2005

SCIENCE, TECHNOLOGY, AND GLOBAL ECONOMIC COMPETITIVENESS

Sherwood L. Boehlert

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SCIENCE, TECHNOLOGY, AND GLOBAL ECONOMIC COMPETITIVENESS

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BEFORE THE

COMMITTEE ON SCIENCE

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

OCTOBER 20, 2005

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SCIENCE, TECHNOLOGY, AND GLOBAL
ECONOMIC COMPETITIVENESS

THURSDAY, OCTOBER 20, 2005

House of Representatives,

Committee on Science,

Washington, DC.

The Committee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

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COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Science, Technology and Global Economic Competitiveness

Thursday, October 20, 2005
10:00 a.m. - 12:00 p.m.

2318 Rayburn House Office Building (WEBCAST)

Witness List

Mr. Norman R. Augustine

Retired Chairman and CEO
Lockheed Martin Corporation

Dr. P. Roy Vagelos
Retired Chairman and CEO
Merck & Co

Dr. William A. Wulf

President

National Academy of Engineering

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HEAHING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Science, Technology, and Global
Economic Competitiveness

THURSDAY, OCTOBER 20, 2005

io:oo A.M.-i2:oo p.m.

2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, October 20, 2005, the House Science Committee will hold a hearing to receive testimony on the report released by the National Academy of Sciences on October 12 entitled Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. The report, which was requested by Congress, recommends ways to strengthen research and education in science and technology.

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 report.

Dr. P. Roy Vagelos, Retired Chairman and CEO of Merck & Co. Dr. Vagelos served on the NAS committee that wrote the report.

Dr. William A. Wulf, President of the National Academy of Engineering and Vice Chair of the National Research Council, the principal operating arm of the National Academies of Sciences and Engineering.

3. Overarching Questions

• What are the principal innovation-related challenges the United States faces as it competes in the global economy?

• What specific steps should the Federal Government take to ensure that the United States remains the world leader in innovation?

4. Brief Overview

• While the U.S. continues to lead the world in measures of innovation capacity — research and development (R&D) spending, number of scientists and engineers, scientific output, etc. — recent statistics on the level of U.S. support for research relative to other countries indicate that this lead may be slipping. Overall U.S. federal funding for R&D as a percentage of gross domestic product (GDP) has declined significantly since its peak in 1965, and the focus of this R&D has shifted away from the physical sciences, mathematics, and engineering — the areas of R&D historically most closely correlated with innovation and economic growth.

• At the same time, other nations — particularly emergent nations such as China and India — have recognized the importance of innovation to economic growth, and are pouring resources into their scientific and technological infrastructure, rapidly building their innovation capacity and increasing their ability to compete with the United States in the global economy.

• In May 2005, at the request of Congress, the National Academy of Sciences (NAS) began a study of “the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology.” NAS assembled a high-level panel of senior scientists and business and university leaders and produced a report in five months.

• The NAS report offers four broad recommendations: (A) increase America’s talent pool by vastly improving K-12 science and mathematics education; (B) sustain and stren^hen the Nation’s traditional commitment to long-term basic research; (C) make the United States the most attractive setting in which to study and perform research; and (D) ensure that the United States is the premier place in the world to innovate. (The executive summary of the NAS report is attached in Appendix A.)

• The NAS report also describes 20 explicit steps that the Federal Government could take to implement its recommendations. The report estimates the total cost of these steps to be $9.2-$23.8 billion per year.

5. Summary of NAS Report

In May of this year, Senators Lamar Alexander and Jeff Bingaman, Chairman of the Energy Subcommittee and Ranking Member of full Senate Committee on Energy and Natural Resources, respectively, 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, Science Committee Chairman Sherwood Boehlert and Ranking Member Bart Gordon wrote to the NAS to endorse the Senate request for a study and suggest some additional specific questions (the text of the Senate and House letters are attached in Appendices B and C). The study was paid for out of internal Academy funds, and NAS released the report on October 12.

The Problem

The NAS report begins by describing how science and engineering are critical to American prosperity. Technical innovations, such as electricity and information technology, have increased the productivity of existing industries and created new ones and improved the overall quality of life in the U.S. The report then examines how the U.S. is doing relative to other countries in science and technology today — looking at indicators such as science and engineering publications, R&D investment, venture capital funding, and student proficiency levels — to see if the U.S. is positioned to make the next generation of innovations needed to maintain U.S. competitiveness and security going forward.

"Worrisome indicators" outlined in the report^ include:

• The United States today is a net importer of high-technology products. Its share of global high-technology exports has fallen in the last two decades from 30 percent to 17 percent, and its trade balance in high-technology manufactured goods shifted from plus $33 billion in 1990 to a negative $24 billion in 2004.

• In 2003, only three American companies ranked among the top 10 recipients of patents granted by the United States Patent and Trademark Office.

• In Germany, 36 percent of undergraduates receive their degrees in science and engineering. In China, the figure is 59 percent, and in Japan 66 percent. In the United States, the corresponding figure is 32 percent.

• Fewer than one-third of U.S. 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). About one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform basic mathematical computations.

The NAS report concludes that education, research, and innovation are essential if the U.S. is to succeed in providing jobs for its citizenry.

Recommendations and Steps the Federal Government Should Take to Implement

Them

The NAS report makes four recommendations, each of which is supported by explicit steps that the Federal Government could take to implement the recommendations. These recommendations and steps are provided verbatim below; more details on each step are available in the report executive summary in Appendix A.

10,000 Teachers, 10 Million Minds and K-12 Science and Mathematics Education

Recommendation A: Increase America’s talent pool by vastly improving K-12 science and mathematics education.

Implementation Steps:

• A-1: Annually recruit 10,000 science and mathematics teachers by awarding four-year scholarships and thereby educating 10 million minds.

^See pages 18-19 of this charter for the pages of the NAS report that contain the sources for these statistics.

• 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 inspire students every day.

• A-3: Enlarge the pipeline by increasing the number of students who take AP and IB science and mathematics courses.

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 Steps:

• B-1: Increase the federal investment in long-term basic research by 10 percent a year over the next seven years.

• B-2: Provide new research grants of $500,000 each annually, payable over five years, to 200 of our most outstanding early-career researchers.

• 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 five years.

• B^: Allocate at least eight percent of the budgets of federal research agencies to discretionary funding.

• B-5: Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency called the Advanced Research Projects Agency-Energy (ARPA-E).

• B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest.

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 Steps:

• C-1: Increase the number and proportion of U.S. citizens who earn physical-sciences, life-sciences, engineering, and mathematics Bachelor’s degrees by providing 25,000 new four-year competitive undergraduate scholarships each year to U.S. citizens attending U.S. institutions.

• C-2: Increase the number of U.S. citizens pursuing graduate study in “areas of national need” by funding 5,000 new graduate fellowships each year.

• C-3: Provide a federal teix credit to encourage employers to make continuing education available (either internally or through colleges and universities) to practicing scientists and engineers.

• C^: Continue to improve visa processing for international students and scholars.

• C-5: Provide a one-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 U.S. institutions to remain in the United States to seek employment. If these students are offered jobs by U.S. -based employers and pass a security screening test, they should be provided automatic work permits and expedited residence status.

• C-6: Institute a new skills-based, preferential immigration option.

• C-7 : Reform the current system of "deemed exports."

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 Steps:

• D-l: Enhance intellectual property protection for the 21st century global economy.

• D-2: Enact a stronger research and development tax credit to encourage private investment in innovation.

• D-3: Provide tax incentives for U.S. -based innovation.

• D-4: Ensure ubiquitous broadband Internet access.

Costs of the Recommendations

The NAS report provides a "back of the envelope" estimate of the annual cost to the Federal Government of each of the implementation steps that are recommended.

• For the three steps in Recommendation A (increase America's talent pool by vastly improving K-12 science and mathematics education): $1.5-$2.4 billion per year.

• For the six steps in Recommendation B (sustain and strengthen the Nation's traditional commitment to long-term basic research): $1.l-$3.4 billion per year.

• For the seven steps in Recommendation C (make the United States the most attractive setting in which to study and perform research): $1.6-$3.6 billion per year.

• For the four steps in Recommendation D (ensure that the United States is the premier place in the world to innovate): $5.1-$14.4 billion per year.

The total cost of these steps would be $9.2-$23.8 billion per year.

6. Issues Related to Specifie Recommendations in the NAS Report and Related Questions for the Witnesses

In the invitation letter for the hearing, each of the witnesses was asked to answer questions about the three specific recommendations discussed below. These were major recommendations that seemed to call for further elaboration.

Recommendation B-1: Inerease the federal investment in long-term basie researeh by 10 percent a year over the next seven years: Numerous reports and groups in recent years have suggested doubling federal funding for basic research, as the NAS report recommends.^ (The authorization bill for the National Science Foundation the Congress passed in 2002 called for doubling that agencVs budget, and Congress did double the budget of the National Institutes of Health over the past six years or so.) While these reports have included a rationale for increasing federal R&D spending, none has explained the reason why a specific level of spending needs to be achieved by a particular date. The U.S. currently spends $56 billion annually on non-defense R&D, more than the rest of the 0-7 countries® combined. Also, total R&D spending (government and industry) in the U.S. has remained relatively constant as a percentage of the U.S. gross domestic product, indicating that investment in R&D has grown as the U.S. economy has grown, begging the question of why increased federal investment is necessary. (This may be especially true if federal R&D is being invested in the same kinds of research as private R&D rather than in kinds of research, particularly basic research, that might otherwise be neglected.)

In addition, the NAS report argues that federal investment in basic research fuels economic growth by contributing new ideas that can eventually lead to commercial products. Yet recent surveys of industry suggest that companies' investments in R&D have had only a very limited impact on the success of the individual companies.'^ What is true for individual companies is not necessarily true for nations as a whole; R&D may contribute greatly to the relative economic success of the U.S. as a whole, while not being so important to any individual company. (This would make sense. Nations stay ahead through innovation, but individual companies may have other comparative advantages.) But the company statistics and attitudes on R&D at least raise the question about whether the contribution of R&D to economic

2 For example, the U.S. Commission on National Security in the 21st Century (the Hart-Rudman Commission, Phase III, 2001) recommended doubling the federal research and development budget by 2010.

®The six non-U. S. members of the G— 7 are France, Great Britain, Germany, Japan, Italy and Canada.

'^Booz Allen Hamilton's Global Innovation 1,000 study was released on October 11, 2005 and is available on line at http:! ! www.boozaUen.com. An example of their findings is that companies in the bottom 10 percent of R&D spending as a percentage of sales under-perform competitors on gross margins, gross profit, operating profit, and total shareholder returns. However, companies in the top 10 percent showed no consistent performance differences compared to companies that spend less on R&D.

success is exaggerated, and how federal R&D investment contributes to overall economic success.

Questions in the witness letters on this recommendation:

• How did the study panel arrive at the recommended 10 percent annual increase in federally-sponsored basic research over the next seven years? What other options did the panel consider and what led to the choice of 10 percent?

• Recent surveys of industry suggest that basic research performed at universities and transformational technological innovation have only a very limited impact on the success of individual companies. Is the impact of research and innovation different for the economy as a whole than it is for individual companies?

Recommendation B^: Allocate at least eight percent of the budgets of federal research agencies to discretionary funding: A number of recent reports have expressed concern that the current grant selection system in most agencies shies away from daring proposals. The view is that when funding is tight (like now), researchers and the peer review system both tend to favor incremental research proposals — projects that are guaranteed to produce results — results that are generally in keeping with existing ideas. In this situation, high-risk research (especially that proposed by young investigators or involving interdisciplinary studies) can be underfunded or neglected entirely. The NAS report recommends that funding be set aside at federal research agencies (and distributed at program officers’ discretion) for high-risk, high-payoff research. While such research is valuable, so is the research that provides steady if incremental advances on existing scientific questions. In addition, not every agency is equally well equipped to solicit and select high-risk projects. Finally, even if setting aside such funding is a good idea, it’s unclear whether eight percent is a reasonable amount.

Questions in the witness letters on this recommendation:

• How did the study panel arrive at the recommended eight percent allocation within each federal research agency’s budget to be managed at the discretion of technical program managers to catalyze high-risk, high-payoff research? What other options did the panel consider and what led to the choice of eight percent?

Recommendation B-5: Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency called the Advanced Research Projects

Agency-Energy (ARPA-E): The recommendation seems to assume that the main reason the U.S. has not made more progress in deploying technologies that use less energy or that use alternative energy sources is that the technology is not being developed. But numerous studies have concluded that the primary problem in energy technology is that existing advanced technologies never get deployed. These studies tend to recommend policy changes to encourage the deployment of advanced technologies, as opposed to recommending (or merely recommending) programs to develop new technologies. For example, a recent American Council for an Energy Efficient Economy study estimated that "adopting a comprehensive set of policies for advancing energy efficiency could lower national energy use by 18 percent in 2010 and 33 percent in 2020."® Similarly, a 2001 NAS study on automotive fuel economy described numerous existing technologies that could reduce dependence on foreign oil, but are not yet deployed.

In addition, it is not clear whether the DARPA analogy is entirely apt. DARPA funds advanced technologies that will eventually be used by the Pentagon. The government itself would not be the main purchaser of technologies developed by ARPA-E, so those technologies would still face existing problems in finding markets. It is also unclear how the research that would be supported by ARPA-E would differ from that already funded by the Department of Energy's current conservation and renewable energy research programs.

Questions in the witness letters on this recommendation:

- Industry and government have both developed numerous energy production and energy efficiency technologies that have not been deployed. How did the study panel arrive at its implicit conclusion that technology development is the greater bottleneck (as opposed to policy) in developing energy systems for a 21st century economy?

^Energy Efficiency Progress and Potential, American Council for an Energy-Efficient Economy, no date.

7. General Issues

Overall Federal Support for R&D

The amount of the country's overall wealth devoted to federal R&D has declined significantly since the post-Sputnik surge in support for R&D. According to Office of Management and Budget statistics, in 1965, funding for federal R&D as a percentage of GDP (measured as outlays), also known as R&D intensity, was slightly over two percent (Chart 1). In 2005, it is estimated to he 1.07 percent.

While this ratio has recently begun to increase again, turning upward over the last five years, the majority of those increases have gone toward short-term defense development and homeland security applications. For example, the Department of Defense (DOD) R&D increases alone — most of which have supported development projects that have very little impact on innovation or broader economic development — has accounted for almost 70 percent of the overall R&D increases of the last five years. Of the remaining increases, 75 percent has gone to the National Institutes of Health (NIH) and the Department of Homeland Security (DHS). At $71 billion and $29 billion, respectively, the R&D budgets of DOD and NIH now account for over 75 percent of all federal R&D. Meanwhile, funding for the physical sciences and engineering — the areas historically most closely associated with innovation and economic growth — have been flat or declining for the last thirty years.

Also, the long-term outlook for the federal budget does not favor future increases in discretionary spending (through which almost all R&D is funded). Absent major policy changes, the growth in mandatory federal spending — primarily for health and retirement benefits and pa 3 Tnents on the national debt interest — will demand a significantly greater share of the government's resources.

Chart 1. Federal Spending (Outlays) on Research and Development as a Percentage of GDP, FYl 950-FY2005. (Source; Office of Management and Budget Historical Tables, Fiscal Year 2006.)

Shift of Private Sector R&D

During the heyday of the corporate research laboratory in the middle decades of the 20th century, U.S. corporate laboratories supported all stages of R&D, from knowledge creation to applied research to product development, and were quite successful in their efforts to nurture innovation. The most notable example of this was AT&T's Bell Laboratories, which grew to be one of the world premier research organizations of the last century, developing numerous breakthrough technologies that changed American life, including transistors, lasers, fiber-optics, and communications satellites. Researchers at Bell Labs and other corporate laboratories were eligible for, and received, grants from federal research agencies such as the National Science Foundation and DOD, but they received core support from the parent company and they conducted basic and applied research directed toward developing technology relevant to the company's business.

While overall growth of industry-funded R&D has remained strong in recent years, the focus of this R&D has shifted significantly away from longer-term basic research in favor of applied research and development more closely tied to product development. Because of market demands from investors to capitalize on R&D quickly, large corporate laboratories of the Bell Labs model are increasingly rare (notable exceptions include companies such as IBM and GE). Instead, corporations now focus research projects almost exclusively on lower-risk, late-stage R&D projects with commercial benefits, leaving the Federal Government as the predominant supporter of long-term basic research.

Increasing Competitiveness of Foreign Countries

While trends of support for the innovation system in the U.S. have showed signs of slowing, other nations are committing significant new resources to building their science and technology enterprises. More than one-third of OECD (Organization for Economic Cooperation and Development) countries have increased government support for R&D by an average rate of over five percent annually since 1995. The European Union has recently established a target to achieve EU-wide R&D intensity of three percent of the EU economy by 2010. (By comparison, the current U.S. R&D intensity, public and private sector combined, is 2.6 percent of GDP.) Similarly, individual nations, including South Korea, Germany, the U.K. and Canada, have recently pledged to increase R&D spending as a percentage of GDP.

However, no nation has increased its support for innovation as dramatically as China. It has doubled its R&D intensity from 0.6 percent of its GDP in 1995 to 1.2 percent in 2002 (this during a time of rapid GDP growth). R&D investments in China by foreign corporations have also grown dramatically, with U.S. investments alone increasing from just $7 million in 1994 to over $500 million in 2000. China is now the third largest performer of R&D in the world, behind only the U.S. and Japan.

The increased innovation capacity of other countries is also becoming evident in output-based R&D benchmarks. For example, the U.S. share of science and engineering publications published worldwide declined from 38 percent in 1988 to 31 percent in 2001, while Western Europe and Asia’s share increased from 31 to 36 percent and 11 to 17 percent, respectively. Similar trends have occurred in the area of U.S. patent applications and citations in scientific journals.

Education and Workforce Issues

While the supply and demand of future scientists and engineers is notoriously difficult to predict, most experts believe that the transition to a knowledge-based economy will demand an increased quality and quantity of the world’s scientific and technical workforce. As is the case with R&D figures, trends in the distribution of the world’s science and engineering workforce are also unfavorable to long-term U.S. competitiveness.

The world is catching up and even surpassing the U.S. in higher education and the production of science and engineering specialists. China now graduates four times as many engineering students as the U.S., and South Korea, which has one-sixth the population of the U.S., graduates nearly the same number of engineers as the U.S. Moreover, most Western European and Asian countries graduate a significantly higher percentage of students in science and engineering. At the graduate level, the statistics are even more pronounced. In 1966, U.S. students accounted for approximately 76 percent of world’s science and engineering Ph.D.s. In 2000, they accounted for only 36 percent. In contrast, China went from producing almost no science and engineering Ph.D.s in 1975 to granting 13,000 Ph.D.s in 2002, of which an estimated 70 percent were in science and engineering.

Meanwhile, the achievement and interest levels of U.S. students in science and engineering are relatively low. According to the most recent international assessment, U.S. twelfth graders scored below average and among the lowest of participating nations in math and science general knowledge, and the comparative data of math and science assessment revealed a near-monopoly by Asia in the top scoring group for students in grades four and eight. These students are not on track to study college level science and engineering and, in fact, are unlikely ever to do so. Of the 25-30 percent of entering college freshmen with an interest in a science or engineering field, less than half complete a science or engineering degree in five years.

All of this is happening as the U.S. scientific and technical workforce is about to experience a high rate of retirement. One quarter of the current science and engineering workforce is over 50 years old. At the same time, the U.S. Department of Labor projects that new jobs requiring science, engineering and technical training will increase four times higher than the average national job growth rate.

Industry Concerns and Reports

Some leading U.S. businesses have become increasingly vocal about concerns that the U.S. is in danger of losing its competitive advantage. In an effort to call attention to these concerns, several industry organizations have independently produced reports specifically examining the new competitiveness challenge and recommending possible courses of action to address it. Prominent among these efforts is the National Innovation Initiative (Nil), a comprehensive undertaking by industry and university leaders to identify the origins of America's innovation challenges and prepare a call to action for U.S. companies to "innovate or abdicate." The December 2004 Nil final report, Innovate America: Thriving in a World of Challenge and Change, is intended to serve as a roadmap for policy-makers, industry leaders, and others working to help America remain competitive in the world economy.

Other industry associations that have also produced recent reports include AeA (formerly the American Electronics Association), the Business Roundtable, Electronic Industries Alliance, National Association of Manufacturers, and TechNet. While the companies and industry sectors represented by these organizations varies widely, one general recommendation was common to all of the reports: the Federal Government needs to strengthen and re-energize investments in R&D and science and engineering education. The Science Committee held a hearing on July 21, 2005 on U.S. Competitiveness: The Innovation Challenge to examine the issues raised in these reports and how federal science and engineering research and education investments impacts U.S. economic competitiveness.

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 percent of measured growth in U.S. income per capita is due to technological change.®

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 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 fo 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.

®For example, work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85 percent of measured growth in U.S. income per capita during the 1890-1950 period could not he 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.

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 U.S. 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 mathematies teachers by awarding four-year seholarships 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 four-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 four years for qualified educational expenses, including tuition and fees, and require a commitment to five 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 five years, to as many as 100 universities and colleges to encourage them to establish integrated four-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 Advaneed Placement and International Bacealaureate (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 one- to two-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) two-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 $2,000 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 percent 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 percent a year over the next seven years, through re-allocation of exist-

ing funds'^ or if necessary through the investment of new funds. Special attention should go to the physical sciences, engineering, 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 U.S. 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 five 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 five 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 eight pereent of the budgets of federal seareh ageneies 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).® 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 four 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 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 advanees 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.

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

® 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.

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 U.S. citizens who earn physical-sciences, life scienees, engineering, and mathematics Bachelor’s degrees by providing 25,000 new four-year competitive undergraduate scholarships each year to U.S. citizens attending U.S. 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 U.S. eitizens 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 eredit to eneourage employers to make continuing education available (either internally or though colleges and universities) to practieing 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 one-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 U.S. 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 one 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 U.S. citizenship. In the interim, the number of H-IB® 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 U.S. universities.

Action C-7: Reform the current system of "deemed exports." The new

system should provide international students and researchers engaged in funda-

®The H— IB 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 hody 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/hlh.htm

10 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

Continued

mental research in the United States with access to information and research equipment in U.S. industrial, academic, and national laboratories comparable with the access provided to U.S. 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 U.S. 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

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 U.S. 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 U.S. 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 eredit to encourage private investment in innovation. The current Research and Experimentation Teix 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,^! and it should be increased from 20 percent to 40 percent of the qualif 5 dng increase so that the U.S. tcix 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 teix 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 aceess. Several nations are well ahead of the United States in providing broadband access for home, school.

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.
i^The current R&D tax credit expires in December 2005.

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 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 U.S. 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 U.S. 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,” ^ 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.^

- For the first time, the most capable high-energy particle accelerator on Earth will, beginning in 2007, reside outside the United States.®

- The United States is today a net importer of high-technology products. Its share of global high-technology exports has fallen in the last two decades from 30 percent to 17 percent, and its trade balance in high-technology manufactured goods shifted from plus $33 billion in 1990 to a negative $24 billion in 2004.4

- 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 60 in China.®

- Fewer than one-third of U.S. 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.®

• U.S. 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 U.S. 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 U.S. scores. No nation scored significantly below the United States.'^

• In 1999, only 41 percent of U.S. 8th grade students received instruction from a mathematics teacher who specialized in mathematics, considerably lower than the international average of 7 1 percent.®

• In one recent period, low-wage employers, such as Wal-Mart (now the Nation's largest employer) and McDonald's, created 44 percent of the new jobs, while high-wage employers created only 29 percent of the new jobs.®

• In 2003, only three American companies ranked among the top 10 recipients of patents granted by the United States Patent and Trademark Office.^®

4 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 Glohal Attitudes Project, July 23, 2005.

2 The Weh 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.

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

4 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.

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

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

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

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

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

4® U.S. Patent and Trademark Office, Preliminary list of top patenting organizations. 2003, http://www.uspto.gov/web/offices/ac/ido/oeip/tal/top03cos.htm.

• In Germany, 36 percent of undergraduates receive their degrees in science and engineering. In China, the figure is 59 percent, and in Japan 66 percent. In the United States, the corresponding figure is 32 percent.^^

• 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.^^

• In 2004, China graduated over 600,000 engineers, India 350,000, and America about 70,000.13

• In 2001 (the most recent year for which data are available), U.S. industry spent more on tort litigation than on R&D.i^

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

12 Colvin, Geoffrey. 2005. “America isn’t ready.” Fortune Magazine, July 25. H-IB visas allow employers to have access to highly educated foreign professionals who have experience in specialized fields and who have at least 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 U.S. universities. See Immigration and Nationality Act Section 101(a)(15)(h)(l)(b).

13 Geoffrey Colvin. 2005. “America isn’t ready.” Fortune Magazine, July 25.

i^U.S. 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.

Appendix B: Senate Letter to National Academy of Sciences

lanitcd States Senate

WASHINGTON, DC 20510

May 27, 2005

Dr. Bruce Alberts
President

National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Dear Dr. Alberts:

The Energy Subcommittee of the Senate Energy and Natural Resources Committee has been given tlie latitude by Chairman Pete Domeniei to hold a series of hearings to identify specific steps our government should take to ensure the preeminence of America's scientific and technological enterprise.

The National Academies could provide critical assistance in this effort by assembling some of the best minds in the scientific and technical community to identify the most urgent challenges the Uni ted States faces in maintaining leadership in key areas of science and technology. Specifically, we would appreciate a report from the National Academies by September 2005 that addresses the following:

• Is it essential for the United States to be at the forefront of research in broad areas of science and engineering? How does this leadership translate into concrete benefits as evidenced by the competitiveness of American businesses and an ability to meet key goals such as strengthening national security and homeland security, improving health, protecting the environment, and reducing dependence on imported oil?

What specific steps are needed to ensure that the United States maintains its leadership in science and engineering to enable us to successfully compete, prosper, and be secure in the global community of the 21st century? How can we determine whether total federal research investment is adequate, whether it is properly balanced among research disciplines (considering both traditional research areas and new multidisciplinary fields such as nanotechnology), and between basic and applied research?

• How' do we ensure that the United States remains at the epicenter of the ongoing revolution in research and innovation that is driving 21" century economies? How can we assure investors that America is the preferred site for investments in new or expanded businesses that create the best jobs and provide the best services?

• How can we ensure that critical discoveries across all the scientific disciplines are predominantly American and exploited first hy firms producing and hiring in America? How can we best encourage domestic firms to invest in invention and innovation to meet new global competition and how can public research investments best supplement these private sector investments?

• What specific steps are needed to develop a well-educated workforce able to successfully embrace the rapid pace of technological change?

Your answers to these questions will help Congress design effective programs to ensure that America remains at the forefront of scientific capability, thereby enhancing our ability to shape and improve our nation's future.

We look forward to reviewing the results of your efforts.

Sincerely,

Lamar Alexander
Chairman

Energy Subcommittee

Appendix C: House Letter to National Academy of Sciences

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

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June 30, 2005

Dr. Bruce Alberts
President

National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Dear Dr. Alberts,

We understand that the National Academies, in response to a request from Senators Alexander and Bingaman, are in the early stages of developing a study related to the urgent challenges facing the United States in maintaining leadership in key areas of science and technology. Because the Science Committee considers ensuring the strength and vitality of the Nation’s scientific and technology enterprise an important part of its broad oversight responsibility, we are writing to endorse the request for this study and to encourage the National Academies to carry it forward expeditiously.

In addition, we would like to suggest some specific questions we hope to see addressed by the study:

• What skills will be required by the future U.S. science and engineering workforce in order for it to command a salary premium over foreign scientists and engineers? Are alternative degree programs needed, such as professional science masters degrees, to meet the needs of industry and to lead to attractive career paths for students?

• Are changes needed in the current graduate education system, such as: a different mix in graduate support among fellowships, traineeships, and research assistantships; more research faculty positions and fewer postdocs and graduate students in traditional graduate programs?

• Should a greater proportion of federal research funding be allocated to high-risk, exploratory research and should funding priorities among broad fields of science and engineering be readjusted?

• What policies and programs will help ensure the rapid flow of research results into the marketplace and promote the commercialization of research in a way that leads to the creation of good jobs for Americans?

The committee looks forwards to reviewing the results of this effort, and hopes that a draft response will be available by September 30, 2005. We hope that the new and innovative ideas you produce as the result of this effort will be able to translate into policies that will enhance U.S. prosperity in the 2P’ century. If you have any questions, please contact Dan Byers of the Majority Staff or Jim Wilson of the Minority Staff.

Chairman BOEHLERT. The hearing will come to order.

Before we start the official part of today’s hearing, I would like to take a moment to recognize a real person to illustrate the importance of the issues we are going to be discussing today. Neela Thangada, who is in the audience today. Neela, would you please stand?

Just yesterday, she won the Discoveiy Channel Young Scientist Challenge. She got into the finals of this contest by doing an individual project on plant cloning and won by demonstrating leadership, teamwork, and scientific problem-solving on a series of experiments related to forces of nature, a very timely thing for this year’s contest. Now let me point out that Neela is 14. She is in the seventh grade. What she is doing is so exciting. She is accompanied by her mom. Where is mom, Neela? You know, when I first met Neela, this is not as a politician, this is just an observation, I didn’t know which one was the student and which one was the mom. Mom, please stand and be recognized. I want to thank you for the guidance you are providing.

Neela is what this whole hearing is about and what the whole Augustine report is about, so we are so pleased to see you, and thank you for joining us.

It is a pleasure to welcome everyone here this morning for our hearing on the new and vitally important National Academy report, “Rising Above the Gathering Storm.” This report is already getting an unusual amount of media coverage, and how refreshing that is to have the media concentrating on something that is not sensational but is critically important, a tribute, in part, to the reputations and work of our witnesses here today, and that is helping to jump-start, and in other quarters, to intensify, a national discussion on research and education and the Nation’s future.

The overarching message of the report is simple and clear, and it is one the Congress had better heed. And the message is this: complacency will kill us. “Where there is no vision, the people perish.” If the United States rests on its withering laurels in the competitive world, we will witness the slow erosion of our preeminence, our security, and our standard of living. That is a very sobering message. We used to be so far ahead of everybody else in the global enterprise that when we looked around, we couldn’t even find a person in second place. Now we can’t even take a nanosecond to look over our shoulder, because they are breathing down our neck.

It is a message that this committee has been trying to send for many, many years, and now, joined by Chairman Wolf of the Appropriations Committee and some of our other friends over there who get it, indeed this committee has pressed, sometimes successfully and, unfortunately, sometimes not, for many of the specific proposals in the Academy report. So Mr. Augustine, you guys are really helping us, and I appreciate it.

We have authorized increased spending on basic research, including funding for research equipment and for more daring and cross-disciplinary research, and we have created programs like the Noyce Scholarships to try to attract more top students into teaching. And Neela, consider teaching as a career, will you please? And like Tech Talent to get more students who express interest in science, math, and engineering to complete majors in those fields.

We have pushed for greater funding for the education directorate at the National Science Foundation and for the basic and applied research programs at the Department of Energy.

But clearly, we haven’t done enough. We have all of the zeal of the most fervent missionary, and we are trying, but we haven’t done enough, and we haven’t succeeded nearly as much as we would like. That is why the Augustine report helps this. Science programs still have to scrounge around for every additional cent. Young scientists still have to beg for funds. Our education system is still producing too many students who can not compete with our counterparts around the world. And the Federal Government is still ignoring our fundamental energy problems while wasting money pandering to special interests.

So I urge our witnesses today, who are among the most prominent and respected leaders in the Nation, to redouble your efforts to get the word out about this report. We need a lot more missionary work, especially in this era of fiscal constraint. While Congress turns its attention to fixing the immediate problems caused by the literal storms that have hit our coasts, we can’t skimp on the funds needed to address the gathering storm described so starkly in your report.

There is an exchange in a Hemingway novel in which one character asks another how he went bankrupt. He answers, “Two ways.

First gradually and then suddenly.” As a nation, we are gradually going bankrupt now in the ways described in the Academy report. If we don’t act, we are going to wake up one day and find ourselves suddenly unable to compete.

I look forward to further guidance this morning on exactly what we should do to compete. And I hope we will have a spirited discussion about the details of the Academy report recommendations. But as we argue about the specifics, and it won’t be so much an argument, it will be sort of a debate, I hope we can all come away with an open and even greater commitment to address the problems that the report lays before us.

[The prepared statement of Chairman Boehlert follows:]

Prepared Statement of Chairman Sherwood L. Boehlert

It’s a pleasure to welcome everyone here this morning for our hearing on the new and vitally important National Academy report “Rising Above the Gathering Storm.” This report is already getting an unusual amount of media coverage — a tribute, in part, to the reputations and work of our witnesses today — and that is helping to jump-start (and in other quarters, to intensify) a national discussion on research and education and the Nation’s future.

The overarching message of the report is simple and clear, and it’s one the Congress had better heed. And the message is this: complacency will kill us. If the United States rests on its withering laurels in this competitive world, we will witness the slow erosion of our preeminence, our security and our standard of living. It’s a sobering message.

It’s also a message that this committee has been trying to send for many years, now joined by Chairman Wolf and some of our other friends on Appropriations. Indeed, this committee has pressed — sometimes successfully, sometimes not — for many of the specific proposals in the Academy report.

We have authorized increased spending on basic research, including funding for research equipment and for more daring and cross-disciplinary research; and we have created programs like the Noyce Scholarships to try to attract more top students into teaching, and like Tech Talent to get more students who express interest in science, math and engineering to complete majors in those fields.

We have pushed for greater funding for the education directorate at the National Science Foundation (NSF) and for the basic and applied research programs at the Department of Energy.

But we clearly haven't done nearly enough. Science programs still have to scrounge around for every additional cent; young scientists still have to beg for funds; our education system is still producing too many students who cannot compete with their counterparts around the world; and the Federal Government is still ignoring our fundamental energy problems while wasting money pandering to special interests.

So I urge our witnesses today — who are among the most prominent and respected leaders in this nation — to redouble your efforts to get the word out about this report. We need a lot more missionary work, especially in this era of fiscal constraint. While Congress turns its attention to fixing the immediate problems caused by the literal storms that have hit our coasts, we can't skimp on the funds needed to address the "gathering storm" described so starkly in your report.

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I look forward to getting further guidance this morning on exactly what we should do to compete, and I hope we have a spirited discussion about the details of your recommendations. But as we argue about the specifics, I hope we can all come away with an even greater commitment to address the problems this report lays before us.

Chairman BOEHLERT. With that, it is a pleasure to turn to my partner in this venture, the Ranking Member from Tennessee, Mr. Gordon.

Mr. Gordon. Thank you, Mr. Chairman.

Let me, once again, concur with your statements and also say that I have witnessed firsthand your passion for these issues. You are a leader in the area, and I appreciate working with you on it.

Let me also thank the Committee for the work you have done, Mr. Augustine. Once again, you have done a tremendous service for the country.

And let me say this, without diminishing what you have done. To a great extent, what you have done is just rehash what we already knew and brought it together from different sources. There is not a lot new here, and I don't mean that as — I mean, I think it is good that we have brought it together. I think that it is good that we can look to your report and say these are leaders in academia, with the private sector, and hopefully get us more energy in trying to accomplish something here. But again, as our Chairman has pointed out, this committee has passed many of these things already.

And so really, what I would like to hear you talk a little bit about is how do we get the private sector, and what do you intend to do to help implement these proposals. I mean, again, you know, we have to have more energy. Clearly, what we are doing is not enough. And I would like to hear something about that.

The other thing that I noted reading through this report is that, with the exception of talking about R&D credits, there really wasn’t much said about the private sector in this area. Now maybe you didn’t think that was your charge, but I think the charge said what are some federal policies that deal with it. The R&D credit is one of those. And I pose this question that I would like to hear more about. There seems to be a growing disparity between top level CEO and other kind of salaries and the salaries of others in those companies in relationship to other countries. And is this lead-

ing us to a situation where those top executives are so pushed because of this type of compensation that they have to be so quarterly oriented to having results that the private sector is not doing its part in R&D? And is there some, I mean, I guess, one, is this accurate? And if it is not, then that is fine. If it is accurate, then is there a federal role in somehow trying to encourage looking beyond the quarter? Looking beyond. I mean, right now folks, in two or three years, can make all of the money they can spend the rest of their life. So you know, as long as they keep the stock up, why should I worry about five years from now? Why should I make these investments?

Again, if I am wrong, I would like to know.

The other thing is in your statement, and it was $10 billion, I hate to say, is a modest amount of money, but it is not, I think in terms of investment and in terms of our budget, it is a reasonable amount of money to spend. And you are talking about how we need to reallocate. We can get part of this by reallocating some funds within, I guess, our current budget. But I didn’t see the section about what to allocate and what were those specifically. So if you have some suggestions in addition to reallocate, which ones we should reallocate, I would like to hear that today.

So with that in mind, again, I want to thank you. This is an important document. This is a document that we all need to wave and that we all need to charge forward with. It is important to our kids and our grandkids. So I thank you for it.

Again, my questions did not try to diminish what you did but to try to take this a step farther.

Thank you.

[The prepared statement of Mr. Gordon follows:]

Prepared Statement of Representative Bart Gordon

I want to join Chairman Boehlert in welcoming everyone to this morning's hearing.

I also want to thank our distinguished panel for not only taking the time to appear before us today, but for their time and effort in preparing this report.

The title of this report, "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," summarizes the challenge before us.

There is a general uncertainty about our country's future economic prospects and a desire for guidance on how to move forward. I think that the report provided by the Panel takes some steps towards providing that guidance.

A few disturbing facts from the report jumped out at me:

The large wage disparity between U.S. -based scientists and engineers and their competitors in China and India; and

The 110 chemical facilities that have closed or are slated for closure in the U.S. coupled with the 120 large chemical plants currently under construction globally — one new plant in the U.S. and 50 in China.

China is producing more than 600,000 engineers per year.

As the report notes, "Thanks to globalization, workers in virtually every sector must now face competitors who live just a mouse-click away, . . ." I'm left wondering where will the good high-paying jobs be for the next generation — in the U.S. or in some other country.

The report outlines a number of specific actions we can take to improve the innovation environment in the U.S. Many of these recommendations are familiar to us because they are what the Science Committee has advocated in legislation.

For example, substantial increases in funding for NSF and the Office of Science at DOE. In the area of science education, the Committee has authorized scholarships for math, science and engineering students to obtain teaching certificates as well as the math and science partnership program to improve the training of new teachers.

There seems to he a hroad consensus on what the U.S. should he doing, hut the Administration has not followed through in its funding requests.

This report highlights that our current federal R&D investment strategies are not up to meeting the global competitive paradigm of the 21st century. The recommendations represent a challenge to the Administration and to Congress to take action now.

I am interested about one of the Panel's statements which is that some of its recommendations "require funds that would ideally come from the re-allocation of existing funds." What is not identified is what funds should be re-allocated or why. I hope our witnesses will provide some more detail into the Panel's thinking.

We can all agree that more R&D will result in more innovation, but one issue not addressed by this report is will it really generate more and better jobs in the U.S.? Or will the exploitation of these innovations quickly move to countries with lower cost labor?

I hope the panel has some thoughts on how to ensure that the development of new technologies leads to the creation of new jobs in the U.S. One only has to look at most types of consumer electronics – the history of VCR technology as an example – to see that we have often lost the economic payoff from technology invented here.

In closing, it seems that we understand the challenges we face and we have agreement on how to address these challenges. What is lacking is the political will to make the investment.

I would like to point out that his report represents a consensus of panelists representing business, academic, and education leaders. I would challenge the Panel to press the Administration and Congress to fund their recommendations. As a nation, we cannot afford not to.

[The prepared statement of Mr. Ehlers follows:]

Prepared Statement of Representative Vernon J. Ehlers

I am delighted with the Academy for producing this report, and am pleased that the Committee is taking the time to delve into the report's recommendations and proposed implementation.

For many years, I have stressed the need to increase our national investment in fundamental research and education. Despite passing an authorization bill to double the budget of the National Science Foundation (NSF) by 2008, we are still falling very short of that goal set by Congress in 2002. Each year, the chasm between the authorization and appropriation broadens, while at the same time the NSF education budget continues to diminish. But today there are an increasing number of voices joining the chorus recognizing the need for change. The voices are louder and clearer as the message begins to unify: build our science, technology, engineering and math skills, and we will maintain the strength and competitiveness of the United States. Business, industry and academic leaders are all drawing attention to the connection between our prosperity and a technically-skilled workforce. As we see the indications that our science and math education is slipping, we are jeopardizing our quality of life and national security, especially for our children and grandchildren. Without bolstering our science and technology infrastructure, we cannot expect these trends to change.

There are many challenging questions raised by the report; it will take the strong dedication of the Committee and Chair to share these recommendations with a variety of stakeholders. I thank the witnesses today for their good work, and encourage them and the others they represent to continue to publicize this problem and lobby Members of Congress to make national competitiveness a priority through their strong support of fundamental research and education. I commend the witnesses for being here today, and look forward to continuing to work with you to not only share your report recommendations, but to actively seek solutions.

[The prepared statement of Mr. Costello follows:]

Prepared Statement of Representative Jerry F. Costello

Good morning. I want to thank the witnesses for appearing before our committee to discuss the report released by the National Academy of Sciences (NAS) on October 12, 2005 entitled. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. I commend Chairman Boehlert and Ranking Member Gordon for holding this hearing today because the recommendations

this report issued will provide our committee with good policy options to explore to ensure new ideas and innovation.

In June of this year, Chairman Boehlert and Ranking Member Gordon wrote to NAS to endorse the Senate request for a study of “the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology,” to provide advice and recommendations for maintaining U.S. leadership in science and technology in the face of growing global competition. Today, Americans are feeling the effects of globalization because a substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe. It comes as no surprise that high-tech jobs are being out-sourced to foreign countries like China and India. Without high-quality, knowledge intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our constituents will face a lower standard of living. I am very concerned about the issue of off-shoring and out-sourcing and how these trends will affect current scientists and engineers, as well as the future employment opportunities and career choices of students.

A few months ago. Ranking Member Gordon and I hosted our first in a series of several bipartisan roundtable discussions to frame what is known and unknown about supply and demand for the Science and Technology workforce, outline factors that influence supply and demand, and explore policy options. From the first Roundtable, we learned that it is difficult to determine how many jobs we have lost because we do not have sufficient or accurate data on the problem. I believe we have to raise awareness of this issue — the federal research and development budget — in order to keep high wage science and engineering jobs here in the U.S.

Despite claims to the contrary by the Administration, the Federal R&D budget is not faring well, particularly the non-defense component which has been flat for 30 years. In FY06, the Administration proposed a 1.4 percent spending reduction in the federal science and technology budget. Reductions like this continue to chip away at the U.S. research base and jeopardize our economic strength and long-term technological competitiveness. Innovation does indeed drive our economic growth, but we must have the knowledge base to drive innovation. Encouraging more children in careers in math and science is a needed start but only the beginning. We must do better in understanding the global competition facing our science and engineering workforce.

I hope this hearing will draw us closer to an answer of how we can ensure the U.S. benefits from innovation, compete with foreign scientists and engineers without lowering salaries, increase funding for basic research in the physical sciences and engineering, and improve teacher recruitment and retention so we can increase student interest levels and their knowledge and understanding of these valuable subjects.

I welcome our panel of witnesses and look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

Prepared Statement of Representative Eddie Bernice Johnson

Thank you, Mr. Chairman and Ranking Member.

The United States has slashed its federal investment in scientific research. In 1966, in the Sputnik era, funding for federal research and development as a percentage of gross domestic product was slightly over two percent. In 2005, it is estimated to be 1.07 percent.

As a result, scientists are not getting the money they need and are pursuing alternative careers. Young people see the trend and opt not to study science.

Meanwhile, other nations have ramped up their technical infrastructure and workforce. The National Academies' recent report on the United States and global competitiveness found that in Germany, 36 percent of undergraduates receive their degrees in science and engineering. In China, the figure is 59 percent, and in Japan 66 percent. In the United States, the corresponding figure is 32 percent.

I concur that these are “worrisome indicators” indeed. Our competitiveness is quietly slipping. We are a net importer of high technology products, and soon we will be a net importer of people with high technology expertise.

I am glad the National Academies published this report and hope the leadership of this Congress will act on these recommendations. Progress is expensive, but decay is intolerable.

[The prepared statement of Mr. Honda follows:]

Prepared Statement of Representative Michael M. Honda

Chairman Boehlert and Ranking Member Gordon, I thank you for holding this important hearing today and for requesting that the study “Rising Above the Gathering Storm: Energizing and Employing America for a Ilrighter Economic Euture” be undertaken.

This report makes a many good recommendations in a number of areas. In the area of education, for example, it suggests that we should recruit new science and math teachers, that we should strengthen the skills of teachers the math, science, and engineering subject areas, and we increase the number of students who take math and science courses.

But what I do not see in the recommendations troubles me. What I think is missing is the idea of teaching innovation.

I’m worried that if we simply try to produce a bunch of new scientists and engineers with the same skills as the ones who are unemployed back home in my district today, things aren’t going to get any better here. China and India will be able to produce more scientists and engineers than us, and if they are paid less, work will still be done overseas.

We have been lucky in the past that a few people who were innately innovative and inventive also had enough knowledge in math and science to make breakthroughs in these areas that started entirely new industries. Skilled scientists and engineers have been able to sustain incremental progress in these new industries, but the pressure from other nations is growing ever greater.

While some people are simply blessed with the special skills of innovation and invention and they have prospered in the past, we need to realize that these skills are teachable and bring them into our curriculum. An MIT-Lemelson/NSF study on invention recognized this and suggested incorporating innovation into our curriculum, and Singapore's Minister of Education has begun to make such changes to his own country's curriculum to prepare his country for the future.

I hope that the witnesses will address this shortcoming of their report during the hearing, and that the Committee will pay attention to this important issue in the future.

[The prepared statement of Mr. Carnahan follows:]

Prepared Statement of Representative Russ Carnahan

Mr. Chairman and Mr. Ranking Member, thank you for again bringing this important issue to our attention in the Science Committee.

For years, the U.S. has felt the backlash of an increasingly competitive global market, most sharply felt in the loss of jobs as they shift overseas. I applaud the effort to look beyond the problems and causes associated with competing in a global marketplace and to look toward solutions.

It is our duty as leaders of this nation to wisely consider options and vigorously advocate for the right changes. Our workforce, and thus many of our constituents' livelihoods, depend on it.

Mr. Augustine, Dr. Vagelos, and Dr. Wulf, thank you for your efforts with this report and for appearing before us today. I look forward to hearing your testimony.

[The prepared statement of Ms. Jackson Lee follows:]

Prepared Statement of Representative Sheila Jackson Lee

Mr. Chairman, let me first thank you for holding this important hearing regarding the recent report published by the National Academy of Sciences. I would also like to thank our witnesses, Mr. Augustine, Dr. Vagelos, and Dr. Wulf, for being here today.

The report being presented to us today highlights what is becoming more and more apparent in recent years, that the United States is losing footing as the dominant knowledge, innovation, and business center of the world; our policies are resulting in the deterioration of our economy. As highlighted in the testimony, an overwhelming amount of evidence points to this. Students today are less prepared to face the global market than they once were, and foreign students are becoming more and more prepared. The most glaring statistic to me contained in the testimony was that in 2003, foreign students earned almost 60 percent of engineering doctorates awarded in U.S. universities!

Our children today are not being given the tools necessary to compete in the world of tomorrow. We are not giving them the proper training, the proper teachers or incentive to succeed. This is an issue that must cross party lines and rest at the heart of all Americans because this is about the future strength of our nation. We became the world's greatest economic power through innovation and education, and today we must renew that challenge to push the boundaries of discovery.

The importance of a strong scientific and technological enterprise is a primary factor in driving economic growth. Substantial and sustained U.S. investments in research and education over the last 50 years spawned an abundance of technological breakthroughs that transformed American society and helped the U.S. to become the world's dominant economy. Economists estimate that these technological advances have been responsible for half of U.S. economic growth since the end of World War II. The relationship between innovation and economic growth has only grown in recent years as the world shifts to an increasingly knowledge-based economy. In an age where information travels around the world at previously unimaginable speeds, the United States must continue to stay steps ahead of everyone else. This means that status quo policies on education will not work.

At the same time, other nations — particularly emerging nations such as China and India — have recognized the importance of science and technology to economic growth, and are pouring resources into their scientific and technological infrastructure, rapidly building their human capital and dramatically increasing their ability to compete with U.S. businesses on the world stage.

As was mentioned in the testimony, there unfortunately will not be a Sputnik-like event, where the United States gets a powerful wakeup call. Instead, our decline in competitiveness is occurring slowly, and from a combination of many factors. The foundation our mothers and fathers laid for us slowly crumbles around us. This is why I find this hearing to be so important. We as the Federal Government must ensure that our nation does not lag behind in innovation and discovery. We must ensure that our children are properly prepared to face the increasingly challenging global market. Finally, we must continue to ensure that we in the United States continue to be the Nation that sets the bar for everyone else.

I would again like to thank our witnesses for being here today, and I look forward to an open and enlightened conversation on the powerful suggestions made in this report.

[The prepared statement of Mr. Baird follows:]

Prepared Statement of Representative Brian Baird

Mr. Chairman, I would like to thank you and Ranking Member Gordon for raising importance to the issue of math and science education as it relates to scientific and technological competitiveness. I would also like to thank the witnesses — Mr. Augustine, Dr. Vagelos, and Dr. Wulf — for testifying today on the recently released National Academy of Sciences report entitled, "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.” One of the recommendations made in this report is to vastly improve K-12 math and science education. I could not agree more. This should be one of the highest priorities of the Federal and State governments and I look forward to reviewing the testimony of our witnesses and the specific recommendations from this report to translate these recommendations into Congressional action.

With the topic of today’s discussion centering around science competitiveness, it could not be more appropriate to honor a guest visiting the Committee today, as she can speak directly to the importance of a quality science education — and she can do so quite well I might add. This honoree is Neela Thangada, the winner of the Discovery Channel Young Scientist Challenge, and her mother, Mrudula Rao Thangada. Neela was named “Top Young Scientist” at an awards ceremony yesterday evening for her project, “Effects of Various Nutrient Concentrations on the Cloning of the Eye of the Solanum Tuberosum at Multiple Stages” or, in la 3 Tnen’s terms, she set out to explore potato cloning.

I had the chance to meet with her and her mother before the hearing, and was impressed with her enthusiasm for science and discovery and her ability to effectively speak about her research. She is indeed an incredible young lady.

Her trip to the House Science Committee today from her home in Texas was the result of an important public-private partnership initiated by the Discovery Channel. Every year since 1999, Discovery has launched the competition in partnership with Science Service to nurture the next generation of American scientists at a critical age when interest in science begins to decline. The cutting-edge competition gives 40 of the Nation’s top middle school students the opportunity to demonstrate their scientific know-how and push the limits of their knowledge in the quest for the title of America’s “Top Young Scientist of the Year.”

More than 9,600 middle school students have formally entered the Challenge since its inception, and these students are drawn from an initial pool of 75,000 students annually. Previous winners have attained more than $500,000 in scholarship awards and participated in science-related trips that have taken them to the far corners of the globe, from the Galapagos Islands to the Ukraine.

This year’s finalists traveled to Washington, D.C., to compete in team-based, interactive challenges designed around the theme of “Forces of Nature.” In the wake of the recent natural disasters that ravaged the Gulf Coast of the United States and Southeast Asia, each student faced simulated challenges — from fog banks to hurricanes to tsunamis — that utilized their broad range of knowledge in order to understand the implications and scope of natural disasters.

Public-private partnerships such as these exist to challenge and engage our students and we must continue to support such programs. However, we must also better prepare and inspire our math and science teachers to provide the highest-quality education for all students throughout the country. We can start by implementing some of the recommendations laid out here today.

Chairman BOEHLERT. Thank you very much.

And you will notice the similarity in theme between, you know, this is not a division. The center of this committee separating the Democrats from the Republicans doesn't separate us at all on the importance of the subject matter today. This is something that Mr. Gordon and I and every single Member of this committee, on both sides, believe passionately in and work, we think, hopefully, effectively on. And that is why we welcome what you bring to the table. And we want to give it as much attention as possible.

I would suggest that this probably, if we are looking on the grand scheme of things on the Hill today of what is going on, there is probably no more important discussion than the one we are having right here. And quite frankly, it doesn't have a lot of sex appeal for a lot of the media. And so we don't get a lot of coverage. I don't care if they print what I say, but I darn sure care about printing what you guys are going to say to us. That message has to get out.

And the other observation I would make, and we have had it in private conversations, but I will make it again for the official record, I know that some of the captains of industry, in circles you travel, you know and they know and we know that we have got to do better. And in the polite conversation we have at these various functions, they will talk about such needs as getting back to the basics of greatly improving K-12 science and math education. There is no more basic building block for the foundation of the future development of this nation than that. And they will talk to me all of the time about it. Some of the great names in the captains of industry will talk to me about that. And then they will talk to me about the importance of our investment in long-range research, about how magnificent the National Science Foundation is, sponsoring university-based research, and why we need young scholars like I have been privileged to introduce here today to inspire them to greater heights. And I say to them, "You know what?" I have told these guys, "You people have got more lobbyists running around this Hill, high-priced lobbyists who know what they are doing, and they are very smart, and they are very effective, and they knock on the door and they come in. You know, they don't come in to talk to me about the importance of K-12 science and math education or investing more in the science enterprise. They are in to discuss the latest tweaking needed in the tax policy or the adjustment necessary for trade policy. They are thinking of the moment and the bottom line for the next quarterly statement." And

I understand that. But there is never enough time to get to the second part of their agenda, which is what we are discussing today.

So that is why I think this is very important, and that is why I applaud what you have done, and so does Mr. Gordon. I mean, we have had conversation about your work, and boy, we couldn't be happier. And we just want to try to — we are going to play the role of dentist this morning and sort of pull from you some new ideas on what we can do beyond the report, because this town is filled with reports that have gone on for years and the libraries of the various Committee rooms and offices have reports that are gathering dust. They read them initially and say, "Oh, what a great report," and then go on to the next thing and never go back to look at the report.

I pledge to you, and I think I can do it for both of us, that we are going to follow through, because some of the things that you have mentioned here we are already doing, but we are nickel-and-diming the issue. We have got to make some substantial investments, and it is an investment that is going to pay handsome dividends.

With that, let me present our distinguished panel.

Mr. Norman Augustine, Retired Chairman and CEO, Lockheed Martin Corporation. Mr. Augustine is a frequent visitor to this committee and to Capitol Hill and has served in so many capacities in government and in the private sector with great distinction. Dr. P. Roy Vagelos, Retired Chairman and CEO, Merck & Company. And Doctor, you are preceded by your reputation, and we thank you for the great work you are doing. And a dear friend of long standing who is constant counsel for this committee. Dr. William Wulf, President of the National Academy of Engineering.

Every day, what good comes from government usually comes because government has the common sense, to work with leaders in the private sector to interact and to be guided and to develop an agenda that offers some positive approaches to some thorny problems. And we have before us three people who are always there to propose workable solutions. And for that, we are eternally grateful.

With that, let me say the general rule, and you know the ground rules, is don't get nervous when the light comes on, but we would ask that you summarize your opening statement. And I'm not even going to put an arbitrary time limit on it, because this is so important and you are the only panel. And we will go right to it.

With that, Mr. Chairman, the floor is yours.

STATEMENT OF MR. NORMAN R. AUGUSTINE, RETIRED
CHAIRMAN AND CEO, LOCKHEED MARTIN CORPORATION

Mr. Augustine. Well, thank you, Mr. Chairman, and Members of the Committee. And I thank you in particular for all of your efforts in this area in the past — really, it was by virtue of your committee and your colleagues in the Senate that gave us the opportunity to take on our study. And we, all 20 members, I can assure you, feel very compassionate about the topic.

Also, I would like to congratulate Neela. My congratulations and ours. She is an example to why we are here.

I would, Mr. Chairman, with your permission, like to submit a longer statement for the record and brief

Chairman BOEHLERT. Without ohjection, your entire statement will appear in the record. And summarize it in any manner you think is appropriate.

Mr. Augustine. Thank you very much.

The thrust of our committee’s findings are fairly straightforward. They would begin by saying that we conclude that individuals’ prosperity, the prosperity of individuals, depends veiy heavily upon the quality of the jobs they can hold. And collectively, our prosperity depends very heavily on the tax revenues that our government can acquire, which, in turn, depend upon the quality of the jobs our citizens can hold. So quality jobs are at the root of our discussions.

But there has been a major change brought about by technology largely in this scenario. That change some people refer to as the “death of distance”. And it has been brought about by the advent of advanced information processing, storage and transmissions that have made those functions almost free in today’s world. What that means is that jobs that used to have to be performed by people who are in near proximity to their work or to each other now can be performed by people all around the world. And that, in turn, means that Americans, when they compete for jobs, will no longer compete with their neighbors. They will compete with people throughout the globe. And that is true not only at the so-called lower end of the job spectrum, it will be true throughout the job spectrum. This is in a world where there are three billion new capitalists who have appeared in the last 15 years since the end of the Cold War.

The United States operates at a considerable disadvantage today in this competition for jobs. You could — I was in Vietnam recently. You could hire 20 assembly workers for the minimum U.S. wage. In India today, you could hire 11 engineers for the cost of one in the United States. And they are very good engineers. Many of them trained at our universities.

And as I said, few jobs are safe. Today, if you go to many hospitals in this country and have a CAT scan or an X-ray, there is a fair chance it will be read by a physician in Bangalore. Similarly, there is an office very near to where we are now that, if you go in their building, they have a fiat screen on the wall, and their receptionist there very pleasantly helps you find the person you are supposed to go see and controls access to the building. She is in Bangalore. I am sure you are familiar with many other examples of this type.

Is this not good that the rest of the world is prospering? And our committee's conclusion is a resounding yes. It will make the world safer. It will create more customers for our products, and it will create less costly products for our consumers. But as with all times of tectonic changes, there are likely to be winners, and there are likely to be losers. And our committee's goal is to help assure that America will be among the winners.

There is an enigma, and your quote from Hemingway, Mr. Chairman, summarizes it better than I am able to do it. But we are in an environment where we are not likely to see sudden warnings such as we had on 9/11, Pearl Harbor, Sputnik. It is more like the proverbial frog being gradually boiled. Thomas Friedman has summarized by saying, in his great book "The World is Flat,"

globalization has "accidentally made Beijing, Bangalore, and Bethesda next door neighbors." And indeed, when it comes to seeking a job, those jobs are just a mouse click away to many people throughout the world.

We operate at a severe disadvantage in the labor cost area, but there are other indicators that are not particularly good, either. One of the things that has been keeping us going, as this committee knows so well, in the area of science, has been the number of very talented foreign-born individuals who have chosen to come to America and live and work here. Today, 38 percent of the Ph.D.s in America working in science and technology are foreign-born. Fifty-nine percent of last year's doctorates in engineering were foreign students, and that is at U.S. universities.

But if you look at how we are doing ourselves with our native-born population, a recent test of mathematical understanding among about tenth grade students conducted in various nations of the world, the United States was in 27th place.

This sort of thing is propagating into the industrial world where last year U.S. chemical companies closed 70 plants in the United States. They have earmarked 40 more to close. At the same time, there are 120 new chemical plants being built in the world, each with a price tag of $1 billion or more. Of those, one is in the tJnited States and 50 are in China.

U.S. companies now spend more money on litigation and related costs than they spend on research and development, Mr. Gordon, to your point. These are trends that we can not long survive. And as we know, once you lose your lead in R&D, it takes a very long time to recover it, if, indeed, one can at all.

The committee that we assembled through the auspices of the National Academies included 20 members, four or five CEOs or former CEOs of Fortune 100 companies, three nobel laureates, presidents of five or six major universities, several former presidential appointees, as far as I know, from both parties. We didn't ask that question. And they, as you said, Mr. Chairman, with regard to your committee, come together in a spirit of unanimity on each of the issues that we have discussed.

I will close my opening remarks by indicating that we have provided four recommendations. They tend to be rather broad. We have backed them with 20 quite specific implementing actions, things you can go do, some of which you are doing, some of which we do need to do more of

Of the four general recommendations, the one that all 20 of us agree is the highest priority, is to fix the K-12 science and technology education system in this country, public education. Secondly is to put more money into basic research in specific fields, namely into the physical sciences, mathematics, engineering, and computer sciences. This should be done not to disinvest in the health and biological sciences, which are very important, but they have just seen a period of major investment. Thirdly, to encourage more students to study math and science and engineering and to make it easier to attract foreign students to study and stay in our country in those fields. And then lastly, to create an environment that makes the United States an attractive place for innovation that will at-

tract companies from abroad as well as our own companies to invest here rather than abroad.

So with that opening, I will turn to my colleagues and thank you for this opportunity. And we look forward to your questions.

[The prepared statement of Mr. Augustine follows:]

Prepared Statement of Norman R. Augustine

Mr. Chairman and Members of the Committee,

Thank you for this opportunity to appear before you on behalf of the National Academies' Committee on Prospering in the Global Economy of the 21st Century. As you know, our effort was sponsored by the National Academy of Sciences, National Academy of Engineering and Institute of Medicine (collectively known as the National Academies). The National Academies were chartered by Congress in 1863 to advise the government on matters of science and technology.

The Academies were requested by Senator Alexander and Senator Jeff Bingaman, members of the Senate Committee on Energy and Natural Resources to conduct an assessment of America's ability to compete and prosper in the 21st century — and to propose appropriate actions to enhance the likelihood of success in that endeavor. This request was endorsed by Representatives Sherwood Boehlert and Bart Gordon of the House Committee on Science.

To respond to that request the Academies assembled 20 individuals with diverse backgrounds, including university presidents, CEOs, Nobel Laureates and former presidential appointees. The result of our committee's work was examined by over forty highly qualified reviewers who were also designated by the Academies. In undertaking our assignment we considered the results of a number of prior studies which were conducted on various aspects of America's future prosperity. We also gathered sixty subject-matter experts with whom we consulted for a weekend here in Washington and who provided recommendations related to their fields of specialty.

It is the unanimous view of our committee that America today faces a serious and intensifying challenge with regard to its future competitiveness and standard of living. Further, we appear to be on a losing path. We are here today hoping both to elevate the Nation's awareness of this developing situation and to propose constructive solutions.

The thrust of our findings is straightforward. The standard of living of Americans in the years ahead will depend to a very large degree on the quality of the jobs that they are able to hold. Without quality jobs our citizens will not have the purchasing power to support the standard of living which they seek, and to which many have become accustomed; teix revenues will not be generated to provide for strong national security and health care; and the lack of a vibrant domestic consumer market will provide a disincentive for either U.S. or foreign companies to invest in jobs in America.

What has brought about the current situation? The answer is that the prosperity equation has a new ingredient, an ingredient that some have referred to as "The Death of Distance." In the last century, breakthroughs in aviation created the opportunity to move people and goods rapidly and efficiently over very great distances. Bill Gates has referred to aviation as the "World Wide Web of the 20th century." In the early part of the present century, we are approaching the point where the communication, storage and processing of information are nearly free. That is, we can now move not only physical items efficiently over great distances, we can also transport information in large volumes and at little cost.

The consequences of these developments are profound. Soon, only those jobs that require near-physical contact among the parties to a transaction will not be opened for competition from job seekers around the world. Further, with the end of the Cold War and the evaporation of many of the political barriers that previously existed throughout the world, nearly three billion new, highly motivated, often well educated, new capitalists entered the job market.

Suddenly, Americans find themselves in competition for their jobs not just with their neighbors but with individuals around the world. The impact of this was initially felt in manufacturing, but soon extended to the development of software and the conduct of design activities. Next to be affected were administrative and support services. Today, "high end" jobs, such as professional services, research and management, are impacted. In short, few jobs seem "safe":

• U.S. companies each morning receive software that was written in India overnight in time to be tested in the U.S. and returned to India for further production that same evening — making the 24-hour workday a practicality.

• Back-offices of U.S. firms operate in such places as Costa Rica, Ireland and Switzerland.

• Drawings for American architectural firms are produced in Brazil.

• U.S. firm's call centers are based in India — where employees are now being taught to speak with a mid-western accent.

• U.S. hospitals have X-rays and CAT scans read by radiologists in Australia and India.

• At some McDonald's drive-in windows orders are transmitted to a processing center a thousand miles away (currently in the U.S.), where they are processed and returned to the worker who actually prepares the order.

• Accounting firms in the U.S. have clients tax returns prepared by experts in India.

• Visitors to an office not far from the White House are greeted by a receptionist on a flat screen display who controls access to the building and arranges contacts — she is in Pakistan.

• Surgeons sit on the opposite side of the operating room and control robots which perform the procedures. It is not a huge leap of imagination to have highly-specialized, world-class surgeons located not just across the operating room but across the ocean.

As Tom Friedman concluded in The World is Flat, globalization has "accidentally made Beijing, Bangalore and Bethesda next door neighbors." And the neighborhood is one wherein candidates for many jobs which currently reside in the U.S. are now just a "mouse-click" away.

How will America compete in this rough and tumble global environment that is approaching faster than many had expected? The answer appears to be, "not very well" — unless we do a number of things differently from the way we have been doing them in the past.

Why do we reach this conclusion? One need only examine the principal ingredients of competitiveness to discern that not only is the world flat, but in fact it may be tipping against us.

One major element of competitiveness is, of course, the cost of labor. I recently traveled to Vietnam, where the wrap rate for low-skilled workers is about twenty-five cents per hour, about one-twentieth of the U.S. minimum wage. And the problem is not confined to the so-called "lower-end" of the employment spectrum. For example, five qualified chemists can be hired in India for the cost of just one in America. Given such enormous disadvantages in labor cost, we cannot be satisfied merely to match other economies in those other areas where we do enjoy strength; rather we must excel . . . markedly.

