Testimony of

Dr. Arden L. Bement, Jr., Director

National Science Foundation

Before the Research and Science Education Subcommittee

House Committee on Science and Technology

February 26, 2008

Chairman Baird, Ranking Member Ehlers and Members of the Subcommittee, I am pleased to present the National Science Foundation's budget for the 2009 fiscal year.

The National Science Foundation (NSF) proposes a fiscal year 2009 investment of $6.85 billion to advance the frontiers of research and education in science and engineering. Our budget request includes an increase of $789 million – or 13 percent – over the current fiscal year 2008 amount. This increase is necessary to put NSF back on the course that was charted by the President's American Competitiveness Initiative (ACI) and by the America COMPETES Act. This year's budget reflects the Administration's continued resolve to double overall funding for the ACI research agencies within 10 years.

An investment in the National Science Foundation is a direct investment in America's economic security. In fact, without a solid basic research foundation for our high-tech economy, no economic security is possible. Basic research underpins all of the technology that constitutes the lifeblood of today's global market. America's sustained economic prosperity is based in part on technological innovation resulting from previous fundamental science and engineering research. Innovation and technology are engines of the American economy, and advances in science and engineering provide the fuel.

While the United States still leads the world in its level of public and private R&D investment, our counterparts around the globe are well aware of the importance of funding R&D. A string of recent reports have found evidence that China is rapidly accruing global technological standing, including an OECD finding that China was set to become the second-highest investor in R&D among world nations in 2006, behind only the United States.[1,2,3] Over the last two decades, U.S. federal support of research in the physical sciences, mathematics, and engineering has been

[1] http://www.oecd.org/document/26/0,2340,en_2649_201185_37770522_1_1_1_1,00.html
[2] http://www.tpac.gatech.edu/hti2007/HTI2007ReportNSF_012208.pdf
[3] http://www.nsf.gov/statistics/nsf07319/pdf/nsf07319.pdf

stagnant when adjusted for inflation. As a percentage of GDP, the U.S. federal government has halved its investment in physical science and engineering research since 1970. Conversely, the Chinese government has more than doubled its GDP percentage expenditure in R&D since 1995.[3]

More than a dozen major studies have now concluded that a substantial increase in federal funding for basic scientific research is critical to ensure the preeminence of America's scientific and technological enterprise.

Just recently, Norman Augustine, former CEO of Lockheed Martin, released a follow-up to "The Gathering Storm" report entitled, "Is America Falling Off the Flat Earth?" His message is clear: "Unless substantial investments are made to the engine of innovation – basic scientific research and development – the current generation may be the first in our country's history to leave their children and grandchildren a lower sustained standard of living."[4]

For over fifty years, NSF has been a steward of the nation's science and engineering enterprise. NSF investments in discovery, learning, and innovation have been important to increasing America's economic strength, global competitiveness, national security and overall quality of life.

With its relatively small size, NSF delivers an enormous "bang for the buck" of federal government research and development (R&D) investment. NSF represents just four percent of the total federal budget for research and development, but accounts for a full fifty percent of non-life science basic research at academic institutions. NSF is the research funding lifeline for many fields and emerging interdisciplines at the frontiers of discovery. In fact, NSF is the only federal agency that supports all fields of basic science and engineering research.

NSF relies on a merit-based, competitive process that is critical to fostering the highest standards of excellence and accountability – standards that have been emulated at other funding agencies around the world.

NSF Supports American Innovation

The Foundation of Innovation

NSF often funds a technology in its earliest stages, frequently before other agencies or industries get involved. NSF funding was involved in the developmental phase of the technology used in magnetic resonance imaging (MRI) now ubiquitous in diagnostic medicine, the research that led to the development of silicon-coated glass used in flat panel displays, and the early investigations that led to green and blue light-emitting diodes used in cell phone displays and traffic lights. In 1952, Caltech professor Max Delbruck used one of NSF's first grants to invent molecular biology techniques that enabled one of his students, James Watson, to discover the molecular structure of DNA, and another Nobel laureate, David Baltimore, to unravel some of its mysteries.

