U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

HEARING CHARTER

Science and Technology in a 21st Century Global Economy

Tuesday, March 13, 2007
1:00 p.m. - 3:30 p.m.
2318 Rayburn House Office Building

1. Purpose

On Tuesday, March 13, 2007, the House Committee on Science and Technology will hold a hearing to receive testimony on the critical importance of science and technology to our nation's prosperity. The focus is on the provisions of the National Academy of Sciences report entitled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* that. Witnesses have been asked to address the reasoning behind the education and research recommendations enunciated in that report.

2. Witnesses

Mr. Norman R. Augustine, Retired Chairman and CEO of the Lockheed Martin Corporation. Mr. Augustine chaired the National Academy of Sciences (NAS) committee that wrote the *Gathering Storm* report.

Mr. Harold McGraw, III, Chairman, President, and CEO of the McGraw Hill Companies. Mr. McGraw is the chairman of the Business Roundtable.

Dr. Robert Dynes, President of the University of California. Dr. Dynes is Professor of Physics and Materials Science and a member of the National Academy of Sciences.

Dr. Craig Barrett, Chairman and CEO of Intel Corporation. Dr. Barrett served on the NAS committee that wrote the *Gathering Storm* report.

Dr. Neal Lane, Malcolm Gillis University Professor at Rice University and Senior Fellow at the James Baker III Institute for Public Policy. Dr. Lane was the Director of the National Science Foundation from 1993 to 1998 and Director of the White House Office of Science and Technology Policy from 1998 to 2001.

Ms. Deborah Wince-Smith, President of the Council on Competitiveness. Ms. Wince-Smith has held numerous positions in government as an expert on innovation policy.

3. Overarching Questions

- Why is the promotion of science and technology so critical to America's prosperity? Where do we stand today, and where do we need to be in the future?

- What should be the federal government's role in advancing the science and technology agenda? What should be the top priorities in science education and research? Do H.R. 362 and H.R. 363 address the most critical needs?

4. Brief Overview

Henry Luce, publisher of Time Magazine, coined the term "the American century" in 1941 to describe his vision of the 20th century. Indeed, after World War II, the US economy grew substantially, and economists estimate that about half of US economic growth was the result of technological innovation. Indeed, during the 20th century, the United States became a world leader in science and technology education and research and in innovation, and economic indicators demonstrated that the United States offered a high standard of living to its citizens.

In the 1990's however, during a period in which the United States was known as the world's lone "superpower", a number of indicators suggested that US prosperity was diminishing. The United States trade surplus in high-technology products that was $54 billion in 1990 turned into a trade deficit of $50 billion in 2004. A number of iconic American companies moved assets, jobs, and ownership overseas. And American students performed poorly in several international assessments of math and science achievement.

In May of 2005, Senators Lamar Alexander and Jeff Bingaman asked the National Academy of Sciences (NAS) to conduct a study of "the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology." In June, Congressmen Sherwood Boehlert and Bart Gordon wrote to the NAS to endorse the Senate request for a study and to suggest some additional specific questions. The National Academy assembled a Committee on Prospering in the Global Economy of the 21st Century, and on October 12, 2005, that committee issued a report entitled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

That report, whose title we abbreviate to *Gathering Storm*, offered four recommendations:

- Recommendation A: Increase America's talent pool by vastly improving K-12 science and mathematics education.
- Recommendation B: Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.
- Recommendation C: Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest

students, scientists, and engineers from within the United States and throughout the world.

- Recommendation D: Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.

Along with each recommendation, the report spelled out several specific action items to pursue in order to implement the recommendation.

On October 20, 2005, the Committee on Science of the 109th Congress held a hearing, entitled "Science, Technology, and Global Economic Competitiveness". The witnesses at that hearing were Norm Augustine, retired Chairman and CEO of Lockheed Martin Corporation and chair of the NAS committee that wrote the *Gather Storm* report; Roy Vagelos, retired Chairman and CEO of Merck & Co. and member of the NAS committee that wrote the report; and William Wulf, President of the National Academy of Engineering. In their testimony, these witnesses promoted the recommendations of the report and argued that the action items were critical and urgent.

The *Gathering Storm* report quickly became influential in promoting a national agenda on innovation and competitiveness. In the 109th Congress, the House Committee on Science reported two pieces of legislation implementing a number of the *Gathering Storm* action items. The first of these bills was H.R. 5356, the Research for Competitiveness Act. The second was H.R. 5358, the Science and Mathematics Education for Competitiveness Act. Together, these bills addressed many of the action items related to Recommendations A and B. The bills were never brought to the floor of the House.

In the 110th Congress, Chairman Bart Gordon introduced three competitiveness bills, again attempting to implement the *Gathering Storm* recommendations that address science and technology. The first of these, H.R. 362, entitled "10,000 Teachers, 10,000,000 Minds Science and Math Scholarship Act", parallels in large part H.R. 5358 from the 109th Congress. The second of these, H.R. 363, entitled "Sowing the Seeds Through Science and Engineering Research Act", parallels in large part H.R. 4346 from the 109th Congress. (The third bill, H.R. 364, is to provide for an Advanced Research Projects Agency for Energy and is not the focus of the present hearing.)

On February 28, 2007, the Committee on Science and Technology marked up H.R. 363 and passed an amended version of the introduced bill. A summary of that bill, along with a summary of H.R. 362, appears below.

5. Specific Questions for the Witnesses

Each witness received a letter of invitation to testify at the hearing. In that letter, the witnesses were asked to address the overarching questions related to the hearing. In addition, each witness was asked to address an aspect of the hearing focus that relates to their realm of expertise.

Mr. Augustine was asked to describe the reasoning behind the priorities that resulted in the recommendations in *Gathering Storm* report. Dr. Barrett was asked the same question, and in addition was asked about his thoughts on what changes are needed in STEM education in order for the nation to meet the future workforce needs of industry.

Mr. McGraw and Ms. Wince-Smith were asked what changes are needed in STEM education in order to meet the future workforce needs of business and industry. The Business Roundtable and the Council on Competitiveness both represent broad coalitions of business interests.

Dr. Dynes was asked to describe the California Teach program: how the Cal Teach model came into being; what the challenges are to putting it in place; what we are learning from the program about recruiting and preparing science, math, and engineering college majors to become STEM teachers; and what factors are important for emulating similar programs on a national scale.

Dr. Lane was asked to comment on the appropriateness of the proposed role of NSF in administering the STEM education programs contained in H.R. 362. In particular, Dr. Lane was asked to address how these NSF programs interact with STEM education activities at the Department of Education.

6. The Provisions of the Bills

H.R. 362 — The "10,000 Teachers, 10 Million Minds" Science and Math Scholarships Act

The bill implements most of the K–12 science education recommendations of the *Gathering Storm* report. It establishes a teacher education program at the National Science Foundation (NSF) to encourage math, science and engineering faculty to work with education faculty to improve the education of science and math teachers and to provide scholarships to science, math and engineering students who commit to become science or math teachers at elementary and secondary schools; authorizes summer teacher training institutes at NSF and DOE to improve the content knowledge and pedagogical skills of in-service science and math teachers, including preparing them to teach Advanced Placement and International Baccalaureate courses in science and math; requires that NSF include support for master's degree programs for in-service science and mathematics teachers within the NSF Math and Science Partnerships; and authorizes funding for the NSF STEM Talent Expansion program and expands the program to include centers for improving undergraduate STEM education.

Sectional Summary of Bill

Section 1 is the Table of Contents**.**

Section 2 reports findings on the role of NSF in K–12 and undergraduate STEM education.

Section 3 spells out definitions used in the bill.

Title I – Science Scholarships

Section 101 is the short title of the bill.

Section 102 reports findings relating the bill to the NAS report recommendations.

Section 103 describes the policy objective of the bill — to increase by 10,000 annually the number of capable K-12 science and math teachers.

Section 104 amends the NSF Noyce Scholarship program, established by the NSF Authorization Act of 2002, to create incentives for colleges and universities to improve the training of STEM teachers and increases the size and duration of the scholarships provided for science, math, and engineering majors who pursue teaching credentials:

- Provides competitive awards to institutions of higher education (or consortia of such institutions) that (1) establish cross-department faculty teams (science, math and engineering faculty along with education faculty) to develop courses of instruction leading to baccalaureate degrees in fields of science, math and/or engineering and also preparing graduates to become certified or licensed to teach in a K-12 classroom, and (2) administer scholarships for students during their sophomore through senior years and summer internships during their freshman years.

- Requires early field teaching experiences for student teachers in the program under the supervision of highly experienced and effective teachers.

- Requires awardees to provide professional development and mentoring support to scholarship recipients, after matriculation.

- Sets scholarship amounts at the cost of attendance at particular institutions, not to exceed $10,000 per year, and provides up to 3 years of scholarship support for any individual.

- Requires scholarship recipients to commit to teaching for up to 6 years following graduation (the period of teaching commitment is based on the number of years of scholarship support), reduces the commitment by one year for individuals who teach at high-need schools, and converts the scholarships to loans if the teaching commitment is not met.

- Authorizes the NSF to accept donations from the private sector to help support scholarships and internships.

- Authorizes $70 million for NSF for FY 2008, $101 million for FY 2009, $133 million for FY 2010, $164 million for FY 2011, and $196 million for FY 2012.

<u>Title II – Mathematics and Science Education Improvement</u>

Section 201 amends the NSF Math and Science Education Partnerships program established by the NSF Authorization Act of 2002:

- Specifies that priority for awards under the program be given to applications that include teacher training activities as a main focus.

- Authorizes teacher training activities to prepare teachers to teach Advanced Placement and International Baccalaureate science or math courses and provides for mentoring by professional scientists, mathematicians and engineers.

- Authorizes the development of master's degree programs for in-service science and math teachers.

Section 202 addresses teacher institute programs at NSF and DOE:

- NSF is directed to establish a grant program to support summer or academic year teacher institutes and authorizes summer teacher institutes as a component of the NSF 21st Century program. Such summer institutes are required to include teacher training activities to prepare teachers to teach Advanced Placement and International Baccalaureate science or math courses.

- Authorizes $32 million for NSF for FY 2008, $35.2 million for FY 2009, and $38.7 million for FY 2010, $42.6 million for FY 2011, and $46.8 million for FY 2012.

- The following amounts are authorized for the existing Laboratory Science Teacher Professional Development program at DOE: $3 million for FY 2008, $8 million for FY 2009, and $10 million for each year FY 2010 through FY 2012.

Section 203 requires NSF to ensure that, under the Math and Science Partnership program, master's degree programs are developed and implemented for in-service math and science teachers, who attend on a part-time basis and who will be able to complete the degree requirements within two years. The programs have the following features:

- Provide stipends to defray the cost of attendance for teachers in the program.

- Allow for support for the development of the courses of instruction and related educational materials and equipment (offering of online learning is an option).

- Require the distribution of awards among institutions of different sizes and geographic locations.

Authorizes for this program $46 million for NSF for FY 2008, $50.6 million for FY 2009, $55.7 million for FY 2010, $61.2 million for FY 2011, and $67.3 million for FY 2012.

Section 204 establishes a national panel of experts to identify and collect K–12 science and mathematics teaching materials that have been demonstrated to be effective and to recommend the development of new materials in areas where effective materials do not exist; and directs NSF and the Department of Education to develop ways to disseminate effective materials and support efforts to develop new materials, in accordance with the recommendations of the national panel.

Section 205 amends the NSF STEM Talent Expansion program established under the NSF Authorization Act of 2002 to create centers for improvement of undergraduate education in STEM fields, including:

- Development of undergraduate curriculum and teaching methods and training for faculty and teaching assistants in effective pedagogical practices.

- Assessment of the effectiveness of the centers and dissemination of information about materials and methods developed.

Authorizes $44 million for NSF for the STEM Talent Expansion program for FY 2008, of which $4 million is available for centers; $55 million for FY 2009, of which $10 million is available for centers; and $60 million for each year of FY 2010 through FY 2012, of which $10 million is available in each year for centers.

H.R. 363 — Sowing the Seeds through Science and Engineering Research Act

The bill implements recommendations related to strengthening long-term basic research contained in the *Gathering Storm* report. It supports outstanding researchers in the early stages of their careers through grants at the National Science Foundation (NSF) and the Department of Energy (DOE) of $80,000 per year for 5 years; establishes a floor of 1.5% of research funding appropriated for NSF for an existing program supporting graduate students in multidisciplinary fields of national importance; establishes a presidential innovation award to stimulate scientific and engineering advances in the national interest; establishes a national coordination office to identify and prioritize research infrastructure needs at universities and national laboratories and to help guide the investments of new infrastructure funds authorized for NSF and DOE; authorizes NSF to support research on innovation; directs the National Institute of Standards and Technology (NIST) and DOE to report on efforts to recruit and retain early-career scientists and engineers; and expresses the sense of Congress that a balanced science program at the National Aeronautics and Space Administration (NASA) contributes significantly to innovation and competitiveness.

Sectional Summary of Bill

Section 1 is the short title of the bill.

Section 2 authorizes NSF to carry out a grant program for awards to scientists and engineers at the early stage of their careers in academia or in nonprofit research organizations. The NSF's existing Faculty Early Career Development (CAREER) program may be designated as the mechanism for awarding these grants. The awards will go to outstanding researchers at the beginning of their careers and are intended for individuals from a variety of types of institutions, including minority serving institutions. The grants provide 5 years of research funding support at a minimum of $80,000 per year per award.

NSF is required to designate at least 3.5% of funds appropriated for Research and Related Activities to the grant program for each of FY 2008 through FY 2012.

Section 3 authorizes DOE to carry out a grant program for awards to scientists and engineers at the early stage of their careers in academia or in nonprofit research organizations to conduct research in fields relevant to the mission of DOE. The awards will go to outstanding researchers at the beginning of their careers and are intended for individuals from a variety of types of institutions, including minority serving institutions. The grants provide 5 years of research funding support at a minimum of $80,000 per year per award, and priority shall go to proposals involving collaborations with researchers at DOE national laboratories. The bill authorizes to DOE $25 million for each year for FY 2008 through FY 2012.

Section 4 directs NSF to allocate at least 1.5% of the amounts appropriated for Research and Related Activities to the Integrative Graduate Education and Research Traineeship (IGERT) program, which provides support for graduate students in fields relevant to national needs. It requires NSF to coordinate with other agencies to expand the interdisciplinary nature of the IGERT program and authorizes NSF to accept funds from other agencies to carry out the program.

Section 5 establishes the Presidential Innovation Award presented periodically, on the basis of recommendations from the Director of the Office of Science and Technology Policy, to citizens or permanent residents of the U.S. who develop unique scientific or engineering ideas judged to stimulate scientific and engineering advances in the national interest, to illustrate the linkage between science and engineering and national needs, and to provide an example to excite the interest of students in science or engineering professions.

Section 6 establishes a National Coordination Office for Research Infrastructure under the Office of Science and Technology Policy to identify and prioritize deficiencies in research facilities and instrumentation in academic institutions and national laboratories and to make recommendations for use of funding authorized. The Office is directed to report to Congress annually at the time of the administration's budget proposal.

Section 7 authorizes NSF, in carrying out its research programs on science policy and the science of learning, to support research on the process of innovation and the teaching of inventiveness.

Section 8 directs NIST to transmit to the House Committee on Science and Technology and the Senate Committee on Commerce, Science, and Transportation, not later than 3 months following enactment of the bill, a report on efforts to recruit and retain early-career scientists and engineers at NIST.

Section 9 expresses the sense of Congress that a balanced and robust program in science, aeronautics, exploration, and human space flight at NASA contributes significantly to national innovation and competitiveness. It also directs the NASA administrator to participate fully in interagency efforts to promote innovation and economic competitiveness through scientific research and development.

Appendix A: Executive Summary of National Academy of Sciences Report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*

The United States takes deserved pride in the vitality of its economy, which forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities. That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Economic studies conducted before the information-technology revolution have shown that even then as much as 85% of measured growth in US income per capita is due to technological change.[1]

Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing.

CHARGE TO THE COMMITTEE

The National Academies was asked by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, with endorsement by Representatives Sherwood Boehlert and Bart Gordon of the House Committee on Science, to respond to the following questions:

> What are the top 10 actions, in priority order, that federal policy-makers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st Century? What strategy, with several concrete steps, could be used to implement each of those actions?

The National Academies created the Committee on Prospering in the Global Economy of the 21st Century to respond to this request. The charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen the quality of life in America—our prosperity, our health, and our security. The committee has been cautious in its analysis of information. However, the available information is only partly adequate for the committee's needs. In addition, the time allotted to develop the report (10 weeks from the time of the committee's meeting to report release) limited the ability of the committee to conduct a

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[1] For example, work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The big unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance", has been widely attributed to the effects of technological change.

thorough analysis. Even if unlimited time were available, definitive analyses on many issues are not possible given the uncertainties involved.

This report reflects the consensus views and judgment of the committee members. Although the committee includes leaders in academe, industry, and government—several current and former industry chief executive officers, university presidents, researchers (including three Nobel prize winners), and former presidential appointees—the array of topics and policies covered is so broad that it was not possible to assemble a committee of 20 members with direct expertise in each relevant area. Because of those limitations, the committee has relied heavily on the judgment of many experts in the study's focus groups, additional consultations via email and telephone with other experts, and an unusually large panel of reviewers. Although other solutions are undoubtedly possible, the committee believes that its recommendations, if implemented, will help the United States achieve prosperity in the 21st century.

FINDINGS

Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthening will benefit the world's economy— particularly in the creation of jobs in countries that are far less well-off than the United States. But we are worried about the future prosperity of the United States. Although many people assume that United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all.

This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of a low-wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return to investors.

RECOMMENDATIONS

The committee reviewed hundreds of detailed suggestions—including various calls for novel and untested mechanisms—from other committees, from its focus groups, and from its own members. The challenge is immense, and the actions needed to respond are immense as well.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans and responding to the nation's need for clean, affordable, and reliable energy. To address those challenges, the committee structured its ideas according to four basic recommendations that focus on the human, financial, and knowledge capital necessary for US prosperity.

The four recommendations focus on actions in K–12 education (*10,000 Teachers, 10 Million Minds*), research (*Sowing the Seeds*), higher education (*Best and Brightest*), and economic policy (*Incentives for Innovation*) that are set forth in the following sections. Also provided are a total of 20 implementation steps for reaching the goals set forth in the recommendations.

Some actions involve changes in the law. Others require financial support that would come from reallocation of existing funds or, if necessary, from new funds. Overall, the committee believes that the investments are modest relative to the magnitude of the return the nation can expect in the creation of new high-quality jobs and in responding to its energy needs.

10,000 TEACHERS, 10 MILLION MINDS IN K–12 SCIENCE AND MATHEMATICS EDUCATION

Recommendation A: *Increase America's talent pool by vastly improving K–12 science and mathematics education.*

Implementation Actions

The highest priority should be assigned to the following actions and programs. All should be subjected to continuing evaluation and refinement as they are implemented:

Action A-1: Annually recruit 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds. Attract 10,000 of America's brightest students to the teaching profession every year, each of whom can have an impact on 1,000 students over the life of their careers. The program would award competitive 4-year scholarships for students to obtain bachelor's degrees in the physical or life sciences, engineering, or mathematics with concurrent certification as K–12 science and mathematics teachers. The merit-based scholarships would provide up to $20,000 a year for 4 years for qualified educational expenses, including tuition and fees, and require a commitment to 5 years of service in public K–12 schools. A $10,000 annual bonus would go to participating teachers in underserved schools in inner cities and rural areas. To provide the highest-quality education for undergraduates who want to become teachers, it would be important to award matching grants, perhaps $1 million a year for up to 5 years, to as many as 100 universities and colleges to encourage them to establish integrated 4-year undergraduate programs leading to bachelor's degrees in science, engineering, or mathematics *with teacher certification*.

Action A-2: Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master's programs, and Advanced Placement and International Baccalaureate (AP and IB) training programs and thus inspires students every day. Use proven models to strengthen the skills (and compensation, which is based on education and skill level) of 250,000 *current* K–12 teachers:

- *Summer institutes*: Provide matching grants to state and regional 1- to 2-week summer institutes to upgrade as many as 50,000 practicing teachers each summer. The material covered would allow teachers to keep current with recent developments in science, mathematics, and technology and allow for the exchange of best teaching practices. The Merck Institute for Science Education is a model for this recommendation.
- *Science and mathematics master's programs*: Provide grants to universities to offer 50,000 current middle-school and high-school science, mathematics, and technology teachers

(with or without undergraduate science, mathematics, or engineering degrees) 2-year, part-time master's degree programs that focus on rigorous science and mathematics content and pedagogy. The model for this recommendation is the University of Pennsylvania Science Teachers Institute.

- *AP, IB, and pre-AP or pre-IB training*: Train an additional 70,000 AP or IB and 80,000 pre-AP or pre-IB instructors to teach advanced courses in mathematics and science. Assuming satisfactory performance, teachers may receive incentive payments of up to $2000 per year, as well as $100 for each student who passes an AP or IB exam in mathematics or science. There are two models for this program: the Advanced Placement Incentive Program and Laying the Foundation, a pre-AP program.
- *K–12 curriculum materials modeled on world-class standards*. Foster high-quality teaching with world-class curricula, standards, and assessments of student learning. Convene a national panel to collect, evaluate, and develop rigorous K–12 materials that would be available free of charge as a *voluntary* national curriculum. The model for this recommendation is the Project Lead the Way pre-engineering courseware.

Action A-3: Enlarge the pipeline by increasing the number of students who take AP and IB science and mathematics courses. Create opportunities and incentives for middle-school and high-school students to pursue advanced work in science and mathematics. By 2010, increase the number of students in AP and IB mathematics and science courses from 1.2 million to 4.5 million, and set a goal of tripling the number who pass those tests, to 700,000, by 2010. Student incentives for success would include 50% examination fee rebates and $100 mini-scholarships for each passing score on an AP or IB mathematics and science examination.

The committee proposes expansion of two additional approaches to improving K–12 science and mathematics education that are already in use:

- *Statewide specialty high schools*. Specialty secondary education can foster leaders in science, technology, and mathematics. Specialty schools immerse students in high-quality science, technology, and mathematics education; serve as a mechanism to test teaching materials; provide a training ground for K–12 teachers; and provide the resources and staff for summer programs that introduce students to science and mathematics.
- *Inquiry-based learning*. Summer internships and research opportunities provide especially valuable laboratory experience for both middle-school and high-school students.

SOWING THE SEEDS THROUGH SCIENCE AND ENGINEERING RESEARCH

Recommendation B: ***Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.***

Implementation Actions

Action B-1: Increase the federal investment in long-term basic research by 10% a year over the next 7 years, through reallocation of existing funds[2] or if necessary through the investment of new funds. Special attention should go to the physical sciences, engineering,

[2] The funds may come from anywhere in an agency, not just other research funds.

mathematics, and information sciences and to Department of Defense (DOD) basic-research funding. This special attention does not mean that there should be a disinvestment in such important fields as the life sciences (which have seen growth in recent years) or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to US prosperity. This investment should be evaluated regularly to realign the research portfolio—unsuccessful projects and venues of research should be replaced with emerging research projects and venues that have greater promise.

Action B-2: Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of our most outstanding *early-career* researchers. The grants would be made through existing federal research agencies—the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Energy (DOE), DOD, and the National Aeronautics and Space Administration—to underwrite new research opportunities at universities and government laboratories.

Action B-3: Institute a National Coordination Office for Research Infrastructure to manage a centralized research-infrastructure fund of $500 million per year over the next 5 years –through reallocation of existing funds or if necessary through the investment of new funds—to ensure that universities and government laboratories create and maintain the facilities and equipment needed for leading-edge scientific discovery and technological development. Universities and national laboratories would compete annually for these funds.

Action B-4: Allocate at least 8% of the budgets of federal research agencies to discretionary funding that would be managed by technical program managers in the agencies and be focused on catalyzing high-risk, high-payoff research.

Action B-5: Create in the Department of Energy (DOE) an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E).[3] The director of ARPA-E would report to the under secretary for science and would be charged with sponsoring specific research and development programs to meet the nation's long-term energy challenges. The new agency would support creative "out-of-the-box" transformational generic energy research that industry by itself cannot or will not support and in which risk may be high but success would provide dramatic benefits for the nation. This would accelerate the process by which knowledge obtained through research is transformed to create jobs and address environmental, energy, and security issues. ARPA-E would be based on the historically successful DARPA model and would be designed as a lean and agile organization with a great deal of independence that can start and stop targeted programs on the basis of performance. The agency would itself perform no research or transitional effort but would fund such work conducted by universities, startups, established firms, and others. Its staff would turn over about every 4 years. Although the agency would be focused on specific energy issues, it is expected that its work (like that of DARPA or NIH) will have important spin-off benefits, including aiding in the education of the next generation of

[3] One committee member, Lee Raymond, does not support this action item. He does not believe that ARPA-E is necessary as energy research is already well funded by the federal government, along with formidable funding of energy research by the private sector. Also, ARPA-E would put the federal government in the business of picking "winning energy technologies" —a role best left to the private sector.

researchers. Funding for ARPA-E would start at $300 million the first year and increase to $1 billion per year over 5-6 years, at which point the program's effectiveness would be evaluated.

Action B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest. Existing presidential awards address lifetime achievements or promising young scholars, but the proposed new awards would identify and recognize persons who develop unique scientific and engineering innovations in the national interest at the time they occur.

BEST AND BRIGHTEST IN SCIENCE AND ENGINEERING HIGHER EDUCATION

Recommendation C: Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.

Implementation Actions

Action C-1: Increase the number and proportion of US citizens who earn physical-sciences, life sciences, engineering, and mathematics bachelor's degrees by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens attending US institutions. The Undergraduate Scholar Awards in Science, Technology, Engineering, and Mathematics (USA-STEM) would be distributed to states on the basis of the size of their congressional delegations and awarded on the basis of national examinations. An award would provide up to $20,000 annually for tuition and fees.

Action C-2: Increase the number of US citizens pursuing graduate study in "areas of national need" by funding 5,000 new graduate fellowships each year. NSF should administer the program and draw on the advice of other federal research agencies to define national needs. The focus on national needs is important both to ensure an adequate supply of doctoral scientists and engineers and to ensure that there are appropriate employment opportunities for students once they receive their degrees. Portable fellowships would provide funds of up to $20,000 annually directly to students, who would choose where to pursue graduate studies instead of being required to follow faculty research grants.

Action C-3: Provide a federal tax credit to encourage employers to make continuing education available (either internally or though colleges and universities) to practicing scientists and engineers. These incentives would promote career-long learning to keep the workforce current in the face of rapidly evolving scientific and engineering discoveries and technological advances and would allow for retraining to meet new demands of the job market.

Action C-4: Continue to improve visa processing for international students and scholars to provide less complex procedures and continue to make improvements on such issues as visa categories and duration, travel for scientific meetings, the technology-alert list, reciprocity agreements, and changes in status.

Action C-5: Provide a 1-year automatic visa extension to international students who receive doctorates or the equivalent in science, technology, engineering, mathematics, or other fields of national need at qualified US institutions to remain in the United States to seek employment. If these students are offered jobs by United States-based employers and pass a security screening test, they should be provided automatic work permits and expedited residence status. If students are unable to obtain employment within 1 year, their visas would expire.

Action C-6: Institute a new skills-based, preferential immigration option. Doctoral-level education and science and engineering skills would substantially raise an applicant's chances and priority in obtaining US citizenship. In the interim, the number of H-1B[4] visas should be increased by 10,000, and the additional visas should be available for industry to hire science and engineering applicants with doctorates from US universities.

Action C-7: Reform the current system of "deemed exports".[5] The new system should provide international students and researchers engaged in fundamental research in the United States with access to information and research equipment in US industrial, academic, and national laboratories comparable with the access provided to US citizens and permanent residents in a similar status. It would, of course, exclude information and facilities restricted under national-security regulations. In addition, the effect of deemed-exports regulations on the education and fundamental research work of international students and scholars should be limited by removing all technology items (information and equipment) from the deemed-exports technology list that are available for purchase on the overseas open market from foreign or US companies or that have manuals that are available in the public domain, in libraries, over the Internet, or from manufacturers.

INCENTIVES FOR INNOVATION AND THE INVESTMENT ENVIRONMENT

Recommendation D: ***Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs that are based on innovation by modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.***

Implementation Actions

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[4] The H-1B is a nonimmigrant classification used by an alien who will be employed temporarily in a specialty occupation of distinguished merit and ability. A specialty occupation requires theoretical and practical application of a body of specialized knowledge and at least a bachelor's degree or its equivalent. For example, architecture, engineering, mathematics, physical sciences, social sciences, medicine and health, education, business specialties, accounting, law, theology, and the arts are specialty occupations. See http://uscis.gov/graphics/howdoi/h1b.htm

[5] The controls governed by the Export Administration Act and its implementing regulations extend to the transfer of technology. *Technology* includes "*specific information* necessary for the 'development,' 'production,' or 'use' of a product" [emphasis added]. Providing information that is subject to export controls—for example, about some kinds of computer hardware—to a foreign national within the United States may be "deemed" an export, and that transfer requires an export license. The primary responsibility for administering controls on deemed exports lies with the Department of Commerce, but other agencies have regulatory authority as well.

Action D-1: Enhance intellectual-property protection for the 21st century global economy to ensure that systems for protecting patents and other forms of intellectual property underlie the emerging knowledge economy but allow research to enhance innovation. The patent system requires reform of four specific kinds:

- Provide the Patent and Trademark Office sufficient resources to make intellectual-property protection more timely, predictable, and effective.
- Reconfigure the US patent system by switching to a "first-inventor-to-file" system and by instituting administrative review *after* a patent is granted. Those reforms would bring the US system into alignment with patent systems in Europe and Japan.
- Shield research uses of patented inventions from infringement liability. One recent court decision could jeopardize the long-assumed ability of academic researchers to use patented inventions for research.
- Change intellectual-property laws that act as barriers to innovation in specific industries, such as those related to data exclusivity (in pharmaceuticals) and those which increase the volume and unpredictability of litigation (especially in information-technology industries).

Action D-2: Enact a stronger research and development tax credit to encourage private investment in innovation. The current Research and Experimentation Tax Credit goes to companies that *increase* their research and development spending above a base amount calculated from their spending in prior years. Congress and the administration should make the credit permanent,[6] and it should be increased from 20% to 40% of the qualifying increase so that the US tax credit is competitive with that of other countries. The credit should be extended to companies that have consistently spent large amounts on research and development so that they will not be subject to the current *de facto* penalties for previously investing in research and development.

Action D-3: Provide tax incentives for United States-based innovation. Many policies and programs affect innovation and the nation's ability to profit from it. It was not possible for the committee to conduct an exhaustive examination, but alternatives to current economic policies should be examined and, if deemed beneficial to the United States, pursued. These alternatives could include changes in overall corporate tax rates, provision of incentives for the purchase of high-technology research and manufacturing equipment, treatment of capital gains, and incentives for long-term investments in innovation. The Council of Economic Advisers and the Congressional Budget Office should conduct a comprehensive analysis to examine how the United States compares with other nations as a location for innovation and related activities with a view to ensuring that the United States is one of the most attractive places in the world for long-term innovation-related investment. From a tax standpoint, that is not now the case.

Action D-4: Ensure ubiquitous broadband Internet access. Several nations are well ahead of the United States in providing broadband access for home, school, and business. That capability will do as much to drive innovation, the economy, and job creation in the 21st century as did access to the telephone, interstate highways, and air travel in the 20th century. Congress

[6] The current R&D tax credit expires in December 2005.

and the administration should take action—mainly in the regulatory arena and in spectrum management—to ensure widespread affordable broadband access in the near future.

CONCLUSION

The committee believes that its recommendations and the actions proposed to implement them merit serious consideration if we are to ensure that our nation continues to enjoy the jobs, security, and high standard of living that this and previous generations worked so hard to create. Although the committee was asked only to recommend actions that can be taken by the federal government, it is clear that related actions at the state and local levels are equally important for US prosperity, as are actions taken by each American family. The United States faces an enormous challenge because of the disadvantage it faces in labor cost. Science and technology provide the opportunity to overcome that disadvantage by creating scientists and engineers with the ability to create entire new industries — much as has been done in the past.

It is easy to be complacent about US competitiveness and pre-eminence in science and technology. We have led the world for decades, and we continue to do so in many research fields today. But the world is changing rapidly, and our advantages are no longer unique. Without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position. For the first time in generations, the nation's children could face poorer prospects than their parents and grandparents did. We owe our current prosperity, security, and good health to the investments of past generations, and we are obliged to renew those commitments in education, research, and innovation policies to ensure that the American people continue to benefit from the remarkable opportunities provided by the rapid development of the global economy and its not inconsiderable underpinning in science and technology.

SOME WORRISOME INDICATORS

- When asked in spring 2005 what is the most attractive place in the world in which to "lead a good life"[i], respondents in only one of the 16 countries polled (India) indicated the United States.
- For the cost of one chemist or one engineer in the United States, a company can hire about five chemists in China or 11 engineers in India. [ii]
- For the first time, the most capable high-energy particle accelerator on Earth will, beginning in 2007, reside outside the United States. [iii]
- The United States is today a net importer of *high-technology* products. Its share of global high-technology exports has fallen in the last 2 decades from 30% to 17%, and its trade balance in high-technology manufactured goods shifted from *plus* $33 billion in 1990 to a *negative* $24 billion in 2004. [iv]
- Chemical companies closed 70 facilities in the United States in 2004 and have tagged 40 more for shutdown. Of 120 chemical plants being built around the world with price tags of $1 billion or more, one is in the United States and 50 in China. [v]
- Fewer than one-third of US 4th grade and 8th grade students performed at or above a level called "proficient" in mathematics; "proficiency" was considered the ability to exhibit competence with challenging subject matter. Alarmingly, about one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform basic mathematical computations. [vi]
- US 12th graders recently performed below the international average for 21 countries on a test of general knowledge in mathematics and science. In addition, an advanced mathematics assessment was administered to US students who were taking or had taken precalculus, calculus, or Advanced Placement calculus and to students in 15 other countries who were taking or had taken advanced mathematics courses. Eleven nations outperformed the United States, and four countries had scores similar to the US scores. No nation scored significantly below the United States. [vii]
- In 1999, only 41% of US 8th grade students received instruction from a mathematics teacher who specialized in mathematics, considerably lower than the international average of 71%. [viii]
- In one recent period, low-wage employers, such as Wal-Mart (now the nation's largest employer) and McDonald's, created 44% of the new jobs, while high-wage employers created only 29% of the new jobs. [ix]
- In 2003, only three American companies ranked among the top 10 recipients of patents granted by the United States Patent and Trademark Office. [x]
- In Germany, 36% of undergraduates receive their degrees in science and engineering. In China, the figure is 59%, and in Japan 66%. In the United States, the corresponding figure is 32%. [xi]
- The United States is said to have 10.5 million illegal immigrants, but under the law the number of visas set aside for "highly qualified foreign workers" dropped to 65, 000 a year from its 195,000 peak. [xii]
- In 2004, China graduated over 600,000 engineers, India 350,000, and America about 70,000.[xiii]
- In 2001 (the most recent year for which data are available), US industry spent more on tort litigation than on R&D. [xiv]

NOTES for SOME WORRISOME INDICATORS:

i Interview asked nearly 17,000 people the question: “Supposed a young person who wanted to leave this country asked you to recommend where to go to lead a good life – what country would you recommend ?” Except for respondents in India, Poland, and Canada, no more than one-tenth of the people in the other nations said they would recommend the United States. Canada and Australia won the popularity contest. Pew Global Attitudes Project, July 23, 2005.

ii The Web site http://www.payscale.com/about.asp tracks and compares pay scales in many countries. Ron Hira, of Rochester Institute of Technology, calculates average salaries for engineers in the United States and India as $70,000 and $13,580, respectively.

iii CERN, http://public.web.cern.ch/Public/Welcome.html.

iv For 2004, the dollar value of high-technology imports was $560 billion; the value of high-technology exports was $511 billion. See Appendix Table 6-01 of National Science Board’s Science and Engineering Indicators 2004.

v "No Longer The Lab Of The World: U.S. chemical plants are closing in droves as production heads abroad", BusinessWeek (May 2, 2005).

vi National Center for Education Statistics, Trends in International Mathematics and Science Study, 2003, http://nces.ed.gov/timss.

vii Data are from National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. Chapter 1.

viii Data are from National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation. Chapter 1.

ix Roach, Steve. More Jobs, Worse Work. New York Times. July 22, 2004.

x US Patent and Trademark Office, Preliminary list of top patenting organizations. 2003, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/top03cos.htm.

xi Data are from National Science Board. 2004. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, VA: National Science Foundation, Appendix Table 2-33.

xii Colvin, Geoffrey. 2005. “America isn't ready”. Fortune Magazine, July 25. H-1B visas allow employers to have access to highly educated foreign professionals who have experience in specialized fields and who have at least a bachelor's degree or the equivalent. The cap does not apply to educational institutions. In November 2004, Congress created an exemption for 20,000 foreign nationals earning advanced degrees from US universities. See Immigration and Nationality Act Section 101(a)(15)(h)(1)(b).

xiii Geoffrey Colvin. 2005. “America isn't ready”. Fortune Magazine, July 25.

xiv US research and development spending in 2001 was $273.6 billion, of which industry performed $194 billion, and funded about $184 billion. (National Science Board Science and Engineering Indicators 2004). One estimate of tort litigation costs in the United States was $205 billion in 2001. (Leonard, Jeremy A. 2003. How Structural Costs Imposed on U.S. Manufacturers Harm Workers and Threaten Competitiveness. Prepared for the Manufacturing Institute of the National Association of Manufacturers. http://www.nam.org/s_nam/bin.asp?CID=216&DID=227525&DOC=FILE.PDF.