The existence of a vibrant domestic market for products and services is another important factor in determining our nation's competitiveness, since such a market helps attract business to our shores. But here, too, there are warning signs: Goldman Sachs analysts project that within about a decade, fully 80 percent of the world's middle-income consumers will live in nations outside the currently industrialized world.

The availability of financial capital has in the past represented a significant competitive advantage for America. But the mobility of financial capital is legion, as evidenced by the willingness of U.S. firms to move factories to Mexico, Vietnam and China if a competitive advantage can be derived by doing so. Capital, as we have observed, crosses geopolitical borders at the speed of light.

Human capital – the quality of our work force – is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally with those of other developed – and even developing – nations . . . particularly in the fields which underpin most innovation: science, mathematics and technology.

Of the utmost importance to competitiveness is the availability of knowledge capital – "ideas." And once again, scientific research and engineering applications are crucial. But knowledge capital, like financial capital, is highly mobile. There is one major difference: being first-to-market, by virtue of access to new knowledge, can be immensely valuable, even if by only a few months. Craig Barrett, a member of our committee and Chairman of Intel, points out that 90 percent of the products his company delivers on December 31st did not even exist on January 1st of that

same year. Such is the dependence of hi-tech firms on being at the leading edge of scientific and technological progress.

There are of course many other factors influencing our nation's competitiveness. These include patent processes, tax policy and overhead costs – such as health care, regulation and litigation – all of which tend to work against us today. On the other hand, America's version of the Free Enterprise System has proven to be a powerful asset, with its inherent aggressiveness and discipline in introducing new ideas and flushing out the obsolescent. But others have now recognized these virtues and are seeking to emulate our system.

But is it not a good thing that others are prospering? Our committee's answer to that question is a resounding "yes." Broadly based prosperity can make the world more stable and safer for all; it can make less costly products available for American consumers; it can provide new customers for the products we produce here. Yet it is inevitable that there will be relative winners and relative losers – and as the world prospers, we should seek to assure that America does not fall behind in the race.

The enigma is that in spite of all these factors, America seems to be doing quite well just now. Our nation has the highest R&D investment intensity in the world. We have indisputably the finest research universities in the world. California alone has more venture capital than any nation in the world other than the United States. Two million jobs were created in America in the past year alone, and citizens of other nations continue to invest their savings in America at a remarkable rate. Total household net worth is now approaching $50 trillion.

The reason for this prosperity is that we are reaping the benefits of past investments — many of them in the fields of science and technology. But the early indicators of future prosperity are generally heading in the wrong direction. Consider the following:

• For the cost of one engineer in the United States, a company can hire 11 in India.

• America has been depending heavily on foreign-born talent. Thirty-eight percent of the scientists and engineers in America holding doctorates were born abroad. Yet, when asked in the spring of 2005, what are the most attractive places in the world in which to live, respondents in only one of the countries polled indicated the U.S.A.

• Chemical companies closed seventy facilities in the U.S. in 2004, and have tagged forty more for shutdown. Of 120 new chemical plants being built around the world with price tags of $1 billion or more, one is in the U.S. Fifty are in China.

• In 1997 China had fewer than 50 research centers managed by multi-national corporations. By 2004 there were over 600.

• Two years from now, for the first time, the most capable high-energy particle accelerator on Earth will reside outside the United States.

• The United States today is a net importer of high technology products. The U.S. share of global high tech exports has fallen in the last two decades from 30 percent to 17 percent, while America's trade balance in high tech manufactured goods shifted from a positive $33B in 1990 to a negative $24B in 2004.

• In a recent international test involving mathematical understanding, U.S. students finished in 27th place among the nations participating.

• About two-thirds of the students studying chemistry and physics in U.S. high schools are taught by teachers with no major or certificate in the subject. In the case of math taught in grades five through 12, the fraction is one-half. Many such students are being taught math by graduates in physical education.

• In one recent period, low-wage employers like Wal-Mart (now the Nation's largest employer) and McDonald's created 44 percent of all new jobs. High-wage employers created only 29 percent.

• In 2003 foreign students earned 59 percent of the engineering doctorates awarded in U.S. universities.

• In 2003 only three American companies ranked among the top 10 recipients of patents granted by the U.S. Patent Office.

• In Germany, 36 percent of undergraduates receive their degrees in science and engineering. In China, the corresponding figure is 59 percent, and in Japan it is 66 percent. In the U.S., the share is 32 percent. In the case of engineering, the U.S. share is five percent, as compared with 50 percent in China.

• The United States is said to have over 10 million illegal immigrants, but the number of legal visas set-aside annually for “highly qualified foreign workers” was recently dropped from 195,000 per year down to 65,000.

• At a time when the world’s nations are clamoring to obtain science and engineering talent, U.S. law will grant a visa for outstanding foreign students to attend U.S. universities only if they promise they will go home when they graduate.

• In 2001 (the most recent year for which data are available), U.S. industry spent more on tort litigation and related costs than on research and development.

As important as jobs are, the impact of these circumstances on our nation’s security could be even more profound. In the view of the bipartisan Hart-Rudman Commission on National Security, “. . .the inadequacies of our system of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine.”

The good news is that there are things we can do to assure that America does in fact share in the prosperity that science and technology are bringing the world. In this regard, our committee has made four broad recommendations as the basis of a prosperity initiative – and offers 20 specific actions to make these recommendations a reality. They include:

o “Ten Thousand Teachers, Ten Million Minds” – which addresses America’s K-12 education system. We recommend that America’s talent pool in science, math and technology be increased by vastly improving K-12 education. Among the specific steps we propose are:

• Recruitment of 10,000 new science and math teachers each year through the award of competitive scholarships in math, science and engineering that lead to a Bachelor’s degree accompanied by a teaching certificate – and a five-year commitment to teach in a public school.

• Strengthening the skills of 250,000 current teachers through funded training and education in part-time Master’s programs, summer institutes and Advanced Placement training programs.

• Increasing the number of students who take Advanced Placement science and mathematics courses.

o “Sowing the Seeds” – which addresses America’s research base. We recommend strengthening the Nation’s traditional commitment to long-term basic research through:

• Increasing federal investment in research by 10 percent per year over the

next seven years, with primary attention devoted to the physical sciences, engineering, mathematics, and information sciences – without

disinvesting in the health and biological sciences.

• Providing research grants to early career researchers.

• Instituting a National Coordination Office for Research Infrastructure to oversee the investment of an additional $500M per year for five years for advanced research facilities and equipment.

• Allocating at least eight percent of the existing budgets of federal research agencies to discretionary funding under the control of local laboratory directors.

• Creation of an Advanced Research Projects Agency-Energy (ARPA-E), modeled after DARPA in the Department of Defense, reporting to the Department of Energy Undersecretary for Science. The purpose is to support the conduct of out-of-the-box, transformational, generic, energy research by universities, industry and government laboratories.

• Establish a Presidential Innovation Award to recognize and stimulate scientific and engineering advances in the national interest.

o “Best and Brightest” – which addresses higher education. In this area we recommend:

• Establishing 25,000 competitive science, mathematics, engineering, and technology undergraduate scholarships and 5,000 graduate fellowships in areas of national need for U.S. citizens pursuing study at U.S. universities.

• Providing a federal tax credit to employers to encourage their support of continuing education.

• Providing a one-year automatic visa extension to international students who receive a science or engineering doctorate at a U.S. university, and providing automatic work permits and expedited residence status if these students are offered employment in the U.S.

• Instituting a skill-hased, preferential immigration option.

• Reforming the current system of “deemed exports” so that international students and researchers have access to necessary non-classified information or research equipment while studying and working in the U.S.

o “Incentives for Innovation” – in which we address the innovation environment itself. We recommend:

• Enhancements to intellectual property protection, such as the adoption of a first-to-file system.

• Increasing the R&D tax credit from the current 20 percent to 40 percent, and making the credit permanent.

• Providing permanent tax incentives for U.S. -based innovation so that the United States is one of the most attractive places in the world for long-term innovation-related investments.

• Ensuring ubiquitous broadband Internet access to enable U.S. firms and researchers to operate at the state-of-the-art in this important technology.

It should be noted that we are not confronting a so-called “typical” crisis, in the sense that there is no 9/11, Sputnik or Pearl Harbor to alert us as a nation. Our situation is more akin to that of the proverbial frog being slowly boiled. Nonetheless, while our committee believes the problem we confront is both real and serious, the good news is that we may well have time to do something about it – if we start now.

Americans, with only five percent of the world’s population but with nearly 30 percent of the world’s wealth, tend to believe that scientific and technological leadership and the high standard of living it underpins is somehow the natural state of affairs. But such good fortune is not a birthright. If we wish our children and grandchildren to enjoy the standard of living most Americans have come to expect, there is only one answer: We must get out and compete.

I would like to close my remarks with a perceptive and very relevant poem. It was written by Richard Hodgetts, and eloquently summarizes the essence of innovation in the highly competitive, global environment. The poem goes as follows:

Every morning in Africa a gazelle wakes up. It knows it must outrun the fastest lion or it will be killed.

Every morning in Africa a lion wakes up. It knows it must outrun the slowest gazelle or it will starve.

It doesn’t matter whether you’re a lion or a gazelle – when the sun comes up, you’d better be running.

And indeed we should.

Thank you for providing me with this opportunity to testify before the Committee. I would be pleased to answer any questions you have about the report.

Response to House Committee on Science Questions

1. How did the study panel arrive at the recommended 10 percent annual increase in federally-sponsored basic research over the next seven years? What other options did the panel consider and what led to the choice of 10 percent?

After reviewing the proposals for enhanced research funding that have been made in recent years, the committee concluded that a 10 percent annual increase over a seven-year period would be appropriate. This achieves the doubling that was in principle part of the NSF Authorization Act of 2002 approved by Congress and the President, but would expand it to other agencies and focus that increase on the physical sciences, engineering, mathematics, and the information sciences as well as DOD basic research.

The committee viewed enhanced funding in these fields as urgent. It chose the 10 percent level and seven-year time frame as the best way for these funds to be spent effectively. The base for this doubling (federal funding for the fields listed plus DOD basic research — not including the specified fields so there is no double-counting) was approximately $8 billion in FY 2004.

By taking this action, the balance of the Nation's research portfolio in fields that are essential to the generation of both ideas and skilled people for the Nation's economy and national/homeland security would be restored. That does not mean that there should be a disinvestment in such important fields as the life sciences (which have in fact seen growth in recent years) or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to U.S. prosperity.

As indicated in the National Academies Committee on Science, Engineering, and Public Policy's (COSEPUP) 1993 report Science, Technology, and the Federal Government: National Goals for a New Era

The United States needs to be among the world leaders in all fields of research so that it can

• Bring the best available knowledge to bear on problems related to national objectives even if that knowledge appears unexpectedly in a field not traditionally linked to that objective.

• Quickly recognize, extend, and use important research results that occur elsewhere.

• Prepare students in American colleges and universities to become leaders themselves and to extend and apply the frontiers of knowledge.

• Attract the brightest young students. ^

2. How did the study panel arrive at the recommended eight percent allocation within each federal research agency's budget to be managed at the discretion of technical program managers to catalyze high-risk, high-payoff research? What other options did the panel consider and what led to the choice of eight percent?

The committee found that at many agencies approximately one to three percent of a program's budget is to be managed at the discretion of the program managers. The committee believes, as shown through the Defense Advanced Research Projects Agency (DARPA) model, that more risky research that crosses disciplinary lines can be funded by using the "strong program manager" approach as is the case at DARPA. Some committee members believed that five percent was sufficient, others 10 percent — in the end a compromise was reached at eight percent. The committee is flexible about the specific number as long as the goal of catalyzing high-risk, high-payoff research (as opposed to incremental research) is achieved. Experience shows that research investments of this type are exceptionally highly leveraged.

3. Industry and government have both developed numerous energy production and energy efficiency technologies that have not been deployed. How did the study panel arrive at its implicit conclusion that technology development is the greater bottleneck (as opposed to policy) in developing energy systems for a 21st century economy?

The committee believes that both policy and technology play a role in responding to the Nation's need for clean, affordable, and reliable energy.

While the implementation of some technologies, such as nuclear energy, is discouraged by policy, we still face environmental and safety challenges only science and engineering research can ameliorate — even if policy-makers were willing to deploy that technology today. There are no doubt questions of cost and policy that affect use of various energy technologies. When was the last nuclear plant commissioned? But those policy decisions are often directly linked to technical capabilities or the absence thereof. No 'final' solutions without serious problems are waiting in the wings for policy changes. Nuclear energy is an (the) important potential source of energy but it has security and waste disposal/storage problems that have not been handled satisfactorily. That is a prime example of a policy problem that requires research to unlock it.

Similarly, the Nation, as the report indicates, has made substantial strides in efficiency, but much more can be done. Yes there is existing efficiency technology that can be deployed, and, following market forces if oil prices do not return to recent levels, will probably be used increasingly.

As a result, the Nation will not significantly decrease energy dependence without technology — policy changes alone are insufficient. The production of electricity and mobility on a worldwide basis cannot go on for ever in their present form. This country is running a significant risk of remaining substantially dependent on foreign oil.

1 COSEPUP. 1993. Science, Technology, and the Federal Government: National Goals for a New Era. Washington, DC: National Academy Press.

The history of science and technology suggests that radical new solutions may well be available. The field of energy has not been viewed as exciting by a generation of engineering students. The time required to effect an energy solution from research to implementation is considerable. The rate of growth of the energy problem (usage) worldwide is likely to have profound effects.

We believe that the Advanced Research Projects Agency (ARPA-E) proposed by the committee can jump start new approaches to high risk/high payoff research of the type that DARPA has historically performed to great effect for the military. It can capture the talents of outstanding young people in industry and academia. DARPA is a demonstrably effective approach to advanced research and development, and Energy is one of the most important challenges to our nation's future.

4. Recent surveys of industry suggest that basic research performed at universities and transformational technological innovation have only a very limited impact on the success of individual companies. Is the impact of research and innovation different for the economy as a whole than it is for individual companies?

There is broad consensus among economists that for decades the growth of the U.S. economy has been driven by technological advances and innovation. These come almost exclusively from two sources — companies and universities. Companies are devoting fewer and fewer resources to longer-term research that contributes to the common base of technology that is available to all; i.e., work that improves our national capacity but doesn't necessarily directly drive that company's profits. Universities are increasingly the only avenue for the research that will lead to fundamentally new things and to a highly-educated workforce. Most large companies now strive for a large percentage of their products to have been developed within the last two or three years. This requires constant and focused innovation. The immediate crowds out the strategic.

Truly transformational technologies do not come along every day, and cannot be readily predicted. But one thing is certain — if we do not invest in research and advanced training for scientists and engineers, they will not occur at all — at least not in the United States.

Because of this, the committee disagrees with the first premise in the question. Industry gains not only from the new knowledge generated as a result of academic research, but also from the skilled people generated as a result of research.

Although many industries as diverse as the pharmaceutical and banking industry understand the linkage of their business to science and technology, others do not always fully understand the linkages between its day-to-day activities and science and technology. For example, at one point, we thought that the trucking industry was not particularly sensitive to science and technology. But the trucking industry certainly has been able to enhance its competitiveness by using tools such as the global positioning system, advanced lightweight materials, the ability to use the Internet, and weather forecasting to enhance its ability to locate the best route to a destination thus lowering its operating cost. In addition, its competitiveness could be enhanced further if new ways are developed for the industry to be more efficient in its use of fuel and if more affordable fuels are developed.

As a result, when looking at its primary operations, a single company may not see direct use of basic research if it has not licensed a patent, contracted for studies or undertaken its own work. But slightly below the surface the substantial contribution of basic research to essentially every company is evident.

For some industries, research provides them with the talented people they need whose education is influenced in substance, thinking and methods by basic research experience/training. Talented graduates for corporate laboratories are a primary deliverable of basic research operations at universities. Many major companies, in addition, support basic research at universities first and foremost to gain access to these people.

Secondly, essentially every company buys technology whose function and cost are controlled by basic research conducted earlier. So companies that assemble products using others’ components may not be involved in basic research directly but their business remains dependent on the basic research behind the component technolo^es that they use.

Third, basic research creates the new technologies and new enterprises that these companies will sell to, or buy from or even become. Frankly, it is difficult to think of a company that does not use technology at some level, and that technology evolved from basic research.

Fourth, the people generated as a result of the higher education they receive, underpinned by basic research, create whole new industries and jobs. For example, in 1997, BankBoston conducted the first national study of the economic impact of a research university. It found that graduates of the Massachusetts Institute of Technology founded 4,000 firms which, in 1994 alone, employed at least 1.1 million people and generated $232 billion of world sales. Further, if the companies founded by MIT graduates and faculty formed an independent nation, the revenues produced by the companies would make that nation the 24th largest economy in the world. Within the United States, the companies founded by MIT graduates employed a total of 733,000 people in 1994 at more than 8,500 plants and offices in the 50 states — equal to one out of every 170 jobs in America. Eighty percent of the jobs in the MIT-related firms are in manufacturing (compared to 16 percent nationally), and a high percentage of products are exported.

COMMITTEE BIOGRAPHIC INFORMATION

NORMAN R. AUGUSTINE [NAE*] (Chair) is the retired Chairman and CEO of the Lockheed Martin Corporation. He serves on the President's Council of Advisors on Science and Technology and has served as Under Secretary of the Army. He is a recipient of the National Medal of Technology.

CRAIG BARRETT [NAE] is Chairman of the Board of the Intel Corporation.

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STEVEN CHU [NAS*] is the Director of the E.O. Lawrence Berkeley National Laboratory. He was a co-winner of the Nobel prize in physics in 1997.

ROBERT GATES is the President of Texas A&M University and served as Director of Central Intelligence.

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CHARLES HOLLIDAY JR. [NAE] is Chairman of the Board and CEO of DuPont.

SHIRLEY ANN JACKSON [NAE] is President of Rensselaer Polytechnic Institute. She is the Immediate Past President of the American Association for the Advancement of Science and was Chairman of the U.S. Nuclear Regulatory Commission.

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JOSHUA LEDERBERG [NAS/IOM] is the Sackler Foundation Scholar at Rockefeller University in New York. He was a co-winner of the Nobel prize in physiology or medicine in 1958.

RICHARD LEVIN is President of Yale University and the Frederick William Beinecke Professor of Economics.

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CHERRY MURRAY [NAS/NAE] is the Deputy Director for Science and Technology at Lawrence Livermore National Laboratory. She was formerly the Senior Vice President at Bell Labs, Lucent Technologies.

PETER O'DONNELL JR. is President of the O'Donnell Foundation of Dallas, a private foundation that develops and funds model programs designed to strengthen engineering and science education and research.

LEE R. RAYMOND [NAE] is the Chairman of the Board and CEO of Exxon Mobil Corporation.

ROBERT C. RICHARDSON [NAS] is the F.R. Newman Professor of Physics and the Vice Provost for Research at Cornell University. He was a co-winner of the Nobel prize in physics in 1996.

P. ROY VAGELOS [NAS/TOM] is the retired Chairman and CEO of Merck & Co., Inc.

CHARLES M. VEST [NAE] is President Emeritus of MIT and a Professor of Mechanical Engineering. He serves on the President's Council of Advisors on Science and Technology and is the Immediate Past Chair of the Association of American Universities.

GEORGE M. WHITESIDES [NAS/NAE] is the Woodford L. & Ann A. Flowers University Professor at Harvard University. He has served as an adviser for the National Science Foundation and the Defense Advanced Research Projects Agency.

RICHARD N. ZARE [NAS] is the Marguerite Blake Wilhur Professor of Natural Science at Stanford University. He was Chair of the National Science Board from 1996 to 1998.

Biography for Norman R. Augustine

NORMAN R. AUGUSTINE was raised in Colorado and attended Princeton University where he graduated with a BSE in Aeronautical Engineering, magna cum laude, an MSE and was elected to Phi Beta Kappa, Tau Beta Pi and Sigma Xi.

In 1958 he joined the Douglas Aircraft Company in California where he held titles of Program Manager and Chief Engineer. Beginning in 1965, he served in the Pentagon in the Office of the Secretary of Defense as an Assistant Director of Defense Research and Engineering. Joining the LTV Missiles and Space Company in 1970, he served as Vice President, Advanced Programs and Marketing. In 1973 he returned to government as Assistant Secretary of the Army and in 1975 as Under Secretary of the Army and later as Acting Secretary of the Army. Joining Martin Marietta Corporation in 1977, he served as Chairman and CEO from 1988 and 1987, respectively, until 1995, having previously been President and Chief Operating Officer. He served as President of Lockheed Martin Corporation upon the formation of that company in 1995, and became its Chief Executive Officer on January 1, 1996, and later Chairman. Retiring as an employee of Lockheed Martin in August, 1997, he joined the faculty of the Princeton University School of Engineering and Applied Science where he served as Lecturer with the Rank of Professor until July, 1999.

Mr. Augustine served as Chairman and Principal Officer of the American Red Cross for nine years and as Chairman of the National Academy of Engineering, the Association of the United States Army, the Aerospace Industry Association, and the Defense Science Board. He is a former President of the American Institute of Aeronautics and Astronautics and the Boy Scouts of America. He is currently a member of the Board of Directors of ConocoPhillips, Black & Decker and Procter & Gamble and a member of the Board of Trustees of Colonial Williamsburg and Johns Hopkins and a former member of the Board of Trustees of Princeton and MIT. He is a member of the President’s Council of Advisors on Science and Technology and the Department of Homeland Security Advisory Board and was a member of the Hart/Rudman Commission on National Security.

Mr. Augustine has been presented the National Medal of Technology by the President of the United States and has five times been awarded the Department of Defense’s highest civilian decoration, the Distinguished Service Medal and has received the Joint Chiefs of Staff Distinguished Public Service Award. He is co-author of The Defense Revolution and Shakespeare In Charge and author of Augustine’s Laws and Augustine’s Travels. He holds eighteen honorary degrees and was selected by Who’s Who in America and the Library of Congress as one of the Fifty Great Americans on the occasion of Who’s Who’s fiftieth anniversary. He has traveled in nearly 100 countries and stood on both the North and South Poles.

Chairman BOEHLERT. Thank you very much.

Dr. Vagelos.

STATEMENT OF DR. P. ROY VAGELOS, RETIRED CHAIRMAN AND CEO, MERCK & CO.

Dr. Vagelos. Thank you, Mr. Chairman and Committee Members. I am delighted to be here to talk about my specific interest in this committee work.

And let me start with K-12 education since that was mentioned by both the Chairman and Mr. Gordon. Mr. Gordon made the statement that much of what is recommended is a rehash of old material. And to some degree, that is true. The problem is that if you go to the American public today, they will tell you that they are not pleased with the results of what we are doing in K-12 education, and therefore, the committee looked very hard. And as

Norm just mentioned, among the committee of 20 people, the unanimous number one priority was to do something in K-12 education.

So let me tell you a couple of things that we focused on. First of all, a recognition that if one is going to teach in science and mathematics, that one should have had some expertise and some courses in those fields that are going to be taught in K-12, especially in grades eight through twelve. What we have found is that many of the teachers have had no major, and not even a good course in the subjects that they are teaching. So you will have a teacher teaching physics or chemistry or mathematics never having had a major course in those areas. And so can we expect such teachers to turn on our young people to be able to enter these fields?

We decided not, and therefore, what are we recommending?

We are suggesting several programs that are aimed at just that kind of thing. For instance, there are students who are already majoring as undergraduates in mathematics, science, and engineering, and there is a program, for instance, it is called “U Teach” at the University of Texas in Austin, which selects these students and offers them scholarships if they will also take some courses in education and learn to teach during the four years that they are already majoring in these subjects that they are going to potentially teach. Now these are the people who really understand their subjects.

And so one of the recommendations is 10,000 students per year of that sort nationally who are going to be expert in their field and who are becoming teachers, and the payback is that they teach for five years.

Another program that we have. So that would cover 10,000 new teachers coming through the mill. If you take the large numbers of people who are already teaching in these subjects and say can we resuscitate them because they don’t really have the expertise. And we have a program, several programs for them.

The one I like best is those people who are willing to come back for a Master’s degree and spend two years, two summers and weekends to take a Master’s in subject matter, whether it is physics, chemistry, technology, or mathematics, and they end up, at the end of two years, as master teachers, really understanding deeply their

subject and being able to turn out other teachers and certainly to
recruit and excite students.

In addition to these Master's programs, there are programs that
are summer institutes, large numbers of these, where teachers
come back for two to four weeks annually have their education in
specific subject matter improved. So these are the kinds of people
who can turn people on and students on.

Now we can do that for teachers. We can also increase the num-
ber of students that are going through middle and high schools who
go into science and math by inducing them to take advanced place-
ment courses and tests or international baccalaureate subjects. And
there is a program, again which was tested and has been going for
10 years in Texas, centered in Dallas in this instance, where both
the teachers are trained in the summer institutes to teach ad-
vanced courses, and students are induced by offering them scholar-
ships, and then if they pass the test, they get a bonus of $100. Not

only do the students get $100, but the teachers get $100. Now this
program has been going on for 10 years, and the number of stu-
dents taking these advanced placement courses and tests has gone
up tenfold, 10 times over the course of 10 years. Now the beauty
of that is that these students who are now taking advanced courses
are more likely to go into such courses when they go to college.

Okay. So those are two programs that I think are really impor-
tant and have been demonstrated to work. And so this is what we
would recommend.

We would also recommend a development of a curriculum, a na-
tional curriculum, that would be voluntary and available through
the Internet to, available to all teachers nationally and all school
districts that could be optimizing all of these subjects that we are
talking about.

To jump ahead, to get students then to go into science, engineer-
ing, mathematics, computer sciences, there would be scholarships,
undergraduate scholarships at the level of $25,000 per year, com-
petitive, picking the best students in the country to go into these,
also 5,000 fellowships for graduate study in such subjects to get our
students in there and in the same subjects, and finally, as Norm
just talked about the international students, we would like to have
a correction and improvement in both the visa and the immigration
policies so that we can continue to attract or attract again those

kinds of top students internationally who were coming to the
United States and have been slowed down because of various problems since 9/11.

So I think, in summary, I think we all agree that K-12 is important. Certainly our higher education is also important. But it is not only important for competitiveness, it is important for the jobs, the high-knowledge jobs of the future that are going to dictate our economy.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Vagelos follows:]

Prepared Statement of P. Roy Vagelos

Mr. Chairman and Members of the Committee.

Thank you for this opportunity to appear before you on behalf of the National Academies' Committee on Prospering in the Global Economy of the 21st Century. As you know, our effort was sponsored by the National Academy of Sciences, National Academy of Engineering and Institute of Medicine (collectively known as the National Academies). The National Academies were chartered by Congress in 1863 to advise the government on matters of science and technology.

Mr. Augustine, Chair of the Committee, has discussed the overall concerns the Committee has about the future vitality of the United States economy. During my testimony, I will focus on the problems that we're having in K through 12 education. The Committee believes the education issue is the most critical challenge the United States is facing if our children and grandchildren are to inherit ever-greater opportunities for high-quality, high-pa 3 dng jobs — and our solution and recommendations to respond to the Nation's challenge in K-12 science, mathematics, engineering, and technology education were the Committee's top priority.

The Committee found that the American public is not satisfied with the K through 12 education available for their children. They are worried about the international comparative surveys that show that children outside the United States — even those in countries with far less resources than ours — rank higher than their own children in their understanding of mathematics or science.

The Committee then made the recommendation we call "10,000 teachers, 10 million minds" which proposes increasing America's talent pool by vastly improving K-12 science and mathematics education.

In developing its action steps to reach this goal, the Committee first focused on what part of K-12 science, mathematics, engineering, and technology education was of greatest concern. The Committee immediately recognized that many of these teachers do not have sufficient education in these fields, and its recommendations respond to that concern.

Of all its action steps, the Committee's highest priority is a program that would annually recruit 10,000 of America's brightest students to the science, mathematics, and technology K-i2 teaching profession. The program would recruit and train excellent teachers by providing scholarships to students obtaining Bachelor's degrees in the physical or life sciences, engineering, or mathematics to gain concurrent certification as K-12 science and mathematics teachers. Over their careers, each of these teachers would educate 1,000 students, so that each annual cadre of teachers educated in this program would impact 10 million minds.

The program would provide merit-based scholarships of up to $20,000 a year for four years for qualified educational expenses, including tuition and fees, and would require a commitment to five years of service in public K-12 schools. A $10,000 annual bonus would go to program graduates working in under-served schools in inner cities and rural areas.

To provide the highest-quality education for undergraduates who want to become K-12 science and mathematics teachers, it would be important to award matching grants, perhaps $1 million a year for up to five years, to as many as 100 universities and colleges to encourage them to establish integrated four-year undergraduate programs leading to Bachelor's degrees in science, engineering, or mathematics with concurrent teacher certification.

This program, modeled after a very successful program in Texas (and which is being replicated in California), takes advantage of those people who are already in science, mathematics, engineering, and technology higher education programs and offer them the ability to get into teaching. It also incorporates in-classroom teaching experiences, master K-12 teachers, and ongoing mentoring — the combination of which produces highly qualified teachers with the skills and support to remain effective in the classroom.

Our second action step focuses on strengthening the skills of 250,000 current K-12 science and mathematics teachers through summer institutes. Master's programs, and Advanced Placement and International Baccalaureate (AP and IB) professional development programs. Each of these activities also builds on very successful model programs that can be scaled up to the national level.

In the case of the summer institutes, the Committee recommends that the Federal Government provide matching grants for state-wide and regional one- to two-week summer institutes to upgrade the content knowledge and pedagogy skills of 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.

For the science and mathematics Master's programs, the Committee recommends that the Federal Government provide grants to universities to develop and offer 50,000 current middle-school and high-school science, mathematics, and technology teachers (with or without undergraduate science, mathematics, or engineering degrees) two-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.

In the case of AP, IB, and pre-AP or pre-IB training, the Committee recommends that the Federal Government support the training of 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 $2,000 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.

The Committee also proposes that high-quality teaching be fostered with world-class curricula, standards, and assessments of student learning. Here, the Committee recommends that the Department of Education 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.

Why are we doing this? Because, as Mr. Augustine mentions, many of the teachers who are teaching subjects have no background in the subjects that they are teaching. It is very hard for someone who does not have a physics education to turn students on to physics, because they have no basic feeling for the subject. Teachers

with strong content knowledge, either through a Bachelor’s or Master’s program, who also have strong pedagogy skills and access to ongoing skills updates can be truly effective at encouraging students in science, mathematics, and technology fields. That is the thesis that we’ve built on.

The Committee also proposes a program that will enlarge the pipeline by encouraging more students to take AP and IB science and mathematics courses and tests through providing more opportunities and incentives for middle-school and high-school students to pursue advanced work in science and mathematics. The Committee suggests a national goal of increasing the number of students in AP and IB mathematics and science courses from 1.2 million to 4.5 million, and setting a goal of tripling the number who pass those tests, to 700,000, by 2010. Student incentives for success would include 50 percent examination fee rebates and $100 mini-scholarships for each passing score on an AP or IB mathematics and science examination.

The reason we are encouraging more students to participate in AP/IB courses is because we have found, through the Dallas-based AP Incentive Program, that those students who take AP/IB courses are twice as likely to enter and complete college as those who do not. Of particular interest is the ability of programs such as the University of California College Prep Program to reach currently under-served areas or populations of students with specific learning needs through online access to teachers and tutors.

We also propose scholarships for American undergraduates who are willing to go into science and technology and engineering and fellowship programs for those pursing graduate science and engineering degrees in areas of national need.

In sum, the Committee is proposing a whole spectrum of recommendations that will enhance the quality of science, mathematics, engineering, and technology education for all American students and providing incentives for Americans to pursue higher education degrees in these fields. By taking the proposed actions, we believe that the United States will be better positioned to compete as a country for future high knowledge jobs.

Thank you for providing me with this opportunity to testify before the Committee. I would be pleased to answer any questions you have about the report.

Biography for P. Roy Vagelos

Dr. Vagelos served as Chief Executive Officer of Merck & Co. Inc., for nine years from July 1985 to June 1994. He was first elected to the Board of Directors in 1984 and served as its Chairman from April 1986 to November 1994.

Dr. Vagelos joined the worldwide health products firm in 1975 as Senior Vice President of Research and became President of its research division in 1976; in addition, starting in January 1982, he served as Senior Vice President of Merck with responsibility for strategic planning. He continued to hold both positions until 1984, when he was elected Executive Vice President.

Before assuming broader responsibilities of business leadership, Dr. Vagelos had won scientific recognition as an authority on lipids and enzymes and as a research manager. This followed a decision early in his career to put his principal energies into research rather than the practice of medicine.

Dr. Vagelos received a A.B. degree (1950) from the University of Pennsylvania, where he was elected to Phi Beta Kappa, the academic honor society. He received his M.D. from Columbia University (1964) and was elected to Alpha Omega Alpha, the medical honor society. After internship and residency (1954^56) at Massachusetts General Hospital in Boston, he joined the National Institutes of Health in Bethesda, Maryland.

At the NIH (1956-66) he served in the National Heart Institute, holding positions in cellular physiology and biochemistry — first as Senior Surgeon and then as Head of Section of Comparative Biochemistry, both in the Laboratory of Biochemistry.

In 1966, Dr. Vagelos joined Washington University in St. Louis, Missouri, as Chairman of the Department of Biological Chemistry of the School of Medicine. In addition, from 1973 to 1976, he assumed more extensive responsibilities as Director of the University's Division of Biology and Biochemical Sciences, which he founded.

Dr. Vagelos has received honorary Doctor of Science degrees from Washington University (1980) for his research achievements and important influence on national science policy; Brown University (1982) for distinguished contributions to the advancement of knowledge as a teacher, research scientist, and head of one of the Nation's outstanding laboratories; the University of Medicine and Dentistry of New Jersey (1984) for outstanding leadership in biomedical research leading to drugs and other therapeutic agents of direct benefits to mankind; New York University (1989) for contributions in helping to discover and produce medicines that both extend and enhance life; Columbia University (1990) for an extraordinary range of accomplish-

ments in biological science, pharmaceutical research, and leadership in the pharmaceutical industry; the New Jersey Institute of Technology (1992) for his contributions to medical research; Pamukkale University in Turkey (1992); and the University of New York at Stony Brook (1994) for outstanding achievement; Mount Sinai Medical School (1997); and the University of British Columbia (1998). He received Honorary Doctor of Laws degrees for leadership in the battle to conquer diseases from Princeton University (1990), the University of Pennsylvania (1999) and Harvard University (2003). Rutgers University (1991) granted him honorary Doctor of Humane Letters degree in recognition of his "ambitious agenda to develop effective cures for the most perplexing illness of our time."

The author of more than 100 scientific papers, he received the Enzyme Chemistry Award of the American Chemical Society in 1967. He was elected in 1972 to the American Academy of Arts and Sciences and the National Academy of Sciences, and in 1993 to the American Philosophical Society. In 1989 he received the Thomas Alva Edison Sciences Award from Governor Thomas Kean. In 1993, he received the Lawrence A. Wien Prize in Social Responsibility from Columbia University. In 1994 he received the C. Walter Nichols Award from New York University's Stern School of Business. In 1995 he received the National Academy of Science Award for Chemistry in Service to Society. In 1998 he was awarded the Prince Mahidol Award conferred by His Majesty the King in Bangkok (Thailand). In 1999 he received the Othmer Gold Medal from the Chemical Heritage Foundation and Bower Award in Business Leadership from Franklin Institute.

Dr. Vagelos was Chairman of the Board of Trustees of the University of Pennsylvania from October 1994 to June 1999, having served as a trustee since 1988. He also served as Co-Chairman of the New Jersey Performing Arts Center from 1989-99, was President and CEO of the American School of Classical Studies at Athens from 1999-2001 and served in the National Research Council Committee on Science and Technology for Countering Terrorism in 2002.

He is currently Chairman of Regeneron Pharmaceuticals, Inc. and Theravance, Inc., two biotech companies. He is also Chairman of the Board of Visitors at Columbia University Medical Center where he also chairs the Capital Campaign. He serves on a number of public policy and advisory boards, including the Donald Danforth Plant Science Center and the Danforth Foundation.

Dr. Vagelos is married to the former Diana Touliatos. They live in New Jersey, and have four children and seven grandchildren.

Dr. Vagelos was born on October 8, 1929, in Westfield New Jersey.

Chairman BOEHLERT. Thank you very much, Doctor.

Dr. Wulf.

STATEMENT OF DR. WILLIAM A. WULF, PRESIDENT, NATIONAL ACADEMY OF ENGINEERING

Dr. Wulf. Good morning, Mr. Chairman.

I have to say I am particularly delighted to be here this morning with Norm and Roy. I would point out that Norm Augustine is a member of the National Academy of Engineering, and in fact, was its Chairman a few years ago.

Just echoing your comments before, I think the issue that we are talking about today is the most important issue facing our country. It may not be the most urgent, but I believe it is the most important.

I wasn’t a member of Norm’s committee, and so I can’t hope to represent the content of “Rising Above the Gathering Storm” as well as Norm or Roy, so I am not going to try, but I would like to make three points.

First, as Norm suggested, the problem is, itself, a creeping crisis. In fact, it is not a problem; it is a set of problems. And those set of problems I view as rather like tiles in a mosaic. Each one of them viewed up close, perhaps, doesn’t sound like a crisis and isn’t, perhaps, likely to provoke action, but if you stand back and you look at the overall mosaic, a pattern emerges. It is a pattern of short-term thinking, a pattern of lack of long-term investment. It

is a pattern for preserving the status quo rather than reaching for the next big goal. It is a pattern that presumes that we in the United States are entitled to a better quality of life than others and that all we have to do is to circle the wagons and defend that entitlement. It is a pattern that does not balance the dangers and opportunities in current circumstances.

I don’t have time to talk about all of the tiles in this mosaic, and I would largely be redundant with the report that is the subject of this hearing if I did, but they include the dramatic decline in industry-based basic research, the flat-to-declining federal support of research in the physical sciences and engineering, the increasingly short-term risk averse nature of the research that is supported, the discouraging effect on foreign students and scholars of our current visa policy and its impact on our ability to get the world’s best and brightest to come to the United States and to contribute to our security and prosperity, the draconian proposals for handling of deemed exports in basic research, and their chilling impact on long-term basic research at universities, and finally, the rapid growth in the use of the category of sensitive but unclassified information and its impact on the free flow of scientific information.

My second point is that although the problems depicted in “Rising Above the Gathering Storm” may not have a Sputnik-like wake-up event, that does not mean they are unimportant. Quite the contrary. In my view, collectively, they are the most important issue currently facing the United States.

I am hardly alone in that view. There is an increasingly wide recognition of it, I believe. In my written testimony, there are references to some recent reports from a variety of sources that reflect this deep concern, from the National Academies, from the private sector, from government agencies, and from academia. Despite the differing perspectives of the authoring organizations, there is surprising consistency among this report.

As is said in the American Electronics Association report, and I quote, “We are slipping. Yes, the United States still leads in nearly every way one can measure, but that does not change the fact that the foundation on which this lead was built is eroding. Our leadership in technology and innovation has benefited from an infrastructure created by 50 years of continual investment, education, and research. We are no longer maintaining that infrastructure.”

In my view, the erosion alluded to by the AEA, if unchecked, will lead to a poorer quality of life for our grandchildren, and quite possibly to a world that is less secure and less free.

My third, and final, point is that it is all about innovation and the multifaceted environment that supports innovation. There is wide agreement in the reports cited in my written testimony that the U.S. ability to innovate has been the source of its prosperity, and hence that ensuring our ability to continue to innovate is central to our future prosperity and security. Each of these reports proposes specific policy options to do this. Many of them are similar, few are identical. I think that is because there is no simple formula for innovation. There is, instead, a multi-component environment that collectively encourages, or discourages, innovation. Just to mention a few of the components of this environment: there must be a vibrant research base; there must be an educated work-

force; there must be a culture that permits and even encourages risk taking; there must be a social climate that attracts the best and brightest to practice engineering, whether from within the country or outside it; there must be “patient capital” available to the entrepreneur; the tax laws must reward investment; there must be adequate and appropriate protection for intellectual property; and there must be laws and regulations that protect the public but also encourage experimentation.

To prosper in the future, we need to attend to all of these components of the innovation environment.

In summary, by almost any objective measure, the United States is doing very well at the moment. But, the prosperity and security that we now enjoy is the result of decades of investment, research, and education. We now see a pattern, a mosaic, of disinvestment, of a retreat from bold research, and of a declining interest of American youth in education in science and engineering. We see a pattern suggesting a shift from creating the new to protecting the status quo. No single tile in this mosaic is going to ruin the American economy, which perhaps makes it all the more dangerous. There is a chance that we won’t take action until the consequences become apparent in a decade or two, at which point it may be too late.

Thank you for the opportunity to testify, Mr. Chairman.

[The prepared statement of Dr. Wulf follows:]

Prepared Statement of William A. Wulf

Good afternoon, Mr. Chairman and Members of the Committee. My name is William (Bill) Wulf and, since 1996, I have been on leave from the University of Virginia to serve as President of the National Academy of Engineering (NAE).

Founded in 1964, the NAE provides engineering leadership in service to the Nation. It operates under the same congressional act of incorporation that established the National Academy of Sciences, signed in 1863 by President Lincoln. Under this charter the NAE is directed “whenever called upon by any department or agency of the government, to investigate, examine, experiment, and report upon any subject of science or art [technology].” The NAE’s 1998 strategic plan, however, goes beyond this reactive, “whenever called upon,” role to one in which we are to “Promote the technological health of the Nation. . ..” It is much in the latter spirit that I am here today.

I am particularly delighted to be here in the company of Norm Augustine, former Chairman of the NAE, to testify on what I believe to be the most important (as opposed to urgent) issue facing our country. I was not a member of Norm’s Committee, but I participated in its initial meeting and tracked its progress closely, so I first want to acknowledge and thank all of the stellar committee members for the enormous energy and creativity that went into producing the report. I hope that the Science Committee will appreciate that the Academies’ committee’s willingness to spend countless hours on this report was the result of their depth of concern over our nation’s future.

I cannot hope to represent the content of “Rising Above the Gathering Storm” as well or as fully as Norm Augustine or Roy Vagelos, so I won’t try — but I would like to draw attention to three points.

First, unfortunately the problem is a “creeping crisis.”

Unfortunately the problems we are concerned about don’t have a Sputnik-like wake-up call.

You all know the storied procedure for boiling a frog. They say that if you drop a frog in boiling water, it will jump out. But, if you put a frog in cool water and heat it very slowly, the frog won’t jump out, and you’ll get a boiled frog. The theory is that each small, incremental rise in temperature is not enough of a crisis to make the frog react. I don’t know if this story is true, but it fits my purpose — the slowly warming water is a creeping crisis for the frog!

Our creeping crisis is not a slow, one-dimensional change like the frog’s water temperature. We are facing a number of problems — each one like a tile in a mosaic.

No one of these problems by itself creates the sort of crisis that provokes action. But if you stand back and look at the collection of problems, a disturbing picture emerges — a pattern of short-term thinking and a lack of long-term investment. It’s a pattern for preserving the status quo rather than reaching for the next big goal. It’s a pattern that presumes that we in the United States are entitled to a better quality of life than others and that all we have to do is circle our wagons to defend that entitlement. It’s a pattern that does not balance the dangers and opportunities in current circumstances.

I do not have the time to discuss all the tiles in this mosaic, and I would be largely redundant with the report that is the subject of this hearing if I did, but they include:

— The dramatic decline in industry-based basic research.

— The flat-to-declining federal support of research in the physical sciences and engineering.

— The increasingly short-term, risk-averse nature of the research that is supported.

— The discouraging effect on foreign students and scholars of our current visa policies, and its impact on our ability to get the world’s best and brightest to come to the U.S. and contribute to our security and prosperity.

— The draconian proposals for handling of “deemed exports” in basic research, and their chilling impact on long-term basic research at universities.

— The rapid growth in the use of the category of “sensitive but unclassified” information, and its impact on the free flow of scientific information.

Second, nonetheless the problem is both important and widely recognized.

Although the problems depicted in “Rising Above the Gathering Storm” may not have a Sputnik-like wake-up event, that does not mean they are unimportant. Quite the contrary; in my view collectively they are the most important issue currently facing the United States. I am hardly alone in that view; there is an increasingly wide recognition of it. Below are references to recent reports from a variety of sources that reflect this deep concern:

— From the National Academies'^-^

— From the private sector^.^.s.e.v.s

— From government agencies,®''^*’''^^''^^ and

— From academia^®’^^

1 National Academy of Engineering. 2005. Engineering Research and America’s Future: Meeting the Challenges of a Global Economy. Washington, D.C.: Nation Academies Press.

2 National Academy of Sciences, National Academy of Engineering, Institute of Medicine. 2005. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, D.C.: National Academies Press.

3AeA (American Electronics Association). 2005. Losing the Competitive Advantage? The Challenge for Science and Technology in the United States. Washington, D.C. AeA.

^Business Roundtable. 2005. Tapping America’s Potential: The Education for Innovation Initiative. Washington, D.C.: U.S. Chamber of Commerce.

^Business Roundtable. March 2005. Securing Growth and Jobs: Improving U.S. Prosperity in a Worldwide Economy. Washington, D.C.: U.S. Chamber of Commerce.

® Council on Competitiveness. 2004. Innovate America. Washington, D.C.: Council on Competitiveness.

"^Electronics Industry Alliance. 2004. The Technology Industry at an Innovation Crossroads. Arlington, VA. Electronic Industry Alliance.

® National Association of Manufacturers. 2005. The Looming Workforce Crisis: Preparing American Workers for 21st Century Competition. Washington, D.C.: National Association of Manufacturers.

® National Intelligence Council. 2004. Mapping the Global Future: Report of the National Intelligence Committee’s 2020 Project. Washington, D.C.: National Intelligence Council.

National Science Board. August 2003. The Science and Engineering Workforce: Realizing America’s Potential. Report NSB 03-69. Arlington, Virginia: National Science Foundation.

President’s Council of Advisors on Science and Technology. January 2004. Sustaining the Nation’s Innovation Ecosystems, Information Technology Manufacturing and Competitiveness. Washington, D.C.

President’s Council of Advisors on Science and Technology — Workforce Education Subcommittee. June 2004. Sustaining the Nation’s Innovation Ecosystem: Maintaining the Strength of Our Science & Engineering Capabilities. Washington, D.C.

12 Council of Graduate Schools. June 2005. NDEA 21: A Renewed Commitment to Graduate Education. Washington, D.C.: Council of Graduate Schools.

I’l American Association of Universities, To be released.

Despite the differing perspectives of the authoring organizations, there is surprising consistency among these reports. They all identify problems like the tiles in my mosaic as representing serious long-term problems for the country — problems that require action now! As is said in the American Electronics Association (AeA) reported:

“We are slipping. Yes, the United States still leads in nearly every way one can measure, but that does not change the fact that the foundation on which this lead was built is eroding. Our leadership in technology and innovation has benefited from an infrastructure created by 50 years of continual investment, education and research. We are no longer maintaining this infrastructure."

In my view, the erosion alluded to by the AeA, if unchecked, will lead to a poorer quality of life for our grandchildren – and quite possibly to a world that is less secure and less free.

Third and finally, it's all about innovation and the multi-faceted environment that supports innovation.

There is wide agreement in the reports cited above that the U.S. ability to innovate has been the source of its prosperity – and hence that ensuring our ability to continue to innovate is central to our future prosperity and security. Each of these reports proposes specific policy options to do this – many of them are similar, but few are identical. I think that is because, in my view, there is no simple formula for innovation. There is, instead, a multi-component "environment" that collectively encourages, or discourages, innovation. Just to mention a few of the components of this environment:

• There must be a vibrant research base.

• There must be an educated workforce.

• There must be a culture that permits and even encourages risk-taking.

• There must be a social climate that attracts the best and brightest to practice engineering – whether from within the country or outside it.

• There must be "patient capital" available to the entrepreneur.

• The tax laws must reward investment.

• There must be adequate and appropriate protection for intellectual property.

• There must be laws and regulations that protect the public while also encouraging experimentation.

To prosper in the future we must attend to all the components of this innovation environment – and in particular we need to be sure that they are attuned to the current and future technologies rather than those of the past (when many of the components of the environment were first created).

In Summary

By almost any objective measure, the U.S. is doing very well at this moment. But, the prosperity and security that we now enjoy is the result of decades of investment, research and education. We now see a pattern, a "mosaic," of disinvestment, of a retreat from bold research, and of a declining interest of American youth in education in science and engineering. We see a pattern suggesting a shift from creating the new to protecting the status quo. No single tile in this mosaic is going to ruin the American economy – which perhaps makes it all the more dangerous. There is the chance that we won't take action until the consequences become apparent in a decade or two, at which point it will be too late.

Thank you for the opportunity to testify, Mr. Chairman. I would be pleased to answer any questions the Committee might have.

Biography for William A. Wulf

Personal:

Wm. A. Wulf, President, National Academy of Engineering, 2101 Constitution Ave., NW, Washington, DC; e-mail: wwulf@nae.edu

University Professor and AT&T Professor of Engineering and Applied Science, Department of Computer Science, Thornton Hall, University of Virginia

Education:

B.S., Engineering Physics, University of Illinois, 1961
M.S., Electrical Engineering, University of Illinois, 1963

Ph.D., Computer Science, University of Virginia, 1968

Positions;

President, National Academy of Engineering, 1996 to present.

AT&T Prof, of Engr., University of Virginia, 1988 to present.

Assistant Director, National Science Eoundation, 1988 to 1990.

Chairman & CEO, Tartan Laboratories Inc., 1981 to 1987.

Professor, Carnegie-Mellon University, 1975 to 1981.

Associate Professor, Carnegie-Mellon University, 1973 to 1975.

Assistant Professor, Carnegie-Mellon University, 1968 to 1973.

Instructor, University of Virginia, 1963 to 1968.

Descriptive Biography:

Dr. Wulf was elected President of the National Academy of Engineering (NAE) in

April 1997; he had previously served as Interim President beginning in July 1996. Together with the National Academy of Sciences, the NAE operates under a congressional charter and presidential executive orders that call on it to provide advice to the government on issues of science and engineering.

Dr. Wulf is on leave from the University of Virginia, where he is a University Professor and the AT&T Professor of Engineering and Applied Science. Among his activities at the University were a complete revision of the undergraduate Computer Science curriculum, research on computer architecture and computer security, and an effort to assist humanities scholars exploit information technology.

In 1988-90 Dr. Wulf was on leave from the University to be Assistant Director of the National Science Foundation (NSF) where he headed the Directorate for Computer and Information Science and Engineering (CISE). CISE is responsible for computer science and engineering research as well as for operating the National Supercomputer Centers and NSFNET. While at NSF, Dr. Wulf was deeply involved in the development of the High Performance Computing and Communication Initiative and in the formative discussions of the National Information Infrastructure.

Prior to joining Virginia, Dr. Wulf founded Tartan Laboratories and served as its Chairman and Chief Executive Officer. Before returning to academe, Dr. Wulf grew the company to about a hundred employees. Tartan developed and marketed optimizing compilers, notably for Ada. Tartan was sold to Texas Instruments in 1995.

The technical basis for Tartan was research by Dr. Wulf while he was a Professor of Computer Science at Carnegie-Mellon University, where he was Acting Head of the Department from 1978-1979. At Carnegie-Mellon Dr. Wulfs research spanned programming systems and computer architecture; specific research activities included: the design and implementation of a systems-implementation language (Bliss), architectural design of the DEC PDP-11, the design and construction of a 16 processor multiprocessor and its operating system, a new approach to computer security, and development of a technology for the construction of high quality optimizing compilers. Dr. Wulf also actively participated in the development of Ada, the common DOD programming language for embedded computer applications.

While at Carnegie-Mellon and Tartan, Dr. Wulf was active in the “high tech” community in Pittsburgh. He helped found the Pittsburgh High Technology Council and served as Vice President and Director from its creation. He also helped found the CEO Network, the CEO Venture Fund, and served as an advisor to the Western Pennsylvania Advanced Technology Center. In 1983 he was awarded the Enterprise “Man of the Year” Award for these and other activities.

Dr. Wulf is a member of the National Academy of Engineering, a Fellow of the American Academy of Arts and Sciences, a Corresponding Member of the Academia Espanola De Ingeniera, a Member of the Academy Bibliotheca Alexandrina (Library of Alexandria), and a Foreign Member of the Russian Academy of Sciences. He is also a Fellow of five professional societies: the ACM, the IEEE, the AAAS, lEC, and AWIS. He is the author of over 100 papers and technical reports, has written three books, holds two U.S. Patents, and has supervised over 25 Ph.D.s in Computer Science.

Discussion

Chairman BOEHLERT. Thank you for leaving us with some degree of comfort by your closing statement, "By almost any objective, the United States is doing very well at this moment." Guess what?

That is not good enough. That might make us feel better, we may be doing very well, but our competition is doing a lot better a lot quicker. So this is serious business.

And Dr. Vagelos, you know, you emphasized something that is so very important. Right back to the basics, K-12 science and math education. You know, I am sort of tired of appearing before business groups, as I do frequently, and to get some guy raising his hand, I will call on him, and you know, he starts moaning and groaning about K-12 education and the high schools are graduating students that we can't hire because they can't function, and we have to start training them. And I listen to them moan and groan, and I acknowledge that it is a serious problem we have got to address, and then I will say to him and all of the other representatives of business in the audience, and I did this a couple of times at a Chamber of Commerce meeting and a National Association of Manufacturers, "All right, you hot shots in business. Let me ask you a question." All right. Well, that is sort of unusual. I say, "How many of your employees, Mr. President of this company, Mr. Manager of that company, how many of your employees serve on a local school board?" You know. The answer, usually the response is, "Gee, we don't know." "Go back and check, will you, please? And then, in a couple weeks, let me know." And I never hear back. You know why? They check and they don't run. Well, gee, we are in business to make a profit, and it is too important. And why not have them run for school boards?

And then the other thing is, and I am giving you some of my pet theories, but I want to work together, because I want to follow through on this and go forward on this. How many letters do you think the average Member of Congress gets from his or her constituents saying, ''You know, we have got to invest more in basic research, as a government," or, "We should do better by the National Science Foundation," which is a primary funder of all university-based research? Do you know how many letters? Probably the average congressperson gets zero. And I doubt if there is a sitting Member of either the House or the Senate who campaigned on doing better by the science enterprise. You know, we have got to reform Social Security. We are going to get out of Iraq. We are going to do all of these things, but they don't talk about these things. And I say, once again, Mr. Augustine, I will say to people like the Chairman of the Board of Lockheed Martin, your former position, "Why don't you look at your Board of Directors?" It reads like a Who's Who in America. All well compensated, all very heavily influential in the political process, some Republican, some Democrat. They are all over the lot. I would suggest that if Board Member X from central Oklahoma or Board Member Y from northern Kansas called up his or her representative and said, "Look. Here is something that Congress is ignoring, and this is very important. You have got to do better by K-12 science and math education, and I don't see how the hell you propose to do so if you are cutting funding for the Education Directorate at the National Science Foundation, and I want you to do something about that." People would begin to take notice.

So I don't think this is too daunting a task, and I want to have some follow-through with you guys after this. You know, there are

435. You get 435 master cards, and we can get a file on each Member of Congress. And then we can just sort of work them and figure out how we can get them to focus on this subject area.

So with that, a sort of preamble of my speech, let me ask you this. Help us prioritize your recommendations. And help us explain how you decided on a 10 percent increase. Can we go with those two?

Mr. Augustine.

Mr. Augustine. Thank you.

I will be glad to begin.

The question of prioritizing, we feel, quite strongly, that one has to view our recommendations as a package. We did single out as the highest priority K-12, because that seemed to underpin everything we are doing. If we don't solve that problem, we have lost.

Beyond that, the reason we view it as a package is, for example, to create more scientists and engineers but to not increase the research budget for them to work on just creates people without jobs. And so this is a closely-knit package that we have proposed. We gathered 60 experts in various fields who came to Washington for two days with us, and they made recommendations as to what we should recommend to you. They made over 150 recommendations, which we boiled down and refined. So what you are seeing is our prioritized list of the very top ones. There were others we didn't consider.

Your question of why 10 percent, and you are referring to the increase in basic research in the specific fields. Our motivation was to, rather quickly, increase the budget in those fields, which have been basically flat in real dollars for 20 years. That contrasts sharply with the progress in the biological sciences. So we wanted to do it as quickly as we could, but we also want to be sure the money is spent efficiently. And it is our view that about 10 percent per year, this is obviously judgmental, is about what you can increase and spend very efficiently. It might be 15 percent. It might be eight percent, but it would be in that range.

The question of why we put the seven-year limit on it; it turns out, of course, that 10 percent per year for seven years roughly doubles the existing $8 billion budget in this area. That is encouraging to us, and seems rational in the sense that the Congress, with your leadership, recently proposed that the NIH budget be doubled. And the Administration supported that. That was through the authorization process, unfortunately not through the appropriations process.

So that would be my answer to your question. I am sorry. Did I say NIH? I meant NSF.

Chairman BoEHLERT. Yeah. Yeah. It is NSF. Well, you know, we are following the NIH model, and everybody got nervous, because we doubled the NIH budget over five years, and I really think the basic reason is because it does so much in research in things like Alzheimer's and cancer and everything else, and Members couldn't vote fast enough, because they had looked out and said there, but for the grace of God, go I and vote aye. And we ought to do the same thing with the physical sciences and following that model. And a lot of people with biological sciences interested in NIH were concerned that I was trying to cut their funding. I don't want to

cut their funding one dime. It is important. But I want to elevate NSF.

But the basic problem is, and this is our problem on Capitol Hill.

We passed the legislation putting the NSF on a path to double its budget over five years. We had a big ceremony down at the White House. The president signed it, we patted each other on the back. Boy, we felt good. But that didn't appropriate one dime. And while we put the agency on a path with authorization from this committee to double a budget over five years, you know, the percentage increase is a little better than flat, but not a heck of a lot better. You know what the total budget is? I bet you if you asked the board members of Merck or Lockheed Martin or anybody else, what do you think NSF gets. You know, they sponsor, basically, all university-based research in America. They wouldn't know, $5 billion a year. You know what, they spend more than that in a coffee break over in the Pentagon. That is another place you are associated with. And I am for national defense, but we have got to get some priorities in order.

My time is expired.

Mr. Gordon.

Mr. Gordon. As I said earlier, I admire my Chairman's passion for this issue. I am also the beneficiary of, hopefully, some extra time that could be allocated to me over the next few weeks because of all of his passion here. And I do admire it.

As the Chairman said, the National Science Foundation, we passed an authorization to double it. It was signed by the President, yet the President never has made those requests. I think one of the benefits of your proposal is that you went beyond flowery rhetoric and gave us some specific recommendations.

You also have specific recommendations for an action plan. You gave us an action plan on what to do. What about an action plan on how to get it implemented, how to get the President to make these proposals, how to get Congress to go forward? Or do you feel like your job is over? Have you given us the sheet and now you all are going home? Mr. Augustine, is there another step?

Mr. Augustine. No, we believe that our job has just begun, and we do have a plan. I should say that we are in a difficult position, because the National Academies don't lobby, by policy. On the other hand, the National Academies do provide information, disseminate information, share views, and we intend to do a lot of that. And we would hope that we will have the opportunity to do that broadly with the Business Roundtable, with labor unions, with other organizations that are interested in this topic, with teachers. And indeed, we do plan to pursue this, and our members have

Mr. Gordon. Good.

Mr. Augustine. — in fact, been

Mr. Gordon. Well, I would hope that you would put together, around my office, I, you know, sort of have a, I don’t know whether it is a saying, but if it is not written down, it is not a plan. And we would hope that, not as extensively as this, but that you might put together an action plan for implementing, whether informally or formally, meet with us and tell us how we can help. And we would all like to work together on that.

The second question that I have, back when the original President Bush was President, he and Congress got together and passed something called PAYGO. We had a big deficit, and we wanted to do something about it, and we all know that the first thing you do when you are in a hole, you stop digging. And that is what PAYGO tried to do. Every time there was legislation that came to the Floor, it had to have a fiscal note to say what it cost. And you had to have either additional revenue or you had to have offsets for that. That was passed two more times under, again, under two Presidents and several Congresses. Unfortunately, it expired in 2002, and we can’t get the current Congress to renew that.

But going back to that same type of idea, it is going to be hard to get additional funds. Nobody likes to talk about taxes, and maybe we will just say fee or something here. Do you have any suggestions as to a fee that might be appropriate on, maybe, the business sector somewhere that would be dedicated for this $10 billion? You know, and that it would be a, you know, somewhat of a tit for tat if we have, you know, one-eighth of a percent additional something here that would go to these various teaching programs? Do you have any recommendations on that?

Mr. Augustine. I am afraid I will have to disappoint you here, because our committee’s charter really didn’t include looking for offsets of

Mr. Gordon. Well, I am just asking you as informed individuals and

Mr. Augustine. As an individual, and not speaking for the committee, you know, kind of the way I look at it is that we have gross domestic product of $12 trillion. The Federal Government spends, as you know, $2 trillion a year. Last year, I am told that our citizens lost $7 billion betting on the Super Bowl. The cost of litigation to corporations in America is about 10 to 20 times what we have asked for here. And so it is our belief that this kind of money can be found. Now I have my own personal list, as I am sure everybody else does, of, you know, where I would start looking for money, but it is not particularly relevant, because I have no expertise in the subject.

Mr. Gordon. Well, we are not voting on a budget today, because there wasn't the ability, the will, or whatever to go from a $35 billion reduction to $50 billion. So that was $15 billion that apparently couldn't be found. And it was a pretty hard effort. Now maybe they will find it next week, I don't know. So yes, there is probably, you know, there is enough money sloshing around. But if that is the answer, then we are not going to get this done.

Mr. Augustine. Well, you know, I, as an individual, feel, I can't speak for other CEOs. I feel so strongly that it is in the best interest of our companies that if it requires an additional tax of some kind to fix some of these problems, and it is not a huge amount of money in the grand scheme of things, I personally would support that kind of thing. But again, I can't speak for the

Mr. Gordon. Well, I think that would be another, again, the follow-up, both in the action plan and implementing this, and if the business community thinks it is important, it would give a lot of credibility and a lot of cover for folks. And I think that we want it as small as possible. It needs to be dedicated so that you know

where it is going, and this old PAYGO kind of process. So I would hope that, again, with all of those big thinkers as you are around doing big thinking, that that might be added to the agenda.

And again, thank you all for your, well, let me add, does anyone else want to comment on any of those subjects?

Dr. Vagelos. Mr. Gordon, I haven't really thought on the source, but there are sources, even within the current research budget of the government that I think could be reallocated. I would not like to discuss them at this time, because I — they just haven't been generalized, but I certainly have ideas. And I certainly would support, also, an increase in taxes that would cover these subjects.

But let me say that although the statements that I have heard today that corporations are not doing enough is a general statement that doesn't cover all corporations. And let me give you an example. At Merck, 15 years ago, we started what we called the

Merck Institute for Science Education and developed a program for K-6 students in the region around our locations in the United States, of which there are several. And we have a person who heads that. Carlo Parravano, who is previously a professor of physical chemistry at a university and with a passion for teaching young people. And the idea is to train teachers in the K-6 level to understand some level of hands-on science in order to excite and demystify science for young children, because it demystifies for those teachers who are exposed in summer institutes, and then they are followed by master teacher visitations during the course of a year to get the children excited about science. Merck started this program about 15 years ago, and it has continued. It is so good that the NSF actually is replicating some of it. And Merck continues to invest in that regard.

So some companies, at least, are doing that. And I know of other companies doing similar programs. So I would like not to leave with a negative thought of all corporations not being interested in K-12, because they are, indeed. And certainly in higher education, many research corporations invest in universities and in high schools to bring up the number of people who are going into technology because they are looking at their future workforce, frankly. It really benefits them to have better people coming through the pipelines.

Mr. Gordon. Yeah, I don't think, hopefully no one overtly or insinuated that everyone is in that boat. What we want is to find incentives to increase that leadership.

But thank you very much.

Chairman BOEHLERT. Thank you.

Mr. Gordon. I would also, in fact, I would like to request if you do have any kind of material on the Merck program

Dr. Vagelos. Yes.

Mr. Gordon. I would like to see that so we might be able to see how we could replicate it, also.

Chairman BoEHLERT. Well, just let me stress that what Merck has done, what Lockheed is doing, Westinghouse scholarships, corporate America is magnificent in its generosity in so many instances, so I don't want anyone to go away from this with the impression that this committee, particularly, does not acknowledge the great contributions corporate America is making. But they need to do a better job, and so do we. And you know, before we start asking you to do a better job, we have got to look ourselves in the mirror and say are we doing a better job. And I hope it — yes. Doctor. Did you want to make an observation?

Dr. Vagelos. I just want to say something about the long-term investment in research, because it is so crucial to what we are talking about. First of all, we have to have people who can do it, so that is K-12 and higher education. But are corporations really making a difference? And have we impacted health? Yeah, we have spent, the Nation has spent, you know, billions in the last 25 years. Has it been worth it? Well, I will give, as an example, what happened in 1981. There was the identification of a new thing called AIDS. It turned out a couple years later, the virus was identified through work at NIH and the Pasteur Institute, but then the universities and industry both focused on how do you handle this virus, a virus which caused the disease which was 100 percent lethal. And within, you know, a decade, you have the development of several different mechanisms of antiretroviral drugs that, in combination, converted a 100-percent lethal disease to a disease, which is a chronic infection where people leave hospitals, go back to work, and live normal lives. Now that is the interaction between basic research investing by government and research investment by industry.

There are other things that are coming today. We heard in the paper today an advance in breast cancer outcomes using Herceptin, a drug that has been around for a while, but it is a monochromal antibody. Here is a technology that has been essentially developed in the United States over the last 25 years and is having an impact now. There is a vaccine being developed both by Merck and by GSK that will prevent cervical cancer. This is against human papilloma virus. This has come from years of basic research now converted to — do you know how long it takes to make a vaccine?

Chairman BOEHLERT. Oh, I know that.

Dr. Vagelos. And do you know the panic now over influenza, avian flu?

Chairman BoEHLERT. Well, that gets into a different subject. Let us get to Ms. Biggert, because she will get us back on course here, because this is such an enthusiastic group that we all could talk forever, but I hope it should not go unnoticed that we have a higher percentage of both sides of the aisle participating in this hearing than I will bet you any other hearing on Capitol Hill, which is a testament to the importance that we view the subject and to the distinguished panel we have.

Ms. Biggert.

Ms. Biggert. Thank you, Mr. Chairman.

First of all, I just wanted to mention that I did serve as President of my local high school school board, and I appreciate all that you are doing. The problem that we always had was, first of all, to find the teachers that were the best and the brightest for what we wanted in our school. And then the second was to keep up with technology and the equipment that changed so to have available for the students.

But I really wanted to talk about or ask questions to focus attention on energy and your proposal for the creation of a DARPA-like entity at the Department of Energy.

It has been my experience representing a DOE National Lab, and serving as the Chairman of the Subcommittee on Energy here in this committee, that the bigger problem is technology transfer, getting new technologies or the products of government-funded research from the lab to the market. And I know that so many times things, for example, right after 9/11, we found that the labs really had done the research, had the products that then could go, for example, to the subway to identify, you know, foreign chemicals in there and things like that that were there, but nobody had ever really processed that or gone further.

So my first question is what specific problem was the committee trying to address through this recommendation, recommendation B5?

Mr. Augustine. There you go. Your question is a very good one and touches on a number of points we have debated at length. Really, the problem we saw, maybe I should say, in the way of background, the company I had the privilege of serving has operated for the DOE a number of National Labs, and so we had some experience with the challenges. And the notion with ARPA-E was to do for the Department of Energy what DARPA has done for the Department of Defense, specifically to take high-risk, very high-payoff transformational research, support that research, and then to transfer it into industry, and to where it could produce products. There does seem to be a gap between the DOE’s ability to produce great new products, great new ideas, just as you have cited, and to make something happen. And our hope was that this might provide that transformational mechanism.

The reason we think it could well work is that ARPA-E, the Advanced Research Projects Agency-Energy that we have proposed, would not do research itself It would support research that was done in universities and done in industry and possibly in the labs of National Labs themselves. It would be competitively awarded, and so there would be a built-in involvement of industry and of universities that you don’t have in the labs themselves. And part of the reason we don’t have it in the labs is the well-meaning conflict of interest rules we have that makes it hard for companies to access some of this information.

Ms. Biggert. I understand that there were a couple, one or more members, that did not agree with this recommendation, and

Mr. Augustine. Yes, of all of the 20 recommendations we made, one member disagreed with one recommendation, and it was this one. And this particular individual felt, and I hope I can do justice to his views, that we already are spending a great deal of money on energy research in the government and that the industrial firms in the field are also devoting a great deal of money to research. And this individual believed that there was no more money needed at this point and also that the government would be in a position of picking winners and losers in terms of research and companies, and that wouldn’t be healthy. Now I personally don’t share that view, but I think I have done justice to his position.

Ms. Biggert. Well, it sounds like, then, that this really is a way to move from the lab to market. Is that the major focus of it, or just the basic research itself?

Mr. Augustine. Well, I think it is two things. The first is what you said. It is a way to build a bridge to getting ideas and research out and applied. The second is to be able to spend more money on transformational, breakthrough, high-risk, long-term research that companies just won’t perform and that the NSF and the NIH and Defense Department are all doing much less of because of their risk aversion.

Ms. Biggert. So much, particularly in the labs, it seems like, you know, the basic research in physical sciences, so many times, what might start out to be a project to work on one item will be able to discover something else, and it will probably, you know, be much more of the thing that is going to change the world or whatever. Will this destroy that at all by having to compete for these grants on specific types of research?

Mr. Augustine. Not at all. And your point is such a good one. And that is one reason, of course, why industry is reluctant to invest in basic research, because what you come up with may help your competitor more than it helps you, and whereas the ARPA-E idea would promote that.

In addition, we had another recommendation that you are familiar with, I am sure, that the government labs be provided latitude to spend eight percent of their budget at the discretion of the people in the lab that know better than the central managers where those other opportunities are popping up.

Ms. Biggert. I think some people have tried to cut that back, which is disturbing, because that is a very

Chairman BoEHLERT. The gentlelady’s time has expired. Thank you very much.

Ms. Biggert. Thank you.

Chairman Boehlert. Mr. Miller, the Floor is yours for 300 seconds.

Mr. Miller. Thank you, Mr. Chairman.

Mr. Chairman, I rarely pass the chance to ask questions to amplify some point, but this panel has made all of the points that I think need to be made.

Mr. Chairman, I will disagree with you on one point. You said you thought no Member of Congress campaigns on the need to fund basic research to provide for science education and to try to move ideas, the product research, from the laboratory to the market. Mr. Chairman, I do. I represent a textile District. I represent a District that has lost a lot of jobs, and I voted against CAFTA, but I tell the folks who ask me all of the time not how are we bringing the jobs back, but where are the new jobs coming from, that our future can not be having low-skilled jobs in labor-intensive industries. It has to be the most innovative economy in the world, and that means research, funding research. It means science education. It means a commitment to community colleges where people learn new job skills throughout their lifetimes and will have to go back again and again. And it means efforts to move to provide the funding and the assistance to take research out of the laboratory to the marketplace.

So Mr. Chairman, I am delighted to he here, and my enthusiasm for this topic, I think, may be the equal of yours.

Chairman BOEHLERT. Dr. Ehlers.

Mr. Ehlers. Thank you, Mr. Chairman.

And I will join Mr. Miller in the ranks of those who campaign for science. In fact, my very first election, I scored a coup on a live TV debate when all of the attorneys running against me were saying that they would come here and straighten out the laws, the business people were coming here saying they would come here to balance the budget. And I pointed out that if we elected an attorney, we would add one to the 175 already here, and I didn't think that would make much difference. If we elected a businessperson, we would add one to the 137 already here, and I didn't think that would make much difference. But if they elected me, they would double the number of scientists in the Congress, and that would make a difference, and it seemed to resonate with the people.

I also am in somewhat the same camp as Mr. Miller. When I read your executive summary, I haven't had time to read the whole report yet, but I just checked them off, and virtually everything, with one small exception, is exactly what I have been advocating for 12 years here. And I want to thank you very, very much for an excellent report, not just because you agree with me, but because you make the case well, and it is what this country needs. And now it is up to us, as a Congress, to implement that.

So I congratulate you. I am afraid I have to go vote somewhere else, but let me just try to clarify one point.

We talked about ARPA-E. And by the way, I think it would be better to call it "DARPE," and maybe you could have a stuffed doll named "DARPE," you know, as a symbol. Come up with something catchy. But DARPA has been a powerful force in basic research in this country. All right.

Chairman BoEHLERT. Only a physicist would have his cell phone with Beethoven's Fifth.

Mr. Ehlers. No, it is only a fourth. I don't drink.

But DARPA has been extremely successful, but it has been very much a basic research agency. And yet, in the discussion I just heard, it sounded like you are talking about this as much a tech transfer as a basic research entity. And I think the Department of Energy badly needs this sort of thing. I am not questioning that, but it is not clear to me precisely what you are trying to accomplish here. If the goal is to have the Department of Energy address, in a more direct way, the national problems that we face, I would heartily welcome that. We have huge energy problems here, and I would like to see that happen. But tech transfer, we have CRADAs. I don't know if they are still around, but they were very successful. And we could address technology transfer through an MEP-like type of program or agriculture extension program, which I would also favor.

But could you just give me a little clarification, a little more clarification I would say? What are you really trying to achieve with the ARPA-E proposal?

Mr. Augustine. I am glad you asked to give us an opportunity to clarify, and I will call on my colleagues, with your permission, to add, and so I will be brief

The intent with the ARPA-E is, indeed, to focus on basic research of a specific kind, namely high-risk, high-payoff, long-term, generic applications. That is the focus. I think where I misled you is I was addressing the question of how, once you have done that, do you get that applied, get it out where it becomes useful. And my answer to that was that ARPA-E would not do research of its own, but rather, with funds, work by others, including universities, industry, and the National Labs competitively awarded. And that is the way I was suggesting that the knowledge could be transferred.

Mr. Ehlers. Yeah. I guess my response to that, and I heard that answer, but that, in itself, won't transfer it unless you have industrial partners for each grant, or something of that sort. But NSE gives direct grants to universities, and that doesn't guarantee the results get transferred. I think you really have to build in a specific mechanism to do it, and that is what I was trying to clarify.

Dr. Vagelos. May I add something to that. Norm, and that is there is the feeling on the committee, as the majority of the committee, that there are ideas and basic observations that are made at universities principally which are not mature enough to be picked up by either industry or the VCs. And these just will not be funded, because they are sort of falling in between the cracks. People are not yet recognizing that these can be applied, and therefore, there would be a committee that includes industry people, who are identifying these ideas that are otherwise not going to be funded, but the best of these to be brought along so that they would gain the visibility so that they would be either picked up by industry or capitalized in some other way.

Mr. Ehlers. So you basically want to bridge the valley of death?

Dr. Vagelos. Exactly.

Mr. Ehlers. Yeah. Well, thank you very, very much for an excellent report. I really appreciate what you have done. Thank you.

Mr. Hall. [Presiding] The Chair recognizes Mr. Green, the gentleman from Texas.

Mr. Green. Thank you, Mr. Chairman. And I thank the Ranking Member as well.

Mr. Augustine, your comments were quite shocking, and I appreciate the way you presented them. They were very much an awakening, to a certain extent. And I appreciate each member of the panel for what you have presented.

I would like to start, if I may, with Dr. Wulf.

Dr. Wulf, sir, your colleagues had indicated that they would support a tax increase, if you will. Do you have a similar view?

Dr. Wulf. Well, of course, I am not a captain of industry like the two gentlemen sitting to my right, but I have to say that more than one CEO has said to me that they can't invest in research within their own company easily, because that detracts from the bottom line, and it is an optional cost. And so the market. Wall Street, will penalize them for doing that. And I think Norm has a marvelous story about that. But if they were taxed the same amount and that money was guaranteed to go into research, they would be happy.

Mr. Green. Thank you.

A quick comment. It appears that with reference to fixing, as it was articulated, K-12, it appears that many of our young people, and even their parents, don't see education as the way out. And I

think that is very unfortunate, but the Powerball, lottery, athletics, rock stars, they seem to dominate the persona of the successful person. And unfortunately, there is this belief among too many young people that that is the way out for them.

So my first question is, is there a one-size-fits-all remedy for fixing K-12, because you have urban versus rural, you have inner city versus outer city, you have some cultural concerns that, in my opinion, will have to be addressed? How do we make sure that when we fix K-12, we fix it for all of the children, regardless of whether they are rural or they are urban, whether they are inner city or outer city? It seems that there is a little bit more to concern ourselves with, if we truly want to leave no child behind.

And I would like for each of you, if you would, to address the aspect of leaving no child behind. And I will start with you, Mr. Augustine, if you would, please.

Mr. Augustine. Well, thank you for that question. And I am very glad you asked it.

Certainly, there has been a change that today the students don't look at education or being a physicist, by and large, as the way out. In my own case, I was the first in my family to go to college. I was the second to go to high school. But my parents made very clear to me that the way out, the way ahead, was education. And that was just fundamental. We have lost that, to a great degree.

The way I think that we address this question of the different backgrounds, different interests of students, is through the teachers, because the one thing that all of those students have in common is the teachers. And if we give them good teachers that show them that know their subject, that know what they are talking about, that inspire them, demand excellence, I don't think it matters where you come from, that is going to make a difference in your life, I think. So that is why we focused on teachers.

Roy?

Dr. Vagelos. Yeah, well, you took the words right out of my mouth on focusing on teachers and getting them to understand the subjects that they teach.

Mr. Green, you come from the State of Texas, and you may have caught, I don't know whether you have caught or were in the room when I mentioned that the advanced placement incentive program, which originated in Dallas, really introduces the concept that you can train teachers who are already teaching to be able to teach advanced placement. You can incentivize students to take that by offering them the courses and a $100 bonus, if they pass. And taking a school district, which is largely poor and has many immigrants and under-served minorities, you can increase the number of students taking advanced placement courses and passing them by tenfold with such a program, it is those students, they won't be stars, or they may not be all of the athletes, but you can increase, including minority students, the number of students taking these advanced programs and the advanced programs are in math and science. So that is one thing that can affect every city. And that is one of the programs we are recommending.

Dr. WULF. Just to answer your question very directly, no, I do not believe that one size fits all. I think all of my adult life we have been collectively, as a society, talking about the problems we have

with K-12 education. And we have made, in my view, very, very little progress. We have this seminal event of "A Nation at Risk" being published and getting a lot of attention focused on the problem, and yet, I think if you objectively look at where we are relative to, what, 15 years ago, when that report was published, I would find it very hard to argue that we have made very much progress. And I think a lot of the reason is that people have advanced one silver bullet after the next and that is not just going to work. We have to attack it on a very broad front. I happen to concur that focusing on teachers is a very, very, very important piece of it, but that is not all of it, either.

Chairman BOEHLERT. Thank you very much.

The gentleman's time has expired.

Let me point out that we created a scholarship program, an incentive program, to get the best and the brightest in the undergraduate years majoring in science, math, and engineering, and agreed to give them a stipend each year and in exchange for an agreement to teach for two years, and we had that on the books authorized from this committee for several years before we got one thin dime. And now we are spending a grand total, I think, of about $5 million a year on it. That shows you where our priorities are, unfortunately.

Mr. Hall.

Mr. Hall. I thank you. And I thank this panel here. And I thank the very distinguished Mr. Chairman, you have mentioned the attendance here. It is no wonder when you read the array of men and women who are giving their time. And Norm Augustine is no stranger here. The Augustine report was a bible for us for about 10 years in the ’80s. Thank you for that and others of you.

And I think it is very, very important that we seek ability to compete in this century with jobs and especially for older people. You know. Norm, I am the oldest guy in Congress, or in the House, and when that guy from West Virginia finally takes everybody’s advice and leaves, well, I will be the oldest in Congress. And jobs are important. Other than my opponents, my wife has even suggested that, you know, I should quit, but at 82, I checked with Wal-Mart, and they weren’t hiring any greeters. I didn’t have a cap and a pistol. I couldn’t be a crossing guard for anybody, but what a wonderful thing it is for you to give your valuable time, and your time to prepare to get here, to give us your time here, and your time staying here.

You know, with China calling us out on the world energy allocation and their end of the space program now, we have got so many, so many reasons to listen to this group here.

But let me ask you this, the 60 subject matter experts, are they of the same caliber? And how do you all work together? And when do the 20 and the 60 ever get together?

Dr. Vagelos. Well, sure. These were experts that were recommended largely by the committee. The committee was invited by the President of the National Academy of Sciences. Twenty-one people were called, as I understand it. Twenty people responded, which is an incredible response rate.

Mr. Hall. Right.

Dr. Vagelos. Now they were asked to suggest their priorities individually and other experts in the United States who would he able to speak to these subjects, and they also were asked to prioritize their recommendations. And then there was one major long weekend around-the-clock meeting, and then numerous conference calls and trading of tons of information through the Internet. That is the way we ran the thing.

Mr. Hall. Peter O’Donnell is a special friend of mine, and

Dr. Vagelos. He was right in the middle of it.

Mr. Hall. — a great and giving person in our part of the country.

And because I was late getting here, I have been on other committees, I don't know what questions have been asked, but if I have any questions, I will submit them to you later, but I am sure that the Chairman and Ranking Member have asked, probably, the proper questions, and I can refer to the record for that.

And I thank you for your time. Very much I thank you for giving your ability to your country.

I yield back.

Chairman BOEHLERT. Thank you very much.

Mr. Honda.

Mr. Honda. Thank you, Mr. Chairman.

I will be real quick and to the point, because we are going to be asked to vote.

I went through the report and just generally perused the recommendations and everything, and I was captivated by the term "innovation" running through the whole report, but you have never addressed the concept of teaching innovation creativity. And I think that that is the piece that we are missing. And when I speak with some of the other folks in education and who have just recently retired from high tech or, you know that their main concern is that if we are talking about producing more science students and more folks adept at math and science, that we will still be outperformed by India and China, because they are going to do the same thing. When we talk about the history of Silicon Valley, we know that Silicon Valley is not only a geographic place, but it is a phenomena of a combination of folks or of factors. And one of the factors is the talent and the people. And one of the factors of the talent of the people is their innate ability to be creative and inventive. We don't teach that, and it is a teachable skill to be able to teach innovation and creativity.

What is your opinion about making education a goal for this nation, the teaching of innovation and creativity? And what do you think the costs may be and with the insights you have from your own report?

Dr. WULF. One of the things that I have focused a lot of my attention on in the last nine years that I have been President of the Academy has been engineering education reform. And a strong theme running through that is that engineering is all about creativity. It is all about — as Theodore von Karman said, "creating what has never been." And so making engineering education better adapted and suited to the actual environment that engineers are going to practice in really involves teaching creativity and innovation.

Mr. Honda. But there

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Dr. WULF. And so that is starting to happen.

Mr. Honda. Right. But there is no curricula that speaks to creativity or innovation, and in the discussion in the report, I don't see that as being highlighted or important. It is mentioned, but you know, teaching math and science, if we keep teaching the way we have taught, we still teach youngsters and people a compartmentalized approach to math and science, and it should be multi-disciplinary and integrated and then teaching how to teach innovation and creativity. And if that is not a stated goal, how will we understand and know that that is going to be one of the outcomes?

Dr. WuLF. There actually are a number of engineering schools around the country now, which make innovation and creativity central to the curriculum.

Mr. Honda. Would you be willing to have a long discussion on that

Dr. WULF. I sure would.

Mr. Honda. — in your report?

Dr. WULF. Well, the report is the report.

Mr. Honda. Well, the report is a document that people look at to refer to from experts in the field, and if it is not specifically mentioned as a goal, but it is only mentioned as one of the things that we look for, but is not specifically addressed, I wonder whether it is going to have the impact that we are looking for.

Dr. WULF. I would be happy to share with you another pair of reports, which collectively have the title, "The Engineer of 2020 "

Mr. Honda. Okay. Thank you.

Dr. WULF. — which focuses on that.

Mr. Honda. Dr. Vagelos, I thought maybe you might have a comment.

Dr. Vagelos. Well, the teaching innovation, I think, is very difficult than you are suggesting. Because the innovators, you can have great scientists who make key observations and then someone else comes along and takes that observation to the next step. An example, the discovery of penicillin, which was about 1928, something like that, by Fleming, and it sat around in his lab for a couple of years, and he essentially gave up. This was taken up by a scientist about 10 years later who saw that it was important, and they took the step to make it in large amounts and discover what this substance was that was able to kill organisms and might be a drug. And so it takes certain kinds of people. And I don’t know that it is. A lot of it is innate. There were lots of people thinking about programming when Bill Gates came along. There is only one Bill Gates.

Mr. Honda. But to say that teaching innovation and creativity is difficult is to beg the issue of whether it should be taught or not, and it is a teachable skill. As a teacher, I know that processes are important. And to have our youngsters in our schools subjected to traditional instruction and not being challenged to think outside the box is, you know. We have a lot of Ph.D.s in my valley that are unemployed. And if we are going to be competitive, I think that, you know, to think out of the box and have them be able to grasp this concept or this ability to innovate

Chairman BoEHLERT. Point well taken.

Mr. Honda. — we will lose

Chairman BoEHLERT. The gentleman’s time has expired. We have a vote on the Floor.

Mr. Carnahan, we would like to get you in. You have been faithful here all morning.

Mr. Carnahan. Thank you, Mr. Chairman, and thank you. I share your passion for this, and Mr. Matheson, I guess I have join him, because I talked about this back home as well, research and innovation, and had a fascinating tour back home in St. Louis recently with the company there who is competing internationally, and not just competing, actually expanding their operations, and they are able to do that because of innovation in unique products. And so it was a great boost for me to see a local company doing that, and to see the power of that innovation.

I also want to compliment all of you for your big ideas and for your frankness about how to really go to the next steps and what this is going to cost, but also talk about how you believe it is worth the cost, because it is so important to our future.

I really wanted to focus on a couple of questions in our short time here.

I think your idea about the scholarships for younger, newer teachers is a good idea. There are some of those out there, but I think we can do more there. I also like the idea of trying to get some of our scientists and engineers that may be laid off or retired to try to get them into teaching programs. But the bottom line is, our ability, I believe, to really improve our system is so much based upon our teachers. And salary levels, we all know, drive that. You know, what about including in these initiatives, you know, doubling the salaries of our teachers in our country? To me, that is fundamental, and I would like your comments about that.

Thank you.

Mr. Augustine. You have raised a point that was difficult for our committee in the sense that we were asked to address things that could be done at the federal level, and so we didn't spend a lot of time on teachers unions, on increasing teachers' salaries. But I think it would be safe to say there is not a one of us that wouldn't think that teachers' salaries should be substantially increased. But I suspect most of us would have added the footnote that the increase should be merit-based and performance-based, that we shouldn't just double every teachers' salary tomorrow. I am sure you didn't imply that. But I think that we would strongly support an increase in teachers' salaries, if it was based on performance. Yes.

Dr. Vagelos. And we did, in part, in some of our recommendations, suggested that the teachers who go through these programs go back with an additional salary increase of $10,000. This is a recommendation, but of course these school districts have to decide what they are going to pay. We can make these recommendations. And if the private sector gets in and buys into these programs, as they have done into the advanced placement incentive program in Texas, then the extra funds can come privately to complement what is being done otherwise.

Mr. Carnahan. I just want to say in closing, I came from our state legislature, where I had served on our Education Appropriations Committee. Not once did we ever hear from anyone from the business community talking about education policy. So to me, it is another important thing. I know you are talking about federal level recommendations, but since the bulk of our education funding and policy is driven at the state level, I think it is vital that we engage policy-makers at the State level to begin some of these innovations and also address some of these key funding issues.

So thank you very much.

Chairman BOEHLERT. Thank you very much.

And unfortunately, time has run out. We have to get over to the Floor for a series of votes, and we are not going to ask you to remain. We understand your busy schedules. We will be submitting, Ms. Jackson Lee, Mr. Wu, and others will be submitting questions, and we would ask that you would consider them and respond in a timely manner.

Let me just conclude the hearing by saying how much we appreciate the service that all of you have contributed to the Nation. The compensation is not high in terms of material value. As a matter of fact, it is zero. But I always tell people that serve as well as you do and as effectively as you do, and Mr. Augustine, I am so familiar with your work over the years, and Dr. Wulf, too. Doctor, I don’t mean to exclude you, but I know you by reputation. Now I have had the privilege of meeting you. Your compensation is a rich and rewarding experience, and the satisfaction of knowing you have contributed something of significance.

And with that, the hearing will adjourn, but not before I remind Mr. Augustine of an outstanding invitation to participate in the December 6 conference summit on competitiveness, and we have just had confirmation this morning that Dr. Jack Marburger, the President’s Science Advisor, will be a participant.

And I will tell you what my goal is. Norm, for this summit. I want people to be madder than hell that they didn’t get an invitation, because we have got a small group, and you got one of them, and I want you to respond in a positive way.

With that, the hearing is adjourned.

Mr. Augustine. Thank you.

[Whereupon, at 11:42 a.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

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Answers to Post-Hearing Questions

Responses on behalf of Norman R. Augustine, Retired Chairman and CEO, Lockheed Martin Corporation; P. Roy Vagelos, Retired Chairman and CEO, Merck & Co.; and, William A. Wulf, President, National Academy of Engineering

Questions submitted by Representative Bart Gordon

Ql. Is there a mismatch between the skill sets of graduating scientists and engineers in the U.S. and industry's needs? Did the NAS committee consider whether there is a need to rethink the Ph.D. degree, or the relative production of Ph.D.s versus professional masters degrees or some another type of advanced degree that would be more valuable to industry?

Al. This is a recurrent question about American universities that needs to be revisited periodically. In 1995, for example, the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP) released a report titled "Reshaping the Graduate Education of Scientists and Engineers."

As part of that effort, COSEPUP surveyed employers and asked for their evaluation of Ph.D. training. In sum, these employers indicated that they were satisfied with the current structure and concept of Ph.D. training and affirmed U.S. superiority in graduate education, although there are some specific difficulties in the relationship between academe and the profession. Some specific comments include the need for an:

- Understanding of the nature of industrial research and an appreciation for applied programs;

- Faster response by graduate programs to changing national policies and industrial needs;

- Education with more breadth as opposed to narrow specialization;

• Expansion of educational experiences beyond the academic environment through hands-on experiences and in multi-disciplinary teams;

• Training in communication skills including teaching and mentoring.

This survey was conducted 10 years ago and conditions may have changed. It is also likely that some progress has been made on these issues since that point.

In terms of the need to rethink the Ph.D., we still support the recommendations in the COSEPUP graduate education report. This report recommended the following:

• Offer a broader range of academic options, while maintaining local initiative and not compromising the need to maintain research excellence, control time to degree, and attract women and minority-group members. Specific actions include:

o Discourage students from overspecializing
o Enhance communication skills and the ability to work in teams
o Focus federal financial support mechanisms for graduate students on traineeships as opposed to research assistantships.

• Provide better information and guidance to graduate students and engineers and their advisers so they can make informed decisions about professional careers. Specific actions should include:

o Development by the National Science Foundation, in concert with other federal agencies, a national database on employment options and trends;
o Provision of career information and advice by academic departments to both prospective and current students in a timely manner;
o Encouragement of students once they have met their qualif 3 dng requirements to consider the current job market and then reflect on three alternative pathways – Master's degree, traditional Ph.D., or Ph.D. with a dissertation of high standards, but designed for non-academic career and which would take less time to complete.

• Devise a national human resource policy for advanced scientists and engineers that would involve examination of the goals, policies, conditions, and unresolved issues of graduate level human resources.

On the issue of the relative production of Master's degree versus Ph.D.s, we have insufficient information to answer that question. In addition, the answer is likely

to change over time. However, based on personal experience, it is the opinion of one of us (Augustine) that there is a need, from a industrial standpoint, to greatly increase emphasis on the Master’s degree — not at the expense of the Ph.D. but rather at the expense of the Bachelor’s as a terminal degree.

Q2. In addition to sponsoring more basic research, should the Federal Government focus more resources on applied, pre-eompetitive research aimed at the gap between support for basic discovery and support for development up to the stage where the private sector is willing to assume the risk of commercialization? Did the NAS committee consider the need for greater federal support for this kind of bridge funding for applied research between basie researeh and proof-of-concept?

A2. The committee that developed the Gathering Storm report agrees that it is important to address this gap — which some have called the “valley of death.” It discussed many different options, and among those, placed priority on the establishment of the Advanced Research Projects Agency-Energy (APRA-E). If it proves successful, it could be replicated for other national goals as well.

Q3. During the past two years the Seienee Committee has heard from academic and industry witnesses about the need for bridge funding, and these witnesses have strongly urged funding for the Advanced Technology Program (ATP). Did the NAS committee consider the ATP program or other possible approaches for addressing this issue?

A3. The committee did discuss the ATP and other related programs. The strengths and weaknesses of ATP have been assessed in prior National Academies studies.

It did not re-evaluate these programs per se, but it did determine that they were insufficient to address the gap described above and so recommended ARPA-E.

Questions submitted by Representative Jerry F. Costello

Ql. I fully agree with your belief that we need better science and math education in our schools. The scholarship idea to provide math, seienee and engineering students with teaching certificates seems a good idea. But how attractive will teaching be to these students in the long-term? For example, how does the average teacher salary compare to that of a seientist or engineer? How do you think this issue will faetor into a student’s deeision on which track to pursue?

Al. Economic studies do indicate that the compensation paid to a teacher affects both the teaching pool and teacher tenure. Certainly, the committee would encourage any efforts to enhance compensation for effective science, mathematics, and technology teachers; however, the committee was asked to address actions that could be taken at the federal level not the State or local level where compensation issues are generally addressed. The committee did, however, develop several mechanisms to enhance teacher compensation through bonuses as opposed to salary increases. For example,

• New teacher recruitment program (action A-1) provides scholarships of up to $20,000 per year and $10,000 per year bonuses for those who teach in under-served schools in inner cities and rural areas;

- Current teachers (action A-2) who participate in the continuing education programs (summer institutes. Master's programs, advanced placement/international baccalaureate (AP/IB) teacher training) would receive incentive stipends of $10,000 annually as long as they engage in classroom and leadership activities;

- AP/IB teachers receive a $100 bonus for each student who passes the AP or IB exam in mathematics or science.

Also important are mentoring programs, particularly for new teachers, which are also recommended as part of these programs.

Q2. The pereeption of many college students is that science and engineering jobs are not remunerative, important and exciting career options. How can careers in science and engineering be made more attractive to students who have the option of pursuing other well paid professional careers with shorter preparation time? Is it enough to offer new scholarships and fellowships as recommended in the NAS report?

A2. The excitement of science and engineering is best conveyed through inquiry-based education and teachers who have a science, engineering, or mathematics background themselves. The committee believes that by enhancing the science and

engineering background of those who teach at the middle and high school level, the excitement of those careers can be conveyed to students. Those students will then take the classes necessary for them to pursue science and engineering careers.

The time for preparation at the Bachelor degree level is somewhat longer in engineering than that in other fields, but the starting compensation is also higher (it is not widely appreciated that the average salary in engineering is very close to that of lawyers, which involves an additional two years of study). Unfortunately, compensation for engineering tends to peak at a lower level than for those business, management, banking, or other such fields. At the graduate level there are also disparities. The National Academies have recommended in past reports that the time to Ph.D. be decreased.

In terms of compensation, salary is just one motivator of those interested in science and engineering careers. Perhaps a bigger influence than compensation on those deciding whether or not to pursue graduate level education is the potential for viable employment and interesting research opportunities. The committee's recommendations in the "Sowing the Seeds" section of the report are meant to address those concerns.

Q3. We know that other nations are increasing their science and technology capabilities and are developing large and very capable technical workforces. In addition, U.S. companies are moving, not only manufacturing, but R&D operations abroad. In light of these trends, what kinds of skills will U.S. scientists and engineers need to be able to command a premium in salary over foreign scientists and engineers? That is, how do we compete in the global economy without lowering U.S. salaries and standard of living?

A3. The United States will continue to be challenged to compete on a pure salary basis with developing countries such as India and China; the primary way to respond to that challenge is to increase the value of our engineers and scientists. The primary mechanism for this is improved education at all levels – which is what the committee suggests. Innovation has been a key U.S. national advantage, and enhancing our emphasis on it at all educational levels plays to our strength. When innovations occur in the United States, it is ahle to capture at least the near-term market in that innovation area. To maintain the Nation's innovation capacity the Nation needs to invest regularly in its people and its research.

Question submitted by Representative David Wu and Representative Jerry F. Costello

Ql. The report contains convincing arguments and recommendations to foster a climate of innovation in the U.S. But an important question is whether innovations generated in the U.S. will be exploited in the U.S., or abroad. For example, VCR technology was developed in the U.S., but the market was taken over by Asian countries. Traditionally, it has been the exploitation of new technologies, producing products and delivering novel services, which created new, high-paying jobs. What do we need to do to ensure that the fruits of research and innovation result in the creation of substantial numbers of good jobs in the U.S.?

Al. As indicated in the question, traditionally it has been the exploitation of new technologies, producing products and delivering novel services, that have created high paying jobs. For the United States to benefit from the jobs created by that innovation, the research that led to that innovation needs to occur to the United States and the environment in the U.S. must be conducive to innovation in general. That research will only occur in the United States if there are economic incentives for companies to stay here as opposed to moving overseas and if the human talent is available to develop and implement the ideas.

In its report, the committee calls for a study that will focus on developing the best economic policies to enable the United States to be one of the most attractive places in the world for long-term innovation-related investment. As time passes, some industries will migrate overseas when the technical skills are adequate and the labor market is less expensive. But that does not happen immediately, and until it does the U.S. is able to benefit in terms of the jobs created by that innovation. This is less likely to be the case if the innovation occurs elsewhere.

The U.S. patent system is the Nation's oldest element of policy on intellectual property. A sound system for patent enhances social welfare by encouraging invention and the dissemination of useful technical information. So, in addition, the United States should enhance intellectual property protection for the 21st century global economy to ensure that systems for protecting patents and other forms of in-

tellectual property underlie the emerging knowledge economy but allow research to enhance innovation. The patent system requires reform of four specific kinds:

• Provide the U.S. Patent and Trademark Office with sufficient resources to make intellectual property protection more timely, predictable, and effective.

• Reconfigure the U.S. 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 U.S. 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 that increase the volume and unpredictability of litigation (especially in information-technology industries).

Questions submitted by Representative Eddie Bernice Johnson

Ql. Action A-1 of the NAS report's recommendations suggests awarding "competitive four -year scholarships." However, I am concerned that minority and under - served students will be at a disadvantage for these awards because they are already noncompetitive due to their circumstances. Why did the Academy not consider this issue?

Al. We share the Congresswoman's concern; however, the committee did consider this issue and identified a wide range of existing federal and non-federal awards available for minority and under-served students should these students decide to become scientists and engineers. The challenge is not so much funding these students at the undergraduate level, but rather providing them with the resources they need at the middle and high school level — these students particularly need teachers with science and engineering backgrounds who will excite them about science and engineering and encourage them to pursue careers in these areas. Action A-1, therefore, provides a $10,000 bonus to teachers who graduate from this program and who teach in under-served schools in inner cities and rural areas. It is committee's belief that strengthening the teaching of science and math in the early grades will benefit all students and better prepare all students to compete in life.

Q2. The total cost of the Academy's Implementation recommendation is between $9.2 to $23.8 billion per year. The entire NIH budget is around $30 billion per year. How realistic is it that this plan will be implemented and how do we get the public to agree to such an expensive proposition?

A2. This proposal includes far more than research funding and should be viewed as an investment in the Nation's future, rather than an expense. All four recommendations in the report are part of the fundamental building blocks for the Nation's economy.

Supporting innovation is a cornerstone of the report's conclusions and innovation requires much more than research. To be sure a vibrant research base is essential, but so are an educated workforce, a culture that supports risk-taking, a tax climate the encourages investment, and a host of other things. The report presents a package of proposals that revitalize many of these necessary components of the "innovation ecosystem."

Without quality science, mathematics, and technology teachers, our students will not be prepared to be part of a highly technical workforce.

Without students who are well-educated and excited about science and en^neering, too few Americans will pursue undergraduate and graduate education in science, engineering, and mathematics. And, if we discourage international talent from coming to the U.S., we will have even less talent available.

If the Nation lacks scientific and technical talent, it will not be able to generate the innovative ideas that create whole new industries. And, if industries relocate overseas because other countries offer better financial incentives, then we won't have high-quality jobs for those in science and engineering or Americans in general. Americans may not fully appreciate the importance of research, but they do recognize the benefits that flow from such research and understand the importance of well paying jobs.

In short, if the Nation's leaders assign as high a priority to the concerns which have been raised, as does this National Academies committee, the proposed funding will be able to compete very strongly with other demands on the federal budget.

Appendix 2:

Additional Material for the Record

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Employing America
for a Brighter

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Rising Above The Gathering Storm
Energizing and Employing America for a Brighter Economic Future

Committee on Prospering in the
Global Economy of the 21st Century:

An Agenda for American Science and Technology

Committee on Science, Engineering, and Public Policy

PRE-PUBLICATION VERSION
February 2006 Edition

THE NATIONAL ACADEMY OF SCIENCES,
THE NATIONAL ACADEMY OF ENGINEERING, and
THE INSTITUTE OF MEDICINE

OF THE NA TIONAL A CADEMIES

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Coimcil, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

Support for this project was provided by the National Academies. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

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PRE-PUBLICATION VERSION

February 2006 Edition

THE NATIONAL ACADEMIES

Advisers to the Halion on Siience, Engineering, ond Medicine

The Natioaal Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon die authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its admirtistration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and reccgnizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy’s purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to file government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

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PREFACE

"Ninety-nine percent of the discoveries are made by one percent of the scientists."

Julius Axelrod, Nobel Laureate^

The prosperity the United States enjoys today is due in no small part to investments the nation has made in research and development at universities, corporations, and national laboratories over the last 50 years. Recently, however, corporate, government, and national scientific and technical leaders have expressed concern that pressures on the science and technology enterprise could seriously erode this past success and jeopardize future US prosperity. Reflecting this trend is the movement overseas not only of manufacturing jobs but also of jobs in administration, finance, engineering, and research.

The councils of the National Academy of Sciences and the National Academy of Engineering, at their annual joint meeting in February 2005, discussed these tensions and examined the position of the United States in today's global knowledge-discovery enterprise. Participants expressed concern that a weakening of science and technology in the United States would inevitably degrade its social and economic conditions and in particular erode the ability of its citizens to compete for high-quality jobs.

On the basis of the urgency expressed by the councils, the National Academies' Committee on Science, Engineering, and Public Policy (COSEPUP) was charged with organizing a planning meeting, which took place May 1 1, 2005. One of the speakers at the meeting was Senator Lamar Alexander, the former secretary of education and former president of the University of Tennessee.

Senator Alexander indicated that the Energy Subcommittee of the Senate Energy and Natural Resources Committee, which he chairs, had been given the authority by the full committee's chair. Senator Pete Domenici, to hold a series of hearings to identify specific steps that the federal government should take to ensure the preeminence of America's science and technology enterprise. Senator Alexander asked the National Academies to provide assistance in this effort by selecting a committee of experts from the scientific and technical community to assess the current situation and, where appropriate, make recommendations. The committee would be asked to identify urgent challenges and determine specific steps to ensure that the United States maintains its leadership in science and engineering to compete successfully, prosper, and be secure in the 21st century.

On May 12, 2005, the day after the planning meeting, three members of the House of Representatives who have jurisdiction over science and technology policy and funding announced that a conference would be held in fall 2005 on science, technology, innovation, and manufacturing. Appearing at a Capitol Hill press briefing to discuss the conference were representatives Frank Wolf, Sherwood Boehlert, and Vern Ehlers. Representative Boehlert said of the conference: "It can help forge a national consensus on what is needed to retain US leadership in innovation. A summit like this, with the right leaders, under the aegis of the federal government, can bring renewed attention to science and technology concerns so that we can remain the nation that the world looks to for the newest ideas and the most skilled people."

In describing the rationale for the conference. Representative Wolf recalled meeting with a group of scientists and asking them how well the United States was doing

^Proceedings of the American Philosophical Society, Vol. 149, No. 2, June 2005.

in science and innovation. None of the scientists, he reported, said that the nation was doing “okay”. About 40% said that we were “in a stall”, and the remaining 60% said that we were “in decline”. He asked a similar question of the executive board of a prominent high-technology association, which reported that in its view the United States was “in decline”.

Later, the National Academies received a bipartisan letter addressing the subject of America’s competitiveness from Senators Lamar Alexander and Jeff Bingaman. The letter, dated May 27, 2005, requested that the National Academies conduct a formal study on the issue to assist in congressional deliberations. That was followed by a bipartisan letter from Representatives Sherwood Boehlert and Bart Gordon, of the House Committee on Science, which expanded on the Senate request. In response, the National Academies initiated a study with its own funds.

To undertake the study, COSEPUP established the Committee on Prospering in the Global Economy of the 2 1st Century: An Agenda for American Science and Technology. The committee members included presidents of major universities, Nobel laureates, CEOs of Fortune 100 corporations, and former presidential appointees. They were asked to investigate 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 the United States can successfully compete, prosper, and be secure in the global community of the 21st century?

• What implementation strategy, with several concrete steps, could be used to implement each of those actions?

This study and report were carried out with an unusual degree of urgency — only a matter of weeks elapsed from the committee’s initial gathering to release of its report.

The process followed the regular procedures for an independent National Research Council study, including review of the report, in this case, by 37 experts. The report relies on customary reference to the scientific literature and on consensus views and judgments of the committee members.

The committee began by assembling the recommendations of 13 issue papers summarizing past studies of topics related to the present study. It then convened five focus groups consisting of 66 experts in K-12 education, higher education, research, innovation and workforce issues, and national and homeland security and asked each group to recommend three actions it considered to be necessary for the nation to compete, prosper, and be secure in the 21st century. The committee used those suggestions and itsown judgment to make its recommendations. The key thematic issues underlying these discussions was the nation's need to create jobs and need for affordable, clean, and reliable energy.

In this report, a description of the key elements of American prosperity in the 21st century is followed by an overview of how science and technology are critical to that prosperity. The report then evaluates how the United States is doing in science and technology and provides recommendations for improving our nation's prosperity. Finally, it posits the status of prosperity if the United States maintains a narrow lead (the current situation), falls behind, or emerges as the leader in a few selected fields of science and technology.

We strayed from our charge in that we present not 10 actions but four recommendations and 20 specific actions to implement them. The committee members deeply believe in the fundamental linkage of all the recommendations and their integrity as a coordinated set of policy actions. To emphasize one or neglect another, the members

decided, would substantially weaken what should be viewed as a coherent set of high-priority actions to create jobs and enhance the nation's energy supply in an era of globalization. For example, there is little benefit in producing more researchers if there are no funds to support their research.

The committee thanks the focus-group members, who took precious personal time in midsummer to donate the expertise that would permit a highly focused, detailed examination of a question of extraordinary complexity and importance. We thank the staff of the National Academies. They quickly mobilized the knowledge resources and practical skills needed to complete this study in a rapid, thorough manner.

Norman R. Augustine

Chair, Committee on Prospering in the Global Economy of the 21st Century

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ACKNOWLEDGMENTS

This report is the product of many people. First, we thank all the focus-group members, listed in Appendix C, for contributing their time and knowledge at the focus-group session in August 2005. Second, we would like to thank all the committees and analysts at other orgmiizations who have gone before us, producing reports and analyses on the topics discussed in this report. There are too m^y to mention here, but they are cited throughout the report and range from individual writers and scholars, such as Thomas Friedman and Richard Freeman, to committees and organizations, such as the Glenn Commission on K-12 education, the Council on Competitiveness, the Center for Strategic and International Studies, the Business Roundtable, the Taskforce on the Future of American Innovation, the President’s Council of Advisors on Science and Technology, the National Science Board, and other National Academies committees. Without their insight and analysis, this report would not have been possible.

This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following for their review of this report:

Miller Adams, Boeing Phantom Works; John Aheame, Sigma Xi; Robert Aiken, CISCO Systems, Inc.; Bruce Alberts, University of California, San Francisco; Richard Atkinson, University of California, San Diego; William Badders, Cleveland Municipal School District; Roger Beachy, Ronald Danforth Plant Service Center; George Bugliarello, Polytechnic University; Paul Citron, Medtronic, Inc.; Michael Clegg, University of California, Irvine; W. Dale Compton, Purdue University; Robert Dynes, University of California, San Diego; Joan Ferrini-Mundy, Michigan State University; Richard Freeman, Harvard University; William Friend, Bechtel Group, Inc. (retired); Lynda Goff, University of California, Santa Cruz; William Happer, Princeton University; Robert Hauser, University of Wisconsin; Ron Hira, Rochester Institute of Technology; Dale Jorgenson, Harvard University; Thomas Keller, Medomak Valley High School, Maine; Edward Lazowska, University of Washington; W. Carl Lineberger, University of Colorado, Boulder; James Mongan, Partners Healthcare System; Gilbert Omenn, University of Michigan; Helen Quinn, Stanford Linear Accelerator Center; Mary Ann Rankin, University of Texas; B^bara Schaal, Washington University; Thomas Sudhof, Howard Hughes Medical Institute; Michael Teitelbaum, Sloan Foundation; C. Michael Walton, University of Texas; Larry Welch, Institute for Defense Analyses; and Sheila Widnall, Massachusetts Institute of Technology.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Floyd Bloom, Robert Frosch, and M.R.C. Greenwood, appointed by the Report Review Committee, who were responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of the report rests entirely with the author committee and the institution.

Finally, we would like to thank the staff who supported this project, including Deborah Stine, study director and associate director of the Committee on Science, Engineering, and Public Policy (COSEPUP), who managed the project; program officers Peter Henderson (higher education), Jo Husbands (national security), Thomas Arrison (innovation). Laurel Haak (K-12 education), and (on loan from the Council on Competitiveness) policy consultant David Attis (research funding and management), who conducted research and analysis; Alan Anderson, Steve Olson, and research associate Rachel Courtland, the science writers and editors for this report; Rita Johnson, the managing editor for reports; Norman Grossblatt and Kate Kelly, editors; Neeraj P. Gorkhaly, senior program assistant, who coordinated and provided support throughout the project with assistance of Marion Ramsey and Judy Goss; science and technology policy fellows John Slanina, Benjamin Novak, and Ian Christensen who provided research and analytic support; Brian Schwartz, who compiled the bibliography; and Riehard Bissell, executive director of COSEPUP and of Policy and Global Affairs.

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EXECUTIVE SUMMARY

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 laige 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 discoveiy and new technology, our economy will suffer and our people will face a lower standard of hving. Economic studies conducted even before the information-technology revolution have shown that as much as 85% of measured growth in US income per capita was due to technological change.^

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 modem 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. This has been aptly referred to as "the Death of Distance."

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 Representative Sherwood Boehlert and Representative 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 policymakers 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. 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 first gathering to report release) limited the ability of the committee to conduct an exhaustive 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 consists of leaders in academe, industry, and government — including 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 e-mail 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.

^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 unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance", has been widely attributed to the effects of technological change.

^ Since the prepublication version of die report was released in October, certain changes have been made to correct editorial and factual errors, add relevant examples and indicators, and ensure consistency among sections of the report. Although modifications have been made to the text, the recommendations remain unchanged, except for a few corrections, which have been footnoted.

FINDINGS

Having reviewed trenck in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthenii^ 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 the 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.

The committee found that multinational companies use such criteria^ as the following in determining where to locate their facilities and the jobs that result:

- Cost of labor (professional and general workforce).
- Availability and cost of capital.
- Availability and quality of research and innovation talent.
- Availability of qualified workforce.
- Taxation environment.
- Indirect costs (litigation, employee benefits such as healthcare, pensions, vacations).
- Quality of research universities.
- Convenience of transportation and communication (including language).
- Fraction of national research and development supported by government.
- Legal-judicial system (business integrity, property rights, contract sanctity, patent protection).
- Current and potential growth of domestic market.
- Attractiveness as place to live for employees.
- Effectiveness of national economic system.

Although the US economy is doir^ well today, current trends in each of those criteria indicate that the United States may not fare as well in the future without government intervention. 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 — fi'om other committees, from its focus groups, and fi-om 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.

^ D.H. Dalton, M.G. Serapio, Jr., P.G. Yoshida. 1999. Globalizing IndustrialResearch and Development. USDeparOnent of Commerce, Technology Administration, Office of Technology Policy. Grant Gross. 2003, October 9. "CEOs defend moving jobs offshore at tech summit." InfoWorld Mehlman, Bruce. 2003. Offshore Outsourcing and the Future of American "High tech in China: is it a threat to Silicon Valley?" 2002, October 28. Business Week orAint. B. Callan, S. Costigan, K. Keller. 1997. Exporting U.S. High Tech: Facts and Fiction about the Globalization of Industrial R&D, Council on Foreign Relations, New York, NY.

The four recommendations focus on actions in K-12 education {10,000 Teachers, lOMillionMinds'), 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.

The committee notes that the nation is unlikely to receive some sudden “wakeup” call; rather, the problem is one that is likely to evidence itself gradually over a surprisingly short period.

10,000 TEACHERS, 10 MILLION MINDS,

AND K-12 SCIENCE AND MATHEMATICS EDUCATION

Recommendation A: Increase America's talent pool by vasdy 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 course 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, on a one-to-one basis, of $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 the physical and life sciences, mathematics, computer sciences, or engineering with teacher certification. The models for this action are the UTeach at the University of Texas and California Te ach at the University of California.

Action A-2: Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master’s programs, and in Advanced Placement (AP) and International Baccalaureate (IB) training programs. 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 the skills and state-of-the-art knowledge of 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 one model for this action.

• Science and mathematics master ’s programs: Provide grants to research universities to offer, over 5 years, 50,000 current middle school and high school science, mathematics, and technology teachers (with or without imdergraduate 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 action 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 science and mathematics. Assuming satisfactory performance, teachers may receive incentive payments of $1,800 per year, as well as $100 for each student who passes an AP or

IB exam in mattiematics 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 a world-class standard: 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 woidd be available free of charge as a voluntary national curriculum. The model for this action is the Project Lead the Way pre-engineering courseware.

Action A-3: Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass AP and 16 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 who take at least one AP or IB mathematics or science exam to 1.5 million, and set a goal of tripling the number who pass those tests to 700, 000.“* Student incentives for success would include 50% examination fee rebates and $100 mini-scholarships for each passing score on an AP or IB science or mathematics examination.

Although it is not included amor^ the implementation actions, the committee also finds attractive the expansion of two 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 conunittnent 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% each year over the next 7 years through reallocation of existing funds^ or, if necessary, through the investment of new funds. Special attention should go to the physical sciences, engineering, 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 or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to US prosperity. Increasingly, the most significant new scientific and engineering advances are formed to cut across several disciplines. This investment should be evaluated regularly to realign the research portfolio to satisfy emerging needs and promises — unsuccessful projects and venues of research should be replaced with research projects and venues that have greater potential.

Action B-2: Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of the nation’s 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

This sentence was incorrectly phrased in the original October 1 2, 2005 edition of the executive summary and has now been corrected.

^ The funds may come from anywhere in government, not just other research funds.

Department of Energy (DOE), DOD, and the National Aeronautics and Space Administration (NASA) — to underwrite new research opportunities at universities and government laboratories.

Action B-3: Institute a National Coordination Office for Advanced Research Instrumentation and Facilities to manage a fund of $500 million in incremental funds 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, instrumentation, 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 catalyz ing high-risk, high-payoff research of the type that often suffers in today’s increasingly risk-averse environment.

Action B-5: Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E).^ 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 and do so in a timely manner. 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 approximately 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 spinoff benefits, including aiding in the education of the next generation of 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 and any appropriate actions taken.

Action B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest. Existing presidential awards recognize 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.

“^One committee member, Lee Raymond, does not support this action item. He does not believe that ARPA-E is necessary, because energy research is alrea<^ well funded by the federal government, along with formidable funding by the private sector. Also, ARPA-E would, in his view, put the federal government into the business of picking "winning energy technologies"— a role best left to the private sector.

BEST AND BRIGHTEST

IN SCIENCE AND ENGINEERING HIGHER EDUCATION

Recommendation C: Make the United States the most attractive setting in which to stu^ 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 ofUS citizens who earn bachelor's degree In the physical sciences, the life sciences, engineering, and mathematics 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, Ei^ineering, 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 ofUS 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 a stipend of $30,000^ annually directly to students, who would choose where to pursue graduate studies instead of being required to follow faculty research grants, and up to $20,000 annually for tuition and fees.

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 productive in an environment 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 US-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-IB 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.^

’ An incorrect number was provided for the graduate student stipend in the ordinal October 12, 2005 edition of the executive summary.

® Since ^e report was released, the committee has learned that the Consolidated Appropriations Act of 2005, signed into law on December 8, 2004, exempts individuals that have received a master’s or higher education degree from a US university from the statutory cap (up to 20,000). The bill also raised the H-lb fee and allocated funds to train American workers. The committee believes that^is provision is sufficient to respond to its recommendation — even though the 10,000 additional vi^s recommended is specifically for science and engineering doctoral candidates from US universities, which is a narrower subgroup.

Action C-7: Reform the current system of “deemed exports”. 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 from the deemed-exports technology list all technology items (information and equipment) 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

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.

Implementation Actions

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 US Patent and Trademark Office with 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 that 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,*® and it should be increased from 20% to 40% of the qualifying increase so that the US tax credit is competitive with those 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 having previously invested in research and development.

Action D-3: Provide tax incentives for US-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

® The controls governed by the Export Administration Act and its implementing regulations extend to the transfer of technology. Technology includes "specific information necessary for frie 'development,' 'production,' or 'use' of a product". 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 ej^^ort, 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.

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

United States, pursued. These alternatives could include changes in overall corporate tax rates and special tax provisions providing 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 and the jobs resulting from that 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 can be expected to 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 and the administration should take action — mainly in the regulatory arena and in spectrum management — to ensure widespread affordable broadband access in the very 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 disparity it faces in labor costs. Science and technology provide the opportunity to overcome that disparity by creating scientists and engineers with die abil

ity to create
entire new indi^tries — much as has been done in the past.

It is e^y to be complacent about US competitiveness and preeminence 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. Some will argue that this is a problem for market forces to resolve — but that is exactly the concern. Market forces are already ar worA: moving jobs to countries with less costly, often better educated, highly motivated workforces and friendlier tax policies.

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 COMPETITIVENESS INDICATORS

US Economy

• The United States is today a net importer of high-technoloS)^ products. Its trade balance in high-technology manufactured goods shifted from plus $54 billion in 1990 to negative $50 billion in 2001 }

• 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.^

• The United States is one of the few countries in which industry plays a major role in providing health care for its employees and their families. Starbucks spends more on healthcare than on coffee. General Motors spends more on health care than on steel.^

• US scheduled airlines currently outsource portions of their aircraft maintenance to China and El Salvador.

• IBM recently sold its personal computer business to an entity in China.^

• Ford and General Motors both have junk bond ratings.*^

• It has been estimated that within a decade nearly 80% of the world’s middle-income consumers would live in nations outside the currently industrialized world. China alone could have 595 million middle-income consumers and 82 million upper-middle-income consumers. The total population of the United States is currently 300 million and it is projected to be 3 1 5 million in a decade. ’’

• Some economists estimate that about half of US economic growth since World War II has been the result of technological innovation.®

• In 2005, American investors put more new money in foreign stock funds than in domestic stock portfolios.^

Comparative Economics

• Chemical companies closed 70 facilities in the United States in 2004 and 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 are in China. No new refineries have been built in the United States since 1976.

• The United States is said to have 7 million illegal immigrants," but under the law the number of visas set aside for “highly qualified foreign workers,” many of whom contribute significantly to the nation’s innovations, dropped to 65,000 a year from its 195,000 peak."

• When asked in spring 2005 what is the most attractive place in the world in which to “lead a good life”, respondents in only one (India) of the 16 countries polled indicated the United States. "

• A company can hire nine factory workers in Mexico for the cost of one in America. A company can hire eight young professional engineers in India for the cost of one in America."

• The share of leading-edge semiconductor manufacturing capacity owned or partly owned by US companies today is half what it was as recently as 2001."

• During 2004, China overtook the United States to become the leading exporter of information-technology products, according to the OECD."

• The United States ranks only 12th among OECD countries in the number of broadband connections per 100 inhabitants."

K-12 Education

• 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 4thgraders and one-fifth of the 8th graders lacked the competence to perform even basic mathematical computations.^*

• In 1999, 68% of US 8th grade students received instruction fi'om a mathematics teacher who did not hold a degree or certification in mathematics.^^

• In 2000, 93% of students in grades 5-9 were taught physical science by a teacher lackir^ a major or certification in the physical sciences (chemistry, geology, general science, or physics).^®

• In 1995 (the most recent data available), US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science.^*

• US 15-year-olds ranked 24th out of 40 coimtries that participated in a 2003 administration of the Program for International Student Assessment (PISA) examination, which assessed students’ ability to apply mathematical concepts to real-world problems.^^

• According to a recent survey, 86% of US voters believe that the United States must increase the number of workers with a background in science and mathematics or America’s ability to compete in the global economy will be diminished.^^

• American youth spend more time watcliing television^ than in school.^^

• Because the United States does not have a set of national curricula, changing K-12 education is challenging, given that there are almost 15,000 school systems in the United States and the average district has only about 6 schools.

Higher Education

• In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore 67%. In the United States, the corresponding figure is 1 5%.^^

• Some 34% percent of doctoral degrees in natural sciences (including the physical, biological, earth, ocean, and atmospheric sciences) and 56% of engineerir^ PhDs in the United States are awarded to foreign-bom students.^*

• In the U.S. science and technology workforce in 2000, 38% of PhDs were foreign-bom. ^

• Estimates of the number of engineers, computer scientists, and information technology students who obtain 2- 3-, or 4-year degrees vary. One estimate is that in 2004, China graduated about 350,000 engineers, computer scientists, and information technologists with 4-year degrees, while the United States graduated about 140,000. China also graduated about 290,000 with 3-year degrees in these same fields, while the US graduated about 85,000 with 2- or 3-year degrees.^® Over the past 3 years alone,

both China^^ and India^^ have doubled their production of 3- and 4-year degrees in these fielc^, while the United States'^ production of engineers is stagnant and the rate of production of computer scientists and information technologists doubled.

• About one-third of US students intending to major in er^ineering switch majors before graduating. ^''

• There were almost twice as many US physics bachelor's degrees awarded as in 1956, the last graduating class before Sputnik than in 2004.^^

• More S&P 500 CEOs obtained their undergraduate degrees in er^ineering than in any other field.^^

Research

• In 2001 (the most recent year for which data are available), US industry spent more on tort litigation than
on research and development.^’

• In 2005, only four American companies ranked among the top 10 corporate recipients of patents granted
by the United States Patent and Trademark Office.^®

• Beginning in 2007, the most capable high-energy particle accelerator on Earth will, for the first time,
reside outside the United States.^^

• Federal funding of research in the physical sciences, as a percentage of GDP, was 45% less in FY 2004
than in FY 1976.‘’°The amount invested annually by the US federal government in research in the
physical sciences, mathematics, and engineering combined equals the annual increase in US health care
costs incurred every 20 days.**^

PERSPECTIVES

• "We go where the smart people are. Now our business operations are two-thirds in the U.S. and one-third
overseas. But that ratio will flip over the next ten years." — Intel spokesman Howard High**^

• “If we don’t step up to the challenge of finding and supporting the best teachers, we’ll undeimine everything else we are trying to do to improve our schools.” — Louis V. Gerstner, Jr., Former Chairman, IBM"

• “If you want good manufacturing jobs, one thing you could do is graduate more engineers. We had more sports exercise majors graduate than electrical engineering grads last year.” — Jeffrey R. Immelt, Chairman and Chief Executive Office, General Electric'”

• “If I take the revenue in January and look again in December of that year 90% of my December revenue comes from products which were not there in January.” — Craig Barrett, Chairman of the Intel Corporation'*^

• “When I compare our high schools to what I see when I’m traveling abroad, I am terrified for our workforce of tomorrow.” — Bill Gates, Chairman and Chief Software Architect of Microsoft Corporation'**

• “Where once nations measured their strength by the size of their armies and arsenals, in the world of the future knowledge will matter most." — President Bill Clinton**^

• “Science and technology have never been more essential to the defense of the nation and the health of our economy.” — President George W. Bush"**

NOTES for SOME COMPETITIVENESS INDICATORS AND PERSPECTIVES

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‘^SaraKehaulani Goo. Airlines Outsource Upkeep. Washington Post August 21, 2005. Available at

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^ Michael Kanellos. 2004. “IBM Sells PC Group to Lenovo.” News.cot?j. December 8. Available at

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^ Paul J. Lim. Looking AheadMeans Looking Abroad New York Times. January 8th 2006.

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As of 2000, the unauthorized resident population in the United States was 7 million. See US Citizensh

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Services. 2003. “Executive Summary: Estimates of the Unauthorized Immigrant Population Residing in the United States:
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Section 21 4(g) of the Immigration and Nationality Act (Act) sets an annual limit on the number of aliens that can receive
H-IB status in a fiscal year. ForFY2000 the limit was set at 115,000. The American Competitiveness in the Twenty -First
Century Act increased the annual limit to 195,000 for 2001, 2002 and 2003. After that date the cap reverts back to 65,000.
H-IB 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
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See Immigration and Nationality Act Section 101(a)(15)(h)(l)(b). See US Citizenship and Immigration Services. 2005.
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A DISTURBING MOSAIC*

In The World Is Flat: A Brief History of the Twenty-First Century^ Thomas Friedman asserts that the international economic playing field is now “more level” than it has ever been.^ The causes of this “flattening” include easier access to information technology and rising technical competences abroad that have made it possible for US companies to locate call centers in India, coordinate the complex supply chains and work flows that enable manufacturing in China, and conduct “back office” service functions abroad. It is not uncommon for radiologists in India, for example, to read x-ray pictures of patients in US hospitals. Architects in the United States have their (i'awings made in Brazil. Software is written for US firms in Bangalore.

Ireland has successfully put into place a set of policies to attract companies and their research activities, as has Finland. The European Union is actively pursuing policies to enhance the innovation environment, as are Singapore, China, Japan, South Korea, Taiwan, and many other countries.

Friedman argues that, despite the dangers, a flat world is on balance a good thing — economically and geopolitically. Lower costs benefit consumers and shareholders in developed countries, and the rising middle class in India and China will become consumers of those countries’ products as well as ours. That same rising middle class will have a stake in the “frictionless” flow of international commerce — and hence in stability, peace, and the rule of law. Such a desirable state, writes Friedman, will not be achieved without problems, and whether global flatness is good for a p^icular country depends on whether that country is prepm'ed to compete on the global playing field, which is as rough and tumble as it is level.

^ Major portions of this chapter were adapted from an article of the same name by Wm. A. Wulf, president of the National Academy of Engineerir^ in the fall 2005 issue of The Bridge, a journal of the National Academies,

^T. L. Friedman, The Worldls Flat: A Brief History of^e Twenty-First Century, New York: Farffl", Sttaus and Giroux, 2005.

^ An alternative point of view is presented in Box 1 - 1

BOX 1-1

Another Point of View: The World Is Not Flat'^

Some believe that although the world is certainly a more competitive place, it is not "flat". It is more competitive because access to knowledge is easier than ever before, but the rise of scientific competence and the apparent flight of high-technology jobs abroad is no more likely to dislodge the United States from its science and technology leadership than were previous challenges from the Soviet Union in the 1950s and 1960s or from Japan in the 1980s.

For example, Americans are alarmed to read of the large numbers of well-educated, English-speaking young people in India vying with US workers for jobs via the Internet. In fact, only about 6% of Indimi students make it to college; of those who do, only two- thirds graduate. Just a small fraction of India's citizenry can read English; of these, a smaller fraction can speak i t well enough to be understood by Americans. In China, where the numbers of engineers and other technically trained people are rising, government skepticism about the Internet and aspects of free markets is likely to hinder the advance of national power.

China and India indeed have low wage structures, but the United States has many other advantages. These include better a science and technology infrastructure, stronger venture-capital markets, an ability to attract talent from around the world, and a culture of inventiveness. Comparative advantage shifts from place to place over time and always has; the earth cannot really be flattened. The US response to competition must include proper retraining of those who are disadvantaged and adaptive institutional and policy responses that make the best use of opportunities that arise.

Friedman asks rhetorically whether his own country is proving its readiness by "investing in our future and preparing our children the way we need to for the race ahead". Friedman's answer, not surprisingly, is no.

This report addresses the possibility that our lack of preparation will reduce the ability of the United States to compete in such a world. Many underlying issues are technical; some are not. Some are "political" — not in the sense of partisan politics, but in the sense of "bringing the rest of the body politic along". Scientists and engineers often avoid such discussions, but the stakes are too high to keep silent any longer.

Friedman's term quiet crisis, which others have called a "creeping crisis", is reminiscent of the folk tale about boiling a frog. If a frog is dropped into boiling water, it will immediately jump out and survive. But a frog placed in cool water tliat is heated slowly until it boils won't respond until it is too late.

Our crisis is not the result of a one-dimensional change; it is more than a simple incre^e in water temperature. And we have no single awakening event, such as Sputnik The United States is instead facing problems that are developing slowly but surely, each like a tile in a mosaic. None by itself seems sufficient to provoke action. But the collection of problems reveals a disturbing picture — a recurring pattern of abundant short-term thinking and insufficient long-term investment. Our collective reaction thus far seems to presuppose that the citizens of the United States and their children are entitled to a better quality of life than others, and that all Americans need do is circle the wagons to defend that entitlement. Such a presupposition does

* This box was adapted from Jagdish Bhagwati. The world is not flat. The Wall SUeet Journal. August 4, 2005. p. A12.

not reflect reality and neither recognizes the dangers nor seizes the opportunities of current circumstmices. Furthermore, it won't work.

In 2001, the H^-Rudman commission on national security, which foresaw large-scale terrorism in America and proposed the establishment of a cabinet-level Homeland Security organization before the terrorist attacks of 9/11, put the matter this way:^

> The inadequacies of our system of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine.

President George W. Bush has said that

> "Science and technology have never been more essential to the defense of the nation and the health of our economy."^

A letter from the leadership of the National Science Foundation to the President's Council of Advisors on Science and Technology put the case even more bluntly: ^

> Civilization is on the brink of a new industrial order. The big winners in the increasingly fierce global scramble for supremacy will not be those

who simply make commodities faster and cheaper than the competition.

They will be those who develop talent, techniques and tools so advanced
that there is no competition.

This chapter addresses the relevant issues in three related clusters. Later chapters examine each cluster in more detail and recommend ways to address the problems that are identified.

CLUSTER 1: TILTED JOBS IN A GLOBAL ECONOMY

Is the world flat, or is it tilted? Many people who once had jobs in the textile, furniture, apparel, automotive, and other manufacturing industries might be forgiven for saying that world is decidedly slanted. They watched their jobs run downhill to countries where the workforce earns far lower wages. The movement of jobs has accelerated sharply in the last 5 years, surprising many employee and employees and disrupting the lives of those who have been underbid by "hungry", skilled job-seekers abroad.

Large companies use various criteria in making a decision to relocate administrative, production, or research and development (R&D) facilities, and they often have a number of options. Some reasons cited for relocations in past studies include capitalizing on:

• Foreign R&D personnel (scientists, engineers, and progr^mers/ who are highly skilled and eager to work.^

^United States Commission on National SQCuhty, Road Map for National Security: Imperative for Change, 2001'
'^Remarks by the President in Meeting with High-Tech Leaders, March 28, 2001,

^The President's Council of Advisors on Science and Technology, Sustaining the Nation's Innovation Ecosystems,
Report on Information Technology Manufacturing md Competitiveness, January 2004

^D.H. Dalton, M.G. Serapio, Jr., P.G. Yoshida. 1999. Globalizing IndustrialResearchandDevelopment U.S.
Department of Commerce, Technology Adminisfration, Office of Technology Policy.

^ Grant Gross. CEOs defend moving jobs offshore at tech summit. InfoWorld. October 9, 2003.

• New science mid technology in fresh environments.^®

• Technological developments abroad.^^

• Joint and cooperative research products.

• Proximity to offshore manufacturing.^^

• Lower costs of conducting R&D, particularly labor costs.

• Reduced labor costs associated with employing foreign workers.

• Proximity to growing markets.

• US regulation and R&D climates, including strict regulatory regimes, high risks of legal liability, and technology transfer limitations.^^

• High-technology centers with skilled personnel, world-class R&D infrastructure, vibrant research cultures, government incentives, and intellectual-property protection.

• Lower corporate tax rates and special tax incentives.

• Increasingly high-quality research universities.

The global forces that affect employment have swirled into the service sector, once thought secure from international competition. First, there was outsourcing, which allows employers to reassign some jobs by contracting them to specialty firms that can do the jobs better or more cheaply. At first, jobs were outsourced within the United States, but “offshoring” soon sent jobs overseas, beyond the reach of US workers. That practice has become especially controversial, and there has been an outcry for measures to protect those jobs for the domestic market. In some states, legislation has been proposed to curb outsourcing through such initiatives as Opportunity Indiana, the Keep Jobs in Colorado Act, and the American Jobs Act of Wisconsin.

Offshoring has become established, however, and it is merely one logical outcome of a flatter world. Furthermore, protectionist measures have historically proved counterproductive.

For several years, US companies that outsource information-technology jobs have all but ordered their contractors to send some portion of the work overseas to gain hiring flexibility, cut employment costs — by 40% in some cases^^ — and cut overhead costs for the home company.^® Employers also hire offshore workers to gain access to better-trained workers or those with specialized skills, to move the workforce closer to manufacturing or production facilities, or to gain access to desirable markets. In India, US companies can hire insurance-claims processors,

^‘’Dalton, 1999.

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“Dinesh C. Sharma and Mike Yamamoto. How India is handling international backlash. CNET news.com. May 6, 2004. .

“ The Garttier Group, an organization that analyzes the information-technology sector, estimates that companies can achieve cost savings of 25%-30% through successful outsourcing. But Gartner also warns that offshoring could produce lower savings than estimated if backup service and other costs are not considered, .

Julia King. Its itineraty: Offshore outsourcing is inevitable. Computerworld, Sept. 15, 2003,

Ron Hira, Rochester Institute of Technology, presentation to Committee on Science. Engineerii^, and Public Policy, Workshop on International Students and Postdoctoral Scholars, National Academies, July 2004.

medical transcriptionists, accountants, engineers, computer scientists, and other English-speaking workers for, on average, about one-fifth the salaries those employees would earn here. Because about three-fourths of all US jobs are now in the service sector, millions of US employees are at risk of losing their jobs to overseas workers.

Offshoring also could place downwM’d pressure on wages at home.^*^ Fewer than a million jobs have been sent overseas so far,^^ but even that number could be broadly affecting the economy as displaced workers seek jobs held by others or are forced to accept lower wages to keep their existing jobs.

Because offshoring of service-sector jobs is a recent phenomenon, few analysts offer predictions about its long-term effects on the US economy. The classical view of free trade, as articulated nearly 2 centuries ago by British economist David Ricardo, states that if a nation specializes in making a product in which it has a comparative cost advantage and if it trades with another nation for a product in which that nation has a similar cost advantage, both countries will be better off than if they had each made both products themselves. But does that theory hold in a world where not only goods but many services are tradable as well? Will wages merely fall worldwide as more knowledge workers enter the jobs arena?

Most economists believe that Ricardo is still correct – that there will be gains for all such nations. They acknowledge that there might be a transition phase in which wages for lower-skilled workers in a rich country like the United States will fall. Some say that there is, however, no reason to believe that wages for highly skilled workers will fall in either the short run or the long run.^^ Economist Paul Romer argues that technological change continues to increase the demand for workers with high levels of education.^^ As a result, wages for US workers with at least a college education continue to rise faster than wages for other workers. Tlie low wages for highly skilled workers seen in such countries as China and India are not a sign that the worldwide supply of highly skilled workers is so large that worldwide wages are now falling or are about to fall, says Romer. In those economies, wages for skilled workers are low because these workers were previously cut off from the deep and rapidly growing pool of technological knowledge that existed outside their borders. As they have opened up their economies so that this knowledge can now flow in, wages for highly skilled workers have grown rapidly.

With the collapse of the high-technology bubble, some highly skilled workers in the United States have experienced a fall in their wages from the values that prevailed at the peak. Moreover, at every level of education, there is wide variation in compensation and career paths. Some engineers and scientists, even now, are unemployed or underemployed, just as some physicians, MBAs, and lawyers are unemployed or underemployed. It would be a mistake,

Geoffrey Colvin. Can Americans compete? Is America Qxe world's 97-lb. weakling? Yortxme. July 25, 2005.

Forrester Research, a technology and market rese^ch company, estimates that 3.3 million white-collar jobs could be sent offshore by 2015. "Tom Pohlman. Topic Overview. Outsourcing, Q3 2005." September 12, 2005, Available at: http:/Avww.forrester.com/Research/Document/0,721 l,37613,00.html.

^‘'Richard Freeman. It’s a flat world, after all. The New York Times. April 3, 2005. Section 6; Colxrmn 1; Magazine Desk; Pg. 33

Colvin, ibid.

^®The Concise Encyclopedia of Economics. "Biography of David Ricardo." Available at; http://www.econlib.org/library/Enc/bios/Ricardo.html.

^^T. L. Friedman. The World Is Flat: A Brief History of ^e Twenty-First Century, p. 227.

E-mail communication from P. Romer to D. Stine, Sept 22, 2005.

Autor, David, Katz, Lawrence, and Melissa Kearney. 2005. Trends in U.S. Wage Inequality: Re-Assessing the Revisionists. National Bureau of Economic Research. Working Paper 1 1627 for a recent summary of the evidence on friis point.

according to Romer, for public policy to limit the training of new physicians only because some of them end up with careers that are not as lucrative or rewarding as they had hoped. In the same way, public-policy decisions about the supply of scientists and engineers should not be guided by an attempt to provide a guaranteed high level of income for every recipient of an advanced degree. It is also important that scientists and engineers tend, through innovation, to create new jobs not only for themselves but also for workers throughout the economy.

Some economists believe that there might be a transition phase in some fields during which wages fall, but they assert that there is no reason to believe that such a dip would be permanent, because the global economic pie keeps growing.^^

It has also been argued that in a period of tectonic change such as the one that the global community is now undergoing, there will inevitably be nations and individuals that are winners or losers. It is the view of this committee that the determining factors in such outcomes are the extent of a nation's commitment to get out and compete in the global marketplace.

New generations of US scientists and engineers, assisted by progressive government policies, could lead the way to US leadership in the new, flatter world — as long as US workers remain among the best educated, hardest-working, best trained, and most productive in the world.

That, of course, is the challenge.

CLUSTER 2: DISINVESTMENT IN THE FUTURE

The most effective way for the United States to meet the challenges of a flatter world would be to draw heavily and quickly on its investments in human capital. We need people who have been prepared for the kinds of knowledge-intensive occupations in which the nation must excel. Yet the United States has for a number of decades fallen short in making the kinds of investments that will be essential in a global economy.

Loss of Human Capital

An educated, innovative, motivated workforce — human capital — is the most precious resource of any country in this new, flat world. Yet there is widespread concern about our K-12 science and mathematics education system, the foundation of that human capital in today's global economy. A recent Gallup poll^^ asked respondents, "Overall, how satisfied are you with the quality of education students receive in kindergarten through grade twelve in the U.S. today — would you say you are completely satisfied, somewhat satisfied, somewhat dissatisfied or completely dissatisfied?" More than 50% were either "completely dissatisfied" or "somewhat dissatisfied" with our schooling. According to the poll results, the critical required change would be to produce better educated, higher-quality teachers. This committee shares that view, particularly in connection with education in science and mathematics. By far the highest leverage

L. Friedman, The Worldls Flat: ABrief History of the Twenty-First Century, p. 227.

Gallup Poll, August 8-11, 2005, ± 3% margin of error, sample size= 1,001. As found at http://www.galiup.com/poll/content/default.aspx?ci=18421 on 14 Sept. 2005.

Gallup Poll, August 9-11, 2004, ± 3% margin of error, sample size= 1,017. As found at on 14 Sept. 2005.

to be found in our education system resides with teachers, if for no other reason than that they influence such a large number of future workers.

Students in the United States are not keeping up with their counterparts in other countries. In 2003 the Organisation for Economic Co-operation and Development's Programme for International Student Assessment" measured the performance of 15-year-olds in 49 industrialized countries. It found that US students scored in the middle or in the bottom half of the group in three important ways: our students placed 16th in reading, 19th in science literacy, and 24th in mathematics.^"^ In 1996 (the most recent data available), US 12th graders performed below the international average of 2 1 countries on a test of general knowledge in mathematics and science.

After secondary school, fewer US students pursue science and engineering degrees than is the case of students in other countries. About 6% of our undergraduates major in engineering; that percentage is the second lowest among developed countries. Engineering students make up about 12% of undergraduates in most of Europe, 20% in Singapore, and more than 40% in China. Students throughout much of the world see careers in science and engineering as the path to a better future.

Higher Education as a Private Good

Our culture has always considered higher education a public good — or at least we have seemed to do so. We have agreed as a society that educated citizens benefit the whole society; that the benefit accrues to us all and not just to those who receive the education. That was a primary reason for the creation in the 1860s of the land-grant college system; it is why early in the 20th century universal primary and secondary schooling was supported; it is why a system of superior state universities was created and generously supported and scholarships were given to needy students; and it is why the Serviceman's Readjustment Act of 1944 — ^the GI Bill — was established and why the National Defense Education Act was passed in 1958 shortly after the launch of Sputnik.

Now, however, funding for state universities is dwindling, tuition is rising, and students are borrowing more than they receive in grants. These seem to be indications that our society increasingly sees higher education as a private good, of value only to the individual receiving it. A disturbing aspect of that change is its consequences for low-income students. College has been a traditional path for upward mobility — and this has been particularly true in the field of engineering for students who were first in their family to attend college. The acceptance of higher education as a personal benefit rather than a public good, the growth of costly private K-12 schooling, and the shift of the cost burden to individuals have made it increasingly difficult for low-income students to advance beyond high school. In the long run, tlie nation as a whole will suffer from the lack of new talent that could have been discovered and nurtured in affordable, accessible, high-quality public schools, colleges, and universities.

” Organisation for Economic Cooperation and Development. "Program for International Student Assessment." Available at: http://www.pisa.oecd.org.

^''The report included results from 49 countries, http://www.pisa.oecd.Org/dataoecd/l/63/34002454.pdf.

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

Trends in Corporate Research

The US research structure that evolved after World War II was a self-reinforcing triangle of industry, academe, and government. Two sides of that triangle — industrial research and government investment in R&D as a fraction of GDP have changed dramatically. Some of the most important fundamental research in the 20th century was accomplished in corporate laboratories — Bell Labs, GE Resem’ch, IBM Research, Xerox PARC, and others. Since that time, the corporate research structure has been significantly eroded. One reason might be the challenge of capturing the results of research investments within one company or even a single nation on a long-term b^is. The companies and nation can, however, capture high-technology discoveries at least for the near term (5-10 years) and enhance the importance of innovation in jobs. For

example, the United States has successfully capitalized on research in monoclonal antibodies, network systems, mid speech recognition. As a result, corporate funding of certain applied resem-ch has been enhanced at such companies as Google and Intel and at many biotechnology companies. Nonetheless, the increasing pressure on corporations for short-term results has made investments in research highly problematic.

Although support for research in the life sciences increased shm'ply in the 1990s and produced remarkable results, funding for research in most physical sciences, mathematics, and engineering has declined or remained relatively flat — in real purchasing power — ^for several decades. Even to those whose principal interest is in health or health care, that seems short-sighted: Many medical devices and procedures — such as endoscopic surgery, “smart” pacemakers, kidney dialysis, and magnetic resonance imaging — are the result of R&D in the physical sciences, engineering, and mathematics. The need is to strengthen investment in the latter areas while not disinvesting in those areas of the health sciences that are producing promising results. Many believe that federal funding agencies — perhaps influenced by the stagnation of funding levels in the physical sciences, mathematics and engineering — ^have become increasingly risk-averse and focused on short-term results. For example, even the generally highly effective Defense Advanced Research Projects Agency (DARPA) has been criticized in this regard in congressional testimony.

Widespread, if anecdotal, evidence shows that even the National Science Foundation and the National Institutes of Health (NIH) have changed their approach in this regard. A recent National Academies study^^ revealed that the average age at which a principal investigator receives his or first grant is 42 years — partly because of requirements for evidence of an extensive “track record” to reduce risk to the grant-makers. But reducing the risk for individual

^'^COSEPUP: 1999, Capitalizing on Investments in S&T. National Academy Press, Washington DC,

See House Science Committee, http://www-house,gov/science/hearings/full05/mavl2/ - The current director of DARPA, however, points out that DARPA’ s job has always been to mine fundamental research, looking for those ideas whose time has come to move on to applied developmental research.

Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research, Board on Life Sciences, National Research Council, National Academies Press, Washington, D,C,, 2004.

Other observers note that part of the reason for this is die length of the biomedical PhD and postdoctoral period and die difficulty of young biomedical researchers in finding initial tenure-track positions, for which many institutions require principal -investigator status on ai NIH grant proposal. These trends, which are occurring in spite

research projects increases the likelihood that breakthrough, “disruptive” technologies will not be found — ^the kinds of discoveries that often yield huge returns. History also suggests that young researchers make disproportionately important discoveries. The NIH roadmap"^*^ established in FY 2004, recognizes this concern, but the amount of funds devoted to long-term, high-payoff, high-risk research remains very limited.

CLUSTER 3: REACTIONS TO 9/11

Three other pieces in the mosaic also appear to provide short-term security but little long-term benefit. These relate to the events of 9/1 1, which profoundly changed our world and made it necessary to re-ex^ine national security issues in an entirely new context. This re-examination led to changes in visa policies, export controls, and the treatment of “sensitive but unclassified” information. There appears today to be a need to better balance security concerns with the benefits of an open, creative society.

New Visa Policies

Much has been written about new immigration and visa policies for students and researchers. Although there have been improvements in the last several months (at this writing, the average time to process a student visa is less dian 2 weeks), there is still concern about response times in particular cases. Some promising students wait a year or more for visas; some senior scholars are subjected to long and sometimes dememiing review processes. Those cases, not the shorter average processing time, are emphasized in the international press. The United States is portrayed less as a welcoming land of opportunity than as a place that is hostile to foreigners.

Immigration procedures implemented since 9/1 1 have discouraged students from applying to US programs, prevented international research leaders from organizing conferences here, and dampened international collaboration. As a result, we are damaging the image of our country in the eyes of much of the world. Although there are recent signs of improvement, the matter remains a concern.

This committee is generally not privy to whatever evidence lies in the government’s library of classified information, but it is important to recognize that our nation’s borders have been crossed by more than 10 million people who are still residing illegally in the United States. Set against this background, a way is needed to quickly, legally, and safely admit to our shores the relatively small numbers of highly talented people who possess the skills needed to make major contributions to our nation’s future competitiveness and well-being.

Some observers are also concerned that encouraging international students to come to the United States will ultimately fill jobs that could be occupied by American citizens. Others worry

of the recent doubling of the NIH grants budget, suggest an imbalance between demand for and supply of recent PhDs.

The purpose of the roadmap was to identify major opportunities and gaps in biomedical research that no single
MH institute could tackle alone but that the agency as a whole must address to make die biggest impact on the
progress of medical research.

that such visitors will reduce the compensation that scientists and engineers receive — diminishing the desire of Americans to enter those professions. Studies show, however, that the financial impact is minimal, especially at the PhD level. Furthermore, scientists and engineers tend to be creators of new jobs and not simply consumers of fixed a set of existing jobs. If Americans make up a larger percentage of a graduating class, a larger percentage of Americans will be hired by corporations. In the end, the United States needs the smartest people, wherever they come from throughout the world. The United States will be more prosperous if those people live and work in the United States rather than elsewhere. History has emphatically proven this point.

The Use of Export Controls

Export controls were first instituted in the United States in 1949 to keep weapons technology out of the hands of potential adversaries. They have since been used, on occasion, as an economic tool against competitors.

The export of controlled technology requires a license from the Department of Commerce or from the Department of State. Since 1994, the disclosure of information regarding a controlled technology to some foreign nationals — even when the disclosure takes place inside the United States, a practice sometimes called “deemed export” — has been considered the same as the export of the technology itself and thus requires an export license.

Some recent reports"^^ suggest diat implementation of the rules diat govern deemed exports should be tightened even further — for example, by altering or eliminating the exemption for basic research and by broadening the definition of “access” to controlled technology.

The academic research community is deeply concerned that a literal interpretation of these suggestions could prevent foreign graduate students from participating in US-based research and would require an impossibly complex system of enforcement. Given that 55% of the doctoral students in engineering in the United States are foreign-bom and that many of these students currently remain in the United States after receiving their degrees, the effect could be to drastically reduce our talent pool.

The United States is not the world’s only country capable of performing research; China and India, for example, have recognized the value of research universities to their economic development and are investing heavily in them. By putting up overly stringent barriers to the exchange of information about b^ic research, we isolate ourselves and impede our own progress. At the same time, the information we are protecting often is available elsewhere.

The current fear that foreign students in our universities pose a security risk must be balanced against the great advantages of having them here. It is, of course, pmdent to control entry to our nation, but as those controls become excessively burdensome they can unintentionally harm us. In this regard, it should be noted that Albert Einstein, Edward Teller, Enrico Fermi, and many other immigrants enabled the United States to develop the atomic bomb and bring World War II to an earlier conclusion than would otherwise have been the case. In addition, immigrant scientists and engineers have contributed to US economic growth throughout

Reports from the inspectors general of the US Departments of Commerce, Defense, and State. As an example, see Bureau of Industry and Security, DeemedExport Controls May Not Stop the Transfer of Sensitive Technology to Foreign Nationals in the U.S., Final Inspection Report No. IPE- 161 76 — March 2004, Office of Inspections and Program Evaluations.

the nation’s history by founding or cofounding new technology -based companies. Examples include Andrew Carnegie (US Steel, bom in Scotland), Alexander Graham Bell (AT&T, bom in Scotland), Herbert Henry Dow (Dow Chemical, bom in Canada), Henry Timken (Timken Company, bora in Germany), Andrew Grove (Intel, bom in Hungary), Davod Lam (Lam Research, bom in China), Vinod Khosla (Sun Microsystems, bom in India), and Sergey Brin (Google, bom in Russia).

Similarly, it has been noted that

- Many students from abroad stay here after their education is complete and contribute greatly to our economy.

- Foreign students who do return home often are our best ^bassadors.

- The United States benefits economically from open trade, and our security is reinforced by rising living standards in developing countries.

- The quality of life in the United States has been improved as a result of shm'ed scientific results. Some foreign-bom students do return home to work as competitors, but others join in international collaborations that help us move faster in the development and adaptation of new technology and thereby create new jobs.

Yet, Section 214b of the Immigration and Nationality Act requires applicants for student or exchange visas to provide convincing evidence that they plan to return to their home countries — a challenging requirement.

Sensitive but Unclassified Infoimation

Since 9/1 1, the amount of information designated sensitive but unclassified (SBU) by the US government has presented a problem that is less publicized than visas or deemed exports but is a complicating factor in academic research. The SBU category, as currently applied, is inconsistent with the philosophy of building high fences around small places associated with the traditional protection of scientific and technical information. There are no laws, no common definitions, and no limits on who can declare information "SBU", nor are there provisions for review and disclosure after a specific period. There is little doubt that the United States would profit from a serious discussion about what kinds of information should be classified, but such a discussion is not occurring.

THE PUBLIC RECOGNIZES THE CHALLENGES

Does the public truly see the challenge to our prosperity? In recent months, polls have indicated persistent concern not only about the war in Iraq and issues of terrorism but also, and nearly equally, about jobs and the economy. One CBS-New Y ork Times poll showed security leading economic issues by only another'*^ showed that our economy and job security are

'‘^CBS News-New York Times poll, June 10-15, 2005; 1,11 1 adults nationwide; 19% found the war in Ira q die most
important problem, 18% cited the economy mdjobs. Available at:
htq?://www.cbsnews-com/htdocs/CBSNews_polls/bush61 6.pdf-

of slightly greater concern to respondents than are issues of national security and terrorism. On the eve of the 2004 presidential election, the Gallup organization asked respondents what issues concerned them most. Terrorism was first, ranked "extremely important" by 45% of respondents; next cmne the economy (39%), health care (33%), and education (32%).'^'^ Only 35% say that now is a good time to find a high-quality job; 61% say that it is not."^^ Polls, of course, only provide a snapshot of America's thinking, but presumably one can conclude that Americans are generally worried about jobs — if not for themselves then for their children and grandchildren.

Investors are worried, too. According to a Gallup poll, 83% percent of US investors say job outsourcing to foreign countries is currently hurting the investment climate "a lot" (61%) or “a little” (22%). The numbers who are worried about outsourcing are second only to the numbers who are worried about the price of energy, according to a July 2005 Gallup poll on investor concems."^^

DISCOVERY AND APPLICATION:

KEYS TO COMPETITIVENESS AND PROSPERITY

A common denominator of the concerns expressed by many citizens is the need for and use of knowledge. Well-paying jobs, accessible health care, and high-quality education require the discovery, application, and dissemination of information and techniques. Our economy depends on the knowledge that fuels the growth of business and plants the seeds of new industries, which in turn provides rewarding employment for commensurately educated workers. Chapter 2 explains that US prosperity since World War II has depended heavily on the excellence of its “knowledge institutions”: high-technology industries, federal R&D agencies, and research universities that are generally acknowledged to be the best in the world.

The innovation model in place for a half-century has been so successful in the United States that other nations are now beginning to emulate it. The governments of Finland, Korea, Ireland, Canada, and Singapore have mapped and implemented strategies to increase the knowledge base of students and researchers, strengthen research institutions, and promote exports of high-technology products — activities in which the United States has in the p^t excelled."*^ China formally adopted a pro-R&D policy in the middle of the 1990s and has been moving rapidly to raise government spending on basic research, to reform old structures in a fashion that supports a market economy, and to build indigenous capacity in science and technology."^^

The United States is now part of a connected, competitive world in which many nations are empowering their indigenous “brainware” and building new and effective performance

ABC News-Washington Post poll, June 2-5, 2005, 1,002 adults nationwide. Of those polled, 30% rated the economy and jobs of highest concern, 24 % rated Iraq of highest concern.

Dennis Jacob, Gallup chief economist, in “More Americans see threat, not opportunity, in foreign trade: Most investors see outsourcing as harmful.” Available at: http://www.galliq).cora/poll/content/default.aspx?ci=14338 .

"'^FrankNewport, Gallup poll editor-in-chief, “Bush approval, economy, election 2008, Iraq, John Roberts, civil rights” Aug. 9, 2005. Available athttp://www.gallup.com/poll/content/?ci=17758&pg=l.

Gallup poll, June 24-26, 2005, ± 3% ma’gin of error, sanple size= 1,009. Available at ht^://www.gallup.com/poll/content/?ci=17605&pg=l on 14 Sept. 2005.

OECD. Main Science & Technology Indicators, 2005. Available at: http://www.oecd. org/docuraent/26/0,2340,en_2649_34451_1901082_l_l_l_l,00.htoil

China 's Science and Technology Policy for the Twenty-First Century— A View from the Top, Report from pMlnerships — and they aiQ doing so with remarkable focus, vigor, and determination. The United States must match that tempo if it hopes to maintain the degree of prosperity it h^ enjoyed in the past.

ACTION NOW

Indeed, if we are to provide prosperity and a secure environment for our children and grandchildren, we cannot be complacent. The gradual change in England's standing in the world since the 1800s and the sudden change in Russia's standing since the end of the Cold War are but two examples that illustrate how dramatically power can shift. Simply maintaining the status quo is insufficient when other nations push ahead with desire, energy, and commitment.

Today, we see in the example of Ireland how quickly a determined nation can rise from relative hunger to burgeoning prosperity. In the 1980s, Ireland's unemployment rate w^ 18%, and during that decade 1% of the population — mostly young people — left the country, largely to find jobs."^^ In response, a coalition of government, academic institutions, labor unions, farmers, and others forged an ambitious and sometimes painful plan of tax and spending cuts and aggressively courted foreign investors and skilled scientists and engineers. Today, Ireland is, on a per capita basis, one of Europe's wealthiest countries. In 1990, Ireland's per capita GDP of $12,891 (in current US dollars) ranked it 23rd of the 30 OCED member countries. By 2002, Ireland's per capita GDP had grown to $32,646, making it 4th highest among OECD member countries.^^ Ireland's unemployment rate (as a percentage of the total percentage of total labor force) was 13.4% in 1990. By 1993, it had risen to 15.6%. By 2004 unemployed declined to 4.5%.^^ Since 1995, Ireland's economic growth has averaged 7.9%. Over the same time period, economic growth averaged 2% in Europe and 3.3% in the United States.

History is the story of people mobilizing intellectual and practical talents to meet demanding challenges. World War II saw us rise to the military challenge, quickly developing nuclear weapons and other military capabilities. After the launch of Sputnik^"^ in 1957, we accepted the challenge of the space race, landed twelve Americans on the moon, and fortified our science and technology capacity.

Today's challenge is economic — ^no Pearl Harbor, Sputnik, or 9/1 1 will stir quick action. It is time to shore up die basics, the building blocks without which our leadership will surely decline. For a century, many in the United States took for granted that most great inventions would be homegrown — such as electric power, the telephone, the automobile, and the airplane — and would be commercialized here as well. But we are less certain today who will create the next generation of innovations, or even what they will be. We know that we need a more secure Internet, more-efficient transportation, new cures for dise^e, and clean, affordable, and reliable sources of energy. But who will dream them up, who will get the jobs they create, and who will profit from them? If our children and grandchildren are to enjoy the prosperity that our forebears

''^William C. Harris, director general. Science Foundation Ireland, personal communication, Aug. 15, 2005.
Thomas Friedman. The End of the Rainbow. New York Times. June 29, 2005.

OECD, OECD Factbook 2005. Available at: http://puck.sourceoecd.org/vl=2095292/cl=23/nw=l/rpsv/factbook/
OECD, OECD Factbook 2005. Available at: http://puck.sourceoecd.org/vl=2095292/cl=23/nw=l/rpsv/factbook
” Robert Samuelson. The world is still round. Newsweek. July 25, 2005.

^'’The fall 1957 launch of SpuUikl, the first artificial satellite, caused many in the United States to believe that we were quickly falling behind the USSR in science education and rese^ch. That concern led to major policy reforms in education, civilian and military research, and federal support for researchers. Within a year, the National Aeronautics and Space Administration and DARPA were founded. In that era, science and technolo^ became a major focus of the public, and a presidential science adviser was appointed.

earned for us, our nation must quickly invigorate the knowledge institutions that have served it so well in the past and create new ones to serve in the future.

CONCLUSION

A few of the tiles in the mosaic are apparent; many other problems could be added to the list. The three clusters discussed in this chapter share a common characteristic: short-term responses to perceived problems can give the appearance of gain but often bring real, long-term losses.

This report emphasizes the need for world-class science and engineering — ^not simply as an end in itself but as the principal means of creating new jobs for our citizenry as a whole as it seeks to prosper in the global marketplace of the 21st century. We must help those who lose their jobs; they need financial assistance and retraining. It might even be appropriate to protect some selected jobs for a very short time. But in the end, the country will be strengthened only by learning to compete in this new, flat world.

2

WHY ARE SCIENCE AND TECHNOLOGY CRITICAL TO AMERICA’S PROSPERITY IN THE 21st CENTURY?

Since the Industrial Revolution, the growth of economies throughout the world has been driven largely by the pursuit of scientific understanding, the application of engineering solutions, and continual technological innovation.* Today, much of everyday life in the United States and other industrialized nations, as evidenced in transportation, communication, agriculture, education, health, defense — and jobs, is the product of investments in research and in the education of scientists and engineers.^ One need only think about how different our daily lives would be without the technological innovations of the last century or so.

The products of the scientific, engineering, and health communities are, in fact, easily visible — ^the work-saving conveniences in our homes; medical help summoned in emergencies; the vast infrastructure of electric power, communication, sanitation, transportation, ^d safe drinking water we take for granted.^ To many of us, that universe of products and services defines modem life, freeing most of us from the harsh manual labor, infectious diseases, and threats to life and property that our forebears routinely faced. Now, few families know the suffering caused by smallpox, tuberculosis, polio, diphtheria, cholera, typhoid, or whooping cough. All those diseases have been greatly suppressed or eliminated by vaccines (Figure 2-1).

We enjoy and rely on world travel, inexpensive and nutritious food, easy digital access to the arts and entertainment, laptop computers, graphite tennis rackets, hip replacements, and quartz watches. Box 2-2 lists a few examples of how completely we depend on scientific research and its application — from the mighty to the mundane.

Science and engineering have changed the very nature of work. At the beginning of the 20th century, 38% of the labor force was needed for farm work, which was hard and often dangerous. By 2000, research in plant and animal genetics, nutrition, and husbandry together with innovation in machinery had transformed farm life. Over the last half-century, yields per acre have increased about 2.5 times,'* and overall output per person-hour has increased fully 10-fold for common crops, such as wheat and com (Figure 2-2). Those advances have reduced the farm labor force to less than 3% of the population.

* Anodier point of view is provided in Box 2-1.

^S. W. Popper and C. S. Wagner. New Foundations for Growth: The US. Innovation System Today and Tomorrow.
Santa Monica, CA; RAND Corporation. The authors state: “The transformation of the U.S. economy over the past
twenty years has made it clear that innovations based on scientific and technological advances have become a major
contributor to our national well being,” p. ix.

^ One study argues that “there has been more material progress in the United States in the 20th century than there
was in the entire world in all the previous centuries combined,” aid most of the examples cited have their basis in
scientific and engineering research. S. Moore and J. L. Simon. The greatest century that ever was: 25 miraculous
trends of the last 100 years. Policy AnalysisTIo. 364. Washington, DC: Cato Institute, Dec. 15, 1999.

‘‘National Research Council. Frontiers in AgriculturalResearch: Food, Health, Environment, and Communities.
Washington, DC: National Academy Press, 2003.

Similarly, the maintenance of a house a century ago without today’s labor-saving devices left little time for outside enjoyment or work to produce additional income.

The visible products of research, however, are made possible by a l^ge enterprise mostly hidden from public view — fundamental and applied research, an intensively trained workforce, and a national infrastructure that provides risk capital to support the nation’s science and engineering innovation enterprise. All that activity, and its sustaining public support, fuels the steady flow of knowledge and provides the mechanism for converting information into the products and services that create jobs mid improve the quality of modem life. Maintaining that vast and complex enterprise during an age of competition and globalization is challenging, but it is essential to the future of the United States.

Box 2-1

Another Point of View: Science, Technology and Society

For all the practical devices and wonders that science and technology have brought to society, it has also created its share of problems. Researchers have had to reapply their skills to create solutions to unintended consequences of many innovations, including finding a replacement for chlorofluorocarbon-based refrigerants, eliminating lead emissions from gasoline-powered automobiles, reducing topsoil erosion caused by large-scale farming, researching safer insecticides to replace DDT, and engineering new waste-treatment schemes to reduce hazardous chemical effluents from coal power plants and chemical refineries.

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incidence of Selected Disease» In the United Stntes

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Americin SIDS Isilkuie, www.Mila.oiv‘neirch'webiale.''tldOOI.htn.

Note: SIDS nle i* per 100.000 live birihi. AIDS deliiilioi naa nibrttntially mpaided in 1985, 1987. and 1993. TB rate prior lo 1930 ia
ctlimaied a< 1.3 limes the ntortalily rate.

FIGURE 2-1 The 20th century saw dramatic reductions in disease incidence in the United States.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculous trends
of the past 100 years. Cato Policy Analysis, No. 364, Dec. 15, 1999, pp. 1-32. based on Historical Statistic of the
United States, Series B 149, B 291,B299-300, B 303; Health, United States, 1999, Table 53; and American SID
Institute, www.sids.org/research/webrates/sld001.htm

Note: SIDS rate is per 100,000 live births. AIDS definition was substantially expanded in 1985, 1987, and 1993. TB
rate prior to 193 0 is estimated as 1.3 times the mortality rate.

BOX 2-2

Twenty Great Engineering Achievements of the 20th Century

Electricity: steam turbine generators; long-distance, high-voltage transmission lines; pulverized coal; large-scale electric grids

Automotive: machine tools, assembly line, self-starting ignition, balloon tire, safety-glass windshield, electronic fuel injection and ignition, airbags, antilock brakes, fuel cells
Aeronautics: aerodynamic wing and fuselage design, metal alloys and composite materials, stressed-skin construction, jet propulsion, fly-by-wire control systems, collision warning systems, Doppler weather radar

Water supply and distribution: chlorination, wastewater treatment, dams, reservoirs, storage tanks, tunnel-boring equipment, computerized contaminant detection, desalination, large-scale distillation, portable ultraviolet devices

Electronics: triodes, semiconductors, transistors, molecular-beam epitaxy, integrated circuits, digital-to-optical recording (CD-ROM), microprocessors, ceramic chip carriers
Radio and television: alternators, triodes, cathode-ray tubes, super heterodyne circuits, AM/FM, videocassette recorders, flat-screen technology, cable and high-definition television, telecommunication satellites

Agriculture: tractore, power takeoff, rubber tires, diesel engines, combine, corn-head attachments, hay balers, spindle pickers, self-propelled irrigation systems, conservation tillage, global-positioning technology

Computers: electromechanical relays; Boolean operations; stored programs; programming languages; magnetic tape; software, supercomputers, minicomputers, and personal computers; operating systems; the mouse; the Internet

Telephony: automated switchboards, dial calling, touch-tone, loading coils, signal amplifiers, frequency multiplexing, coaxial cables, microwave signal transmission, switching technology, digital systems, optical-fiber signal transmission, cordless telephones, cellular telephones, voice-over-Intemet protocols

Air conditioning and refrigeration: humidity-control technology, refrigerant technology, centrifugal compressors, automatic temperature control, frost-free cooling, roof-mounted cooling devices, flash-freezing

Highways: concrete, tar, road location, grading, drainage, soil science, signage, traffic control, traffic lights, bridges, crash barriers

Aerospace: rockets, guidance systems, space docking, lightweight materials for vehicles and spacesuits, solar power cells, rechargeable batteries, satellites, freeze-dried food, Velcro
Internet: packet-switching, ARPANET, e-mail, networking services, transparent peering of networks, standard communication protocols, TCP/IP, World Wide Web, hypertext, web browsers

Imaging: diagnostic x-rays, color photography, holography, digital photography, cameras, camcorders, compact disks, microprocessor etching, electron microscopy, positron-emission tomography, computed axial tomography, magnetic-resonance imaging, sonar, radar, sonography, reflecting telescopes, radiotelescopes, photodiodes, charge-coupled devices

Household appliances; ranges, electric ranges, oven thermostats, nickel-chrome resistors, toasters, hot plates, electric irons, electric motors, rotary fans, vacuum cleaners, washing machines, sewing machines, refrigerators, dishwashers, can openers, cavity magnetrons, microwave ovens

Health technology: electrocardiography; heart– lung machines; pacemakers; kidney dialysis; artificial hearts; prosthetic limbs; synthetic heart valves, eye lenses, replacement joints; manufacturing techniques and systems design for large-scale drug delivery; operating microscopy; fiber-optic endoscopy; laparoscopy; radiologic catheters; robotic surgery
Petroleum and petrochemical technology: diermal-cracking oil refining; leaded gasoline; catalytic cracking; oil byproduct compounds; synthetic rubber; coal tar distillation byproduct compounds, plastics, polyvinyl chloride, polyethylene, synthetic fibers; drilling technologies;

drill bits; pipelines; seismic siting; catalytic converters; pollution-control devices
Lasers and fiber optics: maser, laser, pulsed-beam laser, compact-disk players, barcode scanners, surgical lasers, fiber optic communication

Nuclear technology: nuclear fission, nuclear reactors, elech'ic-power generation, radioisotopes, radiation therapy, food irradiation

High-performance materials: steel alloys, aluminum alloys, titanium superalloys; synthetic polymers, Bakelite, Plexiglas; synthetic rubbers, neoprene, nylon; polyethylene, polyester, Saran Wrap, Dacron, Lycra spandex fiber, Kevlar; cement, concrete; synthetic diamonds; superconductors; fiberglass, graphite composites, Kevlar composites, aluminum composites

SOURCE: G. Constable and B. Somerville.^ Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives. Washington, DC: Joseph Henry Press, 2003,

U.S. Fann Labor Prodticti\it>'

Source: Autbon' calculanoos from data m L WeUeld. fThtre IT# IA« (New York: Simon and Schuster. 198 S).

FIGURE 2-2 From 1800 to 2000, there was a hundredfold increase in US farm labor output, much of it brought about by advancements in science and technology.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculous trends of the past 100 years. Cato Policy AnalysiSyt^o. 364,Dec. 15, 1999,pp. 1-32.

ENSURING ECONOMIC WELL-BEING

Knowledge acquired and applied by scientists and engineers provides the tools and systems that characterize modern culture and the raw materials for economic growth and well-being. The knowledge density of modern economies has steadily increased, and the ability of a society to produce, select, adapt, and commercialize knowledge is critical for sustained economic growth and improved quality of life. Robert Solow demonstrated that productivity depends on more than labor and capital.^ Intangible qualities — research and development (R&D), or the acquisition and application of knowledge — are crucial.^ The earlier national commitment to make a substantial public investment in R&D was based partly on that assertion (Figure 2-3).

Since Solow's pioneering work, the economic value of investing in science and technology has been thoroughly investigated. Published estimates of return on investment (ROI) for publicly funded R&D range from 20% to 67% (Table 2-1). Although most early studies focused on agriculture, recent work shows high rates of return for academic science research in the aggregate (28%),^ and slightly higher rates of return for pharmaceutical products in particular (30%).^*^ Modem agriculture continues to respond, and the average return on investment for public funding of agricultural research for member countries of the Organisation for Economic Co-operation and Development is estimated at 45%.^^

Starting in the middle 1990s, investments in computers and information technology started to show payoffs in US productivity. The economy grew faster and employment rose more than had seemed possible without fueling inflation. Policy-makers previously focused almost entirely on changes in demand as the determinant of inflation, but the surge in productivity showed that changes on the supply side of the economy could be just as important and in some cases even more import^t.^^ Such data serve to sustain the US commitment to invest substantial public funds in science and engineering.*^

^L. B. Holm -Nielsen. Promoting science and technology for development: The World Bank's Millennium Science Initiative. Paper delivered on April 30, 2002, to the First International Senior Fellows meeting. The Wellcome Trust, London, UK.

^ The Organisation for Economic Co-operation and Development (OECD) concludes that "underlying long-term growth rates in OECD economies depend on maintaining and expanding die knowledge base. Technology, Productivity, and Job Creation: Best Policy Practices. Paris. France: OECD, 1998, p. 4.

^R. M. Solow." Technical change and the aggregate production function." The Review of Economics and Statistics
39(1 957):3 12-320 andR,M Solow. "Investment and Technical Progress", 1960, in Arrow, Karlin & Suppes, editors,
Mathematical Models in Social Sciences. For more on Solow's work, see
http://nobelprize.org/economics/laureates/1987/index-html-

^R. M. Solow. "Technical change and the aggregate production function." The Review of Economics and Statistics
39(1957):312-320.

^E. Mansfield. Academic research and industrial 'mRovzixon. Research Policy 20(1 991): 1-1 2.

^°A. Scott, S. Grove, A. Geuna, S. Brusoni, andE. Steinm culler. The economic returns of basic research and the
benefits of university -industty relationships. Report for the office of Science and Techology . Science and
Technology Policy Research: Brighton, 2001. Available at
htty://www-sussex. ac.uk/spru/documents/review_for_ost_final.pdf

^^R. E. Evensoa Economic impacte of agricultural research and extension. In Han(£)ook of Agricultural Economics
Vol 1, eds. B. L. Gardner and G. C. Rausser, pp. 573-628 Rotterdam: North Holland, 2001

^^E. L. Andrews. The doctrine was not to have one; Greenspan will leave no roadmap to his successor. New York
Times, Aug. 26, 2005. p. Cl.

Committee on Science, US House of Representatives. Unlocking Our Future: Toward aNew National Science

Policy (die "Ehlers Report"). Washir^ton, DC: US Congress, 1998. The report notes diat "die growth of economies

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FIGURE 2-3 In the 20th century, US per capita gross domestic product (GDP) rose almost sevenfold.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculous trends of the past 100 years. Cato Policy Analysis, No. 364, Dec. 15, 1999, pp. 1-32.

Of equal interest are studies of the rate of return onprivate investments in R&D.^*^ The return on investment to the nation is generally higher than is the return to individual investors (Table 2-2).^^ One reason that knowledge tends to spill over to other people and other businesses, so research results diffuse to the advantage of those who are prepared to apply them. Those “social rates of return”^® on investments in R&D are reported to range from 20% to 100%, with

throughout the world since the industrial revolution began has been driven by continual technological innovation through the pursuit of scientific understanding and application of engineering solutions” (p. 1).

Council of Economic Advisors. Supporting Research and Development to Promote Economic Growth: The Federal Government’s Role. Washington, DC: White House, October 1995.

Center for Strategic and International Studies. Global Innovation /National Competitiveness. Washington, DC: CSIS, 1996.

“Social rate of return” is defined in C. I. Jones and J. C. Williams. Measuring the social return to R&D. Working Paper 97002. Stanford University Department of Economics. 1997. Available at

http://www.econ.stanford.edu/faculty/workp/swp97002.pdf^search=‘R&D%20social%20rate%20of“/Q20retum.

They state, “One can think of knowledge as an ‘asset’ purchased by society, held for a short period of time to re^ a dividend, and then sold. The return can then be thought of as a sum of a dividend and a capital gain (or loss) ... The dividend associated with an additional idea consiste of two components. First, the additional knowledge directly an average of nearly 50%.^^ As a single example, in recent years, graduates from one US university have founded 4,000 companies, created 1.1 million jobs worldwide, and generated annual sales of $232 billion.'^

TABLE 2-1 Annual Rate of Return on Public R&D Investment

Studies	Subject	Rate of return to public R&D
Gnliches (1958)	Hybrid com	2040"o
Peterson (1967)	Poultr.'	21-25%
Schmilz-Seckler (1979)	Tomato harvester	37-46?o
Gnliches (1968)	Agncultural research	3540^b
Evenson (1968)		

Agricultural research

28-47“.i.

Dans (1979)

Agncultural research

37%

Evenson (1979)

Agricultural research

Dans and Peterson (1981)

Agncultural research

37"/o

Mansfield (1991)

All academic science
research

28“/<.

Huffman and Evenson (1993)

Agncultural research

43-67“b

Cockbum and Henderson (2000)

Pharmaceuticals

30% +

Scott AH et al (2001) compiled following Salter and Martin (2001). [Sources: Grill ches (1995), OTA (1986). and further additions by Scott et al.
Salter and Martin point out that many of these autfiors caution about the reliability of tiie numerical results obtained.]

SOURCE: A. Scott, G. Steyn, A. Geuna, S. Brusoni, and W.E. Steinmueller. The economic returns of basic research
and the benefits of university-industry relationships. Report for the UK Government Office of Science

and
Techology. SPRU (Science and Technology Policy Research), University of Sussex; Brighton, 2001. Available at
http://www.sussex.ac.uk/spru/documents/review for ost finaJ.pdf

raises the productivity of capital and labor in the economy. Second, the additional knowledge changes the
productivity of future R&D investment because of either knowledge spillovers or because subsequent ideas are more
difficult to discover" (pp. 6-8).+

M. I. Nadiri. Innovations and technological spillovers. Economic Research Reports, RR 93-31. New York: C. V.
Stair Center for Applied Economics. New York University Department of Economics, August 1993. Nadiri adds,
“The channels of diffusion of the spillovers vary considerably and their effects on productivity growth are sizeable.
These results suggest a substantial underinvestment in R&D activity."

W. M. Ayers. MIT: The In^ct of Innovation. Boston, MA: Bank Boston, 2002. Available at
http;//web.mit.edu/newsoffice/founders/Eoun ders2.pdf

TABLE 2-2 Annual Rate of Return on Private R&D Investment

Researcher

Estimated Rate of Return %

Private

Social

Nadiri (1993)

20-30

50

Mansfield (1977)

25

56

Terleckyj (1974)

29

48-78

Sveikauskas (1981)

7-25

50

Goto-Suzuki (1989)

26

80

Bemstein-Nadiri (1988)

10-27

11-111

Scherer (1982, 1984)

29-43

64-147

Bemstein-Nadiri (1991)

15-28

20-110

SOURCE: Center for Strategic and International Studies. Global Imovation/National Competitiveness. Washington,
DC: CSIS, 1996.

Although retum-on-investment data vary from study to study, most economists agree that federal investment in research pays substantial economic dividends. For example, Table 2-3 shows the large number of jobs and revenues created by information technology manufacturing and services — an industry that did not exist until the recent past. The value of public and private investment in research is so important that has been described as “fuel for industry”.^^ The economic contribution of science and technology can be understood by examining revenue and employment figures from technology- and service-based industries, but the largest economic influence is in the productivity gains that follow the adoption of new products and technologies.

Council of Economic Advisers, 1995 Economic report of the President. United States Government Printing Office,
Washington, DC.

^D. X Wilson. Is embodied technolc^ical change the result of iq^stream R&D? Industry-level evidence. Review of
Economic Dynamics 5(2)(2002) :342-362.

TABLE 2-3 Sales and Employment in the Information Technology (IT) Industry, 2000

NAICS"

Code

Sales

Revenues
($ billions)

Number
of Jobs
(1 .000)

IT Manufiicturiiig

Computer and peripheral equipment

3341

$110.0

190

Communications equipment

3342

119.3

291

Software

3112

88.6

331

Semiconductors and

other electronic components

3344

168.5

621

IT Services

Data processing services

5142

42.9

296

Telecommunications services

5133

354.2

1,165

SOURCE: National Research Council. Impact of Basic Research on Industrial Performance. Washington, D C:
National Academy Press, 2003.

CREATING NEW INDUSTRIES

The power of research is demonstrated not only by single innovations but by the abdi^ to create entire new industries — some of them the nation's most powerful economic drivers.

Basic research on the molecular mechanisms of DNA has produced a new field, molecular biology, and recombinant-DNA technology, or gene splicing, which in turn has led to new health therapies and the enormous growth of the biotechnology industry. The potential of those developments for health and health care is only beginning to be realized.

Studies of the interaction of light with atoms led to the prediction of stimulated emission of coherent radiation. That, together with the quest for a device to produce high frequency microwaves, led to the development of the laser, a ubiquitous device with uses ranging fiom surgery, precise machining, and nuclear fusion to sewer alignment, laser pointers, and CD and DVD players.

Enormous economic gains can be traced to research in harnessing electricity, which grew out of basic research (such as that conducted by Michael Faraday and James Maxwell) and applied research (such as that by Thomas Edison and George Westinghouse). Furthermore, today's semiconductor integrated circuits can be traced to the development of transistors and integrated circuits, which began with basic research into the structure of the atom and the development of quantum mechanics by Paul Dirac, Wolfgang Pauli, Werner Heisenberg, and Erwin Schrodinger^^ and was realized through the applied research of Robert Noyce and Jack Kilby.

In virtually all those examples, the original researchers did not — or could not — foresee the consequences of the work they were performing, let alone its economic implications. The fundamental research t 5 q)ically was driven by the desire to answer a specific question about nature or about an application of technology. The greatest influence of such work often is

J. I. Friedman. Will innovation flourish in the future? Industrial Physicist, 8(6)(Dec. 2002/Jan. 200

3): 22-25.

removed from its genesis, but the genius of the US research enterprise has been its ability to afford its best minds the opportunity to pursue fundamental questions (Figures 2-4, 2-5, 2-6).

Patents Granted by the United States

19130 1005 1010 1015 1920 1025 1050 [0J5 1040 1045 lOSO 1055)06D 1065 1070 1975 lOSO I0B5 19^1 10«5 190K

Scmrecs: U.S. Patcnl and Tndcinark OlHcc. U.S. 1 790- 199!‘< |Wa!(hin|itun; CiCT'cmnKnl I’nnlmg OlVic c. 1999): and

lojisiana State Unn'cnsity. loif/artsK} Historica! luvnilioNs am InvfKlon. w'iii'tt'.liKUu.cdui'sci/c hcni.‘pqlcnt.'snn6.hlniI.

FIGURE 2-4 Examples of critical technologies patented by US rese^chers.

SOURCE: S. Moore, I L. Simon aid die CATO Institute. The greatest century that ever was; 25 miraculous trends of the past 100 years. Cato Policy Analysis, No. 364, Dec. 15, 1999, pp. 1-32.

^ See, for example. National Research Council Evolving the High Performance Computing and Communications Initiative to Support the Nation 's Information Infrastructure. Washington, DC: National Academy Press, 1995.

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IV1ecab>'tc Prices and Microprocessor Speeds

FIGURE 2-5 Moore’s law maintained: megab 5 d;e prices decrease as microprocessor speeds increase.

Source: S. Moore, J. L. Simon and the CATO Institute. The greatest centuiy that ever was: 25 miraculous trends of the past 100 years. Cato Policy Analysis^l^o. 364, Dec. 15, 1999, pp. 1-32.

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Ft^ur* t Percentage of Children Ages 3 to 17 Who Have Access to a Home

Computer artd Who Use the Internet at Home,

Selected Years. 1984-2001

1984 1989 1997 2000 2001

FIGURE 2-6 Many US children have access to and use computers and the Internet.

SOURCE: Child Trends Data Bank. Available at http://www.childtrendsdatabank.org/flgures/78-Figure-2.gif.

PROMOTING PUBLIC HEALTH

One straightforward way to view the practical application of research is to compare US life expectancy (Figure 2-7) in 1900 (47.3 years)^^ with that in 1999 (77.0 years). Our cancer and heart-disease survival rates have improved (Figure 2-8), and accidental-death rates and infant and maternal mortality (Figure 2-9) have fallen dramatically since the early 20th century.

Improvements in the nation's health are, of course, attributable to many factors, some as straightforward as the engineering of safe drinking-water supplies. Also responsible are the large-scale production, dehvery, and storage of nutritious foods and advances in diagnosis, pharmaceuticals, medical devices, and treatment methods.

Medical research also has brought economic benefit. The development of lithium as a mental-health treatment, for example, saves $9 billion in health costs each year. Hip - fracture prevention in postmenopausal women at risk for osteoporosis saves $333 million annually. Treatment for testicular cancer has resulted in a 9 1 % remission rate and annual savings of $ 1 66 million.^^

^ US Bureau of the Census. Historical Statistics of the United States, Colonial Times to 1970. Part 1, Series B 107-15,p. 55.

^US Census Bureau. Statistical Abstract of the United States: 2000. Table 116, p. 84.

F. Hobbs andN. Stoops. Demographic Trends in the 20th Century. US Census Bureau, CENSR-4. Washington,

DC: US Bureau of the Census, November 2004.

^National Academy of Engineering. A Century of Innovation Washington, DC: National Academy Press. (2003)
W.D. Nordhaus. 1999. The Health of Nations: The Contribution of Improved Health and Living Standards. Albert and Mary Lasker Foundation. Available at http://www.laskerfoundation.oig/reports/pdf/economic.pdf.; Exceptional Returns: The Economic Value of America's Investment in Medical Research. 2000.

Life Expectancy' at Birth, This MilJenniim

FIGURE 2-7a Life expectancy has increased, particularly in the last century.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculo us trends
of the past 100 years. Cato Policy Analysis,'i;^o. 364, Dec. 15, 1999, pp. 1-32.

1M1 1010 1020 1030 1040 1960 1960 1070 1060 1900 2002

FIGURE 2-7b Life expectancy has increased in the United States, particularly in the last
century.

SOURCE: Center for Disease Control and Prevention, Njtfional Centerfor Health Statistics, National Vi tal Statistic
System.

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FIGURE 2-8a Relative cancer survival rates.

SOURCE: Surveillance, Epidemiology, and End Results (SEER) Program (www.seer.cancer.gov) SEER'^Stat Database: Incidence - SEER 9 Regs Public-Use, Nov 2004 Sub (1973-2002), National Cancer Institute, DCCPS, Surveillance Research Program, Cancer Statistics Branch, released April 2005, based on the November 2004 submission.

700

1950 1960 1970 1980 1990 2000 2001 2002

FIGURE 2-8b Heart disease mortality.

SOURCE: National Center for Health Statistics, United States, 2005, Table 29 http://www.cdc.gov/nchs/data/hus/hus05.pdf

FIGURE 2- 9a Infant mortality.

SOURCE: Deaths: FinalData for 2002. Table 11. NVSR Volume 53, Number 5. 116 http://www.cdc.gov/nchs/products/pubs/pubdynvsr/53/53-21.htm

FIGURE 2-9b Maternal mortality.

SOURCE: Deaths: Final Data for 2002. Table 1 1 . NVSR Volume 53. Number 5.116
http://www.cdc.gov/nchs/products/pubs/pubdynvsr/53/53-21.htm

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CARING FOR THE ENVIRONMENT

Advances in our understanding of the environment have led to better systems to promote human health and the health of our planet. Weather satellites, global positioning systems, and airborne-particle measurement technologies also have helped us to monitor and mitigate unexpected environmental problems. Unfortunately, some of these problems have been the consequence of unexpected side-effects of technological advances. Fortunately, in many cases additional technological understanding was able to overcome unintended consequences without forfeiting the underlying benefits.

Water Quality

Early in the 20th century, when indoor plumbing was rare, wastewater often was dumped directly into streets and rivers. Waterborne diseases — cholera, typhoid fever, dysentery, and diarrhea — were rampant and among the leading causes of death in the United States. Research and engineering for modem sewage treatment and consequent improvements in water quality have dramatically affected public and environmental health. Water-pollution controls have mitigated declines in wildlife populations, and research into wetlands and riparian habitats has informed the process of engineering water supplies for our population.

Automobiles and Gasoline

In the 1920s, engineers discovered that adding lead to gasoline caused it to bum more smoothly and improved the efficiency of engines. However, they did not predict the explosive growth of the automobile industry. The widespread use of leaded gasoline resulted in harmful concentrations of lead in the air,^^ and by the 1970s the danger was apparent. New formulations developed by petrochemical researchers not requiring the use of lead have resulted in vastly reduced emissions and improved air quality (Figure 2-10). Parallel advances in petroleum refining and the adoption and improvement of catalytic converters increased engine efficiency and removed harmful byproducts from the combustion process. Those achievements have reduced overall automobile emissions by 31%, and carbon monoxide emissions per automobile are 85% lower than in the 1970s.

Refrigeration

In the early 1920s, scientists began working on nontoxic, nonflammable replacements for ammonia and other toxic refrigerants then in use. In 1928, Frigidaire synthesized the world's first chlorofluorocarbon (CFC), trademarked as Freon. By the 1970s, however, it had become clear that CFCs contribute to losses in the atmosphere's protective layer of ozone. In 1974, scientists identified a chain reaction that begins with CFCs and sunlight and ends with the production of

As noted in Unlocking Our Future, "Pursuing freedom requires confidence about our ability to manage the challenges raised by our increasing technological capabilities."

United States Congress, House of Representatives Committee on Science. Unlocking our future: toward a new national science policy. September 24, 1998. p. 38. Available at Http://www. house.gov/science/science_policy _report.htm.

National Energy Policy Development Group. Natimal Energy Policy. US Government Printing Office. Wadiington DC. Nfey 200 1 .

chlorine atoms. A single chlorine atom can destroy as many as 100,000 ozone molecules. The consequences could be long-lasting and severe, including increased cancer rates and global warming.^*^

In 1987, the Montreal Protocol began a global phase-out of CFC production. That in turn provided the m^ket force that fueled the development of new, non-CFC refrigerants. Although the results of CFC use provide an example of the unintended negative consequences of technology, the response demonstrates the influence of science in diagnosing problems and providing effective solutions.

Agricultural Mechanization

Advances in agriculture have vastly increased farm productivity and food production.

The food supply for the world's population of more than 6 billion people comes from a land area that is 80% of what was used to feed 2.5 billion people in 1950. However, injudicious application of mechanization also led to increased soil erosion. Since 1950, 20% of the world's topsoil has been lost — much of it in developing countries. Urban sprawl, desertification, and over-fertilization have reduced the amount of arable land by 20%.^* Such improvements as conservation tillage, which includes the use of sweep plows to undercut wheat stalks but leave roote in place, have greatly reduced soil erosion caused by traditional plowing and have promoted the conservation of soil moisture and nutrients. Advances in agricultural biotechnology have further reduced soil erosion and water contamination because they have reduced the need for tilling and for use of pesticides.

^'^National Academy of Sciences. Ozone Depletion, Beyond Discovery Series. April 1 996.

Raven. Biodiversity and Our Common Future. 2005. Bulletin of the American Academy of Arts & Sciences 58:20-24.

Comparison of Growth Areas and Emissions

FIGURE 2-10 US air quality has improved despite increases in gross domestic product, vehicle miles traveled, and energy consumption since the 1970s.

SOURCE: US Environmental Protection Agtncy . Air Emissions Trends - Continued Progress Through 2004. Available at http://www.epa.gov/airtrends/2005/econ-emissions.html.

Improvements attributable to declining mortality and better environmental monitoring are compounded by gains made possible by other advances in technology. The result has been a general enhancement in the quality of life in the United States as viewed by most observers.

Electrification and Household Appliances

Advances in technology in the 20th century resulted in changes at home and in the workplace. In 1900, less than 10% of the nation was electrified^ now virtually every home in the United States is wired (Figure 2-1 1).^^ Most of us give little thought to the vast array of electrical apphances that surround us.

US Department of Labor. Report on the American Workprce, 200 J. Department of Labor. Washington, DC. Available at http://www.bls.gov/opub/rtaw/pdf/rtaw2001.pdf

lmpn»'ement in U£. Hoiiinc

ElrctrilicatioD of U^. Ilontei

IW’ 1907 1912 1917 1922 1927 19.?2 l«7 1942 1947 1952 H57 IW2 1967 1972 1977 1982 19S? 1992

FIGURE 2-1 1 The number of US homes with electricity, plumbing, refrigeration, and basic appliances soared in the middle of the 20th century.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculous trends of the past 100 years. Cato Policy Analysis, No. 364, Dec. 15, 1999, pp. 1-32.

Transportation

As workers left farms to move to cities, transportation systems developed to get them to work and home again. Advances in highway construction in turn fueled the automotive industry. In 1 900, one-fourth of US households had a horse, and many in urban areas relied on trolleys and trams to get to work and market. Today, more than 90% of US households own at least one car (Figure 2- 1 2). Improvements in refrigeration put a refrigerator in virtually every home, and the ability to ship food across the country made it possible to keep those refrigerators stocked. The increasing speed, safety, and reliability of aircraft spawned yet another global industry that spans commercial airline service and overnight package delivery.

Communication

At the beginning of the 20th century slightly more than 1 million telephones were in use in the United States. The dramatic increase in telephone calls per capita over the following decades was made possible by advances in cable bundling, fiber optics, touch-tone dialing, and cordless communication (Figure 2-13). Cellular-telephone technology and voice-over-Intemet protocols have added even more communication options. At the beginning of the 21st century, there were more than 300 million telephone communication devices and cellular telephone lines in the United States.

Radio and television revolutionized the mass media, but the Internet has provided altogether new ways of communicating. Interoperability between systems makes it possible to use one device to communicate by telephone, over the Internet, in pictures, in voice, and in text. The “persistent presence” that those devices make possible and the eventual widespread availability of wireless and broadband services will spawn anotlier revolution in communication. At the same time, new R&D will be needed to reduce the energy demands of the new devices and their sensor-net support infrastructures.

Disaster Mitigation

Structural design, electrification, transportation, and communication come together in coordinating responses to natural disasters. Earthquake engineering and related technologies now make possible quake-resistant skyscrapers in high-risk zones. The 1989 Loma Prieta earthquake in central California caused 60 deaths and more than $6 billion in property damage, but occupants of the 49-story Transamerica Pyramid building in San Francisco were unharmed, as was the building itself, even though its top swayed from side to side by more than 1 ft for more than a minute. In December 1988, an earthquake in Georgia in the former USSR of the same magnitude as Loma Prieta led to the deaths of 22,000 people – illustrating the impact of the better engineered building protection available in California.

Geological Survey. Building Safer Structures. Fact Sheet 167-95. Reston, VA: USGS, June 1998. Availab le at
ht^://quake.wr.u^s.gov/prepare/factsheets/SaferStructures/Saf erStructures.pdf.

A US Geological Survey radio system increases safety for cleanup crews during aftershocks. After Loma Prieta, workers in Oakland were given almost a half hour notice of aftershocks 50 miles away, thanks to the speed differential between radio and seismic waves.

Weather prediction, enabled by satellites and advances in imaging technology, has helped mitigate losses from hurricanes. E^ly- warning systems for tornadoes and tsunamis offer another avenue for reducing the effects of natural disasters – but only when coupled with effective on-the-ground dissemination. As is the case for many technologies, this last step of getting a product implemented, especially in underserved areas or developing countries, can be the most difficult. Furthermore, as hurricane Katrina in New Orleans demonstrated, early warning is not enough – sound structural design and a coordinated human response are also essential.

Geological Survey. Speeding Earthquake Disaster Relief. Fact Sheet 097-95. Reston, VA: USGS, June 199 8.
Available alhttp;//quake. wr.usgs.gov/prepare/factsheets/Mitigation/Mitigation.pdf.

Ba

Cutting the Cord

1990 1992 1994 1996 1998

FIGURE 2-13 More telephones than ever are used to make more calls per capita, thanks to enormous technological advances in a host of disciplines.

SOURCE: S. Moore, J. L. Simon and the CATO Institute. The greatest century that ever was: 25 miraculo us trends of the past lOOyears. Cato Policy Analysis, No. 364, Dec. 15, 1999, pp. 1-32.

Energy Conservation

The last century saw demonstrations of the influence of technology in eveiy facet of our lives. It also revealed the urgent need to use resources wisely. Resource reduction and recycling are expanding across the United States. Many communities, spurred by advances in recycling technologies, have instituted trash-reduction programs. Industries are producing increasingly energy-efficient products, from refrigerators to automobiles. Today's cars use about 60% of the gasoline per mile driven that was used in 1972. With the advent of hybrid automobiles, further gains are now being realized. Similarly, refrigerators today require one-third of the electricity that they needed 30 years ago. In the 1990s, manufacturing output in the United States expanded by 41%, but industrial consumption of electricity grew by only 11%. The introduction and use of energy-efficient products have enabled the US economy to grow by 126% since 1973 while energy use has increased by only 30% (Figure 2-14).^^ Those improvements in efficiency are the result of work in a broad spectrum of science and engineering fields.

The U.S. Economy is More Energy Efficient

(Energy Intensity)

Primary Energy Use

Ouadiilllon Btm

Improvements in energy efficiency since the 1 970s have had a major impaa in meeting n^kmal energy needs relative to new supply. If the intensity of U.S. energy use had remained constant since 1972, consumption would have been about 70 qua-

FIGURE 2- 1 4 The efficiency of energy use has improved substantially over the last 3 decades .

SOURCE: National Energy Policy Development Group. National Energy Policy. Washington, DC: U.S.

Government Printing Office, May 2001.

^National Energy Policy Development Group. National Eiiergy Policy. Washington, DC: DOE, May 2001.

UNDERSTANDING HOW PEOPLE LEARN

Today, an extraordinary scientific effort is being devoted to the mind and the brain, the processes of thinking and learning, the neural processes that occur during thought and learning, and the development of competence. The revolution in the study of the mind that has occurred in recent decades has important implications for education.^® A new theory of learning now coming into focus will lead to very different approaches to the design of curriculum, teaching, and assessment from those generally found in schools today.

Research in the social sciences has increased understanding of the nature of competent performance mid the principles of knowledge organization that underlie people's abilities to solve problems in a wide variety of fields, including mathematics, science, literature, social studies, and history. It has also uncovered important principles for structuring learning experiences that enable people to use what they have learned in new settings. Collaborative studies of the design mid evaluation of learning environments being conducted by cognitive and developmental psychologists and educators are yielding new knowledge about the nature of learning and teaching in a variety of settings.

SECURING THE HOMELAND

Scientific and engineering research demonstrated its essential role in the nation's defense during World War II. Research led to the rapid development and deployment of the atomic bomb, radar and sonar detectors, nylon that revolutionized parachute use, and penicillin that saved battlefield lives. Throughout the Cold War the United States relied on a technological edge to offset the larger forces of its adversaries and thus generously supported basic research. The US military continues to depend on new and emerging technologies to respond to the diffuse and uncertain threats that characterize the 21st century and to provide the men and women in uniform with the best possible equipment and support.^'

Just as Vannevar Bush described a tight linkage between research and security, the Hart-Rudman commission a half-century later argued that security can be achieved only by funding more basic research in a variety of fields. In the wake of the 9/11 attacks and the anthrax mailings, it is clear that innovation capacity and homeland security are also tightly coupled. There can be no security without the economic vitality created by innovation, just as there can be no economic vitality without a secure environment in which to live and work.'^'^ Investment in R&D for homeland security has grown rapidly; however, most of it has been in the form of development of new technologies to meet immediate needs.

Human capacity is as important as research funding. As part of its comprehensive overview of how science and technology could contribute to countering terrorism, for example, the National Research Council recommended a human-resources development program similar

^^Nalional Research Council. How People Leant. Washington, DC; National Academy Press, 2000.

Joint Chiefs of Staff. Joint Vision 2020. Washington, DC; Department of Defense, 2000; Department of Defense.
Quadrennial Defense Review Report. Washington, DC; Departaient of Defense, 2001'

Vannevar Bush report. Science: The Endless Frontier. Washington, DC: US Government Printing Office, 1945.
^^U.S. Commission onNational Security. Road Map for National Security: Imperative for Change. Washington,
DC: The Commission. 2001.

Council on Competitiveness, Innovation America. Washington DC: Council on Competitiveness. 2005 p. 19.

to the post-Sputnik National Defense Education Act (NDEA) of 1958. A Department of Defense proposal to create and fund a new NDEA is currently being examined in Congress."^^

CONCLUSION

The science and technology research community and die industries that rely on that research are critical to the quality of life in the United States. Only by continuing investment in advancing technology — through the education of our children, the development of the science and engineering workforce, and the provision of an environment conducive to the transformation of research results into practical applications — can the full innovative capacity of the United States be harnessed and the full promise of a high quality of life realized.

"^^National Research Council Making the Nation Safe: The Role of Science andTechnology in Countering Terrorism. Washington, DC: National Academy Press, 2001 .

"^^See H.R. 1815, National Defense Authorization Act for Fiscal Year 2006, Sec, 1105. Science, Mathematics, and
Research for Transformation (SMART) Defense Education Program — National Defense Education Act (NDEA),
Phase I. Introduced to the House on Apr. 26, 2005; on Jun. 6, 2005 referred to Senate committee; status as of Jul
26, 2005: received in the Senate and read twice and referred to the Committee on Armed Services.

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HOW IS AMERICA DOING NOW IN SCIENCE AND TECHNOLOGY?

By most available criteria, the United States is still the undisputed leader in the performance of basic and applied research (see Box 3-1). In addition, many international comparisons put the United States as a leader in applying research and innovation to improve economic performance. In the latest IMD World Competitiveness Yearbook, the United States ranks first in economic competitiveness, followed by Hong Kong and Singapore.^ The survey compares economic performance, government efficiency, business efficiency, and infrastructure. Larger economies are further behind, with Zhejiang (China's wealthiest province), Japan, the United Kingdom, ^d Germany ranked 20 though 23, respectively.^ An extensive review by the Organization for Economic Co-operation and Development (OECD) concludes that since World War II, US leadership in science and engineering has driven its dominant strategic position, economic advantages, and quality of life.^

Researchers in the United States lead the world in the volume of articles published and in the frequency with which those papers are cited by others.^ US-based authors were listed on one-third of all scientific articles worldwide in 2001.^ Those publication data are significant because they reflect original research productivity and because the professional reputations, job prospects, and career advancement of researchers depend on their ability to publish significant findings in the open peer-reviewed literature.

The United States also excels in higher education and training. A recent comparison concluded that 38 of the world's 50 leading research institutions — ^those that draw the greatest interest of scienc

e and
technology students — are in the United States.^ Since World War II, the United States has been the destination of choice for science and engineering graduate students and for postdoctoral scholars choosing

IMD International. World Competitiveness Yearbook. 2005: Lausanne, Switzerland, 2005. The United States leads the world (with a score of 100), followed in order by Hong Kong (93), Singapore, Iceland, Canada, Finland, Denmark, Switzerland, Australia, and Luxembourg (80).

^ Mainland China ranks 3 1 st.

^ Organisation for Economic Co-operation and Development. Science, Technology and Industry Scoreboard, 2003, R&D Database. Available at http://wwwl.oecd.org/publications/e-book/92-2003-04-l-7294/. The scoreboard uses four indicators in its ranking: the creation and diffusion of knowledge; the information economy; the global integration of economic activity; and productivity and economic stmcture. In the United States, investment in knowledge — tiie sum of investaient in R&D, software, and higher education — amounted to almost 7% of GDP in 2000, well above the share for the European Union or Japan.

""D. a. Kir^. The scientific impact of nations. Nature 430(6997)(July 15, 2004):3 11-316.

^National Science Board. S&E Indicators, 2004. Chap. 5. Arlington, VA: National Science Foundation, 2004.

^Shanghai's Jiao Tong University Institute of Higher Education. Academic Ranking of World Universities, 2004. Available at htty':://ed.sjtu.edu-cn/rMTk/2004/2004Main.htai. The ranking emphasizes prizes, publications, and citations attributed to faculty and staff, as well as the size of institutions. The Times Higher Education Supplement need cit. has provided similar results in comparing universities worldwide.

to study abroad. Our nation — about 6% percent of the world's population — has for decades produced more than 20% of the world's doctorates in science and engineering.

Because of globalization in the fields of science and engineering, however, it is difficult to compare rese^ch leadership among countries. Research teams commonly include members from several nations, and industries have dispersed many activities, including research, across the globe.

SCIENCE AND ENGINEERING ADVANTAGE

The strength of science and engineering in tiie United States rests on many advantages: the diversity, quality, and stability of its research and teaching institutions; the strong tradition of public and private investment in research and advanced education; the quality of academic personnel; the prevalence of English as the language of science and engineering; the availability of venture capital; a relatively open society in which talented people of any background or nationality have opportunities to succeed; the; US custom, unmatched in other countries, of providing positions for postdoctoral scholars;^ and the strength of the US peer-review and free-enterprise systems in weeding out noncompetitive academic and business pursuits.

In addition to such t^gible advantages, US leadership might also be attributed to many favorable public policy priorities: research activities funded by public and private sources that have led to new industries, products, and jobs; an economic climate that encourages investment in technology-based companies; an outward-looking international economic policy; and support for lifelong learning.^

However, things are changing, as noted in Innovate Amen'ca, a 2004 report from the Council on Competitiveness ^

• Innovation is diffusing at an ever-increasing rate. It took 55 years for automobile use to spread to a quarter of the US population, 35 years for the telephone, 22 years for the radio, 16 years for the personal computer, 13 years for the cell phone, and just 7 years for the World Wide Web once the Internet had matured (through technology and policy developments) to the point of takeoff.

• Innovation is increasingly multidisciplinary and technologically complex, arising from the intersection of different fields and spheres of activity.

• Innovation is collaborative. It requires active cooperation and communication among scientists and engineers and between creators and users.

• Innovation is creative. Workers and consumers demand evermore new ideas, technologies, and content.

• Innovation is global. Advances come from centers of excellence around the world and are prompted by the demands of billions of customers.

Central to the strength of US innovation is our tradition of public funding for science and engineering research. Graduate education in the United States is supported mainly by federal grants from the National Science Foundation (NSF) and the National Institutes of Health (NIH) to faculty researchers,

^National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Virginia. National Science Foundation. 2004. .p. 2-36.

^COSEPUP. Internationa! Students and Postdocs, p. 81. Washington, DC: The National Academies Press.

®K. H. Hughes. Facing the global competitiveness challenge. Issues in Science and Technology 21(summer 2005):72-78.

^‘’Council on Competitiveness, National Innovation Initiative. Innovate America. Washington, DC: Council on Competitiveness, 2004, p. 6.

buttressed by a smaller volume of federally funded fellowships. One study reported that 73% of applicants for US patents said that publicly funded research formed part or all of the foundation for their innovations.^^
Much of the nation’s research in engineering and the physical sciences is performed in federal laboratories, pml of whose mission is to assist the commercialization of new technology.

OTHER NATIONS ARE FOLLOWING OUR LEAD— AND CATCHING UP‘^

It is no surprise that as the value of research becomes more widely understood, other nations are strengthening their own programs and institutions. If imitation is flattery, we can take pride in watching ^ other nations eagerly adopt major components of the US innovation model. Their strategies include the willingness to increase public support for research universities, to enhance protections for intellectual property rights, to promote venture capital activity, to fund incubation centers for new businesses, and to expand opportunities for innovative small companies.^"^

Many nations have made research a high priority. To position the European Union (EU) as the most competitive knowledge-based economy in the world and enhance its attractiveness to researchers worldwide, EU leaders are urging that, by 2010, member nations spend 3% of gross domestic product (GDP) on research and development (R&D).*^ In 2000, R&D as a percentage of GDP was 2.72 in the United States, 2.98 in Japan, 2.49 in Germany, 2.18 in France, and 1.85 in the United Kingdom.^^

Many nations also are investing more aggressively in higher education and increasing their public investments in R&D (Figure 3-1). Those investments are stimulating growth in the number of research universities in those countries; the number of researchers; the number of papers listed in the Science Citation Index; the number of patents awarded; and the number of doctoral degrees granted (Table 3-1, Figures 3-2, 3-3, 3-4).”

“M. I. Nadiri. Innovations and Technical Spillovers. Working Paper 4423. Carabrii^e, MA: National Bureau of Economic Research, 1993.

^^For anodier point of view, see Box 3-2.

Council on Competitiveness, National Innovation Initiative. Innovate America. Washington, DC: Council on Competitiveness, 2004, p. 6.

^''K. H. Hughes. Facing the global competitiveness challenge. Issues in Science and Technology Vol. 21 No. 4(Summer 2005):72-78. See also M. Enserink. France hatches 67 California wannabes. Science 309(2005):547.

M. May. Raising Europe’s game. Nature 430(2004) : 83 1 ; P. Busquin. Investing in people. Science 303 (2004): 145.

^^National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlir^ton, VA: National Science Foundation, 2004, Appendix Table 4-43.

Hicks. 2004. Asian countries strengtiien their research. Issues in Science and Technology Vol.20No. 4 (Summer 2004):75-78. The author notes that the number of doctoral degrees awarded in China has increased 50-fold since

1986.

BOX 3-1

Pasteur's Quadrant

The writers of this report, like many others, faced a semantic question in the discussions of different kinds of research. Basic research, presumably pursued for the sake of fundamental understanding but without thought of use, generally is distinguished from applied research, which is pursued to convert basic understanding into practical use.

But that classification quickly breaks down in the real world because "basic" discoveries often emerge from "applied" or even "developmental" activities:

Basic

research

Applied

research

Development

Production

and

operation

In his 1997 book, Pasteur 's Quadrant,* Donald Stokes responded to that complexity with a more nuanced classification that describes research according to intention. He distinguishes four types:

• Pure basic research, performed with the goal of fundamental understanding (such as Bohr's work on atomic structure).

• Use-inspired basic research, to pursue fundamental understanding but motivated by a question of use (such as Pasteur's work on the biologic bases of fermentation and disease).

• Pure applied research, motivated by use but not seeking fundamental understanding (such as that leading to Edison's inventions).

• Applied research that is not motivated by a practical goal (such as plant taxonomy),

In Stokes's argument, research is better depicted as a box tlian as a line:
Consideration of use?

Quest for

fundamental

understanding?

No Yes

Pure basic

research

(Bohr)

Use-inspired
basic research
(Pasteur)

Pure applied
research
(Edison)

In contrast to the basic -applied dichotomy, Stokes's taxonomy explicitly recognizes research that is

simultaneously inspired by a use but that also seeks fundamental knowledge, which he calls "Pasteur's quadrant".

"D. Stokes. Pasteur's Quadrant Washington, DC: Brookir^s Institution Press, 1997.

BOX 3-2

Another Point of View: US Competitiveness

“Americans having another Sputnik moment”, writes Robert J. Samuelson, “one of those periodic alarms about some foreign technological and economic menace. It was the Soviets in the 1950s and early 1960s, the Germans and Japanese in the 1970s and 1980s, and now it’s the Chinese and Indians.”^

Sputnik moments come when the nation worries about its scientific and technological superiority and its ability to compete globally. And, according to Samuelson, the nation tends to be overly concerned.

Sputnik led to the tiieory of a “missile gap that turned out to be a myth. The competitiveness crisis of the 1980s suggested that Japan would surge ahead of us because they were better savers, innovators, workers, and managers. But in 2004, per capita US income averaged $38,324 compared to $26,937 for Germany and $29,193 for Japan.”

Similarly, Samuelson argues that our current fears are unfounded, another “illi^ion” in which “a few selective happenings” are transformed into a “full blown theory of economic inferiority or superiority.” He argues that low wages ^d rising skills in China and India could cost us some jobs, but that US gains and losses in response to the rising economic power of those countries will tend to balance out.

Samuelson indicates that he believes “the apparent American deficit in scientists and engineers is also exaggerated.” He notes that only about one-third of our science and engineering graduates work in science and engineering occupations and that if there were a shortage, salaries for those jobs would

increase
and scientists and engineers would return to them. Of greater importance, Samuelson concludes, is tha
t the
United States must continue to draw on the strengths that overcome its weaknesses: "ambitiousness; openness to change (even unpleasant change); competition; hard work; and a willingness to take and re
ward
risk".

^ R. J. Samuelson. Sputnik scare, updated. Washington Post. Aug. 26, 2005, pA27

TABLE 3-1 Publications and Citations Weighted by Total Population and Nmnber of University Researchers

	United States	European Union
Publications	1,265,608	1,347,985
Publications/population	4.64	3.60
Publications/researcher	6.80	

4.30

Researchers/population

0,68

0.84

Citations

10,850,549

8,628,152

Citations/population

39.75

23.03

Citations/researcher

58.33

27.52

Top 1% publications

23,723

14,099

Top 1% publications/population

0.09

0.04

Tod l%Dublications/researcher

0,13

0,04

Number of publications, citations, and top 1% publications refers to 1997-2001. Population (measured in thousands) and number of university researchers (measured in full-time equivalents) refers to 1999. Each cited paper is allocated once to every author.
European Union totals are adjusted to account for diq)lications by removing papers with multiple EU n

ational authorship to give
an accurate net total,

SOURCE:G. Dosi, P. Llerena, and M, S. Labird. Evaluatir^ and Comparing the Innovation Performance oft he United States and the European Union. Expert report prepared for the Trend Chart Policy Workshop (Jun. 29, 2005). Available at http://trendchart.cordis.liVscoreboards/scoreboard2005/pdfi'EIS%202005%20EU%20versus%20US.pdf

d

Year

-♦-Canada

-♦—Japan

-6- Korea

^EU-15

-o— United States

-♦-China

-♦—Russian

Federation

FIGURE 3-1 R&D expenditures as a percentage of GDP are beginning to rise worldwide

SOURCE: Organisation for Economic Co-operation and Development. Ivbin Science and Engineering Indicators. Paris: OECD,

2005.

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FIGURE 3-2 US patent applications.

Source; Task Force on the Future of American Innovation based on data from National Science Foundation. Science and Engineering Indicators 2004, Appendix Table 6-11. Arlington: APS Office and Public Affairs.

FIGURE 3-3 Total science and engineering articles with international coauthors. Note: Internationally coauthored articles were counted more than once for each country where work was performed represented on the author list. So if an article was written by authors from the US and Switzerland, it would be included in the count for both countries.

SOURCES: Task Force on the Future of American Innovation based on data from National Science Foundation. Science and Engineering Indicators 2004, Appendix Table 6-1 1. Arlington: APS Office and Public Affairs. National Science Board. Science and Engineering Indicators 2004. NSB 04-1. Arlington, VA: National Science Foundation, 2004, Table 5-30.

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FIGURE 3-4 Disciplinary strengths in the United States, the 1 5 European Union nations in the comparator
group (EU 1 5), and the United Kingdom . The distance from the origin to the data point is proportional to
citation share.

SOURCE; D. A. King. The scientific impact ofnations./'toj^re 430(2004) 311-316. Data are from citations in ISI Thompson.

China is emulating the US system as well. The Chinese Science Foundation is modeled after our
National Science Foundation, and peer review methodology and startup packages for junior faculty are
patterned on US practices. In China, national spending in the past few years for all R&D activities rose

500%, from $14 billion in 1991 to $65 billion in 2002. US R&D spending increased 140%, from $177 billion to $245 billion, in the same period.

The rapid rise of South Korea as a major science and engineering power has been fueled by the establishment of the Korea Science Foundation — funded primarily by the national sports lottery — to enhance public understanding, knowledge, and acceptance of science and engineering throughout the nation.^^ Similarly, the government uses contests and prizes specifically to stimulate the scientific enterprise and public appreciation of scientific knowledge.

Other nations also are spending more on higher education and providing incentives for students to study science and engineering. To attract the best graduate students from around the world, universities in Japan, Switzerland, and elsewhere are offering science and engineering courses in English. In the 1990s, both China and Japan increased the number of students pursuing science and engineering degrees and there was steady growth in South Korea.^*^

Some consequences of this new global science and engineering activity are already apparent — not only in manufacturing but also in services. India's software services exports rose from essentially zero in 1993 to about $10 billion in 2002.^^ In broader terms, the US share of global exports has fallen in the past 20 years from 30% to 17%, while the share for emerging countries in Asia grew from 7% to 21%}^ The United States now has a negative trade balance even for high-technology products (Figure 3-5). Tliat deficit raises concern about our competitive ability in important areas of technology.

Although US scientists and engineers still lead the world in publishing results, new trends emerge from close examination of the data. From 1988 to 2001, world publishing in science and engineering increased by almost 40%,^"^ but most of that increase came from Western Europe, Japan, and several emerging East Asian nations (South Korea, China, Singapore, and Taiwan). US publication in science and engineering has remained essentially constant since 1992.^^ Since 1997, researchers in the 1 5 EU countries have published more papers than have their US counterparts, and the gap in citations between the United States and other countries has narrowed steadily. The global increase in the production of scientific knowledge eventually benefits all countries. Yet trends in publication could be a troubling bellwether about our competitive position in the global science community.

*®OECD. Science, Technology and Industry Outlook 2004. Paris, France: OECD, 2(X)4, p. 190. The United States spends significantly more than China on R&D in gross terms and in percentage of R&D. However, if China's US $65 billion in R&D spending were adjusted based on purchasing power parity, it would approach US$300 billion.

’^Korean Ministry of Science and Engineerir^ (MOST). Available at http://www.mostgo.kr/most/englishyi ink_2.jsp.

“National Science Board. S&E Indicators, 2004. Arlington, VA; National Science Foundation, 2004, p. 2-35.

S. S. Athreye. The Indian software industry. Carnegie Mellon Software Industry Center Working Paper 03-04. Pittsburg, PA :
Camgie-Mellon University, Oct 2003.

“For 2004, tire dollar value of high-technology imports was $560 billion; the value of high-technology ej^orts was $511 billion.
“D. R Francis. U.S. runs a high-tech trade gap. Christian Science Monitor. Vol 96. No. 131. (June 2, 2004) p.1-1.

^National Science Board. S&E Indicators, 2004. Arlington, VA; National Science Foundation, 2004, Chap. 5.

“Ibid., Table 5-30.

“D. a. King. The scientific impact of nations. Nature 430(6997)(July 15, 2004) :3 11-316.

1990 1992 1994 19% 1998 2000 2002

FIGURE 3-5 United States trade balance for high-technology products, 1990-2003.

SOURCE: Task Force on the Future of American Innovation based on data from U.S. Census Bureau Foreign Trade Statistics,
U.S. International Trade in Goods and Services. Complied by APS Office of Public Affairs.

The graduate education of our scientists and engineers largely follows an apprenticeship model. Graduate students and postdoctoral scholars gain direct experience under the guidance of veteran researchers. The important link between graduate education and research that has been forged through a combination of research assistantships, fellowships, and traineeships has been tremendously beneficial to students and researchers and is a critical component of our success in the last half-century.

One measure of other nations' successful adaptation of the US model is doctoral production, which increased rapidly around the world but most notably in China and South Korea (Figure 3-6). In South Korea, doctorate production rose from 128 in 1975 to 2,865 in 2001. In China, doctorate production was essentially zero until 1985, but 15 years later, 7,304 doctorates were conferred. In 1975, the United States conferred 59% of the world's doctoral degrees in science and engineering; by 2001, our share had fallen to 41%. China's 2001 portion was 12%.^

Another challenge for US research institutions is to attract the overseas students on whose talents the nation depends. The US research enterprise, especially at the graduate and postdoctoral levels, has benefited from the work of foreign visitors and immigrants. They came first from Europe, fleeing fascism, and more recently th^ have come from China, India, and the former Soviet Union, seeking better education and more economic opportunity. International students account for nearly half the US doctorates awarded in engineering and computer science^^ (Figure 3-7). Similarly, more than 35% of US engineering and computer science university faculty are foreign-bom.^® According to US Census data from 2000, the proportion of doctoral-level employees in the science and engineering research labor force is about equivalent to the percentage of doctorates produced by US universities.

S National Science Board. Science and Er^ineerit^ Indicators 2004 (NSB 04-01). Arlington, Virginia National Science Foundation. 2004. Appendix Table 2-38.

National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Viiginia National Science Foundation. 2004.

''Ibid.

FIGURE 3-6 US doctorate production in science and engineering is decreasing; EU and Asian production is rising but is still well below US levels.

SOURCE: National Science Board. Science and Engineering Indicators 2004. NSB 04-1 . Arlington, VA: National Science Foundation, 2004, Table 5-30,

Many nations are seeking to reap the benefits of advanced education, including strong positive effects on GDP growth. They are working harder to attract international students and to encourage the

movement of skilled personnel into their countries.

• China implemented an “opening-up” policy in 1978 and began to send large numbers of students and scholars abroad to gain the skills they need to bolster that country’s economic and social development.

• India liberalized its economy in 1991 and started encouraging students to go abroad for advanced education and training. Since 2001, the Indian government has been providing money ($5 billion in fiscal year 2005) for “soft loans”, which require no collateral, to students who wish to travel abroad for their education. In 2002, India surpassed China as the largest exporter of graduate students to the United States.^*

• The United Kingdom's points-based Highly Skilled Migrant Programme, which began in the mid-1990s, has increased the number of work permits issued to skilled workers.

• The Irish government permits relatively easy immigration of skilled workers in information technology and biotechnology through intra-company transfers from non-Irish to Irish locations.

Conference Board of Canada. The Economic Implications of International Education for Canada and Nine Comparator Countries; A Comparison of International Education Activiti^ and Economic Performance. Ottawa: Department of Foreign Affairs and International Trade, 1999.

Institute for International Education. Open Doors Report on International Educaticaial Exchange. New York: Institute for Internal Education, 2004.

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• Several EU countries and the EU itself have programs that facilitate networking among students and researchers working abroad, providing contact information, collaborative possibilities, and funding and job opportunities in the EU. The German Academic Exchange Service has launched GAIN (German Academic International Network); the Italian Ministry of Foreign Affairs has launched DAVINCI, an Internet database that tracks the work of Italian researchers overseas; and the EU has its Researcher's Mobility Portal.

• Nigeria and other oil-producing nations use petroleum profits to support the overseas education of thousands of students.

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FIGURE 3-7 Doctorates awarded by US institutions, by field and citizenship status, 1985-2003.

US citizens and permanent residents earn about 62% of the doctorates in all fields of science and engineering, about 60% in the physical sciences, and 41% of those awarded in engineering and the combined fields of mathematics and computer sciences.

SOURCE: National Science Foundation. 2005. Survey of Earned Graduates. Arlington, VA: National Science Foundation

In addition to sending students abroad for training, emerging economic powers, notably India and China, have lured their skilled scientists and engineers to return home by coupling education-abroad programs with strategic investments in the science and engineering infrastructure — in essence sending students away to gain skills and providing jobs to draw them back.^“

The global competition for talent was already under way when the events of September 11, 2001, disrupted US travel and immigration plans of many international graduate students, postdoctoral researchers, and visiting scholars. The intervening years have seen security-related changes in federal visa and immigration policy that, although intended to restrict the illegal movements of only a few, have had a wider effect on many foreign-bom graduate students and postdoctoral scholars who either were already in the United States or were contemplating studying here. Many potential visitors who in the past might have found the United States welcoming them for scientific meetings and sabbaticals now look elsewhere or stay home.^^ Much of this is to our detriment: Hosting international meetings and visiting researchers is essential to staying at the forefront of international science.

The flow of graduate students and postdoctoral researchers is unlikely to be curtailed perm^ently, at least as long as the world sees the United States as the best place for science and engineering education, training, and technology-based employment (Table 3-2). If that perception shifts, and if international students find equally attractive educational and professional opportunities in other countries, including their own, the difficulty of visiting the United States could gain decisive importance.

TABLE 3-2 Change in Applications, Admissions, and Enrollment of International Graduate Students, 2003-2005

Total

Eneineerins

Life Sciences

Physical Sciences

Applications

-2S% (-5%)

-36% (-7%)

-24% (-1%)

-26% (-3%)

Admissions

-18%

-24%

-19%

-17%

Enrollment

-6%

-8%

-10%

+6%

NOTE: There have been large declines in applications and admissions and a more moderate decrease in enrollment. The admissions data for the 2005 academic year are shown in parentheses.

SOURCES: H. Brown andM. Doulis. Findings from the 2005 CGS International Graduate Survey 1. Washington, DC: Council of Graduate Schools, 2005. H. Brown. Council of Graduate Schools Finds Decline in New International Graduate Student Enrollment for the Third Consecutive Year. Washington, DC: Council of Graduate Schools, Nov. 4, 2004.

R. A. Mashelkar. India's R&D: Reachir^ for the top. Science 307(2005):1415-1417; L. Auriol. Why do we need indicators on careers of doctorate holders? Workshop on User Needs for Indicators on Careers of Doctorate Holders. OECD: Paris, Sept. 27, 2004. Available at http://www.olis-oecd.org/olis/2004doc.nsf-

^^COSEPUP.Policy Implications of International Graduate Students and Postdoctoral Scholars, p. 61. Washington, DC: The National Academies Press.

^''Ibid.p. 79-

STRAINS ON RESEARCH IN THE PRIVATE SECTOR

A large fraction of all those with doctorates in science and engineering in the United States — more than half in some fields — find employment in industry (Figure 3-8). There they make major contributions to innovation and economic growth. US industry has traditionally excelled at innovation and at capitalizing on the results of research.^^ For decades after World War 11, corporate central research laboratories paid off in fledgling technologies that grew into products or techniques of profound consequence. Researchers at Bell Laboratories pursued lines of groundbreaking research that resulted in the transistor and the laser, which revolutionized the electronics industry and led to several Nobel prizes.

FIGURE 3-8 The majority of people with science or engineering doctorates obtain nonacademic jobs. About equal numbers work in academic and industrial settings, and about 15% work in government or other sectors.

SOURCE: National Science Foundation. Survey of Doctoral Recipients. Arlington, VA; National Science Foundation, 2004.

Although industry-funded R&D has increased steadily overall (Figure 3-9a), that new money has gone overwhelmingly to activities that are near-term and incremental rather than to long-term or discovery-oriented research and R&D as a share of gross domestic product has declined (Figure 3-9b). Several explanations are offered for industry's turn away from fundamental research. First, the Bell Laborato ries

Steven W. Popper aid Caroline S. Wagner. New foundations for growth: The US innovation system today and tomorrow.
RAND: Arlington, VA Januaty 2002.

The authors note the following advantages of industry: rapid responses, flexibility and adaptability, efficiency, fast entry and exit,
smooth capital flows, and mobility.

^^United States Congress, House of Representatives Committee on Science. Unlocking our future: toward a new national science
policy. September 24, 1998. p. 38 Available at http://www.house.gov/science/science_policy_report.htm.

model was supported by funding from a monopoly that now is dismantled and no longer relevant to the organization of science and engineering research in the United States. Second, Wall Street analysts increasingly focus on quarterly financial results and assign little value to long-term (and therefore risky) research investments or to social returns. Third, companies cannot always fully capture a return that justifies long-term research with results that often spill over to other researchers, sometimes including those of competitors. Fourth, private-sector research is more fragmented across national boundaries in the era of globalization. Capital follows opportunity with little attention to geopolitical borders — this may lead more multinational companies to pursue opportunities outside the United States.

The National Science Board^^has made the following observations:

• Two-thirds of the R&D performed overseas in 2000 by US-owned companies ($13.2 billion of $19.8 billion) was conducted in 6 countries: the United Kingdom, Germany, Canada, Japan, France, and Sweden. At the same time, emerging markets — such as those in Singapore, Israel, Ireland, and

China — were increasingly attracting R&D activities by subsidiaries of US companies. In 2000, each of those emerging markets reached US-owned R&D expenditures of $500 million or more, considerably more than in 1994.

• Three manufacturing sectors dominated overseas R&D activity by US-owned companies: transportation equipment, computer and electronic products, and chemicals and pharmaceuticals.

The same industries accounted for most foreign-owned R&D in the United States, implying a high degree of R&D globalization in those industries.

As some large companies reduce their investment in basic research, smaller research-based enterprises often assume risk as the only way to break into a competitive market. Those startup companies commonly rely on the initial capital provided by their investors to finance early research, coupled with the granting of potential future financial gains in the form of stock options to compensate employees. If the money runs out, they can seldom interest venture capital firms until they have grown considerably larger. Many of those companies thus expire before reaching commercialization.^^

The overall amount of venture capital invested also has collapsed since the stock market decline of 2000, sinking in 2002 to one-fifth the amount invested in 2000^^ (Figure 3-10). Venture capital investments in US companies have since stabilized at around $20 billion in 2003 and 2004'*'^, just one-fifth of their 2000 peak but well above 1998 funding. Led by a resurgence in late-stage financing, total venture capital investment rose 10.5% to $20.9 billion in 2004, according to the MoneyTree Survey by PricewaterhouseCoopers, Thomson Venture Economics, and the National Venture Capital Association (NVCA).'*^ With stock values rising, the climate for initial public offerings and acquisitions has improved, attracting capital from investors considering exit opportunities.

^’National Science Board. Science and Engineering Indicators 2004 (MSB 04-01). Arlington, Virginia. National Science Foundation. 2004, p, 4-65.

^*Nationa] Research Council. Board on Science, Technology, and Economic Policy. The Small Business Innovation Research Program: An Assessment Of The Department Of Defense Fast Track Initiative. Washington, DC; National Academies Press.

2000. Available at: http://books.nap.edu/catalog/9985.html

Committee on Science, US House of Representatives. Unlocking Our Future; Toward a New National Science Policy (the “Ehlers Report’O-Washington, DC: US Ccmgress, 1998. p. 39

^^National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Virginia. N

ational Science
Foundation. 2004. AppendixTable 6-15.

National Venture Capital Association, http://www.nvca.org/ffax.html

PricewaterhouseCoopers. “MoneyTree Survey.” Available at http://www.pwcmoneyhee.com/moneytree/index.jsp. Accessed
December 20, 2005.

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FIGURE 3-9a US R&D funding. By Source of Funds, 1953-2003.

SOURCE: NSF Division of Science Resources Statistics. National Patterns of Research Development Resources, annual series.

Appendix table B-2 and B-22. http://www.ns£gov/statistics/nsfD5308/secta.htm

Paraenl

FIGURE 3-9b R&D shares of US gross domestic product: 1953-2003.

SOURCE: NSF Division of Science Resources Statistics. National Patterns of Research Development Resources, annual series.
Appendix table B-9. http://wvvw.ns£gov/statisics nsfD5308/sectd.htm

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U.S. venture capital disbursements, by stage of
financing: 1992-2CX>2

Millions of U.S. dollars

1992 1994 1990 1996 2000 2002

FIGURE 3-10 Venture capital funding is returning to pre-2000 levels.

SOURCES: Thompson Venture Economics, special tabulations, June 2003. See appendix table 6-16. Science & Engineering
Indicators-2004

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Another positive sign is a recent increase in capital raised by venture funds, suggesting an improving
attitude toward risk taking. According to NVCA and Thomson Venture Economics,'*^ venture funds raised

$17.6 billion in 2004, more than in the prior 2 years combined (albeit at just one-sixth their 2000 peak).

There is a strong funding pipeline to support venture capital investments in 2005, especially early-stage investments with particular emphasis on biotechnology.

In addition to private venture capital, small companies can obtain federal tax incentives and other help through the research and experimentation (R&E) tax credit (Table 3-3) and the federal Small Business Innovation Research (SBIR) program and Advanced Technology Program''^ (Table 3-4).

The US workforce faces the additional pressure of competing with workers in nations with lower wage structures. A US company can hire five chemists in China or at least that many engineers (depending on the field) in India for the cost of one employee of equivalent training in the United States."^”^ The upshot has been the growing trend of corporations moving work offshore because of wage disparities (Figure 3-1 1). Wage differences at the factory and clerical levels are even more pronounced.

A recent McKinsey and Company study reported that the supply of young professionals (university graduates with up to 7 years of experience) in low-wage countries vastly outstrips the supply in high-wage countries. There were 33 million people in that category in 28 low-wage countries, and 15 million in 8 high-wage countries, including 7.7 million in the United States.'*^ With opportunities to study or work abroad or to work at home for a multinational corporation, workers in low-wage countries increasingly will be in direct competition with workers from developed nations.

'‘^PricewaterhouseCoopers. “MoneyTree Survey.” Available athttp://www-pwcmoneytree-com/moneytree/index.jsp. Accessed December 20, 2005.

'‘^The other two programs are the Advanced Technology Program (ATP) in the Department of Commerce and the Manufacturing Technology Program in the Department of Defense. The ATP was nearly eliminated this year, before Congress restored its modest level of funding in a last-minute effort

The website http://www-payscale.com/about.asp tracks and compm’es pay scales in many countries. R. Hira, of tiie University of Rochester, calculates average salaries for engineers in the United States and India as $70,000 and $13,580, respectively.

McKinsey and Company. The Emerging Global Labor Market: Part n — ^The Supply of Offshore Talent in Services. New York: McKinsey and Company, Jun. 2005.

'‘®Ibid.

TABLE 3-3: R&E Tax Claims and US Corporate Tax Returns, 1990-2001

	1 R&E Tax Credit Claims I		
Year	Current Dollars (millions)	2000 Constant Dollars (millions)	Returns
1990	1,547	1,896	8,699
1991	1,585	1,877	9,001
1992	1,515	1,754	

7,750

1993

1,857

2,101

9,933

1994

2,423

2,684

9,150

1995

1,422

1.544

7,877

1996

2,134

2,274 i

9,709

1997

4398

4,609

10,668

1998

5308

5,399

9,849

1999

5381

5396

10,019

2000

7,079

7,079

10,495

2001

6356

6,207 1

10,388

NOTE; Data exclude IRS forms 1 120S (S corporations), 1 120-REIT (Real Estate Investa ent Trusts), an
d
1 120-RIC (Regulated Investment Companies). Constant dollars based on calendar year 2000 GDP price deflator. The R&E credit is designed to stimulate company R&D over time by reducing after-tax costs. Companies that qualify may deduct or subtract from corporate income taxes an amount equal to 20% of qualified research expenses above a base amount. For established companies, that amount depends on historical expenses over a statutory base period relative to gross receipts; startups follow other pr
ovisions.
SOURCE: US Internal Revenue Service, Statistics of Income program, unpublished tabulations.

TABLE 3-4 Early-Stage Venture Capital, Including SBIR, ATP, and Private Sources

Federally and Privately Funded Early-Stage Venture Capital, in millions of dollars.

Year	Federal SBIR	Federal ATP	Private Early-Stage Venture Capital
1990	461	46	1,148
1991	483	93	826
1992	508	48	1,186
1993	698	60	2,100
1994	718		

309

1,581

1995

835

414

2,143

1996

916

19

2,658

1997

1,107

162

3373

1998

1,067

235

4,700

1999

1,097

110

10,995

2000

1,190

144

20,260

2001

1,294

164

764

2002

NA

156

1,813

Notes: ATP, Advanced Technology Program; NA, not available; SBIR, Small Business Innovation Research

Data reflect disbursements funded publicly through federal SBIR and ATP and privately through US venture capital fluids.

Source: National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Virginia.
National Science Foundation. 2004. p.6-31

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uLa4T' rr hJi^Kerai^ rn^iH bSHr^dcd i in inc Lhraif 'ndLa^^^duA^ uhi ojl lul «r

L^m: faii^raiih Ini srArii'lik^ iiufon ur i/kn umi^ die wnl L|uliri£iJ ilmJIci^ nOiDli.^^iiiiJ LIkit

ur dD|fliJ^bi^AdV 'Aui'A^i ^bJ ^limlctiii uT luKh’. TIpj ui||I^iIhii ■ iMl ^‘knlitJ nippncilrq.

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ctil.i'kni^nJ L^uHci ^ Ofprahji^ oaiomi iwlA nO i4J»a Furtta wT liaimmlimo.

^iBKtaadl li rhctisd vd hi br^mn la^^Bm.ii.LhTE i pi^Bka hcn^ki bwiaKwi IUej n'iv kHnhMy74MZvFiW.4A M P FcUldrwd.vHLrA.TT I^Mdl .Wti^p P>4Adnn. K-iil

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Today, with just 5® o of the world's population, the United Slates emplox's nearly one-third of the w orld's scientific and engineering researchers, accounts for 40®o of all R&D spending, publishes 35®o of science and engineering articles, and obtains 44®o of science and engineering citations/ Ilie I 'nited States comes out at or near the top of global rankings for competitiveness, flie International Institute for Management Development ranks the United States first in global competitiveness; the World Economic Forum puts us second (afier Finland) in overall competitiveness and first in technology and innovation.*

I.eadership in science and technology has translated into rising standards of living. Technology improvements have accounted for up to one-half of CiDP growth and at least tw o-thirds of productivity growth since 1 946.* Business Week chief economist Michael Mandel argues that, w ithout innovation, the long-term growth rate of the l^S economy would have been closer to 2.5®o annually rather than the 3.6®o that has been the average since the end of W'orld War II. If our economy had grown at that low er rate over the last 50 years, he says, it w ould be 40®o smaller today, with corresponding implications for jobs, wages. ;uid the standard of living.^

The dominant position of the Ignited States depended substantially on our own strong commitment to science and technology iuid on the comparative weakness of much of the rest of the world. But the age of relatively unchallenged US leadership is ending. 'Hie importance of sustaining our investments is underscored by the challenges of the 21st centurN" the rise of emerging markets, innovation-based economic development, the global innovation enterprise, the new global labor market, and an aging population w itli expanding entitlements.

F!mergiiig Markets

(>\'er the last 2 decades, the global economy has been transformed. With the fall of the l^rlin Wall in 1989, the collapse of the Soviet Union in 1991. China's entrx into the World Trade Oganization in 2001. and India's recent engagement with international markets, almost 3 billion people have joined the global trading system in little more than a decade.

In the coming years, developing markets will drive most economic growih. Goldman Sachs projects that w ithin 40 years the economies of Brazil. Russia. India, and China (the so-called BRICs) together could be larger than those of the G6 nations together — the United States. Japan, the United Kingdom. Germany, France, and Italy (Figure 9-1). The BRICs currently are less than 1 5®o the size of tlie G6.* But India's econom> could be larger than Japan's by 2032. and

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’ IMD- li'orldCompelitiveness FeardooA* (2005); Wwld Economic Forum Vie Global Competitiveness Report

2004-2003 New York; Oxford University lYess 2004.

* G Tassey R&D Trends in the US Economy Strategies and Policy Implications. NIST Planning Report 99-2, Gaithersburg, KfD: Nauonal Institutes of Standards and Technology Apnl, 1999

’ M J Mandel Rational Exuberance: Silencing the Enemies of GroM /h and H 7iv the Future Is Better Than You Think. New York Harper Business. 2004, p 27

’ Goldman Sachs Dreaming with the BRICs: The Path to 2030 Global Economics Paper No: 99 New Yoik, NY : Goldman Sachs. Oct 2003

China could suq)ass even' nation other than the I United States by 20 1 6 and reach parity with the United States by 2041.

bUJURK 9-1 Ch'owih of emerging markeLs.

SOURCE Goldman Sachs Dreaming wth ihe BRJCs: The Palfi lo 2050. Global Economics. Paper 99 New York. NY Goldman Sachs. Oct 2003

Ilie enormoiLs populations of the HRICs (China's population is now 4.4 times and India'.s is 3.6 times the size of Uie US population’) mean that even though per capita income in those nations will remain well below that in the developed world, llie BRICs will have a growing middle class of coasumers. Within a decade, nearly 80^0 of the world's middle-income consumers could live in nations outside the currenth indaslrialized world. China alone could have 595 million middle-income consumers and 82 million upper-middle- income consumers*®, a combined number that is double tite total projected population of the United States in tliat period. China's domestic market is already the largest in the w orld for more than 100 products. With 300 million subscribers and rising. China already is by far the biggest mobile-telephone market in the w orld. Only a small fraction of its population has Internet ac'cess. but China still has 100 million

computer users, second only to the United States. China has become the second largest market for personal computers, and it w ill soon pass the United States.*' Many US companies including Google. Yahoo, eBay, and Cisco — expect China to be their largest market in the next 20 years.'*

For decades, the I 'nited States has been the world's largest ;uul most sophisticated market for an enonnous range of goods and sen'ices. l^S consiuners have stimulated productivity around the world with our apparently insatiable demand. Foreign multinational companies have invested in the United States to gain access to our markets, giving this nation the largest stock of foreign

* US Census Bureau Data Base Total Mid-Year Population, 2004-2050. Available at; http '/WWW census gcn'/ipowww/idbsprd html

‘*P A Laudicina H'orld Out of Balance: Navigating Global Risks to Seize Competitive. Advantage. New York
McGraw Hill, 2005. p 76.

“ C- Prestowitz Three Billion New Capitalists: The Great Shift of Health and Power to the East New' York Basic
Books, 2005. p 74

Dan Gillmw Noh’ Is Time to Face Facts, Make Needed Investment San Jose Mercury News March 1 4. 2004 direct investment in the world and employing 5.4 million .Americans.*^ New products and scn ices are designed, marketed, and launched here. Technical standards are set here. But as other markets overtake us. we could lose these ad\ antages.

Inn<Aation-Bascd Development

I>ri\ ing the rapid groulh in developed economies and in emerging markets is a new emphasis on science and technology. A report of the President’s Council of Advisors on Science and Technology (PC.AST) notes, "‘other countries are striving to replicate the US innovation ecosystem model to compete directly against our own.”*^ Through investments in R&D, infrastructure, and education and aided by foreign direct investment, many nations are rapidly retooling their economies to compete in technologically advanced products and serv ices.

One sign of this new priority is increased R&I) spending by many governments. ITie Kuropean I ^nion (EU) has stated its desire to increase total R&l) spending (government and industrv) from less than 2°o of GDP to 3% (the Ihiitcd States currently spends about 2.7‘^b).** From 1 992 to 2002, China more than doubled its R&D intensity (the ratio of total R&D spending to GDP), although the United States still spends significantly more than China does both in gross terms and as a percentage of GDP. Other nations also have increased their numbers of students, particularly in science and engineering. India and China are large enough that even if only relatively small portions of their populations become scientists and engineers, the size of their science and engineering worklbrce could still significantly exceed that of the United States. India already has nearly as many yomig professional engineers (university graduates with up to 7 years of experience) as the United States does, and China has more than twice as many.’^

Multinational corporations are central to innovation-based development strategies, and nations around the world have introduced tax benefits, subsidies, science-based industrial parks, and worker-training programs to lure the owners of high-technology manufacturing and R&D facilities. China uses those tools and its enormous potential market to encourage technology transfer to Chinese partner companies.^^ Most of the world's leading computer and telecommimications companies have R&D investments in China, and they are competing with local high-technologv' enterprises for market share. High-tech goods w ent from about 5® o of China's exports in 1990 to 20®o in 2000. Foreign enterprises accounted for 80®o of China's exports in capital- and technology-intensive sectors in 1995, but they were only responsible for

50^0 by 2000. The Ignited States now has a S30 billion advanced-technology trade deficit with China.

Tliere was once a belief that developing nations would specialize in low-cost commodity products and developed economies would focus on higli technology, allowing the latter to

Organization for International Invcslmcnl The Facts About Insourcing. Available at: htlp://www-ofii.org/ insourcing'

' PCAST. Sustaining Nation ‘s Innovation Ecosystems. Information Technology Manufactuhr^ and

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25. Available at; http •■'/www’.oecd org'’document/’63.'0.2340.en_2649_33703_33995839_l_l_l_1.00.hlml

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‘^E. H, Preeg The Emerging Chinese Advanced Technology' Superstate. Arlir^ton.VA: Manufacturers Alliance/
MAPI and Hudson Institute. 2005, K. Walsh. Foreign High-Tech RAD in China: Risks, Regards, and Implications
for US-China Relations. Washington, DC: Henry L. Stimson Center, 2003,

maintain a higher standard of living. Developing nations — South Korea. Taiwan. Indiii. and China — have ad% anced so quickly that they can now produce many of the most ad\ anced technologies at costs much lower than in wealthier nations. Most analysts believe that the L'nited States, Kurope, and Japan still maintain a lead in innovation — developing the new products and ser\’ices that will appeal to consumers. Hut even here the lead is narrowing and temporary'. .And while the I iiited States does currently maintain an advantage in terms of the availability of venture capital to underurite innovation, venture capitalists are increasingly pursuing what may appear to be more promising opportunities around the w orld.

The (flobal Innovation Enterprise

•Among the most powerful drivers of globalization has been the spread of multinational corporations. By the end of the 20tli century, nearly 63,000 multinationals were operating worldw ide.** Over the last few decades, corporations have used new' information technologies and management practices to outsource production and business processes. Shifting from a vertically integrated structure to a network of partners allow s companies to locate business activities in the most cost-efllcient manner. The simultaneous opening of emerging markets and the rapid increase in workforce skill levels in those nations helped stimulate the otYshore placement of key functions. First in manufacturing, then in technical support and back-ofTice operations, next in softwiire design, increasingly sophisticated work is being performed in developing economies. Innovation itself is being both outsourced <uid sent offshore.*^ This is all part of the process that ITiomas Friedman calls *ihe flattening of the world".^

Ix)cations that combine strong R&D centers with manufacturing capabilities have a clear competitive advantage. Hence, in addition to the availability of scientists and engineers whose salaries are a fraction of the salaries of their US counterparts. India and China ofler synergies betw een manufacturing and R&D. Top-level R&D and design are still conducted mostly in the l 'nited States, but global companies are becoming increasingly comfortable with offshore R&D. and other nations are rapidly increasing their capabilities.^*

In 1997, China had fewer than 50 research centers that were managed by multinational corporations; by mid-2004. there w ere more than 600.^^ Much of the R&D ciurenth performed in developing markets is designed to tailor products to local needs, but as local markets grow, the most advanced R&D could begin to migrate there. Iliat said, it should be noted that the United States also benefits from offshore R&D — the amount of foreign-funded R&D conducted here has quadrupled since the mid-1980s. In fact, more corporate R&D investment now comes into the United States than is sent out of the country."^

** UNCTAD. IVorU InvesOnenl Rcporl 2004: The Shift Towards Scr\ ices- New Yoiic and Geneva: United Nations, 2004.

’’ Council on Competitiveness. Going Global: The NeM- Shape of American Innovation. Washington, E)C: Council on Competitiveness, 1998.

^T. L Friedman The World Is Flat: A Brief History of the 2Ist Century. New York; Farrar, Straus. Giroux, 2005

PCAST. Sustaining d\e Nation ’s Innovation Ecosystems, Information Tedtnolog}' Manufacturing and Competitiveness. Washingtoa DC: White House Office of Science and Tcchnolog>' Policy. Dec. 2004, p. I I.

^ R. B. Freeman. Docs Globalization of the Scientific/ Engineering Workforce Threaten US Economic Leadership? Working Paper 1 1457. Cambndge, MA: National Bureau of Economic Research, Jun. 2005, p. 9.

^ K. Walsh. Foreign High-Tech R&D in China: Risks, Rewards, and Implications for US-China Relations

Washingt(Mi. EX2: Henry L. Stimson Center. 2003.

The Kmet^iiig (>lobal I.abor Market

The three trends discussed already — the opening of emerging markets, innovation-based development and the global innovation enterprise — have created a new global labor market with far-reaching implications.

In the last few years, the phenomenon of sending service work overseas has garnered a great deal of attention in developed nations. Tlie movement of US manufacturing jobs offshore through llie 1980s and 1990s had major consequences for domestic employment in those sectors, although many argue that productivity increases were responsible for most of the reported job losses.'^ lentil recenlK , it seemed that jobs in the serN'ice sector were safe because most sen ices

are deli\ ered face-to-face and only a small fraction is traded globally. But new technologies and business processes are opening an increasing number of services to global competition, from technical support to the reading of x-ray to stock research to the preparation of income taxes and even to the ordering of hamburgers at drive-tltrough windows. Tliere is a l^S companv that uses a receptionist in Pakistan to welcome visitors to its otTice in Washington via flat-screen television. llie transformation of collaboration brouglil about by information and communications teclinologics means that the global workforce is now more easily tapped by global businesses. It is important to note, however, that a recent McKinscy Company report estimates that only 13^o of the potential talent supply in low-wage nations is suited for work in multinational companies because the workers lack the necessary education or language skills.

But that is 1 3® o of a ver>' large number.

Forrester Research estimates that 3.4 million US jobs could be lost to otTshoring by 2015.^’ Ashok Biirdhan and Cynthia Kroll calculate that more than 14 million US jobs are at risk of bein^ sent ofrshore.‘*'nie Information Technology Association of .America (ITAA), Global Insight.*’ and McKinsey & Company'^ all argue that those losses will be offset by net gains in l^S employment presuming that the United States takes the steps needed to maintain a vibrant economy. Many experts point out that the number of jobs lost to offshoring is small compared with the regular monthly churning of jobs in Ute US economy. McKinsey, for example, estimates that about 225.000 jobs are likely to be sent overseas each year, a small fraction of tlie total annual job chum. In 2004, the private sector created more than 30 million jobs and lost about 29

^ American Electronics Associati<Mi Off^ore Outsourcing in an Increasingly Competitive and Rapidfy Changing IVorld.'A High-Tech Perspective. Washington, DC March 2004

^ S. Milra Kalita Virtual secretary puts new face on Pakistan Washington Post May 10. 2005. p. AOl .

** McKinscy and Company The Emerging Global iMbor Market: Part II-The Supply of Offshore Talent in Services. New York. NY : McKinsev- and Company. Jun. 2005, p 23.

Forrester Research Near-Term Growlh of Offshoring Accelerating, Cambndge. MA Froster Research. May 14. 2004.

^ A. Bardhan and C. Kroll The New tf'env of Outsourcing Fisher Center Research Reports #1 103. Bcrkelc)', Calif.; Unh'crsity of California, Berkeley, Fisher Center for Real Estate and Urban Economics, Nov. 2, 2003.

^ ITAA The Impact of Offshore IT Software and Services Outsourcing on the US Economy and the IT Industr>' Lexington, Mass. : March 2004

^ McKinscy and Cwnpany Offshormg: Is It a IVin-lVin Gam*?' New Y cck, NY : McKmsc)' and Company, Aug 2003.

million; the net gain was 1.4 million jobs. Once again, this suggests that the US economy will continue to create new jobs at a constant rate, an assumption that in turn depends on our continued development of new technologies and training of workers for the jobs of the 2 1st century'. Economists and others actively debate whether outsourcing or more generally, free trade with low-wage countries with rapidly improving innovation capacities will help or hurt the US economy in the long term.^' ITie optimists and the pessimists, however, agree on two fundamental points: in the short term, some US workers w ill lose their jobs and face diillcult transitions to new . higher skilled careers; and in the long term. .America's only hope for continuing to create new high-w age jobs is to maintain our lead in iimovation.

Aging and Ejititleinents

The enormous and grow ing supply of labor in the developing w orld is but one side of a global demographic transfomiation. Ibe other side is the aging populations of developed nations, llie working-age population is already shrinking in Italy and Japan, and it w ill begin to decline in the United Stales, the United Kingdom, and Canada by the 2020s. More than 70 million US baby boomers w ill retire by 2020, but only 40 million new workers w ill enter the w orkforce. Europe is expected to face the greatest period of depopulation since Uie Black Death, shrinking to 7®o of world population by 2050 (from nearly 25®o just after World War II).^ East Asia (including China) is experiencing the most rapid aging in the world. .At the same time, India's working-age population is projected to grow by .335 million people by 2030 — almost equivalent to the entire workforce of Europe and the United States toda> ITiose extreme global imbalances suggest that immigration will continue to increase.

Population dNnamics have major economic implications. Tlie Organization for Economic Cooperation and Development (OECD) projects that the scarcity of working-age citizens w ill hamper economic growth rales betw een 2025 and 2050 for Europe. Japan, and the United Slates. The Center for Strategic and International Studies (CSIS) estimates that the average cost of public pensions in the developed w orld will grow by 7®o of GDP belw een now and the middle of the century; public health spending on the elderly w ill grow by about 6®o of GDP.^’ Iliere are

US Bureau of Labor Statistics NEiVS: Business Employment Dynamics: First Quarter 200S. "November 18 2005- Available at: http.//www. bls.gov/rofod3640.pdf.

While C. Mann.. Globalizatjon of IT Services and Hhi/e Collar Jobs. W'ashingtai. DC; Institute for International Economics. 2003 and J. Bhagw’ati, A. Panagariya, and T. N. Srinivasan. The muddles over outsourcing. Journal of Economic Perspectives 18(summer 2004): 93-114 offer examples of the optimist view. R Gomory and W^ Baumol GlcJ>al Trade and Conflictirtg National Interests. Cambridge, MA MIT l4ess 2001. andP, A. Samuelson. Where Ricardo and Mill rebut and confirm arguments of mainstream economists supporting globalization. Journal of Economic Perspectives 18(summer 2004): 135-1 46 offer a more pessimistic perspective.

P. A. Laudicina Horld Out of Balance: Navigating Global Risks to Seize Competitive Ath'ontage. New York McGraw HUl, 2005. p. 49.

^ United Nations. Department of Economic and Social Affairs. Population Division. The World at Six Billion. October 12, 1999. Available at: hltp:/ www.un.org/esa/populalion'publications.'sixbi!lion.''sixbillion.htm

P. A. Laudicina IVorld Out of Balance: Navigating Gl^al Risks to Seize Competitive Advantage. New Yor

k:
McGraw Hill. 2005. p. 62.

^ Central Intelligence Agenc)’. Long-Term Global Demographic Trends: Reshaping the Geopolitical Landscape.
Lansing. VA: CIA, Jul. 2001. p. 25.

P. G. Peterson. The shape of things to come: Global aging in the 21st century' Journal of International Affairs
56(lXFall 2002). New Y<^, NY: Columbia UniversiW Press

now 3 pension-eligible elders in ihe developed world for everv’ 10 working-age adults. Thirt>-fivc years from now , the ratio w ill be 7 to 10. Here in the Ignited States, the ratio of adults aged 60 and over to w orking-age adults aged 1 5-59 is expected to increase from . 26 to .47 over the same period.^*

Tliose trends have profound implications for US leadership in science and technology:

- ’file I 'S science and engineering w orkforce is aging while the supply of new scientists and engineers who are US citizens is decreasing. Immigration will continue to be critical to filling our science and engineering needs.

- Tlte rapidly increasing costs of caring for the aging population w ill further strain federal and state budgets and add to the expen.se columns of indastries with large pension and health care obligations. It will thus become more diiricult to allocate resources to R&Dor education.

- Aging populations and rising health care costs will drive demand for innovative and cost-effective medical treatments.

Taken together, those trends indicate a significant shifl in the global competitive environment. The importance of leadership in science iuid technology will intensify. .As companies come to see innovation as the key to revenue growth and profitability, as nations come to see innovation as the key to economic growth and a rising standard of living, and as the planet faces new challenges that can be solved only throu^ science and technology, the ability to innovate w ill be perhaps the most important factor in the success or failure of any organization or nation.

A recent report from the Council on Competitiveness argues that “innovation will be the single most important factor in determining .America's success tlirough the 21st centuiy.”^^ ITie I gnited States cannot control such global forces as demographics, the strategies of multinational corporations, and the policies of other nations, but w e can delemiine how we w iint to engage w ith this new world, w ith all of its challenges and opportunities.

“ Richard Jackson and Neil Howe. The 2003 Aging l ulnerability Index. Washington. E>C : CSIS and Wats on Wyatt
Worldwide, 2003, p 43

^ Council on Competitiveness Innovate America: Thriving in a World of Challenge andChange. Washingto n, DC;
Council on Competitiveness December. 2004.

SC ENARIOS FOR AMERIC A’S El Tl RE IN SC IENC E AND TEC IINOEOCJV

To highlight the choices we face, and their implications, it is useful to examine three scenarios that address the changing status of .-America's leadership in science and engineering.

Scenario 1: Baseline
America^ Narrowing Lead

Whal is likely to happen if we do not change our current approach to science and technolog\? 'ITie US lead is so large that it is unlikely iliat any other nation would broadly overtake us in the next decade or so. Tlie National Intelligence Council iirgues dial the United States w ill remain the world's most powerful actor economically, technologically, and militarily— at least tlirou^i 2020.'*'^ But that does not mean the United States w ill not be challenged. Center for Strategic and International Studies concludes, “although l^S economic and technology leadership is reasonably assured out to 2020. disturbing trends now evident threaten the foundation of US technological strenglli.*’^*

Over the last year or so. a virtual Hood of books and articles has appeared expressing concern about the future of US competitiveness.'** The\ identify trends and provide data to show that the relative position of the United States is declining in science and technology, in education, and in high-technology industry."*^ All of this leads to a few' simple e.Mrapolations for our global role over the ne\1 30 years, assuming that w e change nothing in our approach to science and education.

The I'S share of global K&l) spending w ill continue to decline.

• US R&D spending will continue to lead the world in gross terms, but R&D intensity (spending as a percentage of (JDP) will continue to fall behind that of other nations.

• US R&D will rely increasingly on corporate R&D spending.

• Industry spending now accounts for tw o-thirds of all US R&D.

• Total goN’eniment spending on all ph\'sical science research is less than the $5 billion that a single company — IBM spends annually on R&D, although an increasing amount of IBM's research, like that of most large corporations, is now performed abroad.

• Most corporate R&D is focased on short-term product development rather than on long-tenn fundamental research.

• I'S multinational corporations w ill conduct an increasing amoiuit of their R&D overseas, potentially reducing their R&D spending in the United States, because other nations offer

National Intelligence Council Mapping the Globa! Future Report of the National Intelligence Council's 2020 Project Pittsburgh Government Printing Office. Dec. 2004.

Center for Strategic and International Studies Technology' Futures and Global Power. Wealdi and Conflict Washington. DC; Center for Strategic and International Studies. May 2005. p viii

Some of the most prominent publications include A Segal Is Amenca losing its edge*^ Innovation m a globalized world Forergn.-IJ?i»/rs(Nov,/Dw- 2004);2-8.Geofire>’ Colvin Amenca isn't ready Fomme. July 25. 2005, K H Hughes. Building the Next VS Century: The Past and Future of US Economic Competitiveness. Washu^ton. DC. Woodrow Wilson Center Press. 2005, R D Atkinson. The Past and Future of America's Economy: Long Waves

of
Innovation That Power Cycles of Growdt Northamptem, MA E Elgar. 2004. andR Florida. The Flight of the

Creative Class: The New Global Competition for Talent New York Harper Business. 2005
The Task Force on the Future of US Innovatiwi The Knowledge Economy: Is the United States Losing Its Competitive Ei^e. Benchmarks fijr Our Innovation Future. Washmgton. DC: The Task Force cm the Future of US
Innovation Februar>' 2005

lower costs, more government incentives, less bureaucracy, high-quality educational systems, and in some cases superior infrastnicture.

The l^S share of world scientific output will continue to decline.

- 'ITie share of US patents granted to US inventors is already declining, althougli the absolute number of patents to US inventors continues to increase.

- US researchers' scientific publishing will decline as authors from other nations increase their output.

- The number of scientific papers published by US researchers reached a plateau in 1992.““

- Europe surpassed the I'nited States in the mid-1990s as the world's largest producer of scientific literature.

- If current trends continue, publications from the Asia Pacific region could outstrip those from the United States within the next 6 or 7 years."*'

The US share of scientists and engineers will continue to decline.

- Other nations will have larger numbers of students receiving undergradiuite degrees in science and engineering. In 2000. more than 25 countries had a higlier percentage of 24-year-olds with degrees in science and engineering than did the United States."*^

- The number of graduate degrees aw arded in science and engineering will decline.

• The number of new doctorates in science and engineering peaked in the United States in 1998.

• By 2010, China will pnxluce more science and engineering diKtorates than the United States does.*^

• *llie US share of world science and engineering doctorates granted w ill fall to about 15*^0 by 2010. down from more than 50“o in 1970**(Figure 9-2).

• International students and workers will make up an increasing share of those holding l^S science and engineering degrees and will fill more of our workforce.

• In 2003, foreign students earned 38®o of all I’S doctorates in science and engineering, and they earned 59®o of US engineering doctorates.^^

• In 2000, foreign-bom workers occupied 38®o of all l.^S doctoral-level science and engineering jobs, up from 24®ojust 10 years earlier.^^

National Science Board 2004. Science and Engineering Indicators 2004 (NSB 04-01) Arlington. Virginia National Science Foundation. Table 5-30.

A- von BubnofT- Asia squeezes Eurc^'s lead in science. Nature 436(7049XJul- 21, 2005);314-314.

^ National Science Foundation Science and Engineering Indicators 2004. NSB 04-1 . Arlingtoa VA: NSF, 2004,
Appcndi.K Tabic 2-33

* R- B. Freeman Does Globalization of the Scicnlific' Engineering Workforce Threaten US Economic Leadership?
Working Paper 1 1457. Cambndge, MA; National Bureau of Economic Research, Jun. 2005, p.4
"*lbid..p. 5.

^ National Science Foundation. Survey of Earned Doctorates. 2003 Arlington, VA: NSF. 2005,

R, B, Freeman Does Globalization of the Scientific.'' Engineering Workforce Threaten US Economic Leadership?
Working Paper 1 1457-Cambndge, MA: National Bureau of Econcmiic Research, Jun. 2005. p. 36.

FIGl’RE 9-2 Intcnialional production of science and engineering doctorates compared with US production.

SOURCE; R B Freeman Docs Globalization of the Scientific' Engineering Workforce Threaten US Economic Leadership? Working Paper 1 1 457.Cambndgc. MA National Bureau of Economic Research, Jun 2005.

Our ability to attract the best international researchers will continue to decline.

• iToni 2002 to 2003, 1,300 international students enrolled in US science and engineering graduate programs. In each of the 3 years before that, the number had risen by more than 10 , 000 .”

• .Vl^cr a decline of 6®o from 2001 to 2002. first-time, full-time enrollment of students with temporaiy visas fell 8®o in 2003.^^

• Snapshot suiAcys indicate international graduate student enrollments decreased again in 2004 by 6®o^^ but increased by l®o in 2005.

• In the early 1990s. there were more science and engineering students from China. South Korea, and Taiwan stud\ ing at US universities than there were graduates in those disciplines at home. By the mid-1990s, the number attending US uni\‘ersities began to decline and the number studying in .Asia increased signific<mtiy.^

PC.AST obser\es that. ‘Avhile not in imminent jeopardy, a continuation of current trends could result in a breakdown in the web of ‘innovation ecosystems’ that drive the successful l^S innovation system. Economist Richard Freeman says those trends foreshadow a US transition “from being a superpower in science and engineering to being one of many centers of

National Science FoundaUon. Graduate Enrollment in Science and Engmecnng Programs Up in 2003, but Declines for First-Time Fweign Students NSF-05-317 .Arlington, VA: NSF, 2005.

” Ibid

H. Brown Council of Graduate Schools Finds Declines inNew International Graduate Student Enrollment for Third Consecutive Year. Washington. DC; Council of Graduate Schools. Nov 4. 2004. Heath Brown. 2005 Fmdmgs from 2005 CGS International Graduate Admissions Sur\'ey III Admissions and EnrollmenL Washington E)C; Council of Graduate Schools. Available at ht^.//w'ww.cgsnet.org.’pdf/CGS2005Int].AdmitIII_Rep.pdf
^ The Task Force on the Future of US Innovation The Knowledge Economy: Is the United States Losing Its Competitive Edge. Benchmarks for Our Innovation Future. Washmgton, DC; The Task Force on the Future of US Innovation. Feb, 2005.

** PCAST. Sttsfaming the Wation 's Inn(n'ation Ecosystems. Information Technology Manufaetttring a}td Competitis'eness. Washington. DC; WTiite House Office of Science and Technology Policy'. Dec. 2004. p 13 cxccllcncc/*^^ He adds that ‘The countr\ faces a long transition to a less dominant position in science and engineering associated industries.

Ilie I'nited States still leads the world in many areas of science and technology, and it continues to increase spending and output. IBut our share of world output is declining, largely because other nations are increasing production faster than we are. although they are starting from a much lower base. Moreover, the L’nited Slates w ill continue to lead the world in other areas critical to innovation — capital markets, entrepreneurship, and workforce fle.xibility — although here as well our relative lead will slirink as other nations improve their ow n systems.

The biggest concern is that our competitive advantage, our success in global markets, our economic growth, and our .stand;ird of living all depend on maintaining a leading position in science, technologv , and innovation. .As that lead shrinks, we risk losing the advantages on w Inch our economy depends. If these trends continue, there are several likely consequences:

• Tlie I’nited States w ill cease to be the largest market for many high-tecIinolog>' goods, and the US share of high-technologv' e.xports will continue to decline.

• Foreign direct investment will decrease.

• Multinational corporatioas (I’S-based and foreign) will increa.se their investment and hiring more rapidh overseas lh«ui they w ill here.

• Tlie industries and jobs that depend on high-technology e.xports and foreign investment w ill sulTer.

• file trade deficit w ill continue to increase, adding to the possibility of inflation and higher interest rates.

• Salaries for scientists, engineers, and technical workers will fall because of competition from lower-wage foreign workforces, and broader salary pressures could be exhibited across other occupations.

• Job creation will slow.

• GDP growlh will slow.

• Growlh in per capita income will slow despite our relatively high standard of living.

• Poverty rates and income inequality, already more pronounced here than in other industrial ized nations, could increa.se.

foday's leadership position is built on decisions that led to investments made over the past 50 years. ITie slow erosion of those investments might not have immediate consequences for economic growth ajid job creation, but the long-term efTect is predictable and would be severe. Once lost, the lead could take years to recover, if indeed it could be recovered. Like a supertanker, the US economy does not turn on a dime, and if it goes off course it could be veiy dilTicult to head back in the right direction.

Given that they already have a commanding lead in many key sectors, it is likely that L'S multinational corporations will continue to succeed in the global marketplace. To do so, they will shit) jobs, R&D funds, and resources to other places. Increasingly, it is no longer tnie that w hat is good for GM (or GE or IBM or Microsoft) is good for the United States. What it means to be a US company is likely to change as all multinationals continue to globalize their operations and ow nership. .As China and other developing nations become larger markets for many products and

^ R- B- Freeman Does Globalization of the Scientific' Engineering Workforce Threaten US Economic Lead ership?
Working Paper 1 1457. Cambridge, MA; National Bureau of Ecotkotic Research, Jun 2005, p. 2.

Ibid . p. 3

services, and as they maintain their cost advantages. I'S companies will increasingly invest there, hire there, design there, and produce there.

'Iliis nation's science and technology policy must account for the new reality and embrace strategies for success in a world where talent and capital can easily choose to go elsewhere.

Scenario 1 is the most likely case if current trends in government policies continue both here and in other nations and if corporate strategies remain as they are today. Two other scenarios represent departures from recent history . As such, they are more speculative and less detailed.

Sceiianu2: Pessimistic Case
America Falls Dt'cisively Behind

In Scenario 1. the Ignited States continues to invest enough to maintain current trends in science and technology education and performance, leading to a slow decline in competitiveness. Scenario 2 considers what might happen if the commitment to science ;uid technology w ere to lessen. Although that would run counter to our national history', several factors might lead to such an outcome:

• Rising spending on social security. Medicare, and Medicaid (now 42®o of federal outlays compared with 25°o in 1975) limit federal and state resources available for science and technology. In 2005. Social Security. Medicare, and Medicaid accounted for 8.4®o of GDP. If growth continues at the current rate. tJie federal government's total spending for Medicare and Medicaid alone would reach 22% of GDP by 2050.

• The war on terrorism refocuses government resources on short-term sun ival rather tlian long-term R&D.

• Increasingly attractive opportunities overseas draw industrial R&D funding and talented I’S scientists and engineers away from Uie I ’nited States.

• Higher I’S eflective corporate tax rates discourage companies from investing in new facilities and research in the I'nited States.

• Excessive regulation of research institutions reduces the amount of money available for actual research.

'Iliose possibilities would exacerbate and accelerate the trends noted in Scenario 1:

• llie availability of scientists and engineers could drop precipitously if foreign students and workers stop coming in large numbers, either because immigration restrictions make it more dilTicult or because better opportunities elsewhere reduce the incentives to work in the United States.

• US venture capitalists begin to place their funds abroad, searching for hi^er returns.

• Short-term cuts in funding for specific fields could lead to a rapid decline in the munber of students in those disciplines, which could take decades to reverse.

” W B BonviUian Meeting the new challenge to US economic compelililiveness Issues tn Saence cmd Technology 2l(lXFall 2004) 75-82

• If they were faced w ith a lack of qualified w orkers, multinational corporations miglit accelerate their overseas hiring, building the capabilities of other nations w hile the US innovation system atrophies.

• Multinationals from China. India, and other developing nations, building on success in their domestic markets and on supplies of talented. low >cosi scientists and engineers, could begin to dominate global markets, while I'S-based multinationals that still have a large percentage of tlieir employees in the United States begin to fail. atTecting jobs and the broader economy.

• Financing the I'S trade deficit, now more than S600 billion or about 6°o of GDP, requires more than $2 billion a day of foreign investment. Many economists argue that such an imbalance is unsustainable in the long temi.'^ A loss of competitiveness in key export industries could lead to a loss of conlldence in the L^S ability to cover the debt, bringing on a crisis.

• .\s innovation iuid investment move overseas, domestic job creation and wage growth could stall, lowering the overall standard of living in the United States.

The rapid pace of technological change and the increasing mobility of capital knowledge and talent mean that our current lead in science and technology could cN aporate more quickly than is generally recognized if we fail to support it. llie consequences would be enormous, and once lost our lead would be dilTicult to regain.

Scenario 3: Optimistic ('ase
.\nicrica Leads in Key .Vreas

Ilie relative competitive lead enjoyed by the United States will almost certainly shrink as Ollier nations rapidly improve their seienee and technology capacity. Tlial means greater challenges for the I nited States, but it also presents an opportunity to raise living standards and improve quality of life around the world and to create a safer world. I1ic United Stales might have a smaller share of the w orld's economy, but the economy itself w ill be larger. For that reason, the success of other nations need not imply tiie failure of the I nited Slates. But it does require that the United States maintain and e.xtend its capacity to generate value as part of a global innovation system.

If w e increase our commitment to leadership in science and leclmology, tliere are several likely results:

• .Mlhougli the I'S share of total scientific output continues to decline, the I'nited States maintains leadership across key areas.

• I'S researchers become leaders of global research networks.

• 'Ihe US education system sets the standard for quality and innovation, giving graduates a competitive edge over the larger number of lower wage scientists and engineers trained in the developing world.

• CXir universities and national laboratories act as centers for regional innovation, attracting and anchoring investment from around the world.

’’C- Prestowilz Three Bilbon New Capitalists: The Great Shift of Wealth and Toner to the East New York Basic Books. 2005, p xii

• Our economy generates sulTicient grovMh to reduce our trade imbalances, reduce the federal budget dellcit. and support an aging population.

• Investors continue to find it attractive to place their funds in US firms seeking to innovate and generate jobs in America.

• US leadership in science and technology supports our military' leadership and addresses the major challenges of homeland security.

ITie rapid worldwide development that has resulted from advances in science and technology has raised global standards of living, but it also spawned a range of challenges that, paradoxically, will have to be solved through appropriate investments in research:

• To maintain its current rate of growth, by 2020 China will need to boost energy consumption by 1 50° o. and India will need to do so by 100° It will be essential to develop clean, aflbrdable and reliable energy.

• The Increased movement of people around the world w ill lead to more outbreaks of communicable diseases. Meanwhile, aging populations w ill require new treatments for chronic diseases.

• .As the means to develop w eapons of mass destniction become more w idely available, security measures must advance.

• In an increasingly interconnected economy, even small disniptions to communications, trade, or financial flows can have major global coasequences. Methods to manage complex systems and respond quickly to emergencies will be essential.

The strains of managing global growth w ill require global collaboration. .Around the w orld, the grow ing scale and sophistication of science and technoiog\' mean that w e are much more likely to be able to solve those juid other problems dial will confront us. .Advances in information technology, biotechnology, and nanotechnology will improve life for billions of people. The leadership of the United States in science and technology will make a critical contribution to those elTorls and w ill benefit the li\ es of .Americans here at home. Kach challenge

otTers an opportunity for the United States to position itself as the leader in the markets that w il l
be created for solutions to global challenges in such fields as energy, health care, and security.

It is important to recognize that all nations in the global economy are now inextricably linked. Just as global health, environmental, and security issues alTect evervone, so are we all dependent on the continued growth of other economies. It is clearly in .America's interest for China. India, the EU. Japan, and other nations to succeed. Ilieir failure would pose a far greater threat to US prosperity and security than would their success. In the global economy, no nation can prosper in isolation. I lowever, it is the thesis of this report that it is important that such global prosperity be shared by the citizens of the I’nited States.

^ National Intelligence Council Mapping the Global Future Report of the National Intelligence Council's 2020
Project Pittsburgh Government Prinlu^ Office. Dec 2004, p, 62.

C'ONC 1,1 SION

It is easy to be complacent about L^S competitiveness and pre-eminence in science and technology. We have led the world for decades, and we continue to do so in many fields. But the world is changing rapidh , and our advantages are no longer unique. Without a renew ed elTort to bolster the foundations of our competitiveness, it is possible that we could lo.se our privileged position over the coming decades. For the first time in generations, our children could face poorer prospects for jobs, health care, security, and overall standard of living than have their parents and grandparents. We owe our current prosperity, security, and good health to the investments of pa.st generations. We are obliged to renew those commitments to ensure that the US people w ill continue to benefit from the remarkable opportunities being opened by the rapid development of the global economy.

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APPENDIXES

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Appendix A

COMMITTEE AND PROFESSIONAL STAFF BIOGRAPHIC INFORMATION

NORNLVN Al'CrsTINE (NAE) (Chair) retired in 1997 as chair and chief executive officer of Lockheed Martin Corporation. Previously, he ser\ ed as chair and chief executive olTicer of the Martin Marietta Corporation. On retiring, he joined the faculty of die Depiirlment of Mechanical and .-Aerospace Engineering at Princeton University. Earlier in his career, he had ser\ed as under secretarv' of the .Vrmy and as assistant director of defense research and engineering. Mr. . Vugustine has been chair of the National .Academy of Engineering and ser\ ed 9 years as chainnan of the .American Red Cross. He has also been president of the .American Institute of Aeronautics and .Astronautics and seized as chairman of the Jackson Foundation for Militarv’ Medicine.

I le has been a trustee of the Massachusetts Institute of Technology and Princeton. I le is a trustee emeritus of Johns Hopkins I niversity and sen es on the Ih’esident's Council of .Advisors on Science and Technology and on the Department of Homeland Security's .Advisory Council. He is a former chairman of the Defense Science Board. He is on the boards of Black and Decker. Lockheed Martiit Procter and (iamble, and Phillips

Petroleum, and he has sen ed as chainnan of the Business Roundtable Taskforce on Education. He has received the National .Medal of Technologv- and the Department of Defense's hipest civilian award, the Distinguished Service Medal, five times. Mr. .Augustine holds a BSE and an MSE in aeronautical engineering, botli from Princeton University, and has received 19 honorary degrees. He is the author or coauthor of four books.

CR.\IG R. BARRETT [N.AE) is chief executive officer of Intel Corporation. He received a BSc in 1961. an MS in 1963. and a PhD in 1964. all in materials science from Stanford University. .After graduation, he joined tlte facults of Stanford University in the Department of Materials Science and Engineering and remained througli 1974. rising to the rank of associate professor. Dr. Barrett was a Fulbright Fellow at Danish Technical l^niversity in Denmark in 1972 and a Nortli .Atlantic Trade Organization Postdoctoral Fellow at the National Physical I.aborator>' in England from 1964 to 1965. He was elected to the National Academy of Engineering in 1994 and became N.AE chair in July 2004. Dr. Barrett joined Intel in 1974 as a technology-development manager. He was named a vice president in 1984, and w as promoted to senior vice president in 1987 and e.xecutive vice president in 1990. Dr. Barrett w as elected to Intel's Board of Directors in 1992 and w as named the company's chief operating officer in 1993. He became Intel’s fourth president in May 1997 and chief executive officer in 1998. Dr. Barrett is a member of the boards of directors of Qwest Communications International Inc., the National Forest Foundation, .Achieve, Inc., the Silicon Valley Manufacturing Group, and the Semiconductor Industr> .-Vssociation. In addition to ser\’ing as cochairman of the National .Alliance of Basiness Coalition for FAcellence in Education, Dr. Barrett ser\ed on the National Commission on Mathematics and Science Teaching for tlie 2 1 si Ccnlur\-

(also known as the Glenn Commission). Dr. Barrett is the author of over 40 technical papers dealing with the inlluence of microslnicture on the properties of materials and of a te.vtbook on materials science. Principles ofEngineennghfaterials. He was the recipient of the .American Institute Mining Metallurgical, and Petroleum Kngineers Hardy Gold Medal in 1969.

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P. R03’ VAGELOS [NAS lOM] is retired chairman and chief executive ofi’icer of Merck & Co., Inc. He received an AB in 1950 from the L’niversity of Pennsylvania and an MD in 1954 from Columbia University, .\fter a residency at the Massachusetts General I lospital in Boston, he joined the National Institutes of I lealth, where from 1 956 to 1966 he seized as senior surgeon and then section head of comparative biochemistiy.

In 1966, he became chairman of the Department of Biological Chemistrx' at Washington University School of Medicine in St lz)uis; in 1973, he foimded university’s Division of Biology and Biomedical Sciences. He joined Merck Research I^oratories in 1975, where he was president imtil 1985, when he became CEO and later chainnan of the company. He retired in 1994. Dr. Vagelos is a member of the National .Academy of Sciences, the .American .Academy of .Arts and Sciences, .American Philosophical Society. He has received many awards in science and business and 14 honorar\ doctorates. He has been chairman of the Board of the University of Pennsylvania, a member of the Business Council and the Business Roundtable, and a member of tlie boards of TRW, McDonnell Douglas. Estee I^uider, and Prudential Finance. He also sen ed as cochairman of the New Jersey Pertbrming .Arts Center and president and CEO of the .American School of Classical Studies in .Athens. He is chairman of Regeneron Pharmaceuticals and Thcravancc, two biotechnology companies. He is also chairman of the Board of Visitors at Columbia University Medical Center, where he chairs the capital campai^i. He senes on a number of public-policy and advisor> boards, including the Donald Danforlh Plant Science Center and Danforth Foundation.

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centurN tltrougli the Celtic Tiger economy of the 1990s.

R.V('HKL ('Ol’RTLAND is a research associate for the National Academies Committee on Science, Engineering, and Public Policy. She earned her B.A in physics from the University of Pennsylvania in May 2003 and her MS in physics from Emor\' University in 2004. In graduate school, she studied the local perturbation of supercooled colloidal suspensions using two-dimensional confocal microscopy and conducted preparatory work for a National and .Aeronautics Space .Administration PCS pa> load project. As an undergraduate, she led Women Interested in the Study of Physics, an organization created to help to foster a more comfortable environment for women scientists at undergraduate and graduate levels and dedicated to raising awareness of issues facing women in academe.

I.AURRL L.]I.\AK is a program officer for the National .Academies Committee on Science, Engineering, and Public PoIic>\ She received a BS and an MS in biology from Stanford I'niversity. She was the recipient of a predoctoral National Institutes of Health (NIH) National Research Ser\'ice Award and received a PhD in neuroscience in 1997 from Stanford University Medical School, where her research focused on calcium signaling iuid circadian rhythms. She was awarded a National Research Council research (issociateship to work at NIH on intracellular calcium dynamics in oligodendrocytes.

From 2002 to 2003. she was editor of Science's Ne.xt Wave Postdoc Network at the .American .Association for the .Advancement of Scienee. While a postdoctoral scholar, she was editor of the H'onien in Neuroscience new sletter and ser\ ed as president of the organization from 2003 to 2004. She is an ex officio member of the Society for Neuroscience Committee on Women in Neuroscience, has seiz ed on the Biophy'sics Society Early Careers Committee, and was an adviser for the National Postdoctoral .Association.

PI-ynCR inCNDF-RSON is director of the National .Academies Board on Higher FMucation and Workforce (BIIEW). His specializations include posLsecondary education, the labor market for scientists and engineers, and federal science and technology research funding. He oversees BHEW’s Evaluation of the Lucille P. Markey Trust Programs in Biomedical Science and .Assessment of NIH Minority Research Training Programs and super\ ises BHF^W' staff w orking on studies that examine the community-college pathw ay to engineering careers. He has contributed as a study director or stalT member to Building a li'orl^orce for the Information Economy. Measuring the Science and Engineering Enterprise: Priorities for the Division of Science Resource Studies. Attracting Science and Mathematics Ph.D.s to Secondary School Education. Monitoring

International Labor Standards, Trends in Federal Support of Research and Graduate Education, and Observations on the President's Federal Science and Technology Budget. I)r. Henderson holds a master's degree in public policy (1984) from IIar\'ard University's Joltn F. Kennedy School of Cio\'emment and a PhD in American political histor\' from the Johns Hopkins l^niversity (1994). He joined the National .Academies stall' in 1996 and is a recipient of the National .Academies Distinguished Service .Award (2003).

.K) L. IH'SB.AND.S is a senior project director with Development, Security, and Cooperation of the Policy and Cilobal .Affairs division. In that capacity, she is w orking on a project to engage the international scientific commiinih' in addressing the possibility that the results of biotechnology research w ill be misused to support terrorism or biologic weapons. She is also developing new projects related to defense economics and the proliferation of conventional weapoas and technologies. From 1991 througli 2004, she w as director of the National .Academies Committee on International Security and .Arms Control and its Working Group on Biological Weapons Control. Dr. Husbands is an adjunct professor in the security studies program at Cieorgetown University, where she teaches a course on ‘'Hie International .Arms Trade” She holds a PhD. in political science from the Uni\ ersily of Minnesota and a master's degree in international public policy (international economics) from tlie Johns Hopkins University School of .Advanced International Studies. She is a member of the .Advisors Board of Women in International Security and a fellow of the International Union of Pure iuid .Applied Chemislr> .

BKNJ.A.MIN .A. NOWVK (Policy Fellow) is pursuing his MS in public policy and management at Carnegie Mellon l^niversity. He recei\’cd his B.A in political science and his BS in biomedical engineering from the University of Pittsburgli, where he was a member of the l^niversity Honors College. .As an undergraduate student. .Mr. Novak had the unusual experience of completing internships in both technical and policy fields w orking in a \ ariety of places, including tlie US Congress, the House of Representatives Committee on Science, the Vascular Research Center of David Vorp. and the .Artificial Liver I.aborator>’ of Jack Patzer.

STFA'K OLSON is the author of Mapping Human History^ Genes, Race, and Our Common Origins (I loughton MitTlin), w hich w as one of five finalists for the 2002 nonfiction National Book .Award and receiNed the Science-in-Society .Award from the National .Association of Science Writers. His most recent book. Count DoM>n: Six Kids Vie for Glory' at the IVorld 's Toughest Math Competition (I loughton Mifilin), was named a best science book of 2004 by Discover magazine. He has written several other books, including Evolution in Hcm'aii and On Being a Scientist. I le has been a consultant writer for the National .Academy of Sciences and National Research Council, the I low ard Hughes Medical Institute, the National Institutes of Health, the Institute for Genomic Research, and many other organizations. He is the author of articles in The Atlantic .\fonthly. Science. The Washington Post. Scientific American, Washingtonian. Slate. Teacher, Astronomy. Science 82-86, ;md other magazines. I le also is coauthor of an article published in Nature in September 2004 that presented a fundamentally new perspective on human ancestr>'. From 1989 througli 1992, he seized as special assistant for communicatioas in tlie While Hoase Office of Science and Technology Policy. He earned a bachelor's degree in physics from Yale University in 1978.

.lOlI.N B. SL.ViNTNA (Policy Fellow) is a graduate student at the Georgia Institute of Technology (Georgia Tech) ;md a Christine Mirzayan Science and Technology Policy Fellow at the National .Academies. He is pursuing an MS in public policy, and his research encompasses the incoiporalion of innovative practices in the manufacturing sector and regional economic development. He previously received an MS in mechanical engineering at Georgia Tech in 2002, where he pertbrmed research in sensor design for bioengineering applications. During the 2000-2(X)l school year, he .studied engineering at the Ecole Nationale Superieure d'.-Vrts cl Metiers in Metz, France. He earned his undergraduate degrees in mechanical engineering and mathematics from Y oungstow n State finiversity in 2000.

Appendix B

TASK STATEMENTS

STATEMENT OF TASK

This congrcssionally-rcqiicsicd study will address the following questions:

\Miat are the tup 10 artiuns, in priority order, that federal policy makers could take to enhance the science and technology enterprise so the liiited States ran snrressfully compete, prosper, and be secure in the global ronnnuiiity of the 21st (entury ?

hat implementation strategy, w ith several concrete steps, conid be used to iniplement each of those actions?

Bnited States Senate

WASHINGTON, DC 20510
May 27, 2005

Dr. Bruce Alberts
President

National Academy of Sciences
2I01 Constitution Avenue
Washington, DC 20418

Dear Dr. Alberts:

The Energy Subcommittee of the Senate Energy and Natural Resources Committee has been given the latitude by Chairman Pete Etomenici to hold a series of hearings to identify specific steps our government should take to ensure the preeminence of America's scientific and technological enterprise.

The National Academies eould provide critical assistance in this effort by assembling some of the best minds in the scientific and technical community to identify the most urgent challenges the United States faces in maintaining leadership in key areas of science and technology. Specifically, we would appreciate a report from the National Academies by September 2003 that addresses the following:

• Is it essential for the United States to be at the forefront of research in broad areas of science and engineering? How does this leadership translate into concrete benefits as evidenced by the competitiveness of American businesses and an ability to meet key goals such as strengthening national security and homeland security, improving health, protecting the environment, and reducing dependence on imported oil?

What specific steps are needed to ensure that the United States maintains its leadership in science and engineering to enable us to successfully compete, prosper, and be secure in the global community of tbe 21st century? How can we determine whether total federal researeh investment is adequate, whether it is properly balanced among research disciplines (considering both traditional research areas and new multidisciplinary fields such as nanotechnology), and between basic and applied research?

• How do we ensure that the United States remains at the epicenter of the ongoing revolution in research and innovation that is driving 21st century economies? How can we assure investors that America is the preferred site for investments in new or expanded businesses that create the best jobs and provide the best services?

• How can we ensure that critical discoveries across all the scientific disciplines are predominantly American and exploited first by firms producing and hiring in America? How can we best encourage domestic firms to invest in invention and innovation to meet new global competition and how can public research investments best supplement these private sector investments?

• What specific steps are needed to develop a well-educated workforce able to successfully embrace the rapid pace of technological change?

Your answers to these questions will help Congress design effective programs to ensure that America remains at the forefiont of scientific capability, thereby enhancing our ability to shape and improve our nation’s future.

We look forward to reviewing the results of your efforts.

Sincerely,

Lamar Alexander
Chairman

Energy Subcommittee

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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

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June 30, 2005

Dr. Bruce Alberts
President

National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Dear Dr. Alberts:

We understand that the National Academies, in response to a request from Senators Alexander and Bingaman, are in the early stages of developing a study related to the urgent challenges facing the United States in maintaining leadership in key areas of science and technology. Because the Science Committee considers ensuring the strength and vitality of the Nation’s scientific and technology enterprise an important part of its broad oversight responsibility, we are writing to endorse the request for this study and to encourage the National Academics to carry it forward expeditiously.

In addition, we would like to suggest some specific questions we hope to see addressed by the study:

• What skills will be required by the future U.S. science and engineering workforce in order for it to command a salary premium over foreign scientists and engineers? Are alternative degree programs needed, such as professional science masters degrees, to meet the needs of industry and to lead to attractive career paths for students?

• Are changes needed in the current graduate education .system, such as: a different mix in graduate support among fellowships, traineeships and research assistantships; and more research faculty positions and fewer postdocs and graduate students in traditional graduate programs?

• Should a greater proportion of federal research funding be allocated to high-risk, exploratory research and should funding priorities among broad fields of science and engineering be readjusted?

• What policies and programs will help ensure the rapid flow of research results into the marketplace and promote the commercialization of research in a way that leads to the creation of good jobs for Americans?

The Committee looks forward to reviewing the results of this effort, and hopes that a draft response would be available by September 30, 2005. We hope that the new and innovative ideas you produce as the result of this effort will be able to translate into policies that will enhance U.S. prosperity in the 21st century If you have any questions, please contact Dan Dyers of the Majority Staffer Jim Wilson of the Minority Staff

Sincerely,

-f

SHER\V»OD roKHLERT
Chairman

Ranking Member

Appendix C

FOCUS GROUP SESSIONS
AUGUST 6, 2005

llie Committee on Prospering in the Global Hconomy of the 2l8t Centuiy convened focus groups on Saturday, August 6, 2005, from 9 am to 4 pm. The purpose of the focus groups was to gather experts in five broad subjects K* 12 education, higher education, science and engineering research, innovation and workforce, and national and homeland security' to provide input to the committee on how the United States can successfully compete, prosper, and be secure in the global community.

Kach focus-group participant was provided background on the committee members and on other focus-group members. 13 issue papers (sec Appendix D) that summarized past reports on the various topics that were discussed, and a list of recommendations gleaned from past reports and interviews with committee and focus-group members.

llie charge to focus-group participants is listed in full on page 0-3. Mssentially. each group was asked to deline and set priorities for the lop three actions for its subject that federal policy-makers could lake to ramp up the innovative capacity' of the l.'niled .Stales. Each focus group w as chaired by a member of the committee, who presented the group's priorities to the tiill committee during an open discussion session. I'he content of those prescnlaiioas is listed starting on page C-4. Focus group-biographies are listed starting on page C-9.

Agenda

Focus Group Meeting

August 6, 2005

Keck C enter of the National Academies
5<)() 5“" Street, N\\
^^'ushillgt(lll, DC

9:00 Continental Breakfast Available (R<Mini 100)

9:30 Study Overview and Charge to Focus Croups

Sorman Augustine^ (hair, Connnittee on Prospering in the Clobal Kcononiy of the 21”* Centuiy

10:00 Focus Croups Meet

K-12 Education

Room 110

Roy 1 agelos. Chair

Higher Education

Room 101

Chuck test. Chair

Research

Room 201

Dan Mote, Chair

Inn(»vation

Room 204

Oail Cassell, Chair

Socuritv

Room 105

Anita Jones, (hair

12:00 Lunch (Available in meeting rooms)

2:45 Break (Move to Kooni 100)

3:00 F’ocus Croups Report on Results of their Deliberations (Room 1(K))
4:00 Adjourn

Focus CfPoup Charge

ITic Committee on Prospering in the Global Economy of the 21** Century would like to thank you for helping it in its important Ia^^ to address the following queslioas:

U'hat are the top 10 actions, in priority order, that federal policy makers could take to enhance the

science and technology enterprise so the I'nited States can successfully compete, prosper, and be secure in the global community of the 21st ('entury? What implementation strategy, with several concrete steps, could be used to implement each of those actions?

Your rdc. as a focus group participant, is to help the committee, in your area of expertise;

• Identify existing ideas the federal government (President, Congress, or federal agencies) could take, fhe ideas should not be to general they need to be sulliciently actionable that they could be turned into congressional language.

• Brainstorm new ideas

• Evaluate all ideas

• lYioritize all ideas to propose to the committee the top 3 actions the federal government could lake so that the I’nited Slates can successfully compete, prosper, and be secure in the global community of the 21^ century.

Since there arc 5 focus groups, wc expect a total of 1 S prioritized recommendations to result from the focus group session wliich will be presented and discussed at a plenary session at the end of the da y.

Ilicse 1 5 recommendations that would then be used by the committee as input to its decision-making process as it comes up with a "lop 10” list on Sunday.

Each focus group is chaired by a committee member and has a staff member with expertise in the issue and a S&T policy fellow (graduate student) to assist them. Tlie staff is available to put toget her any action list that is produced (no summary' of the discussion is planned).

In evaluating each proposal, here are some evaluation criteria to keep in mind;

Minimum Selection C'riteria

• C'an the actions be taken by those who requested the study? Ilic President, Congress, or the federal agencies?

Evaluation Criteria

• ('ost — What is a rough estimate of how much the action will cost? Is the cost reasonable relative to the financial resources likely to be available? Can resources for this action be diverted from an e.x isling activity as opposed to “new money”?

• Impact — Which degree of impact is the action likely to have on the problem of concern?

• Cost-cffectivcnes-s Which actions provide the most “bang for the buck"?

• fimeframe What is the desired timeframe for the action to have an impact? Is Ute action likely to have impact in the short or long-term or both?

• Distributional EffccLs Who are the winners and the losers? Is this the best action for the nation a s a tvhole?

• Ease of Implementation To what degree is the challenge easy, medium, or hard to implemcml?

• History- Has the action been suggested by another committee or policymaker before? If so. why has it not been implemented? Can the challenges be overcome this time?

• Is the Moment Right for this Action? .Are they likely to be viable in the near-term political and policy context?

K'12 Kducatiun Focus Group Top Recommendation Sumnian
Roy Vagelos, CViair

Sational Objectives

• Lay a foundation for a worklbrce that is capable in science, technology, engineering, and mathematics (STEM) including those who can create, support, and sustain innovation.

• Develop a society that embraces STEM literacy.

• Develop and sustain K-12 teacher corps capable of and motivated to teach science and mathematics.

• Establish meaningful mea.sures.

Top Recommendations

1. The federal government should provide peer-reviewed long-tenn suppoil for prognims to develop and suppoit a K-12 teacher core that is well-pi'epai'ed to teach S TKM subjects.

a. Programs for in-serN ice teacher development tliat provide in-depth content and pedagogical knowledge: some examples include summer programs. Master's programs, and mentor teachers.

b. Provide scholarship funds to in-ser\'ice teachers to participate in summer institutes and content-intensive degree programs.

c. Pro\ ide seed grants to universities and colleges to provide summer institute and content-intensive degree programs for in-service teachers.

2. Establish a program to encourage undergraduate students to major in S I'EM and teach in K-12 for at least 5 years. The program should include support mechanisms and incentives to enable teacher retention.

a. Prov ide a scholarship for joint STEM bachelor's degree + teacher certification program. Mandate a service requirement and pay a federal signing bonus.

b. Encourage collaboration between STEM departments and education departments to train STM K-12 teachers.

3. Provide incentives to encourage students, especially mimuities and women, to complete STM K-12 coursevvork, including

a. Monctarv' incentives to complete advanced coursework.

b. Tutoring and alter school programs.

c. Siunmer engineering and science academies, internships, and research opportunities.

d. Support school and ciuTiculum organization models (state-wide specialty schools, magnet schools, dual-enrollment models, and the like).

4. Support the design of state public sch(H>l assessments that measure necessarv workplace skills to meet inmwation goals and ensure No (hild Left Behind a.sst'ssments include these goals.

5. Provide support to research, develop, and implement a nm generation of instructimial materials (including textbooks, modules computer programs) based on research evidence on student learning outcomes, with vertiral alignment and coherence across assessments and framew orks. Link teacher dev elopment and curricular development.

K-12 Focus (>roup Participants

Roy N’agelos, retired Chair

Carolyn Bacon. Executive Director, O’Donnell Foundation
Susan Bcr.irdi, Consultant

Rolf K. Blank, l>irector of Education Indicators. Council of Chief Stale School Ofllcers
Rodger Bybee. Executive Director, Biological Sciences Curriculum Study
Ilai'Eung Dai. Hirschmann-Makineni Chair Professor of Chemistry, University of Pennsylvania
.loan Ferrini-Mundy, .Associate Dean for Science and Mathematics Education and Outreach, College of Natural Science, Michigan State University
Bruce Fuchs. Director, Oftlce of Science Education. National In.stitutes of Health
Ronald Marx. Professor of Educational Psychology and Dean of Education. University of .Arizona

l>a^id Monk. Professor of Educational .Administration and Dean of College of Education, Pennsylvania State University

C arlo Parravano. Executive Director, Merck Institute for Science Education
.Anne f'. Petersen. Senior Vice President for Programs. W.K. Kellogg Foundation
Helen Quinn. Physicist. Stanford Linear .Accelerator Center, Stanford University
Deborah Roudebiish, Physics Teacher. Fairfax County Public Schools
Daniel K. Rubenstein, Mathematics Teacher, New York City Collegiate School
J. Stephen Simon, Senior Vice President, Ex.xon .Mobil Corporation

Higher Education Focus Group Top Recoiiiineiidatioii Suninian
Charles \'est. Chair

Xationai Objective

Ihc US should lead in the discoverv' of new scientific and technological knowledge and its efficient translation into new products and serN ices in order to sustain its preeminence in technolog> -based industr\ and job creation.

Our higher education system has a critical role in meeting this objective.

Rei ommen Jah on

We recommend that Congress enact the Innovation Development Education and Accelenition Act (The IDEA Act). Its purpose is to increase the number of I'.S. students, consistent with our demography, w ho will become innovation leaders: professional scientists and engineers; and science, mathematics, and engineering educators at all levels.

/. Vnderftraduate Education: Increase the number and proportion of citizens who hold STEM degrees to meet international benchmarks. Le. migrate, over Jive years, from 5% to lO^o of earned first (bachelor' s-tevel) degrees.

a. Provide competitive multi-agency (non-thematic) scholarships for undergraduates in science, engineering, mathematics, technology, and other critical areas. Tlie scholarships would carr>' with them supplemental support for pedagogical innovation for the departments, programs, or institutions in which the students study. This program should support students at 2-year and 4-year colleges and research universities.

2. Graduate Education: Increase the number of VS graduate students in science, engineering, and mathematics programs ut areas of strategic national needs.

a. Create a new multi-agency support program for graduate students in SlI'AI areas related to strategic national needs. This support should include and appropriate mix of competiliv e portable fellowships and competitive training grants.

3. Faculty I*reparation and Support: Support the propagation of effective and creative programs that develop scientific and technological leaders who understand the innovation process

a. Support workshops, preparation of educational materials, and experience-based programs.

4. Create global scientific and technological leaders.

a. Provide a globally-oriented education and opportunity for US students, and maintain the US as the most desirable place to pursue graduate education and or scientific and technological careers.

b. IX'fine the policies that will maintain our long-term security and v itality througli the openness of .American education and research and the free flow of talent and ideas.

Higher Kducation Focus Group

C huck Vest, Chair

M.R.C-. Greenwood, Provost mid Senior N ice President for Academic .Wairs. University of California

Daniel Hastings. Professor of .Aeronautics and .Astronautics and Engineering Systems, Massachusetts Institute of Technology

Randy H. Katz, United Microelectronics Corporation Distinguished Professor in Electrical Engineering and Computer Science, University of California, lierkeley
(ieorge M. Langford, E. E. Just Professor of Natural Sciences and Professor of Biological Sciences. Dartmouth College

Joan F. Lorden. Provost and Vice Chancellor for .Academic .Affairs, University of North Carolina-Charlotte

Claudia Mitchell-Kcman. \ ice Chancellor for CJraduate Studies and Dean of Graduate Division, University of California, Los .Angeles
Stephanie Pfimian. Chair, Department of Environmental Science, Barnard College
Paul Romer, ST.ANCO 25 Professor of Economics. Ch'aduate School of Business, Stanford University

Janies M. Rosser. President and Professor of Health Care Management, California State I’niversity, Los .Angeles

Tim Steams. .Associate Professor of Biological Sciences and Genetics. Stanford University
Debra Stewart. President, Council of Graduate Schools

Orlando L. Taylor, Vice Provost for Research, Dean of Graduate School, and Professor of Commiuiicalions. Howard University

Isiah .M. ^^■amel^ Vice Chancellor for Strategic Initiatives. Louisimia Slate University
Dean /.oilman. University Distinguished Professor, Distinguished University Teaching Schohir, and Head of Department of Physics, Kansas State I 'niversitN

Research Focus (*roup Top Recommendation SummaiT

Dan Mote, Chair

Sational Objective

.America's leadership in S&T has created our prosperity, security and health. That leadership is now threatened. Our leadership resulted from a long-term investment in basic research. In order to keep our leadership position we must re\italize our investments, particularly in the physical, mathematical sciences and engineering.

Hecommendations

1. Set the federal research budget to 1% of GDP within the next five years to su.stam TS

leadership in innovation for prosperity, security and quality of life

a. .Address 21st centurx' global economy grand challenges in energy , security, health and environment through interagencx initiatives

b. Bring phx'sical .sciences, engineering, mathematics, and information science up to the levels of health sciences

c. .All agencies would expand their basic research programs

d. Replace decaying infrastnicture in universities, national labs and other research organizations

e. Longer-term, stable funding

2. To foster bi'eakthroughs hi science and technology, allocate at least 5% of fe<leral

agency research poilfrdios to high-risk basic research

a. .Allow for discretionary distribution for basic research with program oversight

b. Provide at least five years of adequate support for early-career researchers

c. Provide technical program managers in federal agencies with discretionary' funding

3. Make S&'f an attractive career to the best and the brightest

a. C'reate an undergraduate loan forgiveness program for students who complete a PhD in S&T and work as STEM researchers (e.g. $25,000 per year)

b. Create training grants for graduate iuid post-graduate education across federal research budgets

c. Provide five years of transition funding for early career research

d. Cultivate K- 1 2 students to careers in science and teehnologx

e. Actively recruit and support the world's best students and researchers and make it attractive for them to stay: address problems with visas, deemed exports and other barriers

Research Focus (>roup

Dan Mote, President. University of Man. land. Chair

Paul Aver}, Professor of Physics, University of Florida
(ian Bachula. Vice President for Kxtemal Relations. Inteniet2

Angela Belcher. John Chipnian .Associate Professor of Materials Science iuid Engineering and Biological Engineering. Massachusetts Institute of Technology
Elsa M. Gamiire. Sydney E. Jenkins Professor of Engineering. Dartmouth College
Heidi K. Hamm, Earl \V. Sutherland. Jr, Professor and Chair of Pharniacologv', Vanderbilt University

Mark S. Humayun. Professor of Ophthalmology, Biomedical Engineering, and Cell and Neurobiology, University of Southern California
Madeleine Jacobs. Executive Director ,'uid Chief Executive OlTicer, .American Chemical Society
Cato T. 1 .aureiicin. Lillian T. Pratt Distinguished Professor and Chair of Department of Orthopaedic Surger\‘. University of Virginia
Da> Id La\’an. .Assistant Professor of Mechanical Engineering. Yale I’niversily
Phillip LeDuc. .Assistant Professor of Mechanical Engineering. Carnegie .Mellon University
Dcirdrc k. Meldruni. Professor and Director of Cicnomation Laboratoiy, Department of I Jectrical Engineering. University of Washington

Innovation and \\'orkforce Focus (iroup Top Reconiniendation Suniman (vail C'assells, Chair

National Objective

Accelerate the process of innovation to:

• Solve national problems

• Create and retain well-paying jobs

• Ensure prosperity

Recommen dation s

1. Tax Poliev': Make the R&D tax crcHlit pi'mianent, and extend coverage to research conducted in unixersity-iiidustrv consortia

2. National Faiergx' Initiative

a. Sharp increase in agency R&D related to energv' prosperity

b. National Energy Prosperity fellowships

c. Cabinet-level National Council on Energx Prosperity

3. National Agency for Innovation

a. New independent, project-based agency, reports to president

b. University-industiy projects on specific goals

c. Broad. non-militar\'. national interest

d. $3-5 billion per year

e. Outputs: functional prototypes and processes, training, monitoring of U.S. innov ation and competitiveness

f. Issues to resolve: metrics, intellectual property (IP), governance

4. Stimulate interest of young people in S&T

a. National scholarships program for first-generation college students who major in S&E

b. Scholarship recipients available for national S&E role models program to explain to elementary and secondary students what tliey do and how success in school prepared them

Innovation and W'oHiforce Focus (vroup

(iail Cassell, V ice President of Scientific .-UTairs and Distinguished Lilly Research Scholar for Infectious Diseases. Eli Lilly and Compan>, Chair

Miller Adams. \’ice President. lioeing Technolog\ Ventures

Robert J. .Viken. Director of Engineering, International .Academic Research and fechnology Initiatives. Cisco Systems, Inc.

Ron Hlaclovell. Chief Economist, .American Federation of I.abor and Congress of Industrial I'nioas (AFL-CIO)

Craig Blue. Distinguished Research Engineer and Group Leader, Materials Processing Group.

Metals and Ceramics Division. Oak Ridge National Laboratory

Susan Butts. Director. External Technology, Dow Chemical Company

Paul (Itron, Vice l*resident (retired). Technology Polic>' and .Academic Relations, Medtronic, Inc.

Chad Kvan.s, Vice President, National Innovation Initiative. Council on Competitiveness

Kent II. Hughes. Director, Program on Science. Technology. .America and the Global Economy, Woodrow Wilson Intemational Center for Scholars

.Manin Rosters. Resident Scholar, .American Enterprise Institute

Mark B. .Myers. \'i.siting E.xecutive Professor of Management. Wharton School of the I 'niv ersit> of Pennsylvania

.lullana C. Shei. Global Technologx' Manager, General Electric

Nancy \'orona. Vice President, Research Investment. Virginia's Center for Innovative fechnology

Caroline S. M’agner. Researcher, Center for Intemational Science and Technology Policy, George Washington University

Nationul uiid lloiiielaiKl Si'curity Gtx>up Focus Group Top Rccoinmciidation Summani

Anita Jones, Chair

O'iohalizafion is a fact of life

• Science and technology (S&T) provides our qualitative national security advantage

• S&T enables our prosperity, which in turn Hnances strong security

• S&T increasingly originates abroad

• Isolation damages our security and our economy

• Need to engage \\ ith and ensure access to innovators and innovation abroad

SatUmal Objectives

• Stimulate innovation and its adoption to sene security

• Rebalance Security S&T Research Funding Invested in [Basic Research

• Accelerate creation of knowledge in the US and acquisition of knowledge from abroad

• Attract and retain global best and brightest

Oily tlie federal goveniment can provide the framework strategy for balancing contending national interests.

Hecomtnen dati on s

1. To stimulate innovation and its adoption to seiA'e security, create new mechanisms to discover, dex eiop. and exploit new ideas

a. l.cgal refomi - extend liability protection for homeland security providers

b. Create new prototypes for university-industry-nalional lab partnerships

i. Experiment with mix of funding mechanisms, e.g. SEMA'IIlCTI. InQTel. for security

ii. Streamlined, standardized IP provisions based on best practices for universities and national labs

2. To rebalance security S&'f research funding invested in basic research, dedicate 3 percent of national defense homeland security budget to S&T and 20°o of S&T budget to long-temi research.

a. Cost: A of $ in research spending

b. Caveats concerns; Need institutional champion in each agency?

3. Create a single national strategy’ to attract and retain llie global best and brightest to US S&T enterprise

a. Increase support for the National Defense Education Act (NDEA-21)

i. Double the number of US students going into S&E and related security fields

ii. Pro\ ide a national sen ice educational benefit incentive

b. Redesign visa, deemed export, and immigration policies to attract and retain foreign talent

National and Honudand Security Focus (>roup

Anita Jones* Lawrence R. Quarles Professor of Engineering and Applied Science. University of

Virginia. Chair

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the biggest impact in chemisln' in the next centur>' by Chemical and Engineering News and was runner-up for InnoN ator of the Year and runner-up for Researcher of the Year by Small Times Magazine, and finalist for Scientist of the Year by IVired nxigazine. She is a 2001 Packard Fellow, 2001 Alfred P. Sloan Research Fellow, and has received the 2000 I^esidential Early Career Award for Science and Engineering, 2000 Heckman Young Investigator Award, 1999 HuPont Young Investigator Award, and a 1999 Army Research Office Young Investigators Award.

SrSAN BKU.VRDI worked in management andc*mployee de\elopment for nearly lOyears before leaving corporate America to become a full-time mother of three young boys. At such companies as FMC Defense Systems, Motorola, and IDX Systems Corporation, she worked with managers and technical teams to improve the intangible assets that drove performance and bottom-line results. In addition to one-on-one executive coaching, she facilitated and trained numerous technical teams to resolve customer-service and team-performance issues that were hindering company profitability. She also designed selection and retention programs to attract and keep best-in-class technical and managerial talent. As an independent consultant, Ms. Herardi provided leadership training and facilitation for several start-up technology companies in Massachusetts and California. She has been a guest speaker for the Society of C'oncurrent Engineering and the International Council on Systems Engineering. Most recently, Ms. Derardi has been working pro bono for the Reading and North Andover School Districts in Massachusetts, facilitating administrative retreats and bringing teachers and parents together to improve student reading, mathematics, and arts capabilities. She worked with school administrators to create a tool to measure and improve the return on investment of a school district. She has also w ritten several articles on behalf of these schools in an efTort to educate ta.xpayers on budget and curriculum issues, special-education costs and legal requirements, and the importance of foreign languages and the arts in early education. Ms. Derardi has an MA degree in labor relations and a DA from the Universit>' of Illinois.

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She has chaired the National Council of Teachers of Mathcmatics'(NCTM) Research Advisory C'ommittee and the .American Educational Research .Association in Special Interest Group for Research in Mathematics Education, and she was a member of the NCTM Board of Directors. Dr. Ferrini-Mundy came to MSU in 1999 from the National Research Council's Center for Science. Mathematics, and Engineering Education, where she served as director of the .Mathematical Sciences Education Board. Her research interests are in calculus learning and K-14 mathematics-education reform. She chairs the writing group for Standards 2000, the revision of the NCTM standards.

KFv.NNFyiTI FL.A.M.M is the Dean Rusk Professor of International .Affairs at the Lyndon B. Johnson School of Public Affairs at the University of Texas at .Austin. EarlicT. he w orked at the Brookings Institution in Wasliington, DC, where he served for 1 1 years as a senior fellow in the Foreign Policy Studies Program. He is a 1973 honors graduate of Stanford University and received a PhD in economics from the Massachusetts Institute of fechnologv' in 1979. From 1993 to 1995, Dr. Mamm served as principal deputy a.ssi$tant secretary of defense for economic $ccurit>' and special assistant to the deputv' secrctarv' of defense for dual use technology policy. He was awarded the departmenfs Distinguished Public Service Medal by Defense Secrctaiy William J. Perrv- in 1995. Dr. Mamm has been a professor of economics at the Instituto Tecnologico de Mexico in Mexico Cit>\ the University of Massachusetts, and George Washington University. He has also been an adviser to the director general of income policy in the Nlexican Ministn, of Finance and a consultant to the Organisation for Economic C'o-operation and Development, the World Bank, the National Academy of Sciences, the Latin .American Economic System, the US l>epartment of Defense, the US Department of Justice, the US .Agency for International Development, and the Office of I'echnology .Assessment of the US Congress. He has played an active role in the National Research Council's committee on Govemment-Industiy Partnerships and played a key roie in that committee's review of the Small Business Innovation Research l^ogram at the Department of Defense. Dr. F1amm has made major contributions to our understanding of the growth of the electronics industry, with a particular focus on the development of the computer and the US semiconductor industry. He is working on an analytic studv- of the post-Cold War defense industrial base and has e.xpert knowledge of intematiorul trade and high-technologv' industry issues.

BRl^C'Fy Fl'C'IIS, an immunologist who did research on the interaction between the brain and the immune system, is the director of the National Institutes of I lealth (Nil I) Office of Science Education. Dr. Fuchs directs the creation of a scries of K-12 science-education curriculum supplements that highlight the medical research findings of NIH. The supplements are designed to meet teacher educational goals as outlined in the National Science Education Standards and are available free to teachers across the nation.

Ilic office is also creating innov ative science and career-education Web resources that will be accessible to teachers and students with a varietv' of disabilities. Before coming to Kill, Dr. Fuchs was a researcher and teacher at the Medical College of \'irginia with grant support from the National Institute of Mental Health and the National Institute on Drug Abuse. He has a BS in biology from the University of Illino

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career in its R&D organizations. He was the senior vice president in charge of corporate research, advanced development, systems architecture, and corporate engineering from 1992 to 2000. During this period he was a member of the senior management committee in charge of the strategic direction setting of the company. His respon-sibilities included the corporate research centers: P.-VRC in Faio .Alto, California; the Webster Center for Research and Technology near Rochester. New York; the .Xerox Research Centre of Canada, Mississauga, ( )ntario; and the Xerox Research Centre of Europe in Cambridge. England, and CTrenoble, France. l>r. Myers is chairman of the Board of Trustees of Eaiiham

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campus-wide student support and fellowship programs, and graduate academic affairs and works to ensure that standards of excellence, fairness, and cquitv* are maintained across all graduate programs. She is concurrently a professor in the Departments of .Anthropologv and Fsychiatiy and Biobehavioral Sciences. She received her PhD from the Universitv* of California. Berkeley and her B.A and NLA from Indiana Universitv* and was a member of the facult)* at Harvard University before coming to UCLA in 1973. Much of Dr. Mitchell-Keman’s early work was in linguistic anthropologv*. and her classic sociolinguistic studies of black communities continue to be widely cited. Her most recent book, Tlw Decline in Marriage among African Americans, cuedited with M. Belinda fucker, was published in 1995 by Russell Sage. Other books on children's discourse, television and the socialization of ethnic-minoritv* children, and linguistic patteras of black children reflect the breadth of her scholarly interests. She conducts research on marriage and family-formation patterns in the United States among .Americans and West Indian immigrants. Iltroughoui her career, she has maintained an active record of service to federal agencies that sponsor research. President Clinton appointed her to the National Science Board (NSB) for a 6-year term in 1994. .At the national level, she is serving as the dean in residence for the Council of Graduate Schools (CGS), is on the Board of Higher Education and Workforce of the National Research Council, and is on the Board of Directors of the Consortium of Social Science Associations. She has recently served on the Board of Directors of the CGS and chaired its .Advisorv* Committee on Minorities in Graduate Education, as chair of the Board of ITirectors of the Graduate Record Examination, on the .Advisory Board of the National Securitv* Education Program, and on the Board of Deans of the African .American Institute. She has been a member of the Board of I>irectors of the Los .Angeles-based Golden State Minoritv* Foundation and the Board of Directors of the Venice Family Clinic.

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(.’ARIX) PARR.\\'AN() has serv ed as executive director of the Merck Institute for Science Kducation since 1992. He is responsible for the planning, development, and implementation of numerous initiatives to improve science education. Before assuming that positioa Dr. Parravano was professor of chemistrv'

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While at SUN^’ Purchase, he taught courses In general, physical, analytic, and environmental chemistrv’. In addition to his academic and administrative appointments, he served as director of the Center for Mathematics and Science Education of the SUN\’ Purchase* Westchester School Partnership. Dr. Parravano is a recipient of the SUNT Chancellor’s Award for Excellence in Teaching. In 1S>99, he was elected an American .Association for the .Advancement of Science (A.AAS) fellow; and in 2003, he received the National Science Teachers Association's (KSTA) Distinguished Service to Science Education Award. In 2004, he was designated a national associate of the National .Academy of Sciences

and appointed to the Steering Committee for the 2009 National .Assessment of Educational Progress in Science. I>r. Parravano earned a B.A in chemistrv' at Oberlin College and a PhD in physical chemistrv' in 1974 at Universitv' of California at Santa Cruz. His research has been in molecular-beam studies of excited atoms and molecules and the application of physical-chemical techniques to the solution of biochemical and environmental problems. Dr. Parravano is a member of a number of professional organizations, including the AAAS (chair. Education Section, 2003), the .American Chemical Societv’, and the NSTA. He served as founding vice chair of the New Jersey Professional Teacliing Standards Board (1999-2003) and as cochair of the New Jersey Science Curriculum Standards Group. He is a member of the Natioital Research Council's Board on Science Education (H.xecutive Committee) and is on Ute advisorv' boards of the National Science Resources Center, Biolr^ical Sciences Curriculum Study (chair), and the New Jersev’ Business Coalition for Educational Excellence. In 200S, Dr. Parravano was appointed to the New Jersey Mathematics Task Force and to the Qualitv' Teaching and Learning Task Force. He also serves as principal investigator for a National Science Foundation-funded mathematics-science partnership award.

ANNE C-. PFn'ERSEN is the senior vice president for programs at the W.K. Kellogg Foundation of Battle Creek, Michigan. As a senior member of the executive staff since 1S>96, she provides leadership for all programming, including the development of effective programming strategies, teamwork, policies, philosophies, and organization wide systems to accomplish the programmatic mission of the foundation.

Previously, Dr. Petersen was deputv’ director and chief operating officer of the National Science

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STFvPH.V.NIE PFIRNLAN chairs the Department of Environmental Science at Barnard College. Her current research interests include environmental aspects of sea ice in the Arctic, interdisciplinarv' research and education, and advancing women scientists. .As the first chair of the National Science Foundation (NSF)'s .Advisorv' Committee for Environmental Research and Education. Dr. Pfirman oversaw analysis of a 10-year outlook for environmental research and education at NSF. She is also one a co-principal

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DANIEL B. PONEMA.N is a principal of The Scoweroft Group, which provides strategic advice to the group clients in the eneigv', aerospace, information-technology, and manufacturing indastries, and others. For 9 years, he practiced law in Washington, DC, assisting clients in a wide variety of regulatory and policy matters, including e.xport controls, trade policy, and sanctions issues. From 1993 tlirough 1996, I>r. Poncman served as special a.ssistant to the president and senior director for nonproliferation and export controls at the National Security Council (NSC), with responsibilities for the development and implementation of US policy in such fields as peaceful nuclear cooperation, missile-technology and space-launch activities, sanctions determinations, chemical and biologic arms-control efforts, and conventional-arms transfer policy. During that period, he participated in negotiations and consultations with governments in Africa, Asia, Europe, Latin America, and the fonner Soviet Union. Dr. Poneman joined the NSC staff in 1 990 as director of defense policy and arms control after service in the I>cpartmcnt of Energy’. He has served as a member of the Commission to Assess the Oigani/ation of the Federal Government to Combat the Proliferation of Weapons of Mass Destruction and other federal advisory panels. He received .AB and JD from Harvard University and MLitt in politics from Oxford University. I>. Poneman is the author of books on nuclear-energy policy, Korea, and Argentina and is a member of the Council of Foreign Relations.

HE'LEN R. QUINN started her college career at the University of Melbourne, Aastralia. Two years into her degree, she moved to the U'nited States and joined the physics department of Stanford University, where she completed both her BSc and a PhD in physics. After a postdoctoral fellowship at Deutsche Elektronen-Synchrotron in Hamburg. Ciermany, she briefly taught high-school physics and then joined the stair and then the faculty of Harvard University. A few years later, she returned to Stanford to join the Stanford Linear .Accelerator Center and she has been there since 1977. Her research concentrates on theoretical particle physics with a focus on phenomenology of the weak interactions; she is involved in outreach activities to encourage interest in physics. Her work with Robert Peccci resulted in what is now known as the Pcccei-Quinn symmetry. Dr. Quinn was president of the .American Physical Society for 2003. She was named a fellow of the .American .Academy of .Arts and Sciences in 1996 and was elected to the National .Academy of Sciences in 2(X)3. She was awarded the ITirac Medal of the International Centre for Theoretical Physics in 2000 for her work with Peccci and in the (3eorgi-(^inn-Wcinberg computation of how different types of interactions may be unified. In addition to her research Dr. Quinn has

maintained a steady involvement in precollcgc education, working chiefly with local efforts to improve
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P.VUL ROME'R is the STANCO 25 Professor of Economics in the Graduate School of Business at
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foundation for business and government thinking about the dynamics of wealth creation. It addresses one
of the oldest questions in economics; What sustains economic grow th in a physical world characterized

h>' diminishing returns and scarciu? It also sheds new light on current economic issues. Among these. Dr.
Romer is studying how government policy affects innovation and how' faster technologic change might
influence asset prices. Dr. Romer was named one of .America’s 2S most influential people by magazine in
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J.VMKS M. ROSSF'R has scr\'cd os president and professor of health care management at Califonua Stale University, Los .Angeles since 1 979 and as professor of microbiology since 2004. He has served in many civic and community organizations, including the Los .Angeles .Area Council of the Boy Scouts of .America, the Los .Angeles County .Alliance for College Ready Public Schools, the California Chamber of Commerce, .Americans for the .Arts, Community Television of Southern California (KCET). Los .Angeles .After-School Education and Child Care Program"L.A's BEST, the Music Center Performing .Arts Council Education Council, and the California Community Foundation. His professional adilialions have included the .American .Association of Stale Colleges and Universities, the .American Council on Education, the Western .Association of Schools and Colleges, the Woodrow Wilson National Fellowship Foundation, the California Council on Science and Technology. Edison International, the United California Bank, the FEDCO. Inc. Foundation, and numerous committees and commissions of the California Stale University system. He is a past chair of the Education and Human Resources .Advisory Committee of the National Science Foundation. He was chair of die National .Academy of Engineering Forum on Diversity in the Engineering Workforce in 2000-2002.

I)KBOR.\H M. ROl DF'Bl'SH has been a physics teacher for 21 years. She holds national board certification in adolescent and young adult science. She was a 2001 Presidential .Awardee for Excellence in Science Teaching. She ha.s been a physics-teacher resource agent through the .American .Association of Physic.s Teachers since 1992 and is the associate member for A'irginia to the National .Academy of Sciences Teacher .Advisory Council. She has been a reader for advanced placement for computer science and physics since 1996. She has a keen interest in physics-education research and the implications for improving physics teaching at all levels, she is an advocate for the importance of physics and science education for all students to enable data-driven decision-making at all levels of government.

D.VNIEL K. Rl'BENSTEIN is currently the head of the Mathematics Department at Collegiate School in New York City. He has worked in secondary education for 13 years. His first faculty position was teaching mathematic at Sidweli Friends School in Washington. DC. In addition, he spent a semester as assistant director and mathematics teacher at School Year .\hroad Beijing. .Afler 8 years of indepcndent-sch(K>l teaching, a Sidweli alumnus recruited Mr. Kubenstein to help build the mathematics program of the fledgling SHED Foundation Public C'harter School in southeast Washington. DC, w here he remained for 2 years, lie is a nationally board-certified mathematics teacher and a associate member of the National .Academy of Sciences Teacher Advisory Council. In 2002. he received the Presidential Award for Excellence in Mathematics Teaching. He holds bachelor's degree in mathematics from Hamilton College, and a master’s degree from St. Johns College in Santa Fe, New Mexico, and he is enrolled in a dtKtoral program at Columbia Universityin Education l.eadership.

Jl'IX-W’.A C. SlIKI joined the General Electric Global Research Center In 1991. In 1995, she was appointed global technologv' manager and is responsible for the management of ihcR&D Center's Global Technology .Acquisition lYograms. In that role, she has established research collaborations with organizations around the world Ms. Shei was the project manager to establish a GE Research Center in Shanghai, China, in June 2(XH) and now leads Japan Technolog>‘ Initiative in Japan. Ms. Shei is a member of the .American Chemical Society and cochair of the Industrial Research Institute External Technology Directors’ Network. She is the board member for the United States Industn.' Coalition. She was a member of theGore-Chemomyrdin Science & Technologv' delegation in 1997 and served as industry representative for the President's Council of Advisers on Science and Technology in 2002. Shei is veiy active in community service. She w as a founder and the president of the Network, a professional women's organization alfiliated with the National .Association for Female Executives, served xs the board chair for the Chinese Community Center of the Capital District of New York, and is a board member of Japanese Cultural Association of the Capital District. A native of Tokyo. Japan. Ms.Shci obtained her undergraduate degree from National Cheng Rung L’niversity in Taiwan, her MS from the Universitv' of .Massachusetts, and her MB.A from Rensselaer Polytechnic lastitute. Before joining Creneral Electric, she worked at .Ames Laboratorv', the Research Center at the US Steel Corporation, and the Sterling \\'inthrop Research lastitute (f^stman Kodak's Pharmaceutical Division).

.1. STEPHEN SIMON is a senior vice president of Exxon Mobil Corporation. Mr. Simon hold-s a BS degree in civil engineering from Duke Universitv' and an MB.A from Northwestern University. He joined Exxon Company, US.A in July 1967 and shortly thereafler began a 2-year assignment in the US Army.

He returned to Ex.xon USA in July 1969 as a business analyst in the Baton Rouge refinerv'. .Afler holding a varietv' of supervisory and managerial positions throughout the Baton Rouge and Baytown reflneries and in Exxon USA's refining and controller's departments. Mr. Simon became executive assistant to Ex.\on USA's executive vice president in Houston. In 1980. he returned to the Baton Rouge reflneiy as Operatioas Div ision manager and then became refinery manager. In 1983, Mr. Simon moved to New York, where he was executive assistant to the president of E.vxon Corporation. In 1984. he moved to Londoa England, as supply manager in the Petroleum Products Department of Esso Europe Inc. and then supply and iraasportation manager. Mr. Simon returned to Houston in 1986 as general manager of Exxon USA's Supply Department. In 1988, he became chief executive and general manager, Esso Caribbean and Central .America, in Coral Gables, Horida. Simon moved to Italy in 1992 to become executive vice president and then president of Esso Italiana. He returned to the United States in 1997 and was named an executive vice president of Exxon Company, International, headquartered in Florham Park. New Jersey.

In December 1999, he was appointed president of Exxon .Mobil Refining & Supply Company and vice president of Exxon Mobil Corporation. In December 2004. he assumed his current position as senior vice president of the Corporation. Mr. Simon has served on the local boards of many voluntarv- organizations— including l.'nited Way, Boy Scouts, and the Salvation .Army— and is a member of the Ciovemance Committee of the National .Action Council for Minorities in Engineering. He has also served on the boards of the .American Petroleum Institute and the National .Association of Manufacturers. He is a

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TIM STE'ARNS is an associate professor in the Department of Biological Sciences and the I>cpannienl of Cxenctics at Stanford l'nivcrsit\'. He is also an member of the Committee on Cancer Biolog>', the steering group for the cancer-biologv' graduate training program, and he is chair of the Committee on (xraduate Admissions and Policy, which oversees all graduate programs in the bioscienccs at Stanlbrd.

Dr. Steams is the recipient of a Howard Hughes Medical Institute Professor Award, which he has used to develop a program for research-oriented undergraduates, llie laborator>' course for this program. Biosci

54 55, draws sophomore-level students from diverse intellectual backgrounds and has them me interdisciplinaiy approaches to solve problems in cell biolog,v. Dr. Stearns recently cofounded the Advanced Imaging Lab in Biophysics course, and he has taught advanced summer laboratory courses at Cold Spring Harbor Laboratory’ at Woods Hole, and in Chile and South Africa. His research involves ming a combination of imaging, genetics, biochemistry, and structural biolog>’ to understand the cytoskeleton. His laboratory w as one of the first to me green fluorescent protein to visualize cytoskeletal dv namics and is a leader in understanding microtubule organization and its relationship to the cell cycle.

DE^BR-V STEA\ 'ART became the fifth president of the Council of Ciraduate Schools (CGS) in July 2000. Before coming to the CGS. Dr. Stewart was vice chancellor and dean of the Graduate School at North Carolirta State University. She also served as interim chancellor at the l.'niversily of North Carolina-Greensboro (1997) and as graduate dean and then vice provost (1988-1998) at North Carolina Stale. 453 memberTi award over 95®o of all US doctorates and about 70®o of all US. master's degrees. .Among its 1 1 international members. CGS includes nine major Canadian universities. Dr.

Stewart receiv ed her PhD in Political Science from the Univeisity of North C’nrolina-C'hapcl Hill, her ma.ster's degree in government from the Universit>' of Maryland, and her BA from Marquette University.. She is the author or coauthor of numcTom scholarly articles on administrative theory and

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ORL.VNIK) T.X^’I/OR is vice provost for research, dean of the (iradualc School, and professor of communications at Howard University. Before joining the Howard faculty in 1973. I>r. Taylor was a facultv’ member at Indiana Universitv’. He has also served as a visiting professor at Stanford University. Dr. Taylor has served on the Board of I3ircctors of the Council of Graduate Schools and was Board chair in 2001. He is a past president of the Northeastern .Association of Graduate Schools and the National

Communication Association. He is the immediate past president of the Consortium of Social Science Associations and chairman of the Board of the Jacob JaviLs Fellowship Program in the Humanities for the US IX'partmcnt of Education. He also serves as a member of the Board of Fruslecs of the UniversitV' Corporation for Atmospheric Research. Dr, Taylor has served in many capacities at Howard University: he has serv ed as executive assistant to the president, interim vice president for academic affairs, dean of the School of Communications, and chair of the IX'partmenl of Communication .Arts and Sciences. Dr. Taylor's pioneering work in communication disorders, sociolinguistics, educational linguistics, and inlercullural communication has led to the development of new theories and applications. In most of his scholarly work, he has focused on the rich cultural and linguistic diversity of the American people. He is the author of numerous articles, chapters, and books. The .American Speech-Language-Hearing Association awarded him its highest award. Honors of the Association, and the .\lumni .Association of

the
Universitv' of Michigan awarded him its Distinguished Service .Alumni .Award, llie Universitv' of Massachusetts. .Amherst has awarded him the Chancellor's Medal, and Vale University its Bouchet Medal

for leadership in Minority Graduate liducation. Dr. Taylor received his bachelor’s degree from Hampton

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CAROLINK S. >\'.\(»NER is a researcher at the Center for International Science and Technolog\' Policy at George Washington University (GWU). She specializes in science and teclmo]og\' and their relationship to innovation, policy, and society. Among her current advisory commitments, she serves on the Advisoiy Board of Research on Knowledge Systems, a program of the International Development Research Centre of Canada, and on the United Nations Millennium Task Force on Science, Technology, and Innovation. She is a founding member of the Washington Science Policy Alliance. Dr. Wagner joined

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Before joining Rand, she was a professional staff member for the US Congress Committee on Science, Space, and Tcclinolog> . and before that in the congressional Office of Technology Assessment. She has served as an analyst for the US government specializing in global development in science and technology; this included a 2-year assignment as an analyst at the US embassy in Korea. Dr. Wagner has consulted with the World Bank, the European C'ommission, the Organisation for Economic Co-opcTation and Development, the US National Science Foundation, and a number of govemmenLs. She holds degrees in science and technology dynamics from the Universitv' of .Amsterdam; in science, technologv'. and public policy from GWU; and in philosophy from Trinilv' L’niversitv-.

I.Sl.VII W'.VRNKR is Boyd Professor and vice chancellor for strategic initiatives of the Louisiana State System (LSU). He graduated cum laude from Southern University with a BS in chemistiy in 1%8. Affer working for Baltellc Northwest in Richland, Washington for 5 years. Dr. Warner attended graduate school in chemistiy at the Universitv' of Wa.shington, receiving his PhD in chemistn' (analytical) in June 1977.

He was assistant professor of chemistry at Texas .A&M l.^niversity from 1977 to 1982 and was awarded tenure and promotion to associate pnifessor cffeclivu September 1982. How ev er, he elected to join the faculty ofEmoiy Universitv' as associate professor and was promoted to full professor in 1986. Dr.

Warner was named to an endowed chair at Emoiy University in September 1987 and was the Samuel Candler Dobbs Professor of Chemistiy' until he left in .August 1992. During the 1988-1989 academic year, he was on leave to the National Science Foundation xs program officer for analytical and surface chemistiy. In August 1992, Dr. Warner joined LSU as Philip W. West Professor of .Analytical and Environmental Chemistiy. He was Chair of the Chemistiy Department from 1994 to 1997 and was appointed Boyd Professor of the LSU System in July 2000, and Vice Chancellor for Strategic Initiatives in 2001 . The primary research emphasis of VS'arner’s research group is the development and application of improved methodologies (chemical, mathematical, and iastrumcntal) for the studv' of complex chemical systems. His research interests include fluorescence spectroscopy, guest-host interactions, studies in organized media, spectroscopic applicatioas of multi-channel detectors, chromatography, environmental analyses, and mathematical analyses and interpretation of chemical data using chemometrics.

CiKNKRVL LARR^' WEIX 'H (relircd) was the 12!h chief of staff of the US Air Force. As chief, he seized as the senior uniformed Air Force officer responsible for the organization, training, and equipage of a combined active-duty. Guard, reserve, and civilian f(m:e serving at locations in the United States and overseas. Formerly president of the Institute for Defense .\nalyses. General Welch now serves as a senior associate. In addition, he provides expertise to a number of organizations, including the Council on Foreign Relations, the Defease Science Board, the Joint Committee on Nuclear Weapons Suretv', the National Missile Defense Independent Review Team, the US Space Command Independent Strategic .\dv isoiy Group, and the US Strategic Command Strategic .Advisoiy Group. General W'elch received a BS in basincss administration from the Universitv' of Marviand and an MS in international relations from George Washington University.

REAR .VDMIRM, ROBERT II. WER TIIEIM (retired) [N.AE] is a consultant on national-securitv’ and related issues. During his 38 years in the Navy, he was director of strategic systems programs, responsible for the research, development, production, and operational support of the Navy's submarine launched ballistic-missile program. After retirement from the Navy, he served for 7 years as Lockheed Corporation senior vice president for science and engineering; for the last 1 7 years, he has been a private consultant. He is a member of advisorv groups serving the US Strategic Command, the Los .Alamos and IJvermore National Laboratories, and Draper I.aboraloiy. Other current service includes membership on the joint Department of Defense and Department of Energ>‘ (DOE). .Advisoiy Committee on Nuclear Weapons Surety and on the University of California President's Council on the National laboratories. He is a former member of the National .Academy of Sciences C'ommittee on International Sccuritv* and .Arms Control, the IX)E I.aboratory CJpcralions Board, and the Defense Science Board. .Admiral Wertheim graduated with honors from New Mexico Mililaiy Institute in 1942. He graduated with distinction from the Naval .Academy in 194S and received an MS in physics from the Massachusetts Institute of Technology’ in 1954. He has been elected a member of the National Academy of Engineering and of the scientific and engineering societies. Sigma \i and Tau Beta Pi. an honorary member of the .American Society of Naval Engineers: and a fellow of the .American Institute of Aeronautics and .Astronautics and the California Council on Science and Technology. .Admiral Wertheim has been honored w ith the Navy I>istinguishcd Service Medal (twice), the Legion of Merit, the Gold Medal of the .American Society of Naval Engineers, the Rear .Admiral William S. Parsons .Award of the Navy League, the Chairman of the Joint Chiefs of Staff Ifistinguished Public Service Medal, and the Secretary of Defense .Medal for Outstanding Public Service. He was inducted into the New .Mexico Military Institute Hall of Fame in 1987 and has been honored by the US Naval .Academy with its 2005 Distinguished Graduate Aw ard for his lifetime of service to the Navy and the nation.

I)E.V.N ZOELM.VN is University Distinguished Professor, IJistinguished L'niversity Teaching Scholar, and head of the Department of Physics at Kansas State University (KSU). He has focused his scholarly activities on research and development in physics education since 1972. He has received the National Science Foundation (NSF) Ifircclor's Award for Distinguished Teacher Scholars (2004). the Carnegie Foundation for the .Advancement of Teaching Doctoral University' I^rofessor of the A'car (1996X and .American .Association of Physics Teachers* Robert .A. Millikan Medal (1995). His research concentrates on investigating the mental models and operations that students develop as tliey learn physics and how students transfer knowledge in the learning process. He also applies cutting-edge technology to the teaching of physics and to providing instructional and pedagogic materials to physics teachers, particularly teachers whose background dinrs not include a substantial amount of physics. He has twice been a F'ulbright Fellow in Germany. In 1989. he worked at Ludwig-Ma.ximilians University' in Munich on development of measurement techniques for digital video. In 1998, he visited the Iitstilute for Science Education at the University in Kiel, where he investigated student understanding of quantum physics. I>r. /oilman is coauthor of six videodisks for physics teaching, the Physics InfoMall database, and a

textbook. He leads the \ isual Quantum Mechanics project, which develops materials for teaching quantum physics to three groups of students: nonscience students, science and engineering students, and students interested in biology and medicine. His present instructional and research projects include .Modem Miracle Medical Machines, Physics Pathway, and research on student learning.

Appendix D

ISSUE PAPERS

llic Issue Briefs presented in this appendix summarize findings and reeommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 21st Century. 'Ihc papers were provided as background infonnation to the study committee and focus group participants.

Tlie 13 papers, written by members of the committee's stall, are included here only as a historical record and a useful summarv' of relevant reports, scientific literature, and data analysis. Statements in this brief should not be seen as the conclusions of the National .Academies or the committee.

Each issue brief provides an ovcrx'icw of the findings and recommendations of previously released studies from the National .Academies and other groups, llie i.ssue briefs cover topics relevant to the committee's charge, including K-12 education, higher education, research policy, and national and homeland security policy.

Specillcally, the topics addressed are:

• K-12 .Science, Mathematics, and Technology Education

• .Attracting the Most .Able MS. Students to Science and Eaigineering

• Undergraduate. Graduate, and Postgraduate E-duration in Science, Eaigineering, and Mathematics

• Impliralions of (hanges in the E'inanring of Public Higher Education

• International Students and Kesearrliers ui the Tnited States

• .Arhies ing lialanre and .Adequacy in E'ederal Science and Technology E'unding

• The Productivity of Scientific and Technological Research

• Investing In High-Risk and Breakthrough Research

• ICnsuilng That the I'nited States Is .At the E'orefront in Critical fields Of Science and T echnology

• Tnderstanding T rends in Science and T echnology (ritical To C.S.

Prosperity

• Emsuiing That the I'nited States Has the Best E-nsironnient for Innovation

• Scientific C'onimmiiration and .Security

• S&T Issues in .National and Homeland .Security

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This issue paper summarizes findings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Globa! Economy of the 21st Centurv’. Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

K-12 Science, Mathematics, and Technolog> Education

Sumnian

US education in science, technolog)', engineering, and mathematics is undergoing great scrutiny. Just as the launch of Sputnik 1 in 1957 led the United States to undertake tiie most dramatic educational reforms of the 20th centurv’, the rise of new international competitors in science and teclinolog)' is forcing the United States to ask w hether its educational system is suited to the demands of the 21st centur)'.

These concerns ;ire particularly acute in K‘12 education. In comparison with their peers in other countries. IIS students on average do w orse on measures of mathematics and science performance the longer they are in school. On comparisons of problem-solving skills, US students perform more poorly overall than do the students in most of the countries that have participated in international assessments. Some believe the United States has failed to achieve the objective e.stablished in the Goals 2000: Educate .America .Act — for US students to be first in the world in mathematics and science achievement in the year 2000.

National commissions, industrial groups, and leaders in the public and private sectors are in broad agreement with policy initiatives that the federal government could undertake to improve K-12 science, mathematic's, and technology education. Some of these are listed below:

Increasing the Number of Excellent Teachers

• .Allocate federal professional-development funds to summer institutes that address the most pressing professional-development needs of matliematics and science teachers.

• Keep summer-iastitute facilitators— teachers current w ith the most eflective teaching methods in their disciplines and who ha\’e shown demonstrable results of higher student achievement in mathematics and science abreast of new insights and research in science and matliematics teaching by providing fimding for training them.

• Encourage higher-education institutions to establish mathematics and science teaching academies that include faculty from science, mathematics, and education departments through a competitive grant process.

• Support promising students to study science, mathematics, iuid engineering teaching — particularly those obtaining degrees in science, mathematics, or engineering who phm to teach at the K-12 level following graduation througli scholarships and loan programs for students as well as institutional funding. Qualified college .students and midcareer professionals need to be attracted into teaching and gi\en the preparation they require to succeed. Experts in mathematics, science, and technology should be able to become teachers by completing programs to acquire and demonstrate fundamental teaching skills. Recruitment, preparation, and retention of minority-group teachers are particularly important as groups underrepresented in science, mathematics, and engineering become a larger percentage of the student population.

• Conduct an aggre.ssive. national-outreach media campaign to attract young people to teaching careers in mathematics and science.

• Work for broad improvements in the professional status of science, mathematics, and technology teachers. Structured induction programs for new teachers, district-business partnerships, award programs, and other incentives can inspire teachers and eneourage them to remain in tlie field. Most important, salaries for seienee. mathematics, and technology teachers need to reflect what they could receive in the private sector and be in accord w ith their contributions to society, and teachers need to be treated as professionals and as important members of the science and engineering communities.

Enhancing the Quality and Cohesion of Educational Standards

• Help colleges, businesses, and schools work together to link K- 1 2 standards to college admissions criteria mid workforce needs to create a seamless K-16 educational system.

• Provide incentives for states and coalitions of states to conduct benchmarking studies between their standards and the best standards available.

• Foster tlie development of high-quality ciurieula and assessments that are closely aligned w ith world-cla.ss standards.

• Establish ambitious but realistic goals for student performance for example, that 30 ® o of high-school seniors should be proficient in science bv 2010 as measured by the N.AEP.

Changing the Institutional Structure of Schools

• Provide seed money or incentives for new kinds of schools and new forms of schooling. Promising ideas include small higli schools, dual-enrollment programs in high schools and colleges, colocation of schools w ith institutions of higher education, and wider use of .\dvanccd Placement and International Baccalaureate courses.

• Help districts institute reorganization of the school schedule to support teaching and learning. Possibilities include devoting more time to study of academic subjects, keeping schools open longer in the day and during parts of the summer, and pro\'iding teachers w ith additional time for development and collaboration.

• Provide scholarships for low-income students who demonstrate that they have taken a core eurriculum in high school that prepares them to study science, mathematics, or engineering in college.

llic challenge for policy-makers is to find ways of generating meaningful change in an educational system that is large, complex, and pluralistic. Sustained programs of re.search, erxrrdination, and oversight can channel concerns over K-12 science, mathematics, and technology education in productive directions.

Ihe stale of US K-12 education in science, mathemiitics, and tcclmology has become a focus of intense concern. With the economics and broader cultures of the United States and other countries becoming increasingly dependent on science and technology, US schools do not seem capable of producing enough students w ith the knowledge and skills needed to prosper.

On the 1996 National .Assessment of Educational Progress (N.AEP), fewer than one-third of students performed at or above the proficiency level in mathematics and science — with "proficiency" denoting competence in challenging subject matter.' .Alarmingly, more than onc-third of students scored below the basic level in these subjects, meaning they lack the fundamental knowledge and skills they will need to get good jobs and participate fully in our technologically sophisticitted society (sec Figure K12-1).

International comparisons document a gradual decline in performance and interest in mathematics and science as US students gel older. ITiougli fourth graders in the United States perform well in math and science compared w ith their peers in other countries, Iwelfih graders in 1999 were almost last in perfomiance among Ihe countries that participated in the Third International Mathematics and Science Study (TIMMS).^ .Among the 20 countries assessed in advanced mathematics and physics, none scored significantly lower than the Elnited States in mathematics, and only one scored significantly lower in physics.

nierc has been some good news about student achievement.* LIS eighth graders did better on an intcniational assessment of mathematics and science in 2003 111,111 they did in 1995. llic achievement gap scp,ir,iting black and Latino students from Europcan-.American students narrowed during that period (see Figure K 1 2-2). However, a recent assessment by the Program for International .Assessment foimd that US 1 5-year-olds are near the bottom of all countries in their ability to solve practical problems requiring mathcnwtical understanding. .Additionally, testing for the List 30 years has show n that

' US Department of Education, National Center for Education Statistics, NAEP 1999 Trends in Academic Progress: Three Decades of Academic Performance, NCES 2000-469. Washington, DC: US Department of Education, 2000.

^ US Department of Education. National Center for Education Statistics, Pursuing Excellence: A Study of Twelfth-Grade Mathematics and Science Achievement in International Context, NCES 98-049.

Washington. DC: US Government Printing Office. 1998,

’ Rodger W. Bybee and Elizabeth Stage, "No country' left behind," Issues in Science and Technology, Winter 2005. pp 69-75.

although scores among 9- and 1 3-year-olds have increased, scores for 1 7-year-olds have remained stagnsint (see Figure K12-3).

Perhaps the hardest trend to document is a sense of disillusionment with careers based on seienee and teehnologj / Fewer ehildren respond positively when sur\eyed to statements such as "I like math" than has been the ease in the past, llie number of schools offering advanced courses, such as .Advanced Placement and International Baccalaureate has increased dramatieally, but the vast majority of students in higli school w ill never take an advanced science or mathematics course (see Figure K12-4). .And a lack of interest in science, mathematics, and teehnologs is particularly pronounced among disadvantaged groups that have been underrepresented in those fields.

In general, many .Americans do not know enougli about science, technology, and mathematics to contribirte to or benefit from the know ledge-based society that is taking shape around us. .At the same time, other countries have learned from our example that preeminence in science and engineering pays immense economic and social dividends, and they are boosting their investments in these critical fields.

nic traditions of autonomy and pluralism in .American education limit the influence that the federal government can exert on state educational systems, school districts, and individual schools. Nevertheless, the federal government can enable change by leveraging its investments in K- 1 2 education, by providing infonnation and other re.sources to organizations, and by helping to coordinate the many groups and individuals with a stake in science, mathematics, and technology education. Three policy arenas seem particularly promising: teacher preparation, educational standards, mid institutional change.

Iiiiproiliig the Quality of Mathematics, Science, and Tecimulogy Teaching

Students learn about science, mathematics, and technology first and foremost through interactions with teachers. Changing the nature of those interactions is the surest way to improve education in these subjects in the L'nited States.

Many mathematics and science teachers in US schools do not have backgrounds needed to teach these subjects well (see Figure K12-5).* .Many of these teachers at the high-school level— and even more at the middle-school level-do not have a college degree in the subject they are teaching (see Figure K 12-6). Many lack eertifieation to teach mathematics and science, and a subset of teachers start in the classroom without any formal training. The lack of adequate training and background is especially severe at schools sen ing large numbers of disadvantaged students, creating a vicious circle in which a substandard education and low achievement are intertw ined (see Figure K12-7). Ilie stresses on teachers are equally severe; Of new mathematics and science teachers, about a one-third leave teaching w ithin the first 3 years.

^ Committee for Economic Development, Research and Policj' Committee. Learning for the Future: Changing the Culture of Math and Science Education to Ensure a Competitive IVorhforce. New York:

Committee for Economic Development. 2003.

* US Department of Educatioa The National Commission on Mathematics and Science Teaching for the 2 1 St Century, Be/bre/Cs Too Late. Washingtoa DC: US Department ofEducatioa 2000.

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Tlie best predictors ofhigher student aehie\ enient in mathematics and science are (1) full certification of the teacher and (2) a college major in the field being taught.* Teachers need a high-quality education and continued development as professionals throughout their careers. Federal policy initiatives that could help meet these objectives include the following:

• .Mlocatc federal professional-development funds to summer institutes that address the most pressing professional-development needs of matliematics and science teachers.

• Keep summer-institute facilitators.-teachers current with the most effective teaching methods in their disciplines and who have shown demonstrable results of higher student achievement in mathematics and science— abreast of new insights and research in science and mathematics teaching by providing funding for training them.*

• Fneourage higlier-education institutions to establish mathematics and science teaching academies that include faculty from science, mathematics, and education departments through a competitive grant process. *

• Support promising students to study science, mathematics. ;md engineering teaching particularly those obtaining degrees in science, mathematics, or engineering who plan to teach at the K-12 level following graduation tlirougli scholarships and loan programs for students as well as institutional funding. Qualified college students and midcareer professionals need to be attracted into teaching and given the preparation they require to succeed. E.vperts in mathematics, science, and tcchnologs' should be able to become teachers by completing programs to acquire and demonstrate fundamental teaching skills. Recruitment, preptiration. and retention of minority-group teachers are particularly important as groups imderrepresented in science, mathematics, and engineering become a larger percentage of the student population. ”

• Conduet an aggressive national-outreach media campaign to attract young people to teaching careers in mathematics and science.

• Work for broad improvements in the professional st-atus of science, mathematics, and technology teachers.'* Structured induction programs for new teachers, district-business partnerships, award programs, and other ineentives can inspire teachers and encourage them to remain in the field. Most important, salaries for science, mathematics, and technology teachers need to reflect what they could receive in the private sector and be in accord w ith their contributions to society.

‘Ibid
’ Ibid
•ibid
’Ibid
” Ibid

“ National Research Council, Committee on Science and Mathematics Teacher Preparalioa Editcahng Teachers of Science. Mathematics, and Technology: New Practices for the New Millennium. Washington. DC; National Academy Press, 2000.

National Science Foundation, National Science Board, The Science and Engineering IVorlforce: Realizing America 's Potential /\rlington, VA; National Science Foundation. 2003.

and teachers need to be treated as professionals and as important members of the scicnee and engineering eommunities.

Knhancing Ihr Quality and f ohesion of Kducational Standards

Since the early 1990s. states have been developing aeademie standards in mathematies. science, and technology education based in part on national standards developed by the National Council of Teachers of .Mathematics, the National Research Council, the American .Association for the .Advancement of Science, and other organizations, llte use of these standards in eurrieulum development, teaching, and assessment has had a positive elTeet on student perfonnanee and probably contributed to the recent increased perfonnanee of eighth-grade students in international comparisons.'''

But standards still vary greatly from state to state and across districts and often arc not well aligned w ith tlic tests used to measure student performance. In addition, many sets of standards remain focused on lower-level skills that may be easier to measure but are not necessarily linked to the know ledge and skills that students will need to do well in college and in the modern workforce. .A common flaw in mathematics and science curricula and textbooks is the attempt to cover too much material, which leads to superficial treatments of subjects and to needless repetition when hastily taught material is not learned the first time. Standards need to identify the most importmit "big ideas” in mathematies. science, and technology, and teachers need to ensure that those subjects are mastered.

The No Child left Behind legislation requires testing of students' knowledge of science beginning in 2006-2007, iuid the science portion of the N.AEP is being redesigned. Development of such assessments raises profound methodologie issues, such as how to assess inquiry ,and problem-solving skills using traditional large-scale testing fomtats.

Several federal initiatives can serve the national interest in establishing and maintaining high educational standards w hile respecting local respousibility for teaching and learning:

• Help colleges, businesses, and schools work together to link K-1 2 standards to college admissions criteria and workforce needs to create a seamless K-16 educational system,'*

• Provide incentives for states and coalitions of states to conduct benchmarking studies between their standards and the best standards available.

• Foster the development of high-quality curricula and assessments that are closely aligned w ith world-class standards.

• Establish .ambitious but realistic goals for student performance for example, that ,^0 “o of high-school seniors should be proficient in science bv 2010 as measured by the N.AEP.

'* Bybee and Stage. 2005

” National Science Foundation. National Science Board, Preparing Our Children: Math and Science Education in the Sational Interest, Arlington. VA; National Science Foundation. 1999

Changing the Institutional Structure of Schools

Students and teachers remain constrained by several of the key organizational features of schools.'* Tlie structure of the curTiculum. of indi\ idual classes, of schools, and of the school day keeps many students from taking advantage of opportunities that could build their interest in science and technology.

Possible federal initiatives include these:

• Provide seed money or incentives for new kinds of schools and new forms of schooling. Promising ideas include small higli schools, dual-enrollment programs in high schools and colleges, colocation of schools with institutions of higlier education, and wider use of .Advanced Placement and International Baccalaureate coiuses.

• Help districts institute reorganization of the school schedule to support teaching and learning.'’ Possibilities include devoting more time to study of academic subjects, keeping schools open longer in the day and during parts of the summer, and providing teachers w ith additional time for development and collaboration.

• Provide scholarships for low-income students who demonstrate that they have taken a core curriculum in high .school that prepares them to study science, mathematics, or engineering in college.

(iitiilyzing C hange

Hie federal government has ;ui important role to play in catalyzing the efforts of states, school districts, and schools to improve science, mathematics, and technology education. Promising actions include the following:

• I.aunch a large-scale program of research, demonstration, and evaluation in K-12 science, mathematics, and technology education.'* Such a program should include distinguished researchers working in partnership with practitioners and policy-makers and supported by a national coalition of public ;md private funding organiz.ations and other stakeholders.

• Help create a nongovernment Coordinating Council for Mathematics and Science Teaching that w ould bring together groups with a .stake in mathematics and science teaching and monitor progress on teacher recruitment, preparation, retention, and rewards.'*

**US Department of Education, National Education Commission on Tune and Learning, Prisoners of Time, Washington, D.C.: US Department of EducaUon. 1994.

” Ibid.

'* National Research Council, Committee on a Feasibility Study for A Strategic Education Research ProgTum, Impro\'ing Student Learning: A Strategic Plan for EtAicalion Research audits Utilization, Washington, DC: National Academy Press, 1999

” The NaUonal Commission on Mathematics and Science Teaching for the 2 1st Century, 2000

• Support the creation of state councils of business leaders, higlier-cdueation representatives, and K-12 educators to achieve comprehensive, coordinated, system-level improvement in science, mathematics, and technology education from prekindergarten through college,^®

The L'nited States brings unique strengths to the challenge of reforming K-12 science, mathematics, and technology education, including the ne.\ibility of its workforce and its unparalleled legacy of achievement in science and technology. 'Ihe challenge facing poliev'-makers is to find ways of generating meaningful change in an educational system that is large, complex, and pluralistic.

“ Busincss-Higher EducaUon Forum. ^ Commitment to America s Future: Responding to the Crisis in Mathematics and Science Education, Washington. DC: American Council on Education. 2005

K-12 Science, Mathematics, and Technolug> Kducation
Appendix K12 1
Figurt's and Tables

FIOI’RK K12-1A: Studies Suggest That a Large Portion of I’S Students Are l.acking in Science Skills. In 1996, at Least One- Third of Students in 4th, 8th, and 12th (vrade Ferfonned Belo>v Basic in National Tests.

FKU'KK K12-1B: The Results Are Similar for Mathematics; of Students

Scored Below Basic.

TABLE K12-2A: International Comparisons Also Show Problems for the I S. 1995 and 2<N)3 VS 4th-Crade Mathematics TIMSS Scores Remained Constant, Most Nations Improved.

TABLF; K12-2B: 8‘*'-Graders Did Show Improvement from l995to2tM)3, but Scores Were Still Not Among the Best.

TABLE K12-2(.*: Although the L.S Is Still Near the Top in 4th-(>rade Science Scores, in 2003 I'S Placed FifUli. Compared with Second in 1995.

TABLE K12-2D: Thei'e lias Been a Large Improvement in 8th-Grade Science Scores Since 1995.

FKfl'RF. K12-2E: TIMS.S Data for 4th and 8lh (traders Show Performance (>ap Betxveen Blacks, Latinos, and European Americans lias Diminished.

TABLFI K12-3A: Long-Term Trends Show Improvements at Ages 9 and 13, But No Signinc;mt Improvement for 17-^'ear-Oids.

TABLE KI2-3B: Scores in 1996 and 2(MI0 Show a Sex (iap in Mathemathics and Science; Oxerall Fewer Students Perfoniiing at the Basic l/cvel or Better in 2000.

TABLE K12-4A: The Vast Majoritv of Students Will Never Take an Advanced Mathematics C ourse M hile in High School.

T.ABLE K12-4B: Nor an Advanced Science C'ourse,

FlCl’RE K12-4C': Even Though the Number of Schools Offering Advanced Placenient Coui'ses Has Increased Rapidly.

FKil'RE K12-5: In 1993-1994, Over 20% of Mathematics and Science Teaching Positiims Were Filled by NonCertifled Teachers.

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TABLE K12-6: Students \\'ho Take Seience and Mathematics C'ourses Might Not Have Teachers M ho Have Studied in the Fields They Are Teaching.

TABLE K12-7: Many New Science and Mathematics Teachers Report Feeling III Prepared to Handle the C hallenges of Teaching.

FTGl'RE KI2-8: Relevant Data on Students, Teachers, and Costs (Public Schools)

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FIGURE K12-1A: Studies Suggest That a Large Portion of US Students Are Lacking in Science Skills. In 1996, at Least One-Third of Students in 4th, 8th, and 12th Grade Performed Belosv Basic in National Tests.

1996 Science NAEP.
Grade 4; Percentage of Students
Within Each Achievement Level

1996 Soence NAEP.
Grade 12: Percentage of Studenu
Within Each Achievement Level

Source: S.C. Ix>omi-s and ML. Bourque (Eds.) of Edttcational Progress Achievement

Levels. 1 992- 1 998 for Science. Washington. DC: National .Assessment Governing Board. July 2001. .Available at http: www.nagb.org pubs scicnccbook.pdf

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FIGl'RE K12-1B: The Results Are Similar for Mathematics: 30% of Students Score<l lielow Basic.

1996 Mathematics NAER
Grade 4: Percentage of Students
Within Each Achievement Level

1996 Mathematics NAEP,
Grade 12: Percentage of Students
Within Each Achievement Level

1996 Mathematics NAEP.
Grade 8; Percentage of Students
Within Each Achievement Level

3.8% Advanced

Source: S.C. Loomis and M.L. Bourque {^6s.)NaUonal Assessment of Educational Prepress Achievement Levels. 1992-1998 for Science. \Va.shington, IX": Nalional Assessment Governing Hoard. July 2001 .

Available at http: w^vw .nagb.org pubs sciencebook.pdf

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TABLE K12-2A: International Comparisons Also Show Problems for the US.
1995 and 2003 US 4th-Grade Mathematics TIMSS Scores Remained Constant,

Most Nations Improved.

Average mathematics scale scores of fourth-grade
students, by country: 1995 and 2003

, ;]"l-

1995

2003

Singapore

590 ■

Singapore

594

iapan

567 ■

Hong Kong SAR*-’

575

Hong Kong SAR’-*

5S7|

Japan

565

(Netherlands)

549 1

Netherlands'

540

(Hungaiy)

521

La*via-LSS*

533

United States

518

England'

531

(LaWia-LSS)>

499

Hungary

529

(Australia)

495

United States'

518

Scotland

493

Cypius

510

England

484

Australia'

499

Norway

476

New Zealand*

496

Cyprus

475

Scotland'

490

New Zealand*

469

Skwenia

479

(Slovenia)

462

Norway

451

Iran. Islamic Republic of

387

Iran, Islamic Republic of

389

■ Average is higher than the U5. average

Average is rxrt measurably differerK from the U5. average
□ Average is lower than the U.S. average

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parbapaboartfe((n2003 only after
replKement rdt&oU were toduded
fflcQg Koogif aSpecial Adminirtrabve
Region (SAR) of the People's Republic of
Ouaa

BDengntf edLSS becaise only Latvin-
ipeakmg rc&oolt were included in 1995
Fortfiif aialyar.only Latvian-speaking
schools are included in the 2003 average
^n l995.Maon-spcak}Dg students did not
pdsticipate Estunatesin das table are
computed for rtudents taught in En^ish
cnly, uduch representr between 98-99
percent d the student population in both
years

NOTE Comtries «e ordered basedon the
average score Parentheses indcate
countries that didnot meet inleraabooal
sampling <r other guidelmes in 1995 All
countries met international sampling and
other guideltnes in 2003. except as noted
See HCES (1997) for details regardng
1995 data The tests for agniRcmce take
into account the standard error for the
reported difference Thus, a small
dfference between the United States and
one country may be sigiufi cant while a
large dfTerence between the United Slates
and another counBy may not be
significant Countries were re<|siredto
sample rtudents m the upper of the two
grades that contained the most number of
9-year -014 b the United States and
most ccuntnes. this corresponds to grade
4 SeetaUe A1 in appendx Afor details
SOURCE Intemtfacnal Associabon for

the Evaluation of Educational

acbevement (lEA). Trends in
IntemaAonal Madiemabcs and Science

awdy (TIMSS). 1995 and 2003

Source; National Center for Education Statistics. Highlights from the Trends in International Matlien Kitics

and Science Study: TIMSS 2003. Washington, DC: United States Department of Education. December 2004. p.8. Available at: http://nces.ed.gOv/pubs2005/2005005.pdf.

K12-13

368

TABLE K12-2B; 8"'-Graders Did Show Improvement from 1995 to 2003, but

Scores Were Still Not Among the Best.

Average mathematics scale scores of eighth-grade
students, by country: 199S and 200)

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561

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569

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SoMkR^ubBc

(Nadiwlwvk)

Ihjnpn'

(Bul^)

534

520

527

527

fhiwian Fndwation

524

(*^)

509

N«wZ«alanj SOI

NorvMy 498

(SOVWM) 494

(Scodind) 493

United Stiles 492

(Unfia-lSSy 468

(Romaria) 474

Uthuania* 472

Cypnis 468

Veg id»nic Repubic of ^

Russian Federation SOS

Slovak RapubSc 506

Laivi*C5S' SOS

Ausvafca SOS

(United SUtes) 504

lidvuania^ S02

SMeden 499

Scodand* 496

New Zeslarvi 494

Stovenia 49)

Biigaha 476

Romania 47S

Norway 461

Cyprus 4S9

tiag Islerruc Republic of ^

■ iWerage k Nsher dian the U& awrase
Aterage a nor measurabiy dSerem die US. average
□ i^age k tower than the ULS. average

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3Deagnafed LSS because only Latvian- tpealaag tchooltwereiadudedin 1995 Forthit aoalyas. only Latvian -speaking scbooli are included in the 2003 avoage
4Naticinal denied population docs sot cover all of iheiMenubonal detiredpopuLabon
NOTE Countnes are orteed by avenge Kore Paradheses inibcate caunines that thd not meet iniemationU sampling or other guidelines m 1995 or 2003 See appendix A for details regarding 2003 diu SeeNCES(l997} fcrdetnls reining 1995

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EvaluUion of Educational Achievtnient(IEA),
Trends in biienationalMtfhematicsisidSaence
Study (TIMSS). 1995 and 2003

Source: National Center for Education Statistics. Highlights from the Trends in International Mathematics and Science Study: TIMSS 2003. Wa.shington. DC: United States Department of Education. December2004. p.9. Available at: http://nces.ed.gOv/pubs2005/2005005.pdf.

K12-14

369

TABLE K12-2C: Although the US Is Still Near the Top in 4th"Grade Science Scores, in 2003 US Placed Fifth, Compared with Second in 1995.

Differences in average science scale scores
of fourth-grade students, by country: 199S
and 2003

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2003

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565

42 A

Japan

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Hong Kong SAR^’

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England*

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United States'

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(Huigwy)

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(Latvid45S)*

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43 A

(Netherlands)’

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•5

NewZe^and*

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18 A

(AustTahaV

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521

-1

Scotland’

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502

-12T

(Slovenia)

464

490

26 A

Cyprus

450

480

30A

Norway

504

466

■38 T

Iran, Islamic Republic ol

380

414

34 A

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Evaluation of Educational Achievement dEA). Trends tn
btemanonal Mathemancs and Science Study (TTMS5).

1995 Md 2003

Source: National Center for Education Statistics. Highlights from the Trends in International Mathema lics
and Science Study: TJMSS2003. Washington. DC: United States Department of Education. December
2004. p.l6. Available at: hltp://nccs.ed.gov/pubs2005/2005005pdf.

K12-15

TABLE K12-2D: There Has Been a Large Improvement in 8th-Grade Science
Scores Since 1995.

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-19 V

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455

430

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Chk

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430

415

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•9

-tenii

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450

404

t

•36V

sNipeHMs

—

545

577

t

534

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ID 2003 <aly after ref^Kemenl schobli were
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(SAR) of the People'* Re^blic of Oaoa
dBecauie ofoalioaal-levd chaoge* in the ttarting
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Soeenia cannot be cotnparedto 2003
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the international deared population in dl year* for
Lithuania, andin 2003 for lodonetia
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andya*. only Latvian -tpealong tchodt are mciuded
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sampliag and/or odicr guideline* ui 1995, 1999.
■id/or2003 See appendx A fordetat* regarding
2003 dsa See Gouales et at (2000) for detail*
regardng 1995 and 1999 data Countne* were
required to sample (tudenit ui the upper of the two
^ade* that contained the largest ntmber of 1 3-year-'
olds b the United States and most countne*. this
corresponds to ^ade 8 See table A1 to appends A
for detail Detal may not sum to totals because of
rotmdng SOURCE btemabcnal Assoaabon for
the EvaluMoo of Educational Achievement ^EA).
Treads in Intemabonal Mathematics and Science
Study (HMSS). 1995. 1999. md 2003

Source; National Center for Education Statistics. Highlights from the Trends in International Matltem atics
athi Science Study: TIMSS 2003. Washington. DC: United States Dcpaftmcnl of Education. December
2004. p.l 7. Available at; http;//nces.ed.gov/pubs2005/2005005.pdf.

K12-16

371

FIGVRE K12-2R: TIMSS Data for 4th and 8th Graders Show Performance
(>ap Bet>veen Blacks, Latinos, and Kunipean Americans Has Diminished.

White Black Hispanic While Black Hispanic

Source; National Center for Education Statistics. Highlights from the Trends in International Mathematics
andSdence Stuch': TIMSS 2003. Washington, DC; United States Department of Education. December
2004. Tables C8, Cl I, C28. C20. Available at; http;//nces.ed.gov/pubs2005/2005005.pdr

KI2-I7

372

s

TABLE K12-3A: Long-Term Trends Show Improvements at Ages 9 and 13, But
No Significant Improvement for 17- Year-Olds.

Trends in average mathematics scale scores for students 9, 13. and 17; 1973-2004

Scak score

Age 17

Age 13

Age9

J ftwr itfcrh 300*.

NOTL Dashed hMS raorsscM SD«sp«(aisd data.

SOURCE: U.& Depament ed Educaaon. InaMiti e< Educaoon Soencas. Natnnal Canttr fv EdecMw StttMca. Nawrtal Asawemirii of EdocMmal Pnvrn (NAER). saloclod jaen.
1973<2004 lon ek oti twid MadMUMa AsseMments.

Source: National Assessment Governing Board. National Assessment of Educational Progress 2004: Trends in Academic Progress Three Decades of Student Performance in Reading and Mathematics. Washington, E>C: United States Department of Educatioa July 14. 2005.

TABLE K12-3B; Scores in 1996 and 2000 Show a Sex Gap in Mathemathics and Science; Overall Fewer Students Performing at the Basic Level or Better in 2000.
Appendix table 1-4

Students at or above basic and p....... ...jematlcs and science, grades 4, S. and 12. by sex:

1996 and 2000
(Percent)

1996

2000

Variable

Grade 4

Grades

Grade 12

Grade 4

Grades

Grade 12

Mathemabcs

At or above basic

Male- -

65'

62*

70*

70

67

66

Female -

63*

63

69*

68

65

64

At or above proficient
Male- -

24*

25*

18

28

29

20

Female

19*

23

14

24

25

14

Science

At or above basic

Male -

68

62

60*

69

64

54

Female -

67

61

5S

64

67

61

At or above proficient
Male. -

31

31*

2S

33

36

21

Female..................

27

27

17

26

27

16

*SionincanDy AferenI froni 2000.

SOURCES: U.S. Oeparlment ol EducaOon, Nattonal Center (or Eductfton StaBsDcs (NCES. Tl» Hatkm's fiepo rl C»nt hbltmafcs
ZCOO. HCB 2001*517 (WastUngton. OC: (J.S. Department oT Education. 2001 }; and NCES. n» Naton S flepo ft CM: Sdence 2000.

NCES 2003-453 (WaslUngton. OC OS. Depwtment of Educaoon. 2003L

Science A Engineering ln<^cators - 2004

Source: National Science Board Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Virginia. National Science Foundation. 2004. ^pendix Table 1-4.

TABLE K12-4A: The Vast .Majority of Students M ill Never Take an .\dvanced Mathematics Course While in High School.

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H«h ....

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09

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>y •* MM «iatM Itr H» « liMh*» loy IM • S pmM 0> M*. IM • l-K pMOK

MMI - a»-«e MM. MN^I • St-I W IM*

MOTtS # M e OQUM awt (MM MCMMf • 1 *M IM Sm M M • pier IMK #« oaoM MWM* Wl CaoM M n
fiarvMtcMaaiaidnlaNnreMaAa'Btani MntM.Ji^adScanniiancMMiMM^MMMltfeoinB
sounct US Om«M •• MMw. «MM CMr Mn»w 9MM M|ft SM »ne«l SM«. IVM |W1

Sonno S fi nyw nng MacaKw - 3C0<

Source: National Science Board. Science and Engineering I ndicaiors 2004 (NSB 04*01). Arlin^on, Virginia. National Science Foundatioa 2004. A(^endLx Table 1-10.

TABLE K12-4B; Nor an Advanced Science Course,

Mm w*— I i nrt i rt I c«d vtmet n «wi (Wft IWt m» Ht. » ilidwt mi tdted

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•MM •]64»|KM IM m -M* MM

■(miPMteWM»aMMM«mnM6l<1fiBlM«X»MM*MinnWa«MIIMMMMM>»f>MI|Hfc

eMWMacMM — MMMWi|MWHMllf|il> t»MM.*PM— pa MlMlWifM cMt>l>MawblM«IM*Man<aim ■iina imi ri6PM»a|aMM<tM—

I WW f T lift IbpMMUi r ae— MmM^MaaCMMitwIMi ■»»>»■■ PMW

ScMno* 6 Eng m —nug indteaton - J004

Source: National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington. Virginia. Naticmal Science Foundation. 2004. Appendix Table 1-11.

K12-21

376

FIGl'RE K12-4C’: Even Though the Number of Schools OfFeruig Advanced Placement Courses Has Increased Rapidly.

•^School*

Ytar

Source: National Research Council. 2002. Learning and Understanding: Improving Ad\’anced Study of Mathematics and Science in US High Schools. Washington DC: National Academies Press Data courtesy of Jay Labov, Center for Education, National Academies

K 12-22

377

FIGURE K12-5: In 1993-1994, Over 20% of Mathematics and Science Teaching Positions Were Filled by NonCertified Teachers.

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MMi Md H«ti Sckoel UrtlMrMc*

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tjm

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jntf ffw rt wifv
tlCaitnuNmliKhtn
Cttir^a Rttunfig mt

asOHummt^tUucmm
(HMCeMr toObcata M*>.

M,

National Center for Education Statistics. Schools and faffing Survey (1993-1994). Washington. DC: United States Department ofEducation.

K 12-23

378

TABLE K12-6: Students Who Take Science and Mathematics Courses Might Not Have Teachers V\'ho Have Studied in the Fieids Thev Are Teachins.

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PHbUc Wflvtul ili4aib<wtoitiMa)«iNtc*Md KWMi toKtai w|tf«darnnndkiNn*Hfi*(Kl tkUhbrHWty IniliM nMn% • wotnanl
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MtHiiwIca

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RVKdBWICt

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TABLE K12-7: Many New Science and Mathematics Teachers Report Feeiing III Prepared to Handle the Challenges ofTeaching.

Appendix taUe 1-1S

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No

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79.7

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600

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Soonco i Engtn9»nng Indicator - 2004

Source; National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington. Vii^inia. National Science Foundation. 2004. Appendix Tables 1-13. and 1-15

FIGl'KK kl2-8: Kelevant Data on Students, Teachers, and Costs (Public Schools)

Fall 2003 Enrollment K-12' 48,132,518

High School Graduates - 2003-04' 2,771 ,781

Male graduates going to college - 2001^ 60%

Female graduates going to college - 2001^ 64%

T otal number of school teachers - 2003-04’ 3,044,01 2

Total number of math and science teachers (k-12)* 1 ,7(X),0(X)

Total number of math teachers (6-12) lOOS-CW* 191,214

Total number of science teachers (6-12) ISSS-OO* 159,488

Average public school teacher salary - 2(X}3-04' $46,752

Average Spent Per Student' $8,248.

Operating School Districts in the United States’ 15,397

Sources:

1)NaUona! Education Association. Rankings A Estimates: Rankings of the States 2004 ami Estimates of School Statistics 2005- Atlanta, GA: NEA Research. June 2005. Available at: http:/Avww.nea.org<'edstats:images'05ranktngs pdf

2) NaUonal Science Board Science and Engineering Indicators 2004 (NSB 04-01). /Xrlington, Virginia National Science Foundation 2004 Appendev Table 1-19

3) NaUonal Commission on MathemaUcs and Science Teachmg for the 21st Century Before It'sTooLate: A Report to the Nation. September 27, 2000, Available at: http:/Avww.ed gov/inits’^lath/glenrVtoc html

4) NaUonal Center for Education Statistics Digest of Education Statistics 2003. Washington. DC: United States Department of Education. 2004 Table 67.

This paper summarizes findings and reeommendations from a variety of reeently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 21st Century, Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

Attracting the Moitt Able US Students to Science and Engineering

Sumniiin

Tile world economy is growing rapidb’ in fields that require science, engineering, and technologic skills. T he United States can remain a leader in .science and engineering (S&E) only with a well-educated and etTeetively trained population. The most innovative S&E work is done by a relatively small number of especially talented, knowledgeable, and accomplished individuals. Because of the importance of S&E to our nation, attracting and retaining individuals capable of such achievements ouglit to be a goal of federal policy.

It follows that a key component of national and economic security policy must be US S&E students. The United States has relied on draw ing tlie best and brightest from an international talent pool. However, recent events have led some to be concerned that the United States eaiuiot rely on a steady fiow of international students, furthermore, as other developed countries encourage international students to come to their countries and dei eloping countries enhance their postsecondary educational capacity, there is increased competition for the best students, which could further reduce the flow of international students to the United States. Tlierefore. any policies aimed at encouraging student interest in S&E mast have a significant component that focases on domestic talent.

fundamentally, policy levers designed to influence the number of US S&E workers fall into two categories: supply-side and demand-side. .Among supply-side issues are K-12 science, mathematics and technology’ teaching, midergraduate S&E educational experience, graduate training experience, opportunity costs compared with those of other fields and professions, and length of postdoctoral training period. On the demand side are funding for research and availability of research jobs, both of which are powerfully inlluenced by public policies and by public and private expenditures on reseiirch and development.

Past reports have identified a number of options the federal government could take to inlluence the education and career decisions of top US students, including the following:

• Double the number of magnet high sehools speeializing in science, technology, engineering, and mathematics from approximately 100 to 200 over the nexi 10 years.

• Support competitive undergraduate scholarships for students interested in science, mathematics, and engineering.

• Provide scholarships to all qualified students majoring in science or mathematics at a 4-\ear college who have an economic need and who maintain higli levels of academic achievement.

• Provide at least 5,000 portable graduate fellowships, each w ith a duration of up to 5 years, for training in emerging fields, to encourage US students to pursue S&E graduate studies.

• Provide graduate student stipends competitive with opportunities in other venues.

• Support a significant number of selective research assistant professorships in the natural sciences and engineering open to postdoctoral scholars who are US citizens or pemianent residents.

• Partner with industiy to sponsor a series of public-serx ice amiouncements exalting science and technology careers.

(letting an Karly Start: K-12 S&E Programs

One proven way of fostering students' interest in science and technology is through magnet high schools th.at emphasize those subjects. 'Ihere arc approximately 100 such schools in the United States, and studies have shown that graduates from these sehools are more likely to study science, mathematics, or engineering in college and enter those fields during their careers.* It is not known, howev er, w hether these students would have had similar career trajectories even if they had not attended magnet schools.

During the imdergraduate years, involvement in research projects and the guidance of experienced mentors are pow erful means of retaining students in S&E. ^ Mentors can provide advice, encouragement, and infomiation about people and issues in a particular field. .\n early exposure to research can demonstrate to students the kinds of opportunities they will encounter if they pursue research careers.

Trends in ITidergraduiite and (Iraduate Student Interest in S&E

Wlien one examines the issue, it becomes clear that there is a great deal of domestic student interest in undergraduate S&E programs. .About .50“o of students entering college in the United States (of whom over 95*10 are US citizens or pemianent residents) intend to major in S&E fields. This proportion has remained fairly constimt over the last 20 years. However, a considerable gap exists between freshman intentions and suecessfiil degree completion. Undergraduate S&E programs report the lowest retention rate among all academic disciplines. .A National Center for Educational

' Kendall Powell. "HothoUSe HigK” Mature 435 (2005): 874-S75

’ Rena F Subotnik, Karen Maurer Stone, and Cynthia Steiner, “Lost Generation of Elite Talent in Science," Journal of Secondary' Gifted Education 1 3(200 1) :33-43

Statistics (N’CES) longitudinal study of first-year S&E students in 1990 found that fewer than 50®o of undergraduate students entering college declaring a S&E major had completed S&E degrees within 5 years.^ Indeed, approximately 50®o of such undergraduate students changed their major field within the first 2 years/ Undergraduates who opt out of S&E programs are among the most highly qualified college entrants.*^ Tliey are also disproportionately women and nonvvhite students, indicating that many potential entrants are discouraged before they can join the S&E worklbrcc/

Graduate enrollment in S&E programs has been a relatively level 22-26^o of total enrollments since 1993 (see Figures 'fS-l and TS-2). Growth in the number of S&E doctorates awarded is due primarily to the increased numbers of international students but also to the increasing participation of women and underrepresented minority groups/ If the primary objective of the US S&E enterprise is to maintain excellence, a major challenge is to detennine how to continue to attract the best intenialional students and at the same time encourage the best domestic students to enter S&E undergraduate and graduate pro^ams.

l>ecision Points and Disincentives

'ITiere are inherent disincentives that push students away from S&E programs and careers. These disincentives fall into three broad categories: cuiriculum. economics, and environment. Undergraduate attrition may be due partly to a disconnect between the culture and curricula in high schools compared with those at colleges and uni\ersities.^

^ Berkner LK. Cuccaro-Alamm S. and McCormick AC. 1996. Descriptive Summar>’ of 1989-90 Beginning Postsecondar)’ Students 5 Years Later With an Essay on Posisecondary Persistence and Attainment (NCES 96155), Washington DC: National Center for Education Statistics

* Smith T. 2001. The Retention and Graduation Rates of 1993-1999 Entering Science. Mathematics, Engineering, and Technology Majors in 1 75 Colleges and Universities. Norman. OK: Center fw Institutional Data Exchange and Analj'sis (C-IDEA), the Universiw of Oklahoma

* Tobias S. 1990 The}'’n Not Dumb. They 'rv Different. Stalking the SecondTier. Tucson, AZ Research Corporation, Seymour E, and Hewitt N. 1997 Talking About Leaving: ftTiy L’ndergraihiates Leave the Saences. Boulder. CO: WesWiew Press, Ohland MU^ Zhang, G, Thomdyke B, and Anderson TJ 2004 “Grade-Point Average. Changes of Major, and Majors Selected by Students Leaving Engmeering.*' S/*" ASEE/IEEE Frontiers in Education Coitference. Session TIG: 12-17

* Fox MF and Stephan P. 2001 “Careers of Young Scientists: Preferences. Prospects, and Reality by

Gender and Social Studies of Science 31 109-122; Tan DL. 2002. Majors in Saence, Technology.

Engineering, and Mathematics: Gender and Ethnic Differences in Persistence and Graduation, NcMman. OK University of Oklahoma Available at http .'/www.ou edu cducatioiv'csar/litcralure'lan_paper3. pdf;

Building Engineenng and Science Talent (BEST) 2004 The Talent Imperative: Dh’ersijying America’s S&E IVoriforce. San Diego: BEST; Heyman GD, Martyna B, and BhaUa S 2002 "Gender and Achievement-Related Beliefs among Engineering Students " Journal of H’omen and Minorities in S&E 8 33-45

’National Science Foundation 2003 Graduate Enrollment Increases in S&E Fields. Espeaally in Engineenng and Computer Sciences (NSF 03-315) Arlington, VA National Science Foundation

* Vencaa A, Kirst MW. and Antonio AL 2003. Betraying the College Dream: How Disconnected K-1 2 and Postsecondary Education Systems L>i<ili?/7nr/je Student .Aspirations Stanford. CA: The Bndge Project,
Stanford University Available at:

http / ‘v.'W'w Stanford. eda'groupbndgeprojectbetrayingthecollegedream pdf

For example, poor mathematics preparation in higli school may underlie .attrition in undergnaduate physics programs. Underrepresented groups such as blacks and .Vmcriean Indians, who are educated disproportionately in underseraed communities, are on the whole less well prepared for college.’ These types of problems suggest transitional programs to bridge the gap betw een high school and college, but the \ alue of such strategies has not been compared with those .at other levels in the educational system.

Higher education is costly, and employment opportunities fluctuate. Whether a student perceives that a degree w ill lead to a viable career is a major factor determining choice of field."* This is illastrated particularly well in engineering: undergraduate student decisions to major in partieukar fields vary depending on business cycles.

Research indicates th.at large schools, which often fo.ster a competitive "weeding out” environment, have a much higher attrition rate than smaller schools, lliis environment can be compounded by the culture of specific fields. Some researchers argue that a key factor in stemming attrition is feeling coiuieeted to the intellectual and social life of the college." .Another researcher writes of tliree types of uniaersity cultures — the elite (scientific excellence), the pluralist (research, teaching, and seraice), and the communitarian (citizenship) — each carrying its oavn set of values and signals, some of avhich are competing." Departments, colleges and universities, and professional societies each have a role in providing a high-quality, engaging learning environment.

.After a student's detennination of an undergraduate m.ijor or concentration, another key transition point is a decision to enter and complete graduate training."

Major factors to consider include time to degree and economics. '' Unclear job prospects and lost earning potential are major disincentives for many considering an .id\ anced S&F, degree." .An issue raised in several studies on doctoral education is that prospective students are underinformed. .A large, cross-disciplinaryy multi-institutional sun ey on the experiences of doctoral students indicated that students entering doctoral programs entered their programs “w ithout having a good idea of the time, money, clarity of

® Babco E. 2002. Trends in African American and Native American Participation in STEKi Higher Education. Washington DC: Commission on Professionals in Science and Technology.

Clolfeltner CT, Ehrenberg RG, Getz M, and Siegfried JJ. 1991. Economic Challenges in Higher Education. Chicago, IL: The University of Chicago Press,

Teitelbaum MS. 2003 "Do We Need More Scientists?" The Public Interest 153:40-53
" Tinto V. 1993, Leaving College: Rethinking the CaUSes and Curses of Student Attrition. Chicago, IL:

The University of Chicago Press; Braxton JM. 2002. Reworking the Student Departure Puzzle. Nashville,

TN: Vanderbilt University Press

“ Fox MF and Stephan P 2001 "Careers of Young Scientists: Preferences, Prospects, and Reality by Gender and Field.” Social Studies of Science 31 : 109-122.

Lu A. 2002. The Decision Cycle for People Going to Graduate School Stamford, CT: Peterson's Thomson Learning.

“ COSEPUP. 1995. Reshaping the Graduate Education of Scientists and Engineers. Washington EX^: National Academy Press.

Freeman R, Weinstein E, Mahncola E, Rosenbaum J, and Solomon F. 2001 . “CAREERS: Competition and Careers in Biosciences.” Science 294(5550): 2293-2294; Butz W, Bloom GA, Gross N4E, Kelly TK, Kofner A, and Rippen HE. 2003. Is there a Shortage of Scientists and Engineers? How Would We Know? Santa Monica, CA: RAND Corporation, IP-24I-OSTP. Availabel at:

http://www rand org/publicationslPTP241/IP241. pdf; Teitelbaum MS. 2003. "Do We Need More Scientists?” The Public Interest 153:40-53.

purpose, and perseverance that doctoral education entails”,’* ITie burden of being informed does not rest solely on the prospective student. While professional schools make a point to infomi prospective students of the salary and employment le\els of graduates, it appears that S&E graduate programs rarely make such information available.”

Career Prospects in .S&E

Students considering research careers ean faee daunting prospeets. Graduate and postdoeloral training may take over a decade, usually with low pay and few benefits.

Most researchers do not become full-fiedged members of the profession until their mid-30s or later an especially onerous burden for those who are trying to balance the demands of w ork and family.

Even at the end of tliis long training period, many do not find the jobs for which they have been trained, llie stagnation of funding for the physical sciences, mathematics, engineering, and the social sciences over the last decade has led to fewer academic faculty positions in these fields. Even in e.xpanding fields, sueh as the biosciences, tlie number of permanent academie research and teaching positions has not kept up with the growing number of students w ho are entering tliese fields. .‘\s a result, more and more researchers languish in temporary positions.*® llie fa.stest-grovving employment eategory sinee the early 1980s has been “other academic appointments”, which is currently increasing at about 4.9*16 annually .” Tliese jobs are essentially holding positions filled by young researchers coming from postdoctoral positions who would like to join an academie faculty on a tenure track and are w illing to wait. It is an increasingly long wait as institutions are decreasing the number of faculty appointments to decrease the long-term commitments that they entail. From 1993 to 2001, the number of biomedical tenure-track appointments increased by 13.8“o, while those for non-tenure-track faculty increased by 45. 1®6 and other appointments by 38.9“o (see Figure TS-3).

In fields outside the life sciences, most doctorates go on to careers in industry or government (see Figure TS-4). Increasingly, these sectors are providing research opportunities for tlie best students. .At the same time that biotechnology firms are gearing up their R&D operations, top industrial research laboratories, such as Bell Labs andXerox Pare are closing down, leaving physical-science graduates with few options.

Increasingly, mathematics and computer-science graduates are turning to finance and Wall Street. Given these shifts in workforce opportunities, top US students may consider options other than S&E very attractive. Careers in such professions as law, medicine.

'® Goldc CM and Dorc TM. 2001 , At Cross Purposes: lITtat the Experiences of Doctoral Students Rewat about Doctoral Education. Philadelphia PA A Report Prepared for The Pew Chantable TrUSts
’’ Romer P. 2000. Should the Government Subsidize Supply or Demand in the Kfarket for Scientists and Engineers? (Working Paper 7723) Cambridge. MA NaUonal Bureau for Economic Research Availabc at http //WWW nber org/papersAv7723. National Research Council 1998 Trends in the Early Careers of Life ^ientists, Washington. D C.: NaUonal Academy Press

'* National Research Council, Trends in the Early Careers of Life Scientists, Washinglon. DC: NaUonal

Academy Press, 1998

” National Research Council 2005, .4di'ancing the Nation 's Health Needs Washinglon. DC: National Academies Press.

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business, and health serv ices require less training, offer more secure job prospects, and have nnieh higlier lifetime earning potential (sec Table TS-1).

Interest in Research Careers by Top Students Tracks .Job .Market

'nie current contrast between these options and research is intlueneing career decisions. .According to available sources of data, accomplished US students are increasingly turning away from S&E. especially during their undergraduate years. In the 1990s. surveys of .science majors from top universities showed a striking decline of intcrc.st in S&E careers. Retween 1984 and 1998. the percentage of college seniors planning to go to graduate school in the next fall in S&E fields dropped from 17®o to 12”b. .Among those students with .A or .A- grade-point averages, the declines were comparably steep — from 25 t o to 18 “/o.^'

Between 1992 and 2000, the number of college seniors who scored highly on the Ciraduate Record Examination (ORE) and indicated that they intended to study S&E in graduate school fell by 8“6, Tlie number of these top students planning to go to graduate school in fields other than S&E grew by 7®o (Figure TS-5). Hie greatest declines were in engineering (25“o) :uid mathematics (19®o). .Among top GRE scorers, however, enrollment in biological sciences programs showed a 59 “o gain. VV'hen it came to careers outside S&E. the researchers found that the fields attracting the largest growth in top GRE scorers were short training programs in health professions, such as physical therapy, speech and language pathology, and public health drawing 88 t'o more top scorers in 2000 thiin in 1992.

Where are top students going if not into S&E? 'llie top US students do not .appear to be headed in large numbers into law school or medical school, where enrollments have been fiat or declining. But more do seem to be attracted to graduate business schools, where the number of MB.As awarded annually grew by nearly one-third during the 1990s. During this period. m<an\ S&E undergradiurte students also may have entered directly into the workforce after graduating, attracted in p.art by the booming economy. .As the economy slowed in the early part of this decade, some of these students may have returned to graduate school, and more undergraduates may have opted to continue their studies.’^

Indeed. 1999 appears to have been the nadir for student interest in S&E graduate study. The economy's recent slump has prompted growing numbers of top US college graduates to attend graduate school, new d.ata show, sharply reversing course from the late 1990s, when more of the brightest young .Americans headed for quieker-payoff

“ William Zumeta and Joyce S Raveling. “Altracung the Best and the Bnghtesl," Issues in Saence and Technology. Winter 2002, pp 36-40

Engin I. Holmstrom. Caihenne D Gaddy. Virginia V Van Home, and Carolyn M. Zimmerman. “Best and Bnghtesl Education and Career Paths of Top S&E StudenLs,” Washington. DC: Commission on Professionals in Science and Technology. 1997.

“ William Zumcla and Joyce S Raveling. “The Best and the Bnghtesl for Science: Is There a Problem Here?" Pp. 121-161 in M.P, Feldman and A.N. Link (eds.). Innovation Policy in Ihe Knowledge-Based Economy. Boston: Kluwer Academic Publishers, 2001

careers in business and health. By 200 1, with fewer high-technologs jobs beckoning, the share of top US citizen scorers (above 750) on the ORE quantitative scale heading to graduate school in the natural sciences and engineering increased by about 3 1 % compared w ith 1 998. after having declined by 2 1 % in the previous 6 years.^’ This recent increase is comparable w ith the 29 °o gain in the number of all score levels of examinees who intended to enroll in graduate school in S&E. .And the total number of GRE examinees increased by 9 lb between 1998 and 2001, suggesting that more students in a variety of fields were preparing for graduate school.

E'nrollnicnts of International Students"*

.As the number of US students studs ing S&E in graduate schools has dropped, these .schools and employers of scientists and engineers have compensated by enrolling and employing more students and trained personnel from other countries. In 2003, foreign students earned 38 % of doctorates in the S&E, including 59 “ b of engineering doctorates.^^ In 2000, foreign-bom professionals occupied 22 % of all US S&E jobs, up from 14 “b just 10 years before.

But relying on foreign sources of students and research professionals is risky. As systems of higher education and research continue to develop in other countries, it is likely that fewer scientists and engineers will want to come to the United States to study or work. Security concerns also have led to a drop in applications to US graduate programs from international students. Over time, multinational finns may decide simply to locate their R&D facilities overseas, closer to their sources of scientists and engineers. Finally, an overreliance on foreign-bom scientists and engineers may have the subtle elTect of discouraging US students from entering these fields, both because of cultural differences they might encounter during their education (about 20 % of the faculty members in S&E were not bom in the United States’*) and because of a dow nward pressure on wages caused by an abundance of international scientists and engineers eager to work in this country.

^ William Zumela and Joyce S. Raveling, "The Market for Ph.D. Scientists; Discouraging the Best and Brightest? Discouraging All?” AAAS Symposium, February 16, 2004. Press release available at http://www. eurekalert.org /pub_releases/20044)2Aiow-rsl021 304. php
^ See also the Intematronal Students Issue Bnef elsewhere in this report

“ National Academies. Policy Implications of International Graduate Students and Postdoctoral Scholar s
in the United States, W’ashingtoa DC: National Academy Press, in press.

^ National Science Board, S&E Indicators, 2004, .Arlington, VA: National Science Foundation, 2004.

Possible federal actions include the following:

• Double the number of magnet high schools speciali/ing in science, technology', engineering, and mathematics from approximately 100 to 200 over the next 10 years. Federal support for these schools w ould send a pow erful message to the entire K-12 system about the importance of science and technology.

• Sponsor regional, national, and international meetings and competitions for higlt-school students and undergraduates interested in science, mathematics, and engineering. Rxlraciuricular activities and interactions with established scientists, mathematicians, and engineers can be powerful motivating forces for students interested in these subjects.

• Partner w ith industry to sponsor a series of public-service announcements exalting S&E careers.^’

• Provide scholarships to all qualified students majoring in science or mathematics at 4-year colleges w ho have an economic need and who maintain high levels of academic achievement.^* Financial assistance also should be provided to 2-year colleges and to students at those institutions to prepare for careers in S&E and to transfer to 4-year programs. Tax credits could be provided to companies or individuals who contribute to scholarship funds for S&E students.

• Provide at least 5,000 portable graduate fellowships, each with a duration of up to 5 years, for training in emerging fields.”

• Support prestigious fellowships for graduate study in S&E at I’S universities that would inspire the best US students in these fields. Tliough these grants should be linked to the student and therefore portable, an institutional component of each grant would spur competition for these students among institutions.

• Provide graduate-student stipends competitive with opportunities in other venues.^"

• Sub.stantiallv increase the number of undergraduate and graduate S&E students drawn from the "underrepresented majority".*' Today, women, blacks, tiispanics. .\merican Indians, and persons with disabilities make up two-thirds of the US workforce but only 25 <10 of the technical workforce.

Amcncan Electronics Association. Losing Ihn Competitive Challenge? Washington. DC: Amencan Electronics .Association, 2005

** Council on Competitiveness, Innovate America: National Innovation Initiative and Report, Washington,
DC: Council on Competitiveness, 2004

” Ibid

National Science Board, 2003.

Building Engineering & Science Talent. The Talent Imperative, San Diego: BEST. 2004

• Support a signiricant number of selective research assistant professorships in the natural sciences and engineering at luiivcrsities.*" ITiesc would be highly competitive positions open to postdoctoral scholars who arc L'S citizens or permanent residents. Iliey would provide young and creative scholars w itli opportunities to pursue research of their own choosing even if they cannot secure positions at research institutions, fliis would e.xpand the pool of good jobs in S&E in a way that would be e.vpccted to affect young people who arc trying to decide whether to go to graduate school.

• Develop prizes for research goals of particular national interest, such as curing ■AIDS or going into space cheaply. Such prizes can provide Oe.vibility for the researchers striving to achieve them and inspire and educate the public in current research interests.”

William Zumeta and Joyce S Raveling, “Attracting the Best and the Brightest,” Issues in Science and Technology. Winter 2002, pp. 36-40.

“ National Academy of Engineering, “Concerning Federally Sponsored Inducement Pnzes in Engineering and Science." 1999

Attracting the Must Able l^S Students
to Science and Kngineering
Appendix TS 1
Figures and Tables

TS-IO

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Figure TS-1: There Has been a Gradual Increase in the Number of S&E Bachelor’s and Master’s Degrees Awarded, M hile firaduate F.nrollnient and PhD Pi'oduction •Are Just Starting to Increase after Several Years of Declines.

Note: 95“ b of US Bachelor’s Degrees are awarded to US citizens or permanent residents.

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Figure TS-la: Number of S&F^ Master’s Degrees Awarded Flat or Increasing.

F'igure T8-lb: First-Year Graduate Fmrollments Increasing in .VII S&F> F'ields.

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Figure TS-lc; I’S (itizens and Permanent Residents on Average about 60-70% of S&K Doctonil Degrees; About 80% in Life Science's and Socisil Sciences. 60% In Fhysiciii Sciences, and 50% in Kngineering and Mathematics and Computer Sciences.

Source Natiortal Science Foundation Si/rvv>-o/£amedGrotija/^£. Arlington. VA: National Science Founda Uon 2005

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I’lgurt* TS-2: Most I'S Doctorate Degrees Are Awarded In S&K Fields.

Source: Source: Naltonal Science Foundation Survey cf Earned GraduaUs .Arlington. VA National Science Foundation 2005 and
National Center fix Education Statistics Integrated Postsecondar>' Education Data System Compktton Survey, Washington. DC:
Uruled States Department of Education

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Figure TS-3: Most Biomedical Job (>rowth in Industrial Sector; Biomedical Academic Jobs
Are Increasingly Non -Tenure-Track.

Source: National Research Council Afivanang the Nation 's Health Needs. Washington, EXT: National Aca
demics
Press. 2005. Appendix E,

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Fi^re TS-4a: Kqual Numbers of S&F Doctorates Kniployed in Academe and Industry
15% Consistently Employed in Cioemment or Other Sectors.

Source. National Science Foundation. Sune}' of Doctoral Recipients 2003. Arlingtoa VA. National Scien
ce
Foundation 2005.

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Figure TS'4b: S&K PhD Kinployiiient Sector is Dependent I poii Field; Most Social
Scientists Kmployed in Academe, Most Fmgineering Fniployed in Industiy .

Source. Source; National Science Foundation Survey of Doctoral Recipients 2003. Arlington, VA Nationa
l
Science Foundation 2005.

TS.18

Table TS-l: Opportunity Costs are High for Pursuing S&K (traduate Kduaition and Tniining.

A. Median Phi) Salaries of Engineering and Science Graduates, by Occupation and Field of Doctorate in 1997

Occupation

.Ml Sectors

Inlversity

Kconomics

S75.000

55,000 ’

C'omputcr Science

75.000

56,000

PIngineering

73.000

65,000

Physical Science

65,000

52,000

Biological Sciences

56,000

40,000

S&K PhDs in Management, Median .Net income. MDs

92,000

Field

85,000

.Ml Sectors

Inlversity

P^onomics

$69,000

62,000 '

Computer Science

72.000

57,000

Plngineering

75.<HH)

68,0(X)

Physical Science

70,000

54,300

Biological Science.s

60.000

53.000

Source; Richard B Frccmaa Enc Wcinsicm, Elizabeth Nlarincola. Janet Rosenbaum, and Frank Solomon. Careers and Rewards in Bio Sciences: Pie disconnect betw een scientific progress and career progression. 2001. Available at: hltp://www.ascb.org/publicalicais.'compctition html.

Notes Compared with other professionals, such as business-school graduates or la>^yers. who arc generally paid more than PhDs, the salary disadvantage of getting a PhD is marked In the 1990s, median law^yer salaries were on the order of $85,000 and median MBA salaries on the order of $102,000

U. Lifetime income disiid% antage differs by field and is particularly large in fields requiring post doctoral training as a prerequisite for obtaining a permanent position. Case studs': Biosciences, (from Freeman et al, 2001)

Life-time earnings for most doctorates arc lower than in other high-level careers, particularly for bioscicntists. who are paid less than other highly educated workers at any gwen level of job e.xpenence and who take lor^er to obtain full-time jobs. The tM'o factors cumulate to a hi^e lifetime economic disadvantage -on the order of $400,000 in earnings compared with high-paying HiD fields, such as ei^ineering, which also require many years of preparation but in which graduates do not in general delay entry' into the job market to take postdoctoral postions. This is equivalent to a salary' disadvantage of -'$25,000 per year for every year of working life. Medicine, w'hich has a similar career as the biosciences because of residency in hospitals after completion of training, has about twice the lifetime income The economic disadvantage is greater when we compare bioscience with professions that require less preparatory training Ccmsider, for e.xample. a person who has just graduated from a 2-year NiBA program, in 2000 earning $77,000 in base salary* and $12,560 in signing bonus (without stock options) A bioscience PhD who completed postdoctoratal training might earn $50,000 as a starting assistant professor But the N'fBA graduate would have spent 2 years in school compared with the 10-12 years that students ^nd as graduate student and postdoctoratal fellows. The salary* differential cumulates to a lifetime difference in earnings, e.xclusive of stock options, consen-'ativcly estimated at $1.0 million discounted al 3* •—comparable with $62,000 per year of working life. Add in the options and bonuses that managers get. and this differential could easily double.

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Figure TS-5: Top

Number

Students Are Increasingly* Choosing S&E Graduate Study,

ofUS Citizen GRE Examinees Scoring Over 750 on the Quantitative Scale
by Intended S&E Field

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Scttoce Soencet Soeocn

Sour* Edaeaaoa Tttoaf S«me«

Source: W. Zumeta and J. Raveling. The Best and Brightest: Is there a problem here^ 2002. Available http://w\vw.cpst.org^BIssue8.pdf

Note*; The number of US citizen GRE examinees indicating intent to pursue graduate study in S&E fell from 42,170 in 1992 to 3S.373 in 1998.before recovering slightly to just over 36,000 in 2000. This represents a 14.S^ decline from 1992 to 2000. However, new data indicate the trend is in the positive direction: more of the best students are choosing S&E fields for graduate study.

TS-20

*l1iis paper summarizes findings and recommendations from a ' variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 21st Centur\'. Statements in this paper should not be seen as the conclasions of the National Academies or the committee.

Undergraduate, Graduate, and Postgraduate Education
in Science, Engineering, and Mathematics

Summars

As educators of the nation’s future scientists, engineers, mathematicians, and K-

12 teachers. US 2*ycar and 4-year colleges and universities are the central institutions in building the human resources needed for scientific and technological leadership.

However, these institutions face a number of challenges in producing knowledgeable graduates and trained professionals. Today, the United States ranks 17th globally in the proportion of its college-age population that earns science and engineering (S&K) degrees, down from third several decades ago.* Many other nations now have a higher fraction of 24-year-oIds with S&E degrees (see Figure HE- 1). .Vnd even though the proportion of its population who attends graduate school is small, because of its large population China graduates tliree times as many engineers from its colleges as does the United States.

In the past, the United States has relied on international students ;md scientific and engineering professionals to maintain its base of human resources in these fields. Hut global competition for S&E talent is intensifs ing. and enrolling higher percentages of l^S students in tliese programs would have many benefits.

To meet this goal, many believe that the I'nited States will need to attract S&E students from all demographic groups. Today, blacks. Hispanics. and other underrepresented minority groups are about a quarter of the US population but make up only 17.9‘^b of the undergraduate population, 2.5®o of the tliese majors, and 6 ®o of the S&E workforce (see Table H1>1 and Figure HE-2). Only a quarter of this workforce consists of women, though women are almost half the total US workforce. By 2020, more than 40^o of the US college-age population w ill be members of currenth underrepresented minorities.

'fhe federal government has a key role in establishing workforce policies that address national needs and opportunities. Given how many years of education and training are required for someone to become a scientist, engineer, or mathematician, policies may need to focus on long-term opportunities that may help to smooth short-tenn

* Council <xi Compclilivencss, Inncn’ate America, Washington, DC Council on Compclilivcncss, 2004.

labor-market dynamics. .Among the federal actions that organizations have recommended are the following:

Undergraduate Education

• Provide incentives for all institutions of higher education to provide di\crsc internship opportunities for all undergraduates to study science, mathematics, engineering, and technology as early in their academic careers as possible.

• Kxpand funding for programs at 2-ycar and 4-ycar colleges that succeed in attracting and retaining w omen and members of minority groups underrepresented in science, mathematics, and engineering.

Graduate Education

• Establish education and traineeship grants to institutions focused on frontier research areas and multidisciplinary or innovation-oriented studies.

• Require institutions applying for federal grants to report on the size, scope, and performance (student completion rates and career outcomes) of their graduate programs to detennine whether tliese programs are meeting the interests of students in preparing them for diverse careers in academe, industry, goveniment. and the nonprofit sector.

Postdoctoral Training

• Develop federal policies and standards for postdoctoral fellows supported on federal research grants, including letters of appointment, performance evaluations, benefits and leave, and stipend support.

• Help develop creative solutions to the problems faced by dual-career couples so that more I IS students opt to pursue research careers.

• Create standards for and require the submission of demographic infomtation on postdoctoral scholars supported on federal research grants by investigators awarded such grants. Collect data on postdoctoral working conditions, prospects, and careers.

Ihe following discusses these issues in greater depth,

flndcrgradiiiite Kduentiun

'Ihe undergraduate years have a profound innuence both on future profc.ssionals in science and mathematics and on broader public support of those fields. Undergraduate education acts as a springboard for students who choose to major in and then pursue graduate work in science and mathematics. Undergraduate institutions and community colleges train the technical support personnel who w ill keep our technological society functioning smoothly in the years ahead. .And colleges and universities prepare the elementary and secondary teachers who impart lifelong know ledge and attitudes about science and mathematics to their students. For many, the undergraduate years are the la.st opportunity for rigorous academic studs' of these subjects.

Precollege education needs to include quality instniction in standards-based cla.ssrooms and a clear awareness that achies ement in science and mathematics w ill be expected for admission to college. In addition, faculty in these disciplines should assume greater responsibility for the pre-ser%'ice and in-serN ice education of K- 1 2 teachers.

Many introductory undergraduate courses in science and mathematics fields have been taught to select out the best, most committed students and discard the rest. This strategy is being questioned: .^re introductory courses the appropriate place and time for such filtering? .Are the students being turned away any less good than those who stay? Evidence indicates that undergraduates who opt out of S&E programs are among the most highly qualified college entrants.^ Can the United States afford to turn away talented students interested in these fields?

Some argue more broadly that all college students should gain an awareness, understanding, and appreciation of the natural and human-constnicted w orlds and have at least one laboratory experience. Therefore, introductory science and mathematics courses must find ways to provide students both with a broad education in these fields and with the specific skills they need to continue studying these subjects, as is the case with most other introductoiy courses in colleges. Students who decide to pursue nomS&E majors would then have the background and education to make ini'omied decisions about S&E in their personal lives and professional careers.

To serve these multiple objectives, many introductory and lower-level courses and programs would need to be designed to encourage students to continue, rather than end, their study of S&E subjects. Institutions should continually and systematically evaluate the efficacy of courses in these subjects for promoting student learning.

Many of these issues are also highly rele\ ant to students w ho enter 2-year colleges after graduating from high school. For example, about a quarter of the students who earn bachelor's degrees in engineering have taken a substantial number of their low er-level courses at a communits college, and nearly half have taken at least one community college course. .As more students make community colleges their point of entry to postsecondary education, the quality of the S&E education they receive in 2-year institutions becomes increasingly important. Community college students need access to the kinds of lower-division courses that can prepare them for upper-division coursework in science, mathematics, and engineering, either at their own institutions or through partnerships between institutions, distance learning, or other means. Two-y ear colleges need to provide students w ith access to the kinds of equipment, laboratories, and other infrastructure they need to succeed.

The federal government can help promote these institutional changes through the follow ing actions:

• Provide incentives for all institutions of higher education to provide diverse inteniship opportunities for all undergraduates to study science, mathematics, engineering, and technology as early in their academic careers as possible.^

* Tobias S. 1990. They're Not Dumb. They're Different. Stalking the Second Tier. Tucson, AZ. Research

Corporation, Seymour E, and Hewitt N. 1997 Talking About Leaving: tt'hy Undergraduates Leave the Sciences. Eiouldcr, CO: Weslvicw Press; Ohland MW, Zhang, G, Thomdykc B, ar»d Andcrscm TJ. 2004. ■'Grade-Point Average. Changes of Major, and Majors Selected by Students Leaving Engineering." ASEE/IEEE Frontiers in Education Coherence. Session TIG: 12-1 7.

’ National Research Council, Transforming Undergraduate Education in Science. Mathematics. Engineering, and Technology. Washington, DC: National Academy Press, 1 999.

I IE-3

Introducton courses should be integral parts of the standard curriculum, and all colleges should routinely evaluate the success of these courses.

• Encourage science, mathematics, and engineering departments to work with education departments and surrounding school districts to improve the preparation of K-12 students.

• Expand funding for science, mathematics, and engineering programs at 2*year and 4-year colleges that succeed in attracting and retaining women and members of minority groups underrepresented in these programs.^

Master's and Professional Education

The baccalaureate has been the entrx -level degree for many professional positions over the last centurN', but many employers in our increasingly complex economy now recognize the value of employees who have advanced training (see Figure HE-3). Master's degree programs provide students with S&E knowledge that is more in-depth than that provided in baccalaureate programs and supplements this knowledge with skills that have application in business, government, and nonprofit settings. Master's degree programs also can provide the interdisciplinar\' training necessar>’ for real-world jobs and can be structured to provide job-relevant skills in teamwork, project management, business administration, communication, statistics, and infomiatics. Moreover, master's programs have the potential to attract greater numbers of women and minority-group member than do doctoral programs.

A number of reports since the mid-1990s have argued that master's degree programs for students in the S&E with appropriate career aspirations can develop a cadre of professionals who meet employer needs. These reports have called for changes in master’s education to make these programs more appropriate, cost effective, and attractive to students. In engineering, for example, the emphasis on increased skill in communications, business, the social sciences, cross-cultural studies, and important technologies has meant that the first professional degree should not be at the baccalaureate but at the master's level, as is the case in business, law, and medicine.

Options for the federal government include the following:

• Direct the National Science Foundation to fund professional science ma.ster's programs at institutions that demonstrate innovative approaches to orienting master's-level degree programs toward scientific or technical skills needed in Uie US workforce.

Graduate Education

Ciraduate education in the United States is widely seen as the best in the world. .America's universities produce most of the scientists, engineers, and mathematicians who will maintain our preeminence in science and teclmologx' (see Figure HE-4). Tliey

“* National Science Foundation. National Science Board. The Science and Engineering Worfrforce: Realizing America 's Potential, Arlington, VA: National Science Foundation, 2003.

educate the college faculty and K- 12 teachers who will critically influence public support for scientific and technological endeavors .And the intensive research CNpcricnccs that are at the heart of graduate education at the doctoral level produce much of the new knowledge that drives scientific and technological progress.

Students from mans nations travel to the United States to enroll in science, engineering, and mathematics graduate programs and to serve as postdoctoral fellows.

For example, international students aecoiuit for nearly half of all graduate enrollments in engineering and computer science. The presence of large numbers of international students in US graduate schools has both prrsitive and negative consequences.* TItese students enliance the intellectual and cultural enviroiuncnts of the programs in which they arc enrolled. Many remain in the United States after their training is finished and contribute substantially to our scientific and technological enterprise. However, the large numbers of foreign students in US graduate schools may have the elTect of discouraging US students from pursuing this educational pathway because the rapidly inereitsing number of students has diminished the relative rewards of becoming a scientist or engineer.* US colleges and universities have an important role to play in encouraging more US students to pursue graduate education in science, engineering, and mathematics.

The federal government helps support graduate education through research assistantships funded through federal research project grants, fellowship and traineeship programs, and student loans (see Figure HE-5). llie availability, level, and timing of this funding have implic.ations for detennining who can pursue a graduate education iuid how long it w ill take to complete that education. .Also, the type of support — whether a research assistantship, teaching assistantship, traineeship, or fellowship — affects the content of graduate education ruid the kinds of skills one learns during graduate school.

In the 1990s, several events led to a national discussion of the content and process of doctoral education that continues today. In the late 1980s, labor-market forces pointed tow ard an impending shortage of PhDs in the arts and sciences in the early to mid-1990s. When the end of the Cold War, a national recession, state budget cuts, and the end of mandatorx' retirement for college faculty led instead to disappointing job prospects for new PhD's in the early 1990s, a national debate on the doctorate and the job prospects of PhD recipients ensued.

.Also, in the 1990s, for the first time, more than half of PhDs in science and engineering reported that they held positions outside academe (see Figure HF,-6). This trend has generated interest in providing graduate students with more infonnation about their career options, including w hether they should pursue a master's or doctoral degree and whether they should seek opportunities in government, industrv', or nonprofit organizations as well as academe. In turn, this trend has focused attention on the need for training that provides the practical career skills needed in the w orkplace: pedagogic skills, technological proficiency, the ability to communicate well in writing or oral presentations, experience working in teams, and facility in grant writing and project management.

* Comm lUee on Science, Engineering, and Public PoIic>', Reshaping the Graduate Education of Scientists and Engmeers, Washington, DC: National Academy FTess, 1995.

* Ralph E. Gomory and Harold T. Shapiro, “Globalization: Causes and Effects,” Issues in Science and Technology, Summer 2003, pp. 18-20.

HF.-5

One great problem in discussions of workforce issues is the paucitt' of reliable, representative, and timely data. Often policymakers are making decisions about the future based on data that are 2-.^ years old.

Options for the federal government include these:

• I^stablish education and traineeship grants to institutions focused on frontier research areas and multidisciplinaiy or innovation-oriented studies.'

• Eliminate the employer-employee stipulation in OfTicc of Management Budget Circular .•\-21 to encourage the dual benefits to research and education of having graduate students serve as research assistants.®

• Require institutions applying for federal grants to report on the size, scope, and performance (student completion rates and career outcomes) of their graduate programs to determine whether these programs are meeting the interests of students in preparing them for diverse careers in academe, industry, goveniment. and the nonprofit sector.’

• Provide graduate student stipends competitive with opportunities in other venues.'"

• Direct the National Science Foundation to expand its data collection on S&E careers and its research into national and international workforce dynamics."

Postd (K'toral f ra iiiiii g

For more than 2 decades, an increasing percentage of new PhD recipients have been pursuing postdoctoral study instead of employment after graduation. Iliese experiences broaden iuid deepen the research and other skills that scientists and other highly trained professionals need to make major contributious to society (see Figure HE-7). .Most postdoctoral scholars are funded by federal research grants (see Figure HF.-8) and on average have .stipends of under S-tS.OOO per year.

However, mentors, institutious. and funding organization ha\ e sometimes been slow to give postdoctoral fellows the status, recognition, and compensation that are commensurate w ith their skills and contributions to research (see Figure HE-9). Many postdoctoral scholars make substantial economic and familial sacrifices to pursue advanced training, yet they often do not have clearly defined rights, responsibilities, pay scales, access to benefits, or procedures for consideration of grievances.

To ensure a healthy research enterprise, the postdoctoral experience needs to be improved. Ilie federal government should:

• Develop federal policies and standards for postdoctoral fellows supported on federal research grants, including letters of appointment, performance evaluations.

’ibid.

* Association of American Universities, Committee on Graduate Education, Graduate Education,

Washington, DC: Association of American Universities, 1998

’Ibid.

National Science Board. 2003.

“ Committee on Science, Engmeering. and Public Policy, 1995.

HE-6

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benefits and leave, and stipend support. .Ul postdoctoral scholars should have access to health insurance and to iastitutional ser\'ices.'"

• Help develop creative solutions to tlie problems faced by dual-career couples so that more US students opt to pursue research careers.

• Improve the quality and quantity of the data on postdoctoral working conditions, prospects, and careers. Cre.ate standards for and require the submission of demographic infonnation on postdoctoral scholars supported on federal research grants by investigators awarded such grants.

Committee on Science, Engineering, and Public Policy, Enhancing the Posttjocloral Experience for Scientists and Engineers^ Washington. DC: National Academy Press, 2000.

Ibid

HE-7

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ill Science, Kngineeiing, and Matheinalics
Appendix IIK I
Figures and Tables

Figure IIFM: The Number of Bachelur's Degrees Axvarded in S&E Fields Shows Marked F'luctuatiuns I'liat Are AfTected by Market C'unditiuns and Research Funding.

Table IIFM: Increasing Nunihers of Students an- Majoring in S&IC Fields; Substantial (iaiiis among \\'unien and Minority (iroups.

Figure IIFl-2: .Minority-firoup Representation among S&F^ Majors Is Increasing.

Figure IIFl-3: Master's Degree .attainment Increasing fur M'onien and Minorily-Ciroup Menibei's.

Figure IIF'-4: Oxerall S&F) DiK'toral-Degree Production Increa.srd in the F'arly 199l)s. Flattened, and in 2001 Started to Increase again; Minority -(iroup Participation Increased Through the 1980s and 1990s and FAperienced a Dow nturn Starting in 1999.

F'igure IlFl-5: Financing of Duetunil F'ducatiun Comes from Several Sources, but Predominantly from F'ederal Research (ir.ints; Sources of F unding \’ary by C iti/ensliip Status.

Figure IIF^6: .Most S&F^ Graduate Students Obtain .lobs Outside .Vcademe: .Approximately F^qual Numbei's of S&F^ Doctorates F'mployed in .Academe and Industry ; 15% Consistently ICniployed in C^uxemment or Other Sectors.

F'igure IIFl-?: Most PustdiK-tunil Scholars F'eel Positions .Are Preparing rheiii for Independent Positions.

Figure IIF^8: .Most Funding for Postdoctoral Scholars Conies from F'ederal Research Grants.

F'igure IIF,-9: 21)01 Postdoctoral Stipends for S&F. Trainees .Averaged I'nder S32,0tM) Per A'ear.

Figure HE^l: The Number of Bachelor’s Degrees Awarded in S&E Fields Shows Marked Fluctuations That Are Affected by Market Conditions and Research Funding.

Figure 2-11

S&E bachelor's degrees, by field: Selected years, 1977-2000

Number of degrees

NOTE: Geosciences irKlude ecrtb. atmospheric, and ocean tciences.

SOURCES: U.S. Department of Education. Completions Survey;

and National Science Foundation. Division of Science Resources
Stotistics. WebCASR^R database system, http://caspar.nsf.gov.

See appendbc table 2*22.

Source: National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Ariington. Virginia National Science Foundation. 2004. Appendix table 2-23.

Notes: Degree production for many STEM fields increased and computer science decreased in 2001. See graphs in theAttmcting the Most Able US Students to Science and Engineering paper.

Table HE-1: Increasing Numbers of Students are Majoring in S&E Fields:
Substantial Gains among Women and Minority Groups.

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Source: Ntf ional Science Board. Science and Engtneenng Indicators 2004 (NSB 04-01). Arlington. Virginia. National Science Foundation. 2004. T^Ie 2-8.

HE-10

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Figure HE-2: Minority-Group Representation among S&E Majors Is Increasing.

Figure 2-13

Minority share of S&E bachalor's degreos, by
raca/ethnicity: Selected years, 1077-2000

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Source: National Science Board. Science and Engineering Indicators 2004 (NSB 04*01). Arlington, Virginia National Science Foundation. 2004. Figure 2*13.

Figure HE-3: Master’s Degree Attainment Increasing for Women and Minority-Group Members.

Rove 2-17

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Source; Ndtons] Science Board. Science and Engineering Indicators 2004 (NSB 04*01). Arlington. Virginia. National Science Foundation. 2004. Figure 2*17.

Figure HE>*4: Overall S&E Doctoral-Degree Production Increased in the Early 1990s, Flattened, and in 2001 Started to Increase again; Minority-Group Participation Increased Through the 1980s and 1990s and Experienced a Downturn Starting in 1999.

Figure 2*19

$&E doctoral de^ees earned in U3. universities,
by field: 1977-2001

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Figure 2*21

Underrepresented mewri^ S&E doctoral degrees,
by race/etbnicity: Selected years. 1977-2001
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Scene* a E ri gnxnnp Indcmton - 2004

Source: National Science Board Science and Engineenng Indicators 2004 (NSB 04*01). Arlington, Virginia. National Science Foundation. 2004. Figures 2*19 and 2-21.

HE-B

Figure IIK-5: Financing of Doctoral Fducation C ’onies from Several Sources, but Predominantly from Federal Research (i rants; Sources of Funding \ ar> by
(iti/enship Status.

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^’ear Degree Awarded

Source: National Science Foundation 2004. Sunvy of Earned Doctorates 2003. Arlington, VA. National Science Foundation

Other: support from the student or scholar's institution of higher education, state and local government, foreign sources, nonprofit institutions, or private industry, traineeships: educational awards given to students selected by the institution or by a federal agenc>*. researdi assistantships. support for students whose assi^ed duties are primarily in research, teachii^ assistantships: support for students whose assigned duties are primarily in teaching

Figure IIR-6: Most S&F Graduate Students Obtain Jobs Outside Academe: Approximately Kqual Numbers of S&F^ Doctorates Kmployed in Academe and Industry; 15% Consistently Kniployetl in Cioxemment or Other Sectors.

Percent of S&E Doctorates Employed per Sector

'Academic

Industry

■Govemmen

'Other

Sectors

Data from: National Science Foundation 2005 Survey of Doctoral Recipients 2003 Arlington, VA: National Science Foundation

IlE-15

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Figure nF>7; Most Postdoctoral Scholars Feel Positi<His Are Preparing Them for Independent Positions.

To wlut extent do you agix'e wtli the folhming statement?
"My postdoct<iral position Is pivpaniig me to he an independent researcher."

100%

80*i
60%

40^i
20%

O^o

Citizen^ Citizen & Tenporaf>' Teinpocai>'

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□ l=Strongty agree

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□ 3"Nciiher agree nor
disagree

□ 4=Disagree

■ 5=Strt>ng^’ disagree

Source Davis. G. Doctors without orders: Highlights of ^e sigma xi postdoc survey American Scientist 93(3. supplementXMay-June 2005) Available at. http //postdoc sigmaxi org/rcsulls.'

22.1 78 postdoctoral scholars at 46 institutions were contacted, including 1 8 of the 20 largest acad emic
employers of postdoctoral scholars and NIH. Postdoctoral status was confirmed by the institution 8492

(3^/o) responded, 6.775 (31%) of the respondents completed the entire survey, which included over 100

questions

Figure HK~8: Must Funding for Postdoctoral Scholars Comes from Federal
Research (Grants.

■ Non-Federal Sources

□ Research Grants

■ Trameesh^

□ Fellowships

90".>
80®*
70" 0

50^0

40**

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□ Non>Federal Sources

□ Research Grants
■ Trameesh^s

□ Fellowships

Source; National Science Foundation 2004 Survey of Earned Doctorates 2002. Arlington. VA: National Science Foundation.

Non-Federal Sources, support from the institution of higher education, stale and local government, foreign sources, ncmprofit institutions, or private mdustr>'. research grants: support from federal agencies to a principal im estigator. under whom postdoctoral scholars work; traineeshtps: educational awards given to scholars selected by the institution or by a federal agency; fellowships: competitive awards given directly to scholars for financial support of their graduate or postdoctoral studies.

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Figure HK-9: 2001 Postdoctoral Stipends for S&E Trainees Averaged I'nder S32,000Per Year.

Median 2001 Postdoctoral-Scholar Stipends

Life Sciences Physical Science and
Sciences and Hngmeenng
MathenBtics

□ Gtizens and
Permanent Residents

■ Temporal^’ Residents

Source: National Science Foundatioi. 2004. Survey of Earned Doctorates 2002. Arlington, VA: National Science Foundation

HE- 18

This paper summarizes findings and reeommendations from a variety of recently published reports and papers as input to tlie deliberations of the Committee on Prospering in the Global Economy of the 21st Centurv'. Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

Implications of Changes in the Financing of Public Higher Education

Summani

Public colleges and imiversities play a critical role in our nation's integrated system of education, research, and innovation. They educate the majority of undergraduates and con.stitute many of the nation's top research universities. They are training grounds for the people and ideas that drive innovation and improse our lives.

Yet even as public colleges and universities are becoming more important than ever in our knowledge-intensive society, many have come under intense financial pressure. Demographic changes in enrollments arc driving up student enrollment in some places :uid reducing them in others, forcing institutions to adapt to new circumstances, llie increasing costs of higher education have led to difiicult tradeofl's affecting the qualitv' of tlie education and services students receive. E.vtremely tiglit budgets in some states have reduced the relative appropriations to education in tho.se states even as more students are looking to college as a means of personal advancement.

I'hough federal funding for student aid is up, more of this funding is going toward loans and ta.\ benefits as opposed to student grants. .Also, increases in funding have not been sulfieient to match the needs of students, llie result has been a narrow ing of educational choices for some students and concerns over deteriorating quality of public institutions.

Some organizations have proposed that the federal government take ses eral important steps to improve the funding of public higher education and to increase student access to these institutions:

- Expand federal matching programs that encourage increased state appropri.ations for higher education.

- Reform the Medicaid program to slow the grovuh of state commitments tliat crowd out spending on higher education.

- Eocus national resources on improving the purchasing pow er of Pell aw ards.

- Offer matching funds to states based on their fimding of means-tested grant aid.

PHE-1

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The Role of Higher Kdueatiun in the Knuwiedge Kconom\

Higher education has been eentral to the strength of the US economy over the last half-eenlury. Uroadened access for students has created social ;uid economic opportunities for millions of Americiuis. Hie integration of education and research has become a key pillar of our research and innovation system. .And tlie new knowledge generated has pros ided a strong engine for innovation and economic growth.

Public institutions are a particularly important component of .America's higher-education system. 'I1iey enroll :ind educate one quarter of all 4-year undergraduates (see Figure PIIE-I). When community colleges are included, public schools account for more than 70 ®o of all undergraduate enrollment (see Figure PHE-2). Many of tlie nation's top research institutions, particularly in tlie .Midwest and West, are public universities.

A strong system of higlier education is more critical now than ever. Olobal competition in the knowledge economy is growing. Developed and developing countries are working to create higli-quality educational institutions, often using .American colleges and universities as a model. They are developing their own pool of know ledge workers and know ledge-sector firms.

For the United States to compete in this environment. .American higlier education needs to remain preeminent. It must continue to play a central role in the production of knowledge and innovation. It needs to create dynamic en\ ironments that w ill entice knowledge-ba.sed companies to locate in this countrv'. The United States should facilitate w orld leadership of its higher-edueation system by continuing to invest where it counts most.

Stres.ses In the Finiinclal .Structure of Public Higher Fduciiliun

Public higlier education is under severe financial pressures. 'Hie first source of pressure is increasing enrollments. Hie children of the baby boom are now reaching college age and w ill increase enrollments at some institutions over the coming decade (see Figure PHE-3), .At the same time, the value of higher education as a means for students and society to achieve economic, social, and political goals also is boosting enrollments. Because public institutions typically do not charge students for the full cost of their edueation. the financial demands on these institutions are expected to grow significantly.'

.A second stress on the system is the grow ing cost of higlier education. Costs per student in higher education have grown consistently since the 1960s and steeply since tlie 1970s.^ Both intenial and e.xlemal factors appear to be driving up costs. Universities need to compete for high-quality faculty, staff, and students. Computing serv ices, information resources, and other services for students and faculty have added financial biudens (see Figure PHF,-4). To cut costs in other areas, institutions have increased

' Robert C. Dickeson. Collision Course: Rismg College Costs Threaten America 's Future and Require Shared Solutions, Indianapolis. IN. Lumina Foundation for Educatioix Inc.. 2004.

* Joseph L. Dionne and Thomas Kean. Breaking the Social Contract: The Fiscal Crisis in Higher Education (report of the Commission on National Investment in Higher Education), New York Council for

Aid to Education, 1997.

sludentrlaculty ratios, shitted toward lower-cost part-time and non-tenure-track faculty, encouraged early retirement, capped or postponed faculty salarv' increases, and outsourced noncritical missions’ (see Figure PHE-5).

.“X third and perhaps the most important stress on public higher education has been a changing paradigm for public support at both the .state and federal levels (see Figure PHE-6). Public colleges and universities — and even pri\ate ones that receive state support — have e.vperienced strong competition for state resources over the last decade. Other state financial commitments — such as Medicaid payments — have continued to increase both in real dollars and as a percentage of state budget outlays, which has crowded out other spending priorities'* (see Figure PllE-7).

.As a consequence of this Unancial pressure, education funding as a share of state spending, the percentage of education dollars directed to higher education, and the percentage of higher-education dollars going to institutions (as opposed to students) all have declined’ (see Figure PHE-8). In brief, state support as a percentage of total revenue for public colleges and universities is down, and these institutions are adapting by restructuring costs and looking elsewhere (for example, to tuition) for Unancial support (sec Figure PIIE-9).

.At the federal level, spending for higher education appears on the surface to be strong. Spending on the Pell grant program, for example, increased 60 96 in real terms from 1999-2000 to 2003-2004^ (see Figure PHE-10). However, hiding beneath the overall increases in federal support are important shifts in its distribution, 'lire mix of federal support in 2003-2004 was 34 96 grants. 55 % loans, and 5 9o tax benefits, the latter two of which have been growing as a percentage of federal support (see Figure PHE-1 1). Tlius. tliere have been a shift away from grants to other modes of support (for example, subsidized loans, tax credits, and tax-sheltered education accounts) and a shift from need-based to merit-based aid (see Figure PHE-12). Together, these changes have tended to shift subsidies away from students from lower-income families and toward the middle and upper-middle classes.

In addition, while there have been real increases in per student funding under the Pell grant program, they have not been adequate to offset larger increases in college prices, file size of the average grant has increased in real tenns in recent years, but average tuition, fees, and room and board at public 4-year colleges and universities increased faster. .As a result, the average Pell grant in 2003-2004 covered 23 96 of the charges at a public 4-year institution compared w ith 35 9® in 1980-1981^ (see Figure PHE-1 3). Meanwhile, the Leveraging Education .Assistance Partnerships (LE.AP) program, which provides matching funds to states for providing need-based grant aid. has declined 319® in real terms over the last decade.*

’ Ronald G. Ehrenberg and Liang Zhang, “The Changing Nature of Facuhy Employment" (Working Paper 44). Ithaca NY: Cornell Higher Education Research Institute. 2004.

* Thomas J. Kane and Peter R Orszag. "Higher Education Spending: The Role of Medicaid and the Business Cycle” (Pohey Brief #124), Washingtoa DC. The Brookings Institutioa 2003,

’ Michael Rizzo, "State Preferences for Higher Education Spending: A Panel Data Analysis, 1977-2001.”

paper presented at Cornell Higher Education Research Institute's Annual Conference “.Assessing Public

Higher Education at the Start of the 21“ Century,.” Ithaca NY, May 22-23, 2005.

* College Board. Trench in Student Aid 2004, Washington, D.C. College Board. 2004,

’Ibid

“ Ibid

Iniplirutiuns for AITonlability and Quality

These developments have important implieations both for access to higher education and for educational quality. As tuition increases, the array of educational choices for students may be constrained unless the availabilitv’ of financial aid can compeasate. Especially for low-income students, the real and perceived cost increases for college education can limit access and lifetime opportunity (see Figure PHE-14).

Hie second implication is for the quality of teaehing and research. Reductions in funding for public education combined with constraints on tuition increases appear to be causing deterioration in the quality of public colleges ;uid universities compared with prisate institutions.’ Private universities benefit from larger endowments, have constrained enrollment growth to control costs, and have steadily increased tuition to olTset infiation and provide new resources for qualitative improvement. Public institutions are less able to use these measures for fiscal control and as a result are falling behind private colleges and universities, in endowments, faculty salaries. student:faculty ratios, student services, and facilities (see Figure PHE-15). .Also, to the e.xtent that changes in faculty composition — such as increases in part-time and non-lenure-track staff affect the qualits' of leaching and mentoring and the availabilits of tenure-track faculty as role models, tliey may affect undergraduate persistence, graduation rates, and the propensity to continue to graduate school, llie consequences include a more stratified, less dynamic society and a more limited workforce available for generating knowledge and innovation in the economy.

Issues of attainment also have come to the fore. With a growing number of postsecondary students starling out at community colleges and intending to transfer, 2- and 4-year institutions need to work to improve transfer and articulation agreements and processes to facilitate smooth transfers.” Colleges and universities must make a commitment to the students tliey admit by supporting retention efforts so that students do not drop out of college w ith higli debts and no degree.

Ensuring .\dequate Funding for Public Higher Education

The federal government has a number of options that could help public institutions receive revenues that reflect the true costs of higlier education:

• Design or e.xpand federal matching programs that encourage increased stale appropriations for higher education. For e.xample, to encourage states to expand means-tested grant aid. the federal government could olTer matching funds to states based on their funding of such programs.

• Reform the Medicaid program to slow the growth of state commitments that crowd out spending on higher education."

’ Jeny' Kissler, “Why It Is in the Interest to Address the Growaig Gap Between Public and Pnvate Universities.’’ Oakland, CA; University of California. 2005.

National Research Council, Enhancing the Community College Pathway to Engineering Careers, Washington, DC: National Academics Press, forthcoming
" Kane and Orszag, 2003

Create "Leani Grant Universities” through a federal “Learn Grant Act” as significant as the Morrill Act of 1862 and the GI Bill of 1944.

Enact a "Higher F.ducation Millennium Partnership .Act” tliat would integrate technology into the curriculum, create more flexible educational opportunities for part-time and nonresidential students, and develop new partnerships with schools, businesses, and local communities.'^

Create a “Millennium F.ducation Trust Fund” using the sale of unused communications spectrum over the next few years (w ith proceeds possibly greater than $18 billion) to provide students w ith the skills necessary for an age of innovation.

Iniprosing .Vcccss to Higher Fiduralion

In addition, the federal goveniment can help the states improve access to higher

education for all .Americans tlirough several actions:

- Focus national resources on improving the purchasing power of Pell awards.'*

- Increase llexibility for states to buy more subsidized loan eligibility from the federal government.'''

- F'xpand and restructure the LE.AP program to allow private-sector matches from such organizations as Scholarship .America and community foundations. '*

- Institute a voucher program that would give more money to students from low-income homes.'*

- Mandate that both public and private institutions use the average “net price” of attendance instead of the stated “sticker price” in all federal grant and loan programs to detennine who qualifies for student-aid awartls and how much they should be aw arded. Using sticker prices as the olTieial institutional “cost of attendance” misrepresents the actual average cost of attendance in most federal and state student-aid programs.'*

- Consider eliminating the Free .Application for Federal Student .Aid. Changing law s to pennit tlie use of Internal Revenue Service data to assess qualification for financial aid can simplify processes, save hundreds of millions of dollars, and remove bureaucratic barriers to postsecondary access.'*

“ Janies J Duderstadt and Fams VV Womack. Beyond the Crossroads: The Future of the Public University in America, Baltimore The Johns Hopkins University Press. 2003
” Dickeson. 2004
'* Ibid

" Ibid

Richard Vedder. Grmving Broke By Degree: BTry College Costs TooSiuch, Washington. DC: AEI Press. 2004

'* Ale.xander, F. King. “Policy Implications of Changes in Higher Education Finance.” presentation to the
National Academies' Board on Higher Education and Workforce. Washington. DC. April 21-22. 2005
'• Dickesou 2004

Implications ofC'hanges in the Financing
of Public Higher F'ducatioii

Figures and Tables

F'igure PHF'.-I5: lmplicati<ms for Quality: Public Institutions Have Not Been Keeping Pace w ith Private I'niversities in F'aculty Salaries.

PHE-7

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Figure PIIK-1 : Public Institutions Account for Nearly a Quarter of All FnroHed 4-Vear I nclergniduate Students.

Distribution of BA-granting institutions

■ For-profit

■ Nonprofit
□ Public

Source Sarah Turner Policy Implications of Changing Funding for Public Higher Etiucation. Presentation to National Academ ies' Board on Higher Education and Workforce. April 2005

Figure PIIK-2A: Public 4-^'ear and 2-^'ear Colleges Knixill 70% of All Indergraduates.

Share of
1st lime FT

Distribution of students

Undergraduate Enrollment in-state

1967 1996 1996

Communitjr’ Colleges

2]%

37«.b

92. 7»/.

Other Public

m.

33%

81.5%

Flagship Public

13*/.

9%

72.0%

AH Private

2S%

21%

54.2%

Research I Private

3*/.

2%

23.6%

Liieral Arts CoUeee

4*.

2%

43 2%

ScHirce SarahTumer, Policy Implications of Changing Funding for Public Higher Education. Presentation to NaticHial Academies' Board on Higher Education and Workforce. April 2005

PHH-8

Figure PIIE-2B: In 2000* 15.5 Million I'lidergraduiites M ere Enrolled m i*S
Institutions.

Source; National Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington. Virginia National Science Foundation, 2004

pnE-9

Figure PHE-3: National Trends. Percent of 18 to 24 Year Olds Enrolled In College Shows a General Upward Trend. A Steep Slope in Total Enrollment Started in 1955 and Then in 197U Resolved into a Shallower Upward Slope.

18.000,000

16,000.000
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12 . 000.000
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I

8.000,000

1

6.000.000

4.000. 000

2.000. 000

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1920 1930 1940 1950 1960 1970 1980 1990 2000

Source; Sarah Turner. Policy Implications of Changing Funding for Public Higher Education, l^cscnlali on
to National Academies' Bo^d on Higher Education and Workforce, Ajm”!! 2005.

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37.S00

39X00

33.900

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Source: Thomas J. fCaiK. The Role of Federal Government in Financing Higher Education. Presentation t o
National Academics' Board on Higher Education and Woricforcc March 21, 2005

PHE-10

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Figure PIIIv3B: Projected Increases in C'oUege-Age Population Over the Next 25 d eal's May Translate into Additional Expenses as Institutions Work to Create Additional Capacity.

Population Growth Projections, Ages 18-24

United Stales — - -Texas — — California New York |

Source; Thomas J, Kane. The Role of Federal Government in Fmandng Higher Education. Presentation to National Academies' Board on Higher Education and Workforce. March 2 1 . 2005. Calculations based on Bureau of Census, Population Projections.

PIlE-11

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Figure PHE-4: Instructional Expenses Are But 37% of Public-Institution
Expenditures.

Figure 13. Expenditures of All Public Institutions, 2001

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MalntMiMC* FtPtiwihltw

7% 6%

Vwrir: EmtUrntnl in nMittottdarr itirtfitfiiMi. Ml 2001 tini Ftnamul Sttitttics. FY JOOi, Table 29, N
CES 2004‘1S!>.

Source: National Center for Education Statistics. Enrollment in Postsecondary Institutions, Fall 2001 and
Financial Statistics, Fiscal Year 2001 (NCES 2004-155). Washington, DC: United States Department of
Education. December 23, 2003. Table 29. Available at:
http://nces.ed.gov/pubsearch^ubsinfo.asp?pubid=2004155

431

Figure PHE-5: Sludent:Faculty Ratio Has Remained Fairly Stable at Public Institutions
and Decreased at Private Institutions.

Source; Thomas J Kane. The Role of Fetkral Government in Financing Higher Eiiucation. R’eseniation to

National Academies' Board on Higher Education and Workforce. March 21, 2005.

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Figure PHE-6A: Direct Government Support of Public Higher Education Has
Steadily Decreased While Grant and (Contract Sources Have Increased.

Figure 12. Revenue Sources for All Public Degree-Granting Institutions.

1980-81 to 2000-01

Source: The College Board. Trends in College Pricing. 2004. Washington. DC. 2004, p. 20 Available at:

http:/Avww.collegeboard.com/prod_downloads/|M'ess/cost04/041 264TrcndsPricing2004_FlNAL.pdf

1955 1960 1965 1970 1975 1980 1985 1990 1995 2000

Budget Year

Source: Sarah Turner. Policy JmfAications of Cltanging Funding for Public Higgler Educalion. Presentation
to National Academies' Board on Higher Education and Workforce, April 2005.

Figure PHE-6B: Public and Prhate Institutions Have Access to Different Revenue
Sources.

Current Fund Revenues Tuition

state Federal Private Endow. Tuition

Aux.

In-state Out-of-

& Local

& Other

State

Communly Collies

57.5%

11.7%

1.0%

0.1%

20.2%

9.5%

$1,814

$4,362

Other Public

36.3%

10.7%

4.0%

0.4%

18.3%

30.2%

$2,725

$6,981

Flagship Public

29.0%

14.8%

6.4%

1.3%

17.2%

31.4%

$3,493

$9,998

All Private

2.8%

10.3%

9.1%

5.1%

41.9%

30.8%

$12,881

Research I Private

2.3%

16.1%

9.5%

5.7%

22.9%

43.5%

$19,814

Liberal Arts Colleges

1.4%

3.0%

9.1%

10.5%

55.5%

20.5%

$17,648

Source: Sarah Turner. Policy Implications of Changing Funding for Public Higher Education. Presentali on
to National Academies* Board on Higher Education and Worhforce. April 2005.

Figure PHE-7: Medicaid Expenses Have Begun to Compete with State Higher-
Education .Appropriations.

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Source: Thomas J. Kane. The Role of Federal Oovemmentin Financing Higher Education. Presentalion to
National Academies' Board on Higher Education and Workforce, March 21, 2005.

Figure PHE-8A: Higher-Education Expenses Have Fallen as a Share of State
Expenses in Parallel with Increases in Medicaid Spending.

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Source: Thomas J. Kane. The Role of Federal Oovemmentin Futancing Higher Education Presenlalion to Niiiona) Academies' Board on Higher Education and Woikforce. March 21, 2005.

Figure PHE-8B: State Appropriations for Higher Education Have Fallen as a Share of Personal Income, Also In Parallel with Increases in Medicaid Spending.

Source: Thomas J. Kane. The Role of Federal Oovemmentin Financing Higher Education Presentation to National Academies' Board on Higher Education and Woricforce, March 21, 2005.

Figure PHE>9A: Average Published Tuition and Fee Charges Have Increased at Public and Private Inslitutions.

Source; Sancfy Bauni CfKUjges in Ftimingjbr Public Higher Educaiion:

College Prices and Student Aid. Presentation to N^iona! Academies' Board on Higher Education and Workforce. April. 2005. Data are from Collie Board Trends in Higher Ecktcation Series. 2004.

Figure PHE-9B: Decreases in Instructional .Appropriations Precede Increases in Tuition and Fees at Public 4-Vear Inslitutions.

Source; Sandy Baum. Changes in PwuSfigJbr Public Higher Erhcation:

College Prices and Student Aid. Presentation to National Academies ' Board on Higher Education and Workforce, April, 2005. Data arc from Collie Board Trends in Higher Education Series, 2004.

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Figure PHE>10: Pell Grant Expenditures Are Increasing, But Average Grant Size HasNot Changed Substantially Since 1981.

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Source: Sandy Baum.. Chemges in FufuSfig^ PuNic Higfter Education:

College Prices and Student Aid I^esentation to National Academies' Board on Higher Education and Workforce, April, 2005. Data are from Collie Board Trends in Higher Edicadon Series, 2004

Figure PHE-11: The Federal Government i.s Responsible for a Significant Amount of School Funding Through Student financial Aid.

Source: Sandy Baum. . Changes in Funding for Public Higher Education:

College Prices and Student Aid. FVesentation to National Academies' Board on Higher Education and Workforce, April, 2005. Data are from College Board Trends in Higher Edicahcm Series, 2004.

PHE-18

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Figure PHK-12A: Federal Aid Awarded to Students Has Doubled Since 1993.

Federally-Supported Programs (Millions
93-94

03-04

Grants

1

Pell Grants

$7,196

$12,861

SEOG

$742

$760 1

LEAP

$64

Veterans

$1,518

$2365 :

Military

$615

$981

Other Grants

$245

$^

Subtotal

$10,308^

$17,184

Federal Work Study

$952

$1,218 :

loans

i

Perkins Loans

$1,169

$1,201 1

Subsidized Stafford

$18,018

$25,291

Unsubsidized Stafford

S2.029

$23,105

PLUS

SI, 943

$7,072

SLS

S4,415

Other Loans

S580

S125

Subtotal

$28,708

$56,794

Education Tax Benefits

$6,298

1

Total Federal Aia i

$81,494

State Grant Aid

$6,017

'Institutional Grante '

Total Federal. State Institutior^l

$11,852

$54,872

$23,253

$110,764

Nonfederal Loans

-

$11,271

Source. Sarah Turner. Policy Implications of Changing Funding for Public Higher Education Presentatio
n

to National Academ ies’ Board on Higher Education and Workforce. April 2005.

PHE-19

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Figure PHE-12B: Merit-Based Slate Grant Aid per Student Has Increased 4-Fold Since 1981.

Source; Sandy Baum. Changes in Funding for Public Higher Educaticxi;

College Prices and Student Aid Presentation to National Academies’ Board on Higher Education and Workforce, April, 2005. Data are from College Board Trends m Higher Education Series, 2004.

PHE-20

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F'igure PHE-12C: The Volume of I'nsub.vidized Student Loans Has Increased Substantially.

Loan Dollars (in Billions)

Source; SarahTumer. P<Uicy Impticatiom of Changing Fnntiingjdr PuUic Higiwr E(kicai<m. Presentation to National Academies’ Board on Hi^cr E^cation and WoiWbrcc. April 2005.

Figure PHE-13: Purchasing Power of Pell Grant Has Decreased

Maximum PHI Grant as Percentase ofCosI of Attendance at Public and lYlvate Four-Year Colleges. 1981 82 to 2002-03.

Source: Sandy Baum. Changes in Funding for Public Higher Education;

College lYices and Student Aid. Presentation to National Academies' Board on Higher Edication and Workforce. April. 2005. Data are from College Board l>end5 in Higiier Edicdion Series. 2004.

Figure PHli-14A: Enrollment by Income: Transitions from High School to College Show Marked Difference for Low- and High-Income Families.

	Total	Low Income (bottom 20%)	High Income (top 20%)
1972	49.2%	26.1%	63.8%
1980	53.9%	33.6%	67.6%
1996	65.0%	48.6%	78.0%

Source: Sarah Turner. Policy Implications of Changing Funding for Public Higher Education. Presentati

on
to National Academies' Board on Higher Education aid Workforce. April 2005.

Figure PHE-14B:Annual Loan Limits Reduce Borrowing Options for Students.

Annual Loan Limits for Sutisidczadand Unsubsidiiad Stafford Loans

Graduata Studsnt

OapaiKlanl Undsrgraduala
Studant

1 Indspaadsnt Undargraduata I
1 Stwdbat

iMYaM

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laYMt

Only SZA^SortlMtMiKHjnl
may ba m wibudUrO burn

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SSSOO

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Only SS SOOof tNiMKHint
Rwy ba m uAiklUMd hMnt

$700

)iiJwid4tbYmn

tssoo

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Only SSsBXIottMiMnouni
Nwy ba In wjbUdtzad lornt

tiasoo

Maximum total dsbt from Stafford Loans whan you graduata

tindatgoduM* itudNit

Uytof lASDOoKhacaOtcru: ywi
toahrSASODol thh amount nay bam

S46kOOOaiMmdeaandtntgndf(-
gwOwW UudtfH tonty f ZSJOOot
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SlS&SDOatgoduatao* wotrtuonal
Uudarrf (onhr S6&.SD0 oI(Mim«ouM
may ba m wbiaJaad toanv
iWamtuaeaMWNiiKhKai suikMd
lam mMad tat itK%

Source; Sarah Turner. Policy Implications of Changing Funding for Public Higher Education. Presentation
to National Academies’ Board on Higher Education and WoHcforce, April 2005.

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Figure PHF>14C: Reduced I^an Purch;ising Po>\er and A>':iilabilit\ Create a
DifTerential Net Cost of Attendance as a Percentage of Family Income.

!l

B h.

t V

eo%

TO

60%

60%

40%

30%

20 %

10 %

0 %

PliblicTwo-Yfar ColIrsK

Lowest Quaitiie Lowet Middle Uppet Middle HtghestOuamle

Family Income Quartile

Public Pour-VMr C'ollcces and I'nlversltjn

Family Income Qiiartile

Source: SskI>' Baum. Changes in Funding for Public Higher Edication:

College Priees aid Student Aid Presentation to National Academies’ Board on Hi^er Education and Workforce. April. 2005. Data are from College Board Trends in Higher Educraion Series, 2004.

PHE-23

Fjoure PHK-15: Implications for Quality: Public Institutions Have Not Been Keepino Pace with Private Universities in Faculty Salaries.

Source; Thomas J Kane The Role of Federal Govigmment m Financing Higher Education, Presenialion lo National Academies' Board on Higher Education and Workforce. March 21, 2005,

This paper summarizes findings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 2 1st Centuiy . Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

International Students and Researchers in the United States

Sumnian)

The United States has experienced a steadily grow ing influx of graduate students and postdoctoral scholars from throughout the world. International students now constitute more than a third of US science and engineering (S&E) graduate-sehix^l enrollments, up from less than a quarter in 1982. More than half the S&E postdoctoral fellows arc temporaiy residents, half of whom earned a doctorate degree outside the United States. Including undergraduates, more than a half-million foreign citizens are studying at colleges and universities in the Ihhted States.

Many of the international students educated in this country choose to remain here affer receiving their degrees. More than 70®o of the foreign-bom S&E doctorates w ho received their degrees in 2001 remained in the United States for more than 2 years, up from about half the 1989 doctorate recipients. 'Hiese skilled migrants are an import«mt source of innovation for the US economy.

Tlie terrorist attacks of September 1 1, 2001, caused drops in the numbers of international students applying to and enrolling in US graduate programs. In addition, other countries are developing their ow n sv^tems of graduate education to recruit and retain more hi^ly skilled students and professionals. In this environment of increased competition and reduced international mobility, the US education ;uid reseiirch enterprise will have to readjust to be able to keep attracting the best students from home and abroad.

International exchanges of students and skilled professionals can benefit both the sending and receiving countries. Certainly, the United States S&E research enterprise depends critically on inteniational students and scholars. Recommendations that various groups have made to maintain and enhance the ability of the United States to attract these highly skilled people include the following:

• Create new nonimmigrant visa categories exempted from the 214b provision for doctoral-level graduate students and postdoctoral scholars.

• E.xtend the validity of Visas Mantis security clearances for international students and scholars from the current 2-year limit to the duration of their academic appointments.

• .Allow international students, scholars, scientists, and engineers to renew their visas in the I'nited States.

• Implement a points-based immigration policy, similar to that of Canada or the United Kingdom, in which graduate education and S&E skills count toward obtaining citizenship.

IS-1

The exchange of people and ideas across borders, accelerated in the last 2 decades by perestroika and Uie emergence of East .Asia as a world economic power, has transformed institutions and individuals. Most countries today send briglil young people to study abroad.' Many of them stay and contribute in lasting ways to their adopted coiuUries. .And whether they stay, return home, or move on to a third eountrv'. they become part of a global network of researchers, practitioners, and educators that provides cultural and intellectual support for students and scholars w hatever their origins.

Since World War II. the United States has been the most popuhir destination for S&E graduate students and postdoctoral scholars choosing to study abroad. With about 6®o of the world's population, the I'nited States has been producing over 20®o of the S&E PhD degrees.* International graduate students and postdoctoral researchers, man>' of whom stay in tlie United States after completing their studies, make substantia] contributions to our society by creating and applying new know ledge.

Tlie total number of S&E graduate students in US institutions has grown consistently over the last several decades, w ith an acceleration during the 1990s.^ These increases have taken place despite evidence that US graduate schools give preference to domestic applicants."* Since the 1970s, the strongest inftow of graduate students has been from .Asian countries. From 1985 to 2001, students from China, Taiw an. India, and South Korea earned more than half the 148,000

L^S science and engineering doctoral degrees awarded to foreign students, four times the number awarded to students from Europe.

The percentage of international students in US graduate schools has risen from 23.4®o in 1982 to 34.5'^o in 2002 (sec Figure IS-I). In 2002. international students received I9.5®oof all doctorates awarded in the social and behavioral sciences. 18.0®o in the life sciences. 35.4®6 in the physical sciences, and 58.7®o in engineering.^ For doctorate>granting institutions, total enrollment of international S&E graduate students increased dramatically betw een 2000 and 2002. In 2002. 55. 5*?© of international S&E graduate students were enrolled at Research I (Rl) universities; Rls also enroll the highest proportion (26.0%) of international students (see Figure IS-2). 'foday, the total number of foreign citizens studying in US universities (including undergraduates) has passed the half-million mark.

.A recent study further delineates the changing demographics of graduate students in US institutions.® In 1966, l^S-bom males accounted for 71% of S&E PhD graduates, and 6®o were aw arded to US-bom females; 23^o of doctorate recipients w ere foreign-born. In 2000, 36°o of doctorate recipients were l^S-bom males. 25®o US-born females, and 39®o foreign-bom. .Among postdoctoral scholars, the participation rate oflemporar> residents has increased from 37.4'^<i in

* Todd M Davis. 2003 Allas of Student Mobility'. New York Institute of International Education

^ National Science Board. 2004. Science and Engineering Indicators 200-t (NSB 04-1), Arlu^toa VA; National

Science Foundation

%bid

* Gregory Attiych and Richard Attiych 1997. “Testing f^Bias in Graduate School Admissions." Journal of
Human Resources 32.524-548.

* National Science Foundation. Survey of Graduate Students and Postdoctorates in Science and Engineering 2002.
Arlington. VA National Science Foundation. 2004. Life sciences include biological sciences, agricultural sciences,
and health fields, social sciences include p^'chology. and f^ysical sciences include ph>'sics. chemistry,
mathematics, computer science, and earth sciences

* R-B- Freeman. E. Jin, and C.-Y. Shen 2004 llTiere Do fvew US-Trained Science-Engineering PhDs Come From?
(Working Paper Number 10544), Cambndge, MA National Bureau of Economics Research

1982 to 58.8®o in 2002 (see Figure IS-3). Similarly, the share of foreign-bom faculU who earned their doctoral degrees at I'S universities has increased from 1 1 .7®o in 1973 to 20.4®o in 1999. In engineering fields, the share increased from 18.6®o to 34.7®o in the same period.’

Stay Kates of International (Graduate Students and Scholars

Representation of foreign-bom scientists and engineers in I ’S S&E occupations varies by field, countjy of origin, economic conditioas in tlie sending countiy , and when the PhD was awarded. In total, foreign-bom scientists and engineers were 22.7®o of the US S&E labor force in 2000, an increase from I2.7®o in 1980. Foreign-bom doctorates were 37.3®o of the US S&E labor force, an increase from 23.9®o in 1990.

One study found that 45®o of international students from developing countries planned to enter the US labor market for a time, and 15®o planned to slay pemianently; another 15®o planned to go to a third countr\’.^ .Another study show ed that the stay rate of international doctorate scientists and engineers has increased steadily and substantially in the last decade.^ file proportion of foreign-bom doctorates remaining in the United States for at Iea.st 2-years after recei\ing their degrees increased from 49®o for the 1989 cohort to 71®'o for the larger 2001 cohort.’

Slay rales were highest among engineering, computer-science, and physical-science graduates. Stay rales also varied dramatically among graduate .students from the top source countries — China (%®o). India (86® o), Taiwan (40®b), and Korea (21^o). l>eci.sions to stay in the United States appear to be strongly aft'ected by conditions in the students' home countries, primarily the unemploN'ment rate, the percentage of the labor force that works in agriculture, and per capita GDP.”

Costs and Ik'neftts of Intcniational Mobility

Skilled migrants contribute to the US economy a.s technicians, teachers, and researchers and in other occupations in w hich technical training is desirable (see Table IS-1). Some research suggests that they generate economic gains by contributing to industrial and business innovation, resulting in a net increase in real w ages for both citizen and immigrant workers. One study, for example, found Uiat the immigration of skilled workers added to local skills rather than

National Science Board 2004 Sa<ince and Engmeenng Indicators 200J (HSB04AX fid\inglon,V A National Science Foundaticm Appendix table 5-24 Available at http //u'ww nsf gov/sbe''srs/'seind02.'^pend/c5 'at05-24 xls

* N. Aslanbeigui and V Montecinos 1998 “Foreign Students m US Doctoral pTog,riia\&.'' Journal of Economic Perspechws 1 2 . 1 7 1 - 1 82

* Although ifHemahonal student is usually taken to mean a student cm a temporaiy visa, the figures sometimes include students on both tempenary and permanent visas to compensate for the large number of Chinese

students in
the 1990s who became permanent residents by special legal provisions This issue is discussed m greater detail by
Finn (see next footnote), who finds the slay rate for those on tempc^aiy arxl permanent visas almost the same
‘®MichaelG Finn 2003 Slay Rateso/ForeignDoctorate Recipientsyrom US Universities, 2001, OdkRitSi^e.TN:
Oak Ridge Institute for Science and Education The stay rate was defined as remaining in the United States for at
least 2 years aher receipt of the doctorate, but Finn estimates that these rates do not fall appreciably during the first 5
years aher graduation

” D L Johnson 2001 Relationship BetMeenSta^' Rates ofPhD Recipients on Temporaiy lisas and Relative Economic Conditions in Country of Origin (Working Paper), Oak Ridge. TN Oak Ridge Institute for Science and
Educaticm

substituting for thcm.’^ The authors' econometric analyses suggest that a 10% increase in the number of international graduate students would raise university patent grants by 6® b and nonuniversity patent grants by 4°o. Ilie authors concluded that bureaucratic hurdles in obtaining student visas may impede innovation if they decrease the inflow of international graduate students.

Foreign-bom and foreign-educated scientists and engineers have made a disproportionate number of ‘"exceptional" contributions to the S&E enterprise of the United States.*^ Since 1990, almost half the US Nobel laureates in science fields were foreign-bom; 37®o received their graduate education abroad. The large number of foreign-bom scientists and engineers working in the United Stales who were educated abroad suggests that the Ignited Stales has benefited from investments in education made by other countries.

Many people believe that emigration of technically skilled individuals ofien called a “brain drain"- is detrimental to the countr\’ of origin. However, the concept of brain drain may be too simplistic ina.smuch as it ignores the many benefits of emigration, including remittances, international collaborations, the return of skilled scientists and engineers, diaspora-facilitated international business, and a general investment in skills caused by the prospect of emigration.'^ .'Vs the R&D enterprise becomes more global, some obsers ers propose that “brain drain" be recast as “brain circulation"'^ juid include the broader topics of the international circulation of thinkers, knowledge workers, and rights to knowledge.' Such a discussion would include issues of local resources: many countries lack the educational and technical iiifrastnicture to support advanced education, so aspiring scientists and engineers have little choice but to seek at least part of their training abroad, and in many instances such travel is encouraged by governments. Supporting the concept of brain circulation is the finding that ethnic networks developed in the Ignited States by international students and scholars help to support knowledge transfer and economic development in both the United States and the sending country.'’

In other countries, migration for employment, particularly for highly skilled w orkers, remains a core concern.'* Kuropean Union (EU) countries, especially tlu>se w ith developed S&K capacity, have implemented strategies to facilitate retention and immigration of the technically

G- Chelleraj. K.E. Maskus, and A. Mattoo. 2004. The Contribution of Skilled Immigration and International Graduate Students to US Inno\'ation (Working Paper N. 04-10), Boulder. CX): University of Colorado.

P.E. Stephan and S.G. Levin 2005. “Foreign Scholars in US Science: Contributions and Costs." In: Science and the University, eds Ronald Ehrenbcrg and Paula Stephan, Madison, WI: University of Wisconsin Press (forthcoming). The authors use six criteria to indicate “exceptional" contributions (not all contributions) in S&E; individuals elected to the National Academy of ScierKes(NAS) and'or National Academy of Engineering (NAE), authors of citation classics, authors of hot papers, the 250 most-cited authors, authors of highly cited patents, and scientists who have played a key role in launching biotechnology firms

D Kapur and J. McHale 2005. "Sojourns and Sofiware Internationally Mobile Human Capital and High-Tech Industry Development in India. Ireland, and Israel " In; From Underdogs to Tigers: The Rise and Growth of the Sofhvare Industry in Israel Ireland and India, A AroraandA Gambardella. Oxford, UK: Oxford University Press

‘*OECD. 2002. International Mobility of the Highfy Skilled (Policy Brief 92 2002 01 1P4). Wa.shmgton. DC: OECD- Available at: http: Vwww.oecd.org/dataoecd’9/20/1950028-pdf

Bogumil Jewsiewicki 2003 The Brain Drain in an Era of Liberalism, Ottaw'a, ON Canadian Bureau for International Education

William Kerr. 2004. Ethnic Scientific Communities and International Technology Difiusion (Working paper). Available at: http-7/econ-www.mit-edu faculty'downloadjxifphp?id“994-

OECD members countries include Australia, Austria, Belgium, Canada, the Czech Republic. Denmark, Finland, France, Germany. Greece, Hungary. Iceland, Ireland, Italy, Japan, Korea. Luxembourg, Me.xico, Netherlands, New Zealand, Norw'ay, Poland, Portugal, the Slovak Repi^lic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

skilled. Several Organisation for Economic Co-operalion and Development (OECD) countries have relaxed their immigration laws to attract higlt-skilied students and workers.*^ Some are increasing growtii in tlieir international student populations and are encouraging tliese students to

apply for resident statas.

Point-based immigration systems for high-skilled workers, while not widespread, are starting to develop.^® Cmiada. Aastralia. and New^ Zealand use such sv-slems to recruit highly skilled workers. The United Kingdom has been doing so since 2001, and the Czech Republic set up a pilot project that started in 2004. In 2004. tlie European ETnion Justice and International .-UTairs council adopted a recommendation to facilitate the immigration of researchers from non-EU countries, asking member states to waive requirements for residence permits or to issue them automatically or through a fast-track procedure and to set no quotas that w ould restrict their admission. Also, the European Commission has adopted a directive for a special admissions procedure for third-w orld nationals coming to the EU to perform research.

Recent T rends in Graduate School Enrollment

Declines in international student applications forentn. to US graduate school have stimulated considerable discussion and more than a few warnings that our national S&E capacity may have begun to w eaken. In 2002. National Science Foundation noted a decrease in first-time full-time S&E graduate enrollments among temporarv residents, by about 8°o for men and \% for women.^^ At the same time, first-time full-time S&E graduate-student enrollment increased by almost I4®o for US citizens and pennanent residents — 15®o for men and more than 12®o for women (see Figure IS-1).

More recent surveys by the Council on Graduate Schools showed dramatic decreases in applications among international students for the 2003 academic year but much smaller decreases in admissions. Applications and admissions for domestic students did not change appreciably during this period, whereas enrollments decreased by 5®b. TItere appear to be much smaller efl'ects on applications for the 2004 academic year (see Table IS-2)

Tliese declines w ere partly in response to the terrorist attacks of September 1 1, 2001, after w Inch it became clear to ever> one that the issuance and monitoring of visas are as important to graduate education as the training experience. Even moreso, however, the declines reflect increasing global competition for graduate students amid the globalization of S&E education and research.

Rising (>lobal Capacirii’ for Higher F'ducatioii

Given Uie fast-rising global tide of S&E infrastructure and training, it w ould be surprising if the S&E education and research enterprise currently dominated by the United States did not begin to change into a more global network of scientific and economic strengtli. Indeed, there is considerable evidence that that process has begun. Students have been leaving their home

Karine Tremblay, “Links Between Academic Mobility and Immigration,** SvTnposium tm Intematiwial Labour and Academic Mobility: Emerging Trends and Implications for Public Policy. Toronto. October 22, 2004
^OECD. 2005 Trends m International KUgraticm: 2004 Annual Report Pans Organisation for Economic Co-operation and Development See htlp;^’www.workpermiLcom' for more information on immigration policies in English-speaking countries and the European Uniem.

National Science Foundation. Graduate Enrollment tn Saence and Engineering Fields Reaches Ncm’ Peak: First-Time Enrolbnent of Foreign Students Declines (H'SP 04-326). Arlington, VA National Science Foui>dation. 2004

countries in search of academic opportunities abroad for thousands of years. For scientists and engineers, the trend gained importance with the rise of universities and the need for formal training unavailable at home. .As early as the late ISHh century, many .Americans were drawn abroad to German universities to gain expertise in fast-growing new technical fields. In the following decades, that trend gradually reversed as US universities gained technical strength and attracted both faculty and students. US universities also benefited from an influx of educated refugees fleeing war-tom Europe during and after World War II.

Now, even while the United States can boast of 17 of the world's top 20 universities.^^ the US share of the world's S&E graduates is declining rapidly. European and .Asian universities have increased degree production w hile the number of students obtaining US graduate degrees has stagnated (see Figure IS-4). .As countries develop know ledge-based economies, they seek to reap more of the benefits of international educational activities, including strong positive effects on GOP growth. Emