House Committee on Science and Technology
Subcommittee on Research and Science Education

Hearing on National Science Foundation Reauthorization: Part II

Written Testimony Submitted
by

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On behalf of
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Good afternoon. My name is Jeffrey Welser and I am on assignment from the IBM Corporation to serve as the Director of the Nanoelectronics Research Initiative (NRI). I am testifying today on behalf of the NRI; the IBM Corporation; the Semiconductor Industry Association; and the Semiconductor Research Corporation.

The Nanoelectronics Research Initiative (NRI) is a research consortium that supports university basic research in novel computing devices, to enable the semiconductor industry to continue technology advances beyond the limits of the CMOS[1] technology

[1] Complementary Metal Oxide Semiconductor

that we have been using for the past four to five decades. The NRI leverages industry, university, and both U. S. state and federal government funds, to support research at universities that will establish the U.S. as the world leader in the nanoelectronics revolution. Fundamental breakthroughs in physical sciences and engineering resulting from NRI leadership will ensure that the U.S. remains a world leader in high-technology.

At IBM, we strive to lead in the creation, development and manufacture of the industry's most advanced information technologies, including computer systems, software, networking systems, storage devices and microelectronics. We translate these advanced technologies into value for our customers through our professional solutions and services businesses worldwide, which account for nearly three quarters of our annual revenues.

The Semiconductor Industry Association (SIA) has represented America's semiconductor industry since 1977. The U.S. semiconductor industry has 46 percent of the $248 billion world semiconductor market. The semiconductor industry employs 232,000 people across the U.S., directly contributes $60 billion to U.S. GDP and is one of America's largest export sectors.

The Semiconductor Research Corporation is a world class university research management consortium that seeks to solve the technical challenges facing the semiconductor industry and to develop technical talent for its member companies. SRC manages several semiconductor research programs including the NRI. Since its founding 25 years ago, the SRC has managed through its core program $854 million in research funds supporting 5,586 students and 1,244 faculty at 218 universities resulting in 31,865 technical documents, and 270 patents.

Executive Summary

- The semiconductor industry strongly supports doubling the NSF research budget as part of our complete set of competitiveness recommendations. These recommendations include increased availability of green cards and H-1Bs visas through immigration reform; increased numbers of science, technology, engineering and math graduates and improved K-12, undergraduate and graduate math/science education; enactment of a permanent and enhanced R&D credit; and increased awareness of the impact of foreign tax incentives.

- The National Science Foundation's (NSF) support for research, development, and math and science education is a vital component of America's science and technology enterprise. NSF's activities under gird the nation's innovation capacity, promote long-term economic growth, and enhance international competitiveness of the United States.

- The semiconductor industry supports significant funding increases for NSF as proposed in the House Democratsô Innovation Agenda and the Presidentõs American Competitiveness Initiative. The Semiconductor Industry Association (SIA) also has endorsed H.R. 363, The Sowing the Seeds Through Science and Engineering Research Act, that was reported out of the full Science and Technology Committee on March 8, 2007.

- SIA believes strongly that NSFõs education programs need to be expanded and monetarily supported, and SIA also has endorsed H.R. 362, The 10,000 Teachers, 10 Million Minds Science and Math Scholarship Act. Continued robust NSF activities in the areas highlighted in the bill are vital for the future competitiveness of the United States.

- Semiconductor technology advances have been credited with driving the increased productivity that the U.S. economy has enjoyed since the mid-1990õs. The government sector has also benefited from faster and cheaper computing ï receiving $152 billion of ñfreeò computing cumulatively as a result of technology improvements and resulting price declines in the last ten years.

- One way in which NSF contributes directly to U.S. competitiveness is by funding basic research in nanotechnology jointly with industry. As we approach the fundamental limits of the current technology which has driven the high tech industry, the country whose companies are first to market in the subsequent technology transition will likely lead the coming nanoelectronics era the way the U.S. has led for half a century in microelectronics.

- The Nanoelectronics Research Initiative (NRI) leverages industry, university and government resources (both state and federal) to fund university research that will keep America at the forefront of the nanoelectronics revolution. NRI currently works largely through three regional university centers headquartered in California, Texas, and New York.