In a more recent example, NSF CAREER awardee Jay Keasling, now the head of the NSF-sponsored Synthetic Biology Engineering Research Center at the University of California-

[4] Augustine, Norman. Is America Falling off the Flat Earth? National Academies Press

Berkeley, and two postdoctoral researchers from his lab founded Amyris, a company that is taking a revolutionary approach to chemical manufacturing by harnessing metabolic processes in microorganisms. Through genetic engineering, the researchers "program" the microbes to churn out useful chemicals, bypassing traditional, more expensive methods. Amyris has engineered a strain of yeast that can produce large quantities of artemisinic acid, a precursor to a compound found naturally in a plant that fights malaria but is currently in short supply. Amyris is also developing a fermentation process to deliver a biofuel gasoline substitute. NSF funding of the early research conducted at Berkeley enabled the discoveries that led to this promising new company, named 2007 "Business Leader of the Year" by *Scientific American* magazine.

NSF as an agency is itself the origin of transformative practices. One new NSF innovation is Research.gov, which is fulfilling our vision of a seamless interface between government funding agencies and the investigators we support. Research.gov is a one-stop shop, where researchers can go to manage their existing portfolio of grants and explore new opportunities. Research.gov is a tool that streamlines the process of applying for federal grants, making it easier and more cost-effective for the federal government to serve its customers.

Educating Tomorrow's Workforce

Beyond all of our efforts to advance the frontiers of knowledge and spur innovation, NSF is dedicated to educating and training the nation's skilled labor force. NSF plays a role in science, technology, engineering, and math (STEM) education at every educational level. Our contribution to education may ultimately be NSF's most profound and meaningful legacy.

The scientists, technologists, engineers, and mathematicians trained through NSF's integration of research and education transfer the latest scientific and engineering concepts from universities directly to the entrepreneurial sector when they enter the workforce.

Our graduate research fellowship (GRF) program has supported several notable technologists and scientists early in their professional training. Prominent economist Steven Levitt, co-author of the popular book *Freakonomics*, was an NSF GRF recipient from 1992 to 1994. Sergey Brin, co-founder of Google, was an NSF graduate research fellow in the mid-1990s when he began thinking about how to create an internet search engine. NSF's GRF program is as old as the foundation itself, and gives young scientists an early career charge, allowing them to go on to greatness. At least three Physics Nobel Prize winners are former NSF GRF recipients. We are extremely pleased with the proposed $29 million increase in the GRF program's funding for fiscal year 2009 which will enable us to fund an additional 700 promising young American investigators. A recent article from the National Bureau of Economic Research suggests that an increase in the number of GRF awards would help to supply an increased demand for talented individuals in the American science and technology workforce that will result from an increase in R&D spending.[5]

At some point in their careers, nearly 200 Nobel Prize-winning scientists received NSF funding for research in chemistry, physics, medicine, and economics. And scores of NSF-supported scientists shared a measure of the 2007 Nobel Peace Prize as members of the United Nation's Intergovernmental Panel on Climate Change.

[5] Freeman, Richard. The Market for Scientists and Engineers. *NBER Reporter*, 2007 No. 3, pp. 6-8.

To strengthen the educational institutions that benefit from NSF awards, the Directorate for Education and Human Resources (EHR) program, Innovation through Institutional Integration (I^3), challenges institutions to think strategically about the creative integration of NSF-funded awards. This provides the opportunity for NSF-grantees at particular institutions to cooperate and share a common vision for improved educational excellence at their institution.

America COMPETES Act Compliance

The America COMPETES Act contains several requirements for NSF. We are actively processing those directives and devising plans to implement them in a timely manner. In the FY 2009 request, activities that overlap with the President's American Competitiveness Initiative receive top priority. These priority areas do include strong links to other fields, and our request includes across-the-board increases for all directorates.

We are currently evaluating how to best ramp up the Robert Noyce Teacher Scholarship Program to bring an infusion of talented teachers into the nation's K-12 education system. To launch such a large-scale program, we will carefully evaluate what we need to do to maximize its societal impact and success. We will apply what we have learned from our other successful scholarship programs to ensure the program is administered in the best possible way.

We are also working how best to evaluate grant applicants' plans for training undergraduates, graduate students, and postdocs in responsible and ethical conduct of research. A number of our programs including our Centers and the Integrative Graduate Education and Research Traineeship (IGERT) program already contain ethics components. We will add a new certification requirement for institutions, which will require the institution to have a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research for all undergraduates, graduate students, and postdocs participating in the NSF-funded research project.

Open access to research results is an essential component of a strong and healthy scientific enterprise. We currently make available the citations of NSF-funded research on both the NSF website and on Research.gov. To further the goal of disseminating the results of NSF-funded research, we will develop revised reporting guidelines for NSF principle investigators (PIs). These guidelines will enable the PIs to summarize the key accomplishments of their NSF-funded work, including scientific findings, student training, and professional development activities. This information will be made available on the NSF website.

2009 Budget Request Highlights

At NSF, we understand that new discoveries are the main driving force behind societal progress. As the nation's premier funding agency for basic research, our mission is to advance the frontiers of knowledge, where high-risk, high-reward research can lay the foundation for revolutionary technologies and tackle complex societal problems. The NSF budget for 2009 reflects this vital agenda, and I'm pleased to present it to you today.

Let me begin with the big picture. As noted earlier, the President is requesting $6.85 billion for the NSF in FY 2009. That's an increase of almost $789 million, or 13 percent above the current 2008 appropriated amount. While it seems like a large increase, this level is necessary to fulfill the President's vision for physical science and basic research set forth in the American Competitiveness Initiative. The FY 2009 request is squarely in line with the goal of doubling of ACI research agency budgets over 10 years. This increased investment will reinforce NSF's leadership in basic science and engineering and allow us to preserve America's preeminence in the global technology economy.

In this year's proposed budget, funding levels increase for every major NSF appropriations account. Research and Related Activities investments increase by 16 percent, and our Education and Human Resources account is increased by 8.9 percent. We need rapid progress in these areas to stimulate the discoveries in research we need to maintain our standing in the global marketplace, and to keep our students engaged and ready to perform in the global workforce. Our budget includes increases for every Directorate and Office within NSF.

Here are highlights of some of the key investments we are emphasizing in our 2009 budget.

Cyber-enabled Discovery and Innovation
Cyber-Enabled Discovery and Innovation (CDI) is expected to create revolutionary science and engineering research results using "computational thinking" – thinking that encompasses all possible computational concepts, methods, models, algorithms, and tools. Computational thinking is relevant to all fields of science, engineering and education, and promises to have a profound impact on our nation's ability to generate and apply new knowledge. We expect CDI research to produce paradigm shifts in our understanding of a wide range of science and engineering phenomena, and we anticipate socio-technical innovations to create new wealth and enhance the national quality of life. By investing in CDI, NSF continues its leadership in enabling the United States to preserve its role as the world leader in information technology.
Requested Funding Level: $100 million

Science and Engineering Beyond Moore's Law
"Moore's Law" refers to the empirical observation made in 1965 by Intel co-founder Gordon Moore that the speed of computer processing based on semiconductor integrated circuits doubles about every 18 months. With current silicon technology, we expect to reach the physical and conceptual limits of Moore's Law within 20 years. If we are ever to solve the computational challenges inherent in today's great scientific questions, we must find a way to take computing power and communications beyond Moore's Law. To get there, we'll need entirely new scientific, engineering, and conceptual frameworks. Fundamental research across many disciplines will be called upon to deliver the new hardware, architectures, algorithms, and software of the computers of tomorrow.
Requested Funding Level**:** $20 million

Adaptive Systems Technology
Recent progress in probing the secrets of biological systems has been explosive. We are only just beginning to see the application of these new and transformational discoveries to the development of engineered systems, especially at the interface between human and machines. We call our new interdisciplinary endeavor – research at the convergence of human and mechanical systems – Adaptive Systems Technology (AST). New applications and technologies

resulting from AST have already demonstrated substantial economic potential. Artificial retinas and cochlea, electronic language translators, and smart hand-held electronics are just a handful of the products that have already come to market at the human-machine interface. NSF's broad portfolio encompasses the diverse research areas involved in this new interdisciplinary effort. Biologists uncover nature's progression from simple to complex nervous systems; physicists and chemists explain the fundamental processes underlying complex neural organization and communication pathways; mathematicians, computer scientists and cognitive scientists explore how systems compute; learning and behavioral scientists provide insights into how organisms learn and adapt to their environment; while engineers allow the design, analysis and construction of systems that mimic living nervous system networks. By working together, these scientists and engineers can benefit from the knowledge and experience of experts in other fields, developing new concepts through collaboration and idea-sharing.
Requested Funding Level: $15 million

Dynamics of Water Processes in the Environment
This activity will build upon NSF's considerable track record on fundamental water research, while utilizing our unique ability to cross disciplinary boundaries to bring together the separate communities of researchers working on the varying aspects of water science. Water is fundamental to every economic activity in the country, and yet, we do not have a full understanding of the effects of human interventions and changing environmental conditions on the availability and quality of fresh water. The economic driving forces for understanding water processes are compelling: droughts alone cause average damages of $6 to $8 billion dollars annual in the United States. Understanding water dynamics is also essential to understanding climate and environmental change. NSF's investment in Dynamics of Water Processes in the Environment will enhance our ability to understand complex freshwater systems at regional and local levels, taking advantage of advanced observation networks, cyberinfrastructure, and integrated databases.
Requested Funding Level**:** $10 million

National Nanotechnology Initiative
NSF leads the U.S. nanotechnology research effort, and we remain strongly committed to supporting this vital emerging industry. Our goal is to support fundamental research and catalyze synergistic science and engineering research and education in emerging areas of nanoscale science and technology. We are also committed to research directed at the environmental, health, and safety impacts of nanotechnology. Novel materials, devices, and systems – with their building blocks designed on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to control and manipulate matter at this scale, science, engineering, and technology are realizing revolutionary advances in areas such as individualized pharmaceuticals, new drug delivery systems, more resilient materials and fabrics, catalysts for industry, and order-of-magnitude faster computer chips.
Requested Funding Level: $397 million

Climate Change Science Program
Scientists predict that the climate of the earth is changing rapidly, and we have much to learn about how climate affects human activities, how human activities affect climate, and what we can do to protect human life and health in the face of disruptive climate events. The Climate Change Science Program (CCSP) was established in 2002 in response to the challenge of

understanding climate and climate variability. Science-based knowledge is absolutely essential to our ability to predict the changes that are likely to take place, and devise informed plans to mitigate the negative impacts of climate change on humanity. The CCSP engages thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and development of products for decision-makers. Consistent with the FY 2009 Interagency Implementation Priorities memo, NSF provides support for the broad range of fundamental research activities that form a sound basis for other mission-oriented agencies in the CCSP, and the nation at large.

Building on our agency's particular strengths, NSF encourages interdisciplinary activities and focuses particularly on Earth system processes and the consequences of change. Our priorities include the management of enormous amount of data necessary for accurate global change modeling and research, the refinement and improvement of computational models, and the development of new, innovative earth observing instruments and platforms.
Requested Funding Level: $221 million

International Science and Engineering
International collaboration is essential to the health of the nation's research enterprise. The importance of international partnership continues to increase as globalization "shrinks" our world. Consequently, our funding request for the Office of International Science and Engineering is increased by nearly 15 percent to $47.4 million. A major focus in our budget is the Partnerships for International Research and Education (PIRE) program, which increases by $3.0 million to $15.0 million. This program funds innovative, international collaborative research projects that link U.S. institutions and researchers at all career levels with premier international collaborators to work at the most promising frontiers of new knowledge.

Broadening Participation
NSF remains a leader in efforts to broaden participation in science and engineering, so that America's science and engineering enterprise is as diverse as the nation from which it draws its workforce. Our 2009 request for the Experimental Program to Stimulate Competitive Research (EPSCoR) program increases to $113.5 million. We are also increasing our request for several programs designed to reach out to underrepresented groups, including Alliances for Graduate Education and Professoriate (AGEP), the Historically Black Colleges and Universities-Undergraduate Program (HBCU-UP), the Louis Stokes Alliances for Minority Participation (LSAMP), and Centers of Research Excellence in Science and Technology (CREST).

Enhancing Opportunities for Beginning Researchers (CAREER)
The 2009 request provides an increase of approximately $14 million for funding of the CAREER program. This increase will allow us to award some 34 more CAREER awards than in FY 2008. CAREER awards support exceptionally promising college and university junior faculty who are committed to the integration of research and education. Our experience with previous CAREER awardees has proven that these faculty become the research leaders of their respective fields, and this program is vital to fostering the success of emerging science and technology leaders.
Requested Funding Level: $182 million

Stewardship
NSF's Stewardship goal, to support excellence in science and engineering research and education through a capable and responsive organization, remains a priority in the 2009 budget, with a 13 percent increase to $404.3 million. Our request increases the NSF workforce by 50 staff to enable us to manage our growing and increasingly complex workload. Investments in information technology (IT) increase by 32 percent to $82.0 million, with an emphasis on increasing the efficiency, productivity, and transparency of NSF's business processes. In this request, NSF's IT portfolio is realigned to tie funding for mission-related activities more directly to NSF's programs.
Requested Funding Level: $404 million

Major Research Equipment and Facilities Construction (MREFC) account
NSF will continue to support a portfolio of ongoing projects in the Major Research Equipment and Facilities Construction account (MREFC), including the Atacama Large Millimeter Array, Ice Cube, and Advanced LIGO.

The Foundation continues to be committed to the Alaska Regional Research Vessel (ARRV), the National Ecological Observatory Network (NEON), and the Ocean Observatories Initiative (OOI). However, in keeping with new NSF policies, Administration and Congressional mandates, and guidance from the National Science Board, NSF has adopted more stringent budget and schedule controls to improve our stewardship of taxpayer dollars. We are postponing requests for additional funding for those projects until they have undergone a final design review, completed a risk management plan, and developed a rigorous baseline budget, including carefully considered contingencies.

NSF's MREFC portfolio includes late-stage design-phase funding for the proposed Advanced Technology Solar Telescope (ATST), which if carried into the construction phase would be the first large U.S. solar telescope built in the past 30 years. ATST would reveal critical information needed to explore crucial mysteries such as: What are the mechanisms responsible for solar flares, coronal mass ejections and space weather, with their associated impact on satellites, communications networks, and power grids? What are the processes that cause solar variability and its impact on the Earth's climate and evolution? The ATST project is managed by the National Solar Observatory, which administers the world's leading collection of solar telescopes.
Requested Funding Level: $2.5 million

Concluding Remarks

Mr. Chairman, I've touched on just a handful of programs found in NSF's diverse and vibrant portfolio. NSF's research and education activities support the nation's innovation enterprise. America's present and future strength, prosperity and global preeminence depend directly on fundamental research. This is not merely rhetoric; the scientific and economic record of the past 30 years is proof that an investment in R&D is an investment in a secure future.

NSF may not be the largest agency that funds science and engineering research, but our size serves to keep us nimble. Our portfolio is continually evolving as we identify and pursue new research at the frontiers of knowledge. An essential part of our mission is to constantly re-think

old categories and traditional perspectives. This ability is more important than ever, as conventional boundaries constantly shift and disappear – boundaries between nations, between disciplines, between science and engineering, and between what is basic and what is applied. NSF, with its mandate to support all fields of science and engineering, is uniquely positioned to meet the needs of researchers exploring human knowledge at these interfaces, whether we're organizing interdisciplinary conferences, enabling cyber-sharing of data and information, or encouraging new collaborations and partnerships across disciplinary and national borders. No other government agency comes close to our flexibility in STEM education and basic research.

In today's high-tech economy, the supply of new jobs is inextricably linked to the health of the nation's innovation endeavor. NSF is involved in all aspects of innovation; NSF not only funds the discoveries that directly become the innovations of tomorrow, we also fund discoveries that lead to still more discoveries that lead to the innovations of tomorrow, and, perhaps most critically, we train the technologists who dream up the discoveries that lead to the discoveries and innovations of tomorrow.

Industry increasingly relies on government support for high-risk, high-reward basic research. If we fail to provide adequate support of the technological sector now, we may well reduce our own economic security. It is no accident that our country's most productive and competitive industries are those that benefited the most from sustained federal investments in R&D – including computers and communications, semiconductors, biotechnology, and aerospace.

As we look to the century ahead of us, we face the reality that the other nations in this world are eager to create jobs and robust economies for their citizens. In this context, "globalization" is shorthand for a complex, permanent, and challenging environment that calls for sustainable, long-term responses, not just short-term fixes. Regardless of our action or inaction as a nation, the world is full of highly motivated and increasingly skilled workers who are working hard to improve their economic standing and well-being. We can either innovate, and keep our economic prosperity, or stagnate, and suffer the consequences of inaction.

Despite some of the more pessimistic forecasts of some observers, I believe that America can continue to be on the leading edge of ideas and research. Through strong federal leadership, we can maintain the standing of our businesses and universities. We must not only maintain our position, we must actively seek to increase our strengths: leadership in fundamental discovery, including high-risk, high-reward transformational research, state-of-the-art facilities and infrastructure, and a world-class S&E workforce. With a firm commitment to these fundamental building blocks of our high-tech economy, we can solidify America's role as the world leader in innovation.

Mr. Chairman and members of the Committee, I hope that this brief overview has given you a taste of just how very important the National Science Foundation and its activities are to the future prosperity of the United States. I look forward to working with you in months ahead, and I am happy to answer any questions you may have.