy. It is, plain and simply, tax policy. And countries have to be competitive.

Chairman INGLIS. Income tax policy, or property tax policy?

Mr. KVAMME. No, corporate tax policy. It has to be competitive. Now, obviously, you can't compete with every little knick and knack that somebody is going to incentivize you with. Look at how our states compete with one other for siting. That plant that I mentioned was a fight between Texas and New York, frankly, as I understand the details. And I don't understand all the details on that.

So, just take that example, and move it to the corporate, to the country level, and I think I am hoping that in the new look at this, this revision of the tax policy, we will look at our global competitiveness at the corporate tax level. Because, frankly, we are not very competitive right now.

Now, by the way, on the positive side, why did those folks stay here, with \$3 billion? Why did they stay, at a \$1.3 billion cost? They were afraid of IP, that many of us mentioned. They were afraid it would leak, and so, they decided it was worth \$1.3 billion to stay here, for that reason. Well, that is not a bad reason, so, having a very strong IP protection thing, obviously, is a contributor.

Do you have to get equal to the other guys? I don't think so. I just think in most cases, \$1.3 billion out of \$3 billion makes a huge difference.

Chairman INGLIS. May I ask you a quick followup in 30 seconds?

Mr. O'CONNOR. Sure, if I may. From a Motorola perspective, most of our nanotechnology research and development, almost all of it, is here in the U.S., for a number of reasons. Close to facilities. And I think, really, the early applications for what we are seeing. I agree with Floyd on the concept of tax and just the incentives on trying to make sure we are incentivizing the proper type of development in this area, is for us a big issue.

Chairman INGLIS. Ms. Hooley.

Ms. HOOLEY. Thank you. I will also try to do a quick question. Thank you all for this wonderful discussion that you have given us today. Really appreciate your comments.

Dr. Cassady from Oregon State was here in May, and suggested the need for a DARPA-like organization to support nanotechnology development efforts that are closer to commercialization of products and processes. Opinion on that. Needed, not needed, okay?

Mr. O'CONNOR. I will start quickly with an answer.

Ms. HOOLEY. Okay.

Mr. O'CONNOR. Absolutely. It would be great. Some of our best innovations are via DARPA programs in our different areas. We have had great success with it. It is a good example of collaboration between government and the private industry, and a lot of good successes. And I think that would be a very worthwhile initiative.

Mr. KVAMME. I think the first step is to, as we have been referring, rapidly look to use nanotechnology within the existing agencies, the mission-driven programs like DARPA, the 6.2, 6.3 funding, et cetera, NIH—down the line, energy, et cetera. There may very well be a good role for looking across those, creating that pot of funds that looks for synergies that will not be realized in any one agency.

Ms. HOOLEY. Okay.

Mr. KVAMME. I would say that in the '70s and '80s, when I had a lot of involvement with DARPA, by the way, they were good at saying no.

Ms. HOOLEY. It is always nice to have someone who can do that.

Mr. KVAMME. Yeah. They would cut off projects. They are an example that is contrary to what I said before.

Ms. HOOLEY. Thank you.

Chairman INGLIS. That is all. I want to thank the witnesses. I appreciate you taking the time to testify. I thank the Members for participating, and the hearing is adjourned.

[Whereupon, at 11:55 a.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by E. Floyd Kvamme, Co-Chair, President's Council of Advisors on Science and Technology

Questions submitted by Representative Bart Gordon

Q1. The National Research Council of the National Academies of Science reviewed the National Nanotechnology Initiative (the NNI) and issued a report in 2002 (Small Wonders, Endless Frontiers) that included a number of recommendations. On the basis of the PCAST's more recent review of the NNI, could you comment on how the initiative has responded to the following NRC findings and recommendations:

Q1a. The NRC stressed that the NNI should provide "strong support for the development of an interdisciplinary culture" since nanoscale science and technology involves research at the convergence of many different disciplines. Did you find evidence that this is happening, and do you judge the mix of federal funding among awards for individuals, small groups, and large multi-disciplinary groups about right?

A1a. During its review of the NNI, PCAST met with representatives from the federal agencies that fund research under the NNI as well as with investigators at research institutions around the country. Based on these interactions, I and other PCAST members found that in fact the initiative recognizes the need for and strongly supports an interdisciplinary culture in order to promote advancement in nanoscience and nanotechnology. In addition, I tended to rely on my personal experience from the beginnings of the semiconductor industry when interdisciplinary activity was crucial to gaining a full understanding of all the different aspects of semiconductor research. Nanotechnology discovery will have similar traits. Your question, however, prompted me to look in greater depth into the means by which the NNI supports interdisciplinary research. They include:

- National Science Foundation (NSF) Nanoscale Science and Engineering Centers (NSECs) are required to involve multiple departments and multiple research institutions, as well as industry partners. Each NSEC is focused on a research problem that cannot be addressed practically by single investigators or small groups. Each NSEC typically receives \$2.5 million/year for five years, with an option for an additional five years. Currently active are 14 NSECs with participation by over 30 universities across the country. NSF will announce two new NSECs, one focused on societal issues and one on nanomanufacturing, before the end of this fiscal year.
- NSF Nanoscale Interdisciplinary Research Teams (NIRTs) involve researchers from 3–5 different disciplines within one or more research institutions. Each NIRT receives approximately \$1–\$2 million over four years. During the period from FY 2001 through FY 2005, over 250 NIRTs will be created. Additional information about both NSECs and NIRTs can be found on the NSF website at <http://www.nsf.gov/erssprgm/nano/>.
- The Department of Defense (DOD) Multidisciplinary University Research Initiatives (MURIs) are required to involve researchers from more than one discipline and often include multiple universities. Since FY 2001, the DOD has awarded nearly 40 MURI grants that are focused on nanotechnology research. Each MURI receives on average \$1 million/year for three years, with an optional two year extension.
- The Institute for Soldier Nanotechnologies (ISN) is an interdepartmental research center at MIT. Established in 2002 by a five-year, \$50 million contract from the U.S. Army, the ISN's research mission is to use nanotechnology to dramatically improve the survival of soldiers. The ISN brings together researchers from 10 different departments and supports more than 100 students and post-doctoral fellows.
- The DOD also supports interdisciplinary research at its in-house laboratories. One example is the Naval Research Laboratory Institute for Nanoscience, which supports multi-disciplinary research critical to the Navy's mission. The Institute is housed in a new state-of-the-art facility that provides the highly controlled environmental conditions and advanced equipment that is often required to perform nanoscale research.
- The Department of Energy (DOE) is constructing five Nanoscale Science Research Centers (NSRCs), co-located with major x-ray and neutron facilities at

Oak Ridge National Laboratory, Argonne National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories (jointly with Los Alamos National Laboratory), and Brookhaven National Laboratory. The NSRCs are under construction (the Center for Nanophase Materials Science at Oak Ridge National Laboratory is nearing completion and will begin accepting users in early FY 2006), and will be operated as user facilities for the broad research community with multi-disciplinary staff support. The facilities are designed specifically to bring together laboratory staff from a variety of fields and disciplines in order to better serve the user community and to foster interdisciplinary in-house research.

- In 2002, NASA established four University Research, Engineering and Technology Institutes (URETI) using a model that is similar to the NSF NSECs. Each NASA institute receives approximately \$3 million/year for five years, with a possible five year extension. All four institutes are implemented as consortia and all place a special emphasis on the union of biology and nanoscale technology in order to address NASA's particular requirements.
- More recently, the National Cancer Institute (NCI) of the National Institutes of Health (NIH) released its Cancer Nanotechnology Plan. The Plan includes programs and activities that are aimed specifically at bringing physical and computer scientists together with biologists and cancer researchers to develop nanotechnology for diagnosis, detection, and treatment of cancer. In addition to funding (beginning this fiscal year) interdisciplinary research teams at several Centers of Nanotechnology Cancer Excellence, NCI is creating, along with the National Institutes of Standard and Technology (NIST) and the Food and Drug Administration (FDA), the Nanotechnology Characterization Laboratory to develop critical capabilities for accelerating the transition of nanomaterials into clinical applications. More information about the Cancer Nanotechnology Plan can be found at <http://nano.cancer.gov>.

The above are just a few examples that illustrate the strength and breadth of the NNI's support for multi-disciplinary research. Moreover, the fact that agencies such as NSF are only able to fund a small percentage of the proposals for multi-disciplinary research that pass peer review indicates that an interdisciplinary "culture" has taken hold across the university research community. The role of the NNI in establishing such an interdisciplinary culture was specifically noted by the most recent outside review of NSF programs.

While a substantial portion of funding now goes to support large centers, the majority (~80 percent at NSF) of funding for nanoscale research is for individual investigators and small research teams. The NNI is cognizant of the need to maintain a balance among these funding mechanisms and the members of PCAST believe that the current mix is appropriate.

Q1b. The NRC criticized the initiative for having 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. Did your review find any evidence of stronger collaboration among the federal agencies, and are there examples of joint agency funding of large research projects?

A1b. PCAST found that the agencies are working in a coordinated fashion to advance the goals of the initiative. The Council noted in particular the following mechanisms and activities that are the result of joint planning or execution by the agencies.

- *Strategic Plan.* The National Science and Technology Council's Nanoscale Science, Engineering, and Technology (NSET) Subcommittee is the inter-agency body that coordinates and manages the NNI. As called for by the 21st Century Nanotechnology Research and Development Act (the Act), in December 2004 the NSET Subcommittee released an updated strategic plan identifying the goals and priorities of the initiative as a whole, and activities across the Federal Government by which to achieve those. The plan also describes the relationship between the participating agencies and the areas of research (program component areas) and the areas of application. Subgroups of the NSET Subcommittee have been formed to further coordinate work within the PCAs identified in the plan.
- *Annual Budget Supplement.* Also in accordance with the Act, the NSET Subcommittee prepared a supplement to the President's FY 2006 Budget, in which is outlined the activities taking place across the Federal Government. The report emphasizes in particular numerous interagency planning, coordi-

nation, and collaboration efforts that will support the FY 2006 budget priorities.

- *Regular Interagency Meetings.* The NSET Subcommittee meets monthly and many of the subgroups that have been formed to address specific areas that benefit from interagency attention also meet regularly. Current subgroups include:
 - Nanotechnology Environmental and Health Implications (NEHI) Working Group provides for exchange of information among agencies that support nanotechnology research and those with responsibilities for protecting health and the environment, worker safety, etc. The NEHI Working Group is working to identify and prioritize research needs to support science-based regulatory decision-making. Its members include representatives from the Environmental Protection Agency, Food and Drug Administration, National Institute for Occupational Safety and Health, National Institute of Environmental Health Sciences, Department of Agriculture, Department of Energy, Department of Defense, National Science Foundation, Occupational Safety and Health Administration, Consumer Product Safety Commission, and National Institute of Standards and Technology.
 - Nanotechnology Innovation and Liaison with Industry (NILI) Working Group promotes the development of nanotechnology for practical benefit and the transfer of NNI research results to commercial products and services for public use. Under the NILI Working Group are a number of liaison groups, also known as Consultative Boards for Advancing Nanotechnology (CBANs), made up of NSET Subcommittee members and representatives from particular industry sectors, including the semiconductor and chemical industries. The CBANs provide channels for exchange of information relating to the industries' nanotechnology needs and nanotechnology research results.
 - Global Issues in Nanotechnology (GIN) Working Group was formed relatively recently to track nanotechnology activities globally, to identify opportunities for international collaboration on nanotechnology R&D, and to provide joint agency input to balance U.S. Government commercial, diplomatic, and security interests within nanotechnology activities on the international level.
 - Nanotechnology Public Engagement Group (NPEG) is developing strategies for informing the public about nanotechnology and for getting input from the public regarding benefits of particular interest and risks of particular concern.
- Numerous examples of multi-agency support for nanotechnology R&D can be found in the FY 2006 NNI Supplement to the President's Budget. Those include:
 - A solicitation jointly funded by EPA, NSF, and NIOSH for research on environmental, health, and safety implications.
 - A cooperative effort to develop appropriate test methods among the National Cancer Institute (NCI), the National Institute for Standards (NIST) and Technology, and the Food and Drug Administration (FDA). These tests will be used by researchers at the NCI Nanotechnology Characterization Laboratory to test nanomaterials and nanostructures that have potential application for the detection, diagnosis, and treatment of cancer.

Even where programs are not funded jointly, where appropriate, agencies have combined program reviews in order to better share the results of individually funded projects in a particular area.

Q2. The NRC recommended the creation of programs for the invention and development of new instruments for nanoscience. Has this recommendation been addressed by the initiative, and in general, what level of priority did you find that the NNI assigns for this purpose?

A2. PCAST found that the NNI has recognized the need for increasingly powerful instrumentation for the visualization, measurement, and characterization of new nanomaterials and nanostructures. Specific activities include:

- Leading-edge nanotechnology measurement research, including development of instrumentation, is a core mission of NIST. With its Advanced Measure-

ment Laboratory now operational, the agency appears well-equipped to remain at the forefront in this area.

- NSF's program within Mathematical and Physical Sciences Division aimed specifically at instrumentation research and development.
- The National Nanotechnology Infrastructure Network (NNIN) is a 13-university network that supports both research on state-of-the-art tools and methods for synthesis and characterization and user facilities for the use of advanced instrumentation by the broader research community. In the first three quarters of FY 2005, over 7,500 users have benefited from NNIN facilities and expertise.
- DOE is funding the development of a next generation Transmission Electron Aberration-corrected Microscope (TEAM) to allow for even greater capabilities for visualization and characterization at the nanoscale. The TEAM project supports efforts at Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Frederick Seitz Materials Research Laboratory at the University of Illinois at Urbana-Champaign.

Q3. The PCAST report notes that an important role of the Federal Government in the development and commercialization of new technologies is an "early adopter" customer. How is the National Nanotechnology Initiative helping mission agencies to identify opportunities to develop and use products that arise from federal nanotechnology research under the NNI?

A3. As the PCAST report has just issued, there has not been time for the initiative to take steps to address this recommendation, however, PCAST will be interested in and will be monitoring how the initiative does so.

Q4. An important potential obstacle to commercialization of nanotechnology will be environmental, health, and safety concerns. Does PCAST find the current level of funding in the National Nanotechnology Initiative sufficient to address this set of issues adequately?

A4. As part of its review, PCAST convened a panel of experts in environmental, health, and safety (EHS) of nanomaterials from government, industry, and academia to assess this very question. The panel's input, along with information from the agencies led PCAST members to conclude that the initiative is giving appropriate priority and funding to this important area. Activities aimed at addressing EHS concerns, including research to understand the effects of nanomaterials, have increased within agencies such as the National Institute for Occupational Safety and Health (NIOSH), EPA (which shifted its emphasis for new grants from environmental applications to EHS implications), and the National Institute of Environmental Health Sciences (NIEHS). NSF has listed environmental implications as a specific focus area for its nanoscience research program since the initiative's inception in FY 2001.

PCAST noted that in addition to the funding that is being spent on R&D with a primary purpose of understanding EHS implications of nanomaterials (nearly \$40 million requested in the FY 2006 Budget), there is also underway considerable research on applications and in fields such as metrology that is related to and advances our understanding of EHS implications. Furthermore, agencies such as EPA and FDA are devoting substantial other resources other than research funds to assess risks and take appropriate steps to protect the public and the environment.

Agencies are also engaged in international activities related to EHS concerns, including standards development for accurate and reliable measurement and characterization of nanomaterials. These and other efforts to understand the EHS effects of nanotechnologies are the concern, and the responsibility, of all nations that are investing in the development of new nanomaterials. As our report notes, the United States invests approximately 25 percent of the total amount spent on nanotechnology R&D by all governments. PCAST hopes that other countries also are investing in EHS R&D and that all countries will cooperate to share the results of these efforts and, to this end, PCAST members have visited with their European counterparts to promote such open cooperation.

Finally, our report also indicated that the primary area for immediate concern is in the workplace, where nanomaterials are being used or manufactured and where the greatest likelihood for exposure exists. While the Federal Government will play a role in addressing occupational safety, industry must also provide leadership in the research and development of safe products and in maintaining a healthy workplace and a clean environment. Clearly, the sharing of research results among gov-

ernment and industry stakeholders will contribute to our collective knowledge and will benefit everyone.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

July 14, 2005

The Honorable Robert Inglis
United States House of Representatives
330 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Inglis:

I am writing in regard to a subject that was raised by Congressman Sherman during the recent hearing held by the House Science Committee Research Subcommittee on nanotechnology and U.S. competitiveness in this important emerging area. Mr. Sherman asked what steps are being taken under the Federal nanotechnology program known as the National Nanotechnology Initiative (NNI) to address certain provisions of the 21st Century Nanotechnology Research and Development Act (the Act) related to societal implications, in particular, the use of nanotechnology in the enhancement of human intelligence and in developing artificial intelligence. Those provisions, which Mr. Sherman added during the drafting of the legislation, call for the NNI to address the societal concerns mentioned above and for the National Academies to study the need for specific measures to ensure that such concerns are taken into account as part of the responsible development of nanotechnology.

I write because I feel that my exchange with Mr. Sherman was grounded partially in some misunderstandings on both sides. Following that exchange, you offered me the opportunity to provide subsequent comments and, after looking into the matter further, I would like to take advantage of your kind offer.

First, I would like to clarify the role of the President's Council of Advisors on Science and Technology (PCAST). PCAST is an independent advisory committee that serves solely to advise the President. While PCAST was designated as the Act's National Nanotechnology Advisory Panel (NNAP) in July 2004, it is not PCAST's role actually to implement the program requirements of the Act.

Rather, the statute provided the NNAP with specific direction to assess and review program progress. Upon being designated as the NNAP, PCAST members took very seriously these statutory mandates, and sought to respond to each specific tasking. The Act provided seven areas for the NNAP review to encompass, and I hope you agree that our report succeeded in fully complying with the Act's mandates.

As I indicated at the hearing, PCAST made a broad assessment of the NNI activities aimed at societal implications and recommended continued development of activities specifically focused on ethical, legal, and other societal aspects of nanotechnology. In that regard, I wanted to provide additional details of NNI activities related to such societal issues. Research in this area is being funded primarily by the National Science Foundation (NSF). A number of individual investigator grants have been awarded along with a Nanoscale Interdisciplinary Research Team award to researchers at the University of South Carolina. In addition, in direct response to the Act, NSF will be announcing within the next few weeks, a new network of centers and research programs on the topic of Nanotechnology and Society. Research across the network will include activities that address precisely the types of concerns raised by Mr. Sherman.

In addition to supporting research, the NNI has held two workshops on the topic of societal implications of nanotechnology, with the report of the most recent to be published shortly. You will find additional information on specific ongoing and planned activities under the Program Component Area on Societal Dimensions in the NNI Supplement to the President's FY 2006 Budget (see enclosure; the full report is available at www.nano.gov).

Finally, the National Academies is undertaking the first triennial review called for by the Act, which is to include an assessment of the need for standards, guidelines, or strategies for the responsible use of nanotechnology for applications such as human enhancement and artificial intelligence. The resulting report is expected to be released in early 2006.

Since the Act was signed in December 2003, the NNI has worked steadily to put into place research programs and other activities that will provide the framework under which societal concerns, including those raised by Mr. Sherman, will be addressed. Although the results are for the most part still forthcoming, clearly the provisions of the Act are being implemented, not ignored.

In its role as the National Nanotechnology Advisory Panel called for by the Act, PCAST looks forward to working with the agencies and Congress, especially the Science Committee and your subcommittee, to maintain a strong federal nanotechnology program. Thank you for your continued support for nanotechnology research.

Sincerely,

A handwritten signature in black ink, appearing to read "E. Floyd Kvamme". The signature is fluid and cursive, with a large initial "E" and "K".

E. Floyd Kvamme
Co-Chair

cc: The Honorable Darlene Hooley, U.S. House of Representatives
The Honorable Brad Sherman, U.S. House of Representatives

Attachment