- The partnership between NSF and industry in NRI results in a more productive research program because it brings together the technical expertise of industrial research managers and university scientists. Moreover, by jointly funding research with industry, NSF can focus basic research efforts on scientific questions that have maximum potential economic impact. It is a classic win-win situation.

- To strengthen these partnerships and nanoelectronics research overall, we recommend giving NSF the flexibility to participate in industry consortia, funding basic science research at universities. We also recommend NSF continue to support centers, such as the Nanoscale Science and Engineering Centers (NSECs), and group awards, such as the Nanoscale Interdisciplinary Research Teams (NIRTs) and Nanoscale Exploratory Research (NER) awards, as very effective vehicles for pursuing research topics of national interest.

NSF funding should be significantly increased

Let me state at the outset that the semiconductor industry strongly supports doubling the NSF research budget, as envisioned in the House Democratic Innovation Agenda, and the 2006 American Competitiveness Initiative. The industry's support for increased research funding is part of our complete set of competitiveness recommendations which include increased availability of green cards and H-1Bs visas through immigration reform; increased numbers of science, technology, engineering and math graduates and improved K-12, undergraduate and graduate math/science education; enactment of a permanent and enhanced R&D credit; and increased awareness of the impact of foreign tax incentives.

Federal funding of basic research, and in particular, funding in nanoelectronics research, is vital to America's future economic growth and global competitiveness. Simply put, as we approach the fundamental limits of the current technology which has driven the high tech industry, the country whose companies are first to market in the subsequent technology transition will likely lead the coming nanoelectronics era the way the U.S. has led for half a century in microelectronics, and NSF can play a critical role in ensuring that America earns this leadership position.

Today I would like to share our thoughts on the critical need to continue semiconductor technology advances, the Nanoelectronics Research Initiative (NRI) as an example of NSF collaboration with industry on fundamental university research, the importance of research in services as example of another industry where collaboration with NSF is highly valued, and the vital role NSF plays in promoting math and science education.

To continue semiconductor technology advances, we must find a new switch

Semiconductors are the enabling technology for computers, communications, and other electronics products that in turn have enabled everything from internet commerce to sequencing the human genome.

Better, faster, and cheaper chips are driving increased productivity and creating more jobs throughout the economy. For over three decades the industry has followed Moore's Law, which states that the number of transistors on a chip doubles about every eighteen months. The transistor is the basic building block within the semiconductor chip and can be thought of as an electronic switch or as a device to retain one bit (a one or a zero) in memory. The transistor is composed of a series of precisely etched and deposited layers of materials, and with as many as two billion transistors integrated on a single silicon chip, modern computer chips are some of the most complex products manufactured on the planet.

Today the cost of making one million transistors is one penny.

The phenomenal advances in technology may slow drastically as semiconductor technologists have concluded that we will soon be reaching the fundamental limits of CMOS technology, the process that has been the basis of innovation for the semiconductor industry for the past 30 years. By introducing new materials into the basic CMOS structure and devising new CMOS structures and interconnects, further improvements in CMOS can continue for the next ten to fifteen years, at which time CMOS begins to reach its physical (layers only a few atoms thick) and power dissipation limits. For the U.S. economy to benefit from continued information technology productivity improvements, there will need to be a “new logic switch” to replace the current CMOS-based transistor.

There are a number of candidates for the new switch, including devices based on spintronics (changing a particle’s spin) and molecular electronics (changing a molecule’s shape). Scientists must address many challenges in many different basic research fields (chemistry, physics, engineering) in the search for the new switch, including measuring the dimensions, shapes, and electrical characteristics of individual molecules; manipulating and measuring the spin of individual electrons; fabricating whole new classes of materials with unique electronic properties, and then characterizing their fundamental physical behavior and their long-term reliability; inducing novel chemical compounds to self-assemble into the precise structures needed by the new devices and architectures; and finally finding ways to interconnect the devices and integrate them into our technology infrastructure in a cost-effective manner that will enable us to continue the historical cost and performance trends for information technology.

Industry Research Consortia

Much of the early progress of the semiconductor industry derived from technology developed in large, corporate research and development facilities, such as Bell Laboratories. In the early 1980s, industry leaders, such as Bob Noyce of Intel and Erich Bloch of IBM, perceived a decline in the output of such corporate research facilities and a need to bolster underlying technology as a means to keep the U.S. semiconductor industry globally-competitive.

To this end, the SIA’s Board of Directors established the Semiconductor Research Corporation (SRC), a non-profit consortium of companies representative of the full spectrum of the semiconductor industry. Erich Bloch of IBM was the first Chairman of the SRC and later became a Director of the National Science Foundation.

In its current form, the SRC provides research management and administrative services on behalf of the companies that participate in three semiconductor research consortia: the Global Research Collaboration (GRC), the Focus Center Research Program (FCRP) and the Nanoelectronics Research Initiative (NRI).

Global Research Collaboration Program

The Global Research Collaboration program is the core research program of the SRC. Its purpose is to: (i) sponsor university research in order to expand the number of students and the capability of universities engaged in semiconductor-related research; and (ii) generate basic research results that are relevant and available to the entire industry.

The approach of the GRC is to fund, on a competitive basis, project proposals from individual university faculty, assisted by students, in targeted areas of semiconductor research. Since 1982, the GRC has funded approximately $850 million of university research projects.

Focus Center Research Program

In 1997, the Defense Department and the U.S. semiconductor industry launched the FCRP -- a jointly funded program to support a new type of university research in semiconductor technology. By focusing on mid- to long-term technology challenges of greatest interest to the Defense Department and the semiconductor industry, the FCRP seeks to marshal university efforts into integrated and sustained centers of research.

Oversight of the FCRP is through a governing council which includes industry participants and officials from the Defense Advanced Research Projects Agency (DARPA). It currently operates on approximately $20 million in Defense Department annual funding managed through DARPA, coupled with $20 million of industry funds. FCRP contracts directly with the lead university at each center conducting the research.

Current FCRP funding supports select research projects at five university clusters involving 38 universities, 200 research professors and 400 graduate students. The five university centers receive three-year contracts as a result of a joint Defense Department-industry solicitation and award for breakthrough research proposals.

Nanoelectronics Research Initiative

As the laws of physics narrow the potential for the kind of scaling that has historically characterized the semiconductor industry, attention has turned to the development of a new logic switch as a means to continue the progress depicted by Moore's Law. To take on the daunting task of identifying and demonstrating the commercial feasibility of a new logic switch, the SIA launched, under the SRC umbrella, the Nanoelectronics Research Initiative.

The NRI is an industry-university-government partnership to find a new switch

The NRI pulls together semiconductor companies, 25 universities in 13 states, state governments, and the NSF. The industry contribution through the NRI is about $5 million per year. This is in addition to about $60 million that the semiconductor industry is investing in universities through research consortia, with millions more invested directly by individual companies.

The research activity is organized within three NRI university centers that were established in 2006, plus NRI and NSF supplemental co-funding of nanoelectronics projects at 10 existing NSF university centers. The three NRI university centers are virtual centers, grouped largely by geography, and while all of the centers are working on research aimed at finding a new logic switch, the focus of the programs at each center has its own specific character:

The Western Institute of Nanoelectronics (WIN) is headquartered at the UCLA and includes the UC Berkeley, UC Santa Barbara, and Stanford University. WIN focuses solely on spintronics and related phenomena, extending from material, devices, and device-device interaction all the way to circuits and architectures. In addition to its NRI funding, this center receives additional direct support from Intel and the California's UC Discovery program.

The Institute for Nanoelectronics Discovery and Exploration (INDEX) is headquartered at the State University of New York-Albany (SUNY-Albany) and includes the Georgia Institute of Technology, Harvard University, the Massachusetts Institute of Technology, Purdue University, Rensselaer Polytechnic Institute and Yale University. INDEX focuses on the development of nanomaterial systems; atomic-scale fabrication technologies; predictive modeling protocols for devices, subsystems and systems; power dissipation management designs; and realistic architectural integration schemes for realizing novel magnetic and molecular quantum devices. INDEX also receives additional direct support from IBM and New York State.

The South West Academy for Nanoelectronics (SWAN) is headquartered at the University of Texas – Austin and includes UT-Dallas, Texas A&M, Rice, Notre Dame, Arizona State and the University of Maryland. SWAN focuses on a variety of new devices, including spin-based switches, nanowires, nano-magnets, and devices which use electron wave or phase interference. In addition, work is being done on modeling; novel interconnects, such as plasmonics; and nano-metrology techniques. In addition to its NRI funding, SWAN receives additional support from Texas Instruments and the Texas Emerging Technology Fund.

In addition to these centers, NRI and NSF co-fund supplemental grants for NRI-related research at existing NSF nanoscience centers (Nanoscale Science and Engineering Centers (NSECs), Materials Research Science and Engineering Centers (MRSECs), and the Network for Computational Nanotechnology (NCN)). We are currently supporting 12 projects at 10 NSF centers, which range from advanced computer simulation of spin-based devices to measurements of non-equilibrium coherent transport in single-layer graphene sheets to directed self-assembly of quantum dot and wire structures for novel devices. The goal in making this joint investment with NSF is not only to complement the work going on in the NRI centers, but also to leverage the work going in the NSF centers, with the NRI program gaining from the knowledge being created in the NSF center as a whole and the NSF centers gaining from the industry involvement through NRI. We see the NSF centers as a very valuable resource for pursuing nanoelectronics research requiring the integration of multiple science and engineering disciplines, and strongly support NSFõs continued investment in the centers and multi-year, group awards.

Collaborative research is a classic win-win situation

The U.S. semiconductor industry is investing in basic university research because it recognizes that the country whose companies are first to market will likely lead the coming nanoelectronics era the way the U.S. has led for half a century in microelectronics. Investment in universities not only results in the science and engineering breakthroughs needed to continue the rapid progress in semiconductor technology, but also increases the number of students with advanced degrees in the appropriate areas to work in the industry, increasing our competitiveness in the long-term.

Industry recognizes that the tight collaboration of industry-university-government involvement will be crucial to the success of this large research endeavor. Due to the magnitude of the scientific challenges ahead, and the large diversity of scientific disciplines required, NSF involvement in the effort to find a new switch is absolutely critical. The House Appropriations Committee recognized this fact when it singled out the NSFõs work with the NRI as well as its Silicon Nanoelectronics and Beyond program in its committee report and encouraged such work to be continued.[2]

The partnership between universities, industry, and the National Science Foundation in NRI results in a more productive research program because it brings together the technical expertise of industrial research managers and university scientists. In creating the NRI university centers, the NRIõs Technical Program Group (TPG), which has members from all NRI member companies, released an open call for proposals to all US universities, to identify the most promising technical ideas to pursue. From these proposals, the three university centers were created, and the technical project plans are continually managed and evaluated by a joint team of professors and the TPG. In addition, industry researchers work on-site at some of the universities, to further insure a close, on-going connection between academia and industry.

The NRI has also partnered with the NSF to fund work at existing NSF centers. Again the proposals are chosen from an open call to the NSF centers, with technical review by both the NSF and the NRI TPG, and the NRI stays closely linked to the work through industrial liaison teams assigned to interact with each specific project.

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[2] ñThe Committee commends NSF for its Silicon Nanoelectronics and Beyond program and its partnership with the Nanoelectronics Research Initiative, which involves the sponsorship of research in the areas of information' technology and electronics. The Committee encourages NSF to continue its support for such research in Fiscal year 2007. ñ House Report 109-118 - Science, State, Justice, Commerce, And Related Agencies Appropriations Bill, Fiscal Year 2006.

In addition to the direct co-funding of research at the NSF centers, the NRI has welcomed input from the government on our overall program, and would like to see these partnerships increase going forward. NSF, DARPA, and NIST already attend the NRI's Governing Council meetings which provide executive oversight to the program, and we would like to expand these partnerships in the future to allow more joint funding and technical management of the NRI work at the university centers

As the research begins to come to fruition, prior industry involvement will facilitate technology transfer. Rapid commercialization of academic research is in the interests of universities and government funding agencies as well as industry, as it directly contribute to American competitiveness. The NRI is building on 25 years of experience by its parent, the SRC, in managing university research, in partnership with industry and the government.

Salient Features of Semiconductor Research Consortia

The GRC, FCRP and NRI have proven themselves to be highly durable and successful models for engaging universities in research. These consortia's relationship to universities is quite standard: it is generally defined by sponsored research contracts or, in some cases, grants. What is unique is the structure of the consortia themselves. These structures call for a sharing of effort and risk, benefits and costs. They have a number of salient features:

- Consortia provide multi-year support for research, faculty and students; industry participants must make a two- to three-year financial commitment and shoulder the risks inherent in such a commitment.

- Research areas are derived from the International Technology Roadmap for Semiconductors (ITRS) and have wide potential applications from personal consumer, defense, telecommunications and computing applications.

- Research is generic in nature, long-term in content and pre-competitive for industry.

- Intellectual property (IP) derived from research is available to participants on an equal, non-exclusive basis.

- Participants proceed as partners and in accordance with consensus, with no single participant able to dominate.

The combination of these features results in a consortium structure that enables participants to contribute to a broad research agenda, leverage their funding and extract what they can use. In contrast to the colloquial meaning of the term "partnership" as any form of joint activity, the consortia structures establish a partnership through a coming together of participants to share equally or proportionately in a common activity.

Overlap of Semiconductor Research Consortia with NSF's Mission

At the same time, the semiconductor industry's consortia operate in a manner that is wholly compatible with and complementary to the NSF mission.

- Both provide substantial support to university faculty and students.
- Both proceed in response to university proposals focused on basic scientific research.
- Both distribute funds based on merit review and competition.
- Both allow universities to manage and conduct the research themselves; neither industry consortia nor NSF undertake research.
- Both are dedicated to seeing the research put to use.

There are, of course, some significant differences between the approach of semiconductor industry consortia and NSF. Consortia research has been more focused and targeted to industry needs. Consortia bring more industry input and perspective to both the solicitation and award of university research proposals. Finally, because of industry involvement, the path to commercialization is more direct and widespread for universities dealing with semiconductor industry consortia.

Yet, none of these differences conflict with the primary NSF mission. On the contrary, they provide additional means that NSF could exploit and leverage in pursuing its mission.

Cooperation of Semiconductor Research Consortia with NSF

Over the years, semiconductor industry consortia have utilized three primary avenues of cooperation with NSF. First, the consortia have funded a few individual university centers such as the NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing at the University of Arizona. The centers were solicited and awarded separately by SRC and NSF, but were based on a single statement of work and coordinated oversight.

Second, the SRC has entered into a Memorandum of Understanding (MOU) with NSF which provides for specific and voluntary interaction between industry and NSF in nanotechnology. The principal elements of the agreement are:

- SRC is to provide input to NSF for possible use in certain NSF solicitations.
- SRC is to provide a contact list of suggested industry expert reviewers who agree to serve on proposal selection panels if requested to do so by NSF Program Managers.

- SRC agrees to review the selected awards, maintain contact with recipients and offer the opportunity for voluntary participation in the SRC technology transfer processes.

To date, over $20 million in annual research conducted under the auspices of the NSF program has been subject to SRC involvement along the lines outlined above.

Third, as mentioned above, NRI has coordinated with NSF Nanotechnology Centers on supplemental solicitations. Industry has endorsed certain university proposals and made charitable contributions in support of NSF supplemental grants.

The three means of active cooperation between NSF and semiconductor industry consortia have been productive and well-received by universities. However, the cooperation has been largely informal, with NSF and industry consortia proceeding separately in accordance with their own rules and procedures.

Building on the NSF-industry NRI partnership

As is clear from the discussion above, the semiconductor industry has a long history of working with the NSF and other government agencies to support basic research and has built strong and effective partnerships. As the House Science Committee undertakes the reauthorization of the NSF, it should consider how it might provide NSF with more flexibility to work with industry in support of university research, and in particular, areas of multidisciplinary research.

By participating in these consortia, NSF could exploit a new research avenue to enhance the value of its efforts. But maximizing the value of the consortia structure implies more than merely issuing grants or cooperative agreements. It requires NSF to join in the consortia. NSFõs participation can improve the operation of the consortia and increase the value of the research results coming out of universities. By becoming a participant in NRI, for example, NSF would gain a new and powerful dimension for its work in nanoelectronics.

For it to participate fully with semiconductor industry consortia, however, NSF needs more flexibility and scope for innovation than its enabling legislation currently allows. While a grantor-grantee role or a contractor-supplier role are appropriate for engaging universities, they are not well-suited to engage with industry consortia, at least if NSF seeks to participate directly with these consortia. As a participant in semiconductor industry consortia, NSF would have an equal status and would be able to share the risks, costs and benefits of the research, like any other participant.

In order for NSF to fully engage with consortia that sponsor university research, new authority would be most helpful. DARPA, for example, has participated in the Focus Center Research Program through the so-called õother agreementsö authority (10 USC 2371), which dispenses with many of the contractual requirements and overhead of the Federal Procurement Regulations. In FCRP, industry and government money is pooled, and decisions to fund university programs are approved through a merit-based process by a governing council that includes both industry and Defense Department representatives. Providing NSF access to this authority or similar authority could open the door to greater collaboration among industry, NSF and universities. This could leverage the funds going to universities, orient university research in more productive directions and enhance the prospects for commercialization of research results.

In short, NSF could benefit from statutory authority to expand beyond its current charter, with tools to enable participation in industry consortia, giving NSF the maximum flexibility to determine the most appropriate way to achieve the research objectives.

Increases in NSF nanoelectronics research funding have tremendous public benefits.

Given the importance of maintaining technology leadership, the semiconductor industry supports increased research funding at the NSF, particularly in the area of nanoelectronics. The Administration's budget proposes $390 million for nanotechnology for 2008, a 4.6 percent increase over the $373 million for 2007. This is $86 million below the $476 million authorized for nanotechnology at NSF under the 21st Century Nanotechnology Research and Development Act passed in 2003, and should be increased.

Research investments to continue Moore's Law have immense benefits to the U.S. economy. Harvard economist Dale Jorgenson has noted, "The economics of Information Technology begins with the precipitous and continuing fall in semiconductor prices." Professor Jorgenson attributed the rapid adoption of IT in the U.S. for driving substantial economic growth in the U.S. gross domestic product since 1995, concluding, "Since 1995, Information Technology industries have accounted for 25 percent of overall economic growth, while making up only 3 percent of the GDP. As a group, these industries contribute more to economy-wide productivity growth than all other industries combined."[3]

To see the impact of the productivity gains on a single sector, it is instructive to consider the benefits the government (federal, state, and local) receives as a consumer of semiconductors. The Department of Commerce's Bureau of Economic Analysis has data indicating that the government sector of the economy purchased $6.8 billion of computers in 2005, but that they would have had to spend $34 billion for that same amount of computing power if they had to pay 1997 prices. The cumulative benefit from technology improvements and resulting price declines from 1997 to 2006 is $152 billion of "free" computing. In this tight budget year, it is important to remember that the federal investments made to support basic research are not only beneficial to the overall

[3] Dale W. Jorgenson, "Moore's Law and the Emergence of the New Economy" in "2020 is Closer than You Think", 2005 SIA annual report.

U.S. economy, but they also allow the government itself to do more with less as a result of falling computing costs.

Increased funding needed for services-related education programs and multidisciplinary research

Another critical area where the National Science Foundation is leading among federal agencies is in its support for multidisciplinary research and education in the emerging field of services science. Importantly, Chairman Baird and Ranking Member Ehlers referenced this NSF role in their remarks at the March 20 subcommittee hearing on NSFõs reauthorization.

Services make up about 80 percent of the U.S. economy, while employing approximately the same percentage of the U.S. labor force. As a country, we need to invest in the skills needed for 21st century jobs -- jobs that almost certainly will be dominated by the services market. High-value services jobs require skills, beyond simple programming or systems administration. They require the ability to integrate scientific, management, engineering and other disciplines like law, economics or operations research with the people aspect of business. This talent is needed not only by the technology sector but also by every sector employing and utilizing services, including banking, health care, retail, education, government and manufacturing. In short, more skilled professionals are needed to design and implement modern service architectures that drive productivity and create new value for all types of clients, whether they are public or private sector.

The National Science Foundation is blazing new ground in this area by partnering with industry and U.S. universities to support services science research and curricula development at the undergraduate and graduate levels. This important but little-known work within the Engineering and the Education and Human Resource directorates supports the high value-added, service-sector jobs that will differentiate the U.S. economy from those of our competitors around the world. Increasing NSFõs overall budget for research and education supports the nascent but incredibly important work they are doing in this field ï research and curricula development that to our knowledge is not being done by any other federal agency. Establishing the academic discipline of services science will help keep the U.S. workforce competitive and prepared to lead in a rapidly evolving global economy.

NSF education programs need to be increased

A number of studies have documented the nationõs crisis in math and science education. For example, the National Academiesô ñRising Above The Gathering Stormò report stated, ñFewer than one-third of US 4th grade and 8th grade students performed at or above a level called ñproficientò in mathematics; ñproficiencyò was considered the ability to exhibit competence with challenging subject matterò and recommended that the nation ñincrease Americaøs talent pool by vastly improving Kï12 science and mathematics educationò through steps including ñannually recruiting 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds, and strengthen the skills of 250,000 teachers through training and education programs at summer institutes and other programs.[4]

The NSF has an important role to play in expanding the talent pipeline by supporting programs and adequate appropriations to improve science, technology, engineering and mathematics (STEM) education and attract students to these disciplines at the K-12, undergraduate, and graduate levels. For example, the additional funding for the Robert Noyce Scholarship program, named after the co-inventor of the integrated circuit, provides scholarships for undergraduates majoring in STEM disciplines in return for a commitment to teach K-12 math or science. Other NSF education programs include the Math and Science Education Partnership program to prepare undergraduates for K-12 math and science teaching, and the STEM Talent Expansion Program (STEP), which awards competitive grants to institutions of higher education to boost the number of undergraduate majors in STEM disciplines. The semiconductor industry fully supports Chairman Gordonøs "10,000 Teachers, 10 Million Minds" Science and Math Scholarship Act (H.R. 362) that increases the authorizations for many of these programs.

Another important NSF program is the Advanced Technology Education program which helps community colleges with workforce development. The ATE program was instrumental in establishing the Maricopa Advanced Technology Education Center, an organization that helps community colleges around the country train technicians to work in semiconductor factories. Community colleges are also an important source of transfer students to four year colleges and universities, and thus should have a key role in any strategy to increase nationøs engineering talent.[5] We would encourage the House Science Committee to draw greater attention to this opportunity as part of the reauthorization process.

It should be noted that the semiconductor industry is doing its part to support education. SIAøs member survey shows that in the period 2001 to 2005 the combined spending by member companies on K-12 programs is over $250 Million with more than 370,000 teachers and 7 Million students reached by the programs these companies support.

Summary

The US government, and the NSF in particular, is an important player in the strategy to maintain U.S. technology leadership, at a time when we face fundamental limits on the

[4] National Academies; ñRising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future,ò October 2005; available at: http://www.nationalacademies.org/morenews/20051012.html

[5] See National Academy of Engineering, ñEnhancing the Community College Pathway to Engineering Careersò (2005) at http://www.nap.edu/catalog/11438.html

base devices which have been driving the information technology economy for the past half-century.

Discovering, developing, and implementing a new logic device is a daunting task, but not unprecedented. In the 1940's, when vacuum tubes were the state-of-the-art but were reaching their own limits, the US government realized there was a critical need for finding smaller, faster, lighter devices for its radar and guided missile systems. A concerted effort began between the government, universities, and industry labs to find alternatives, with approximately $5 billion of federal money (in today's dollars) being invested in semiconductor research specifically to answer this challenge. The result was not only technology to enable advanced weapon systems, but the birth of the solid-state transistor, which became the foundation of the information technology revolution that drives our economy to this day. And it was only the combination of the best basic science research coming out of the universities; the practical guidance and mission-focus of the industrial labs; the significant research funding from the government; and the collaborative interaction of all of these groups that enabled both the scientific breakthroughs and the reduction to practical implementation necessary for such a project to succeed.

We now face a similar transition, as we look for a switch to replace our current CMOS transistor. We are just beginning this research, and the initial efforts are small in comparison to what was done in the 40's and 50's. It is critical we grow these efforts significantly over the next several years, and finding flexible models for industry and government to interact will be critical to success. To this end, increasing research funding at NSF particularly in the Nanoelectronics area, and expanding NSF's collaboration with the semiconductor industry is absolutely essential if we are to continue our accelerated economic growth and productivity and if America is to lead in the coming nanoelectronics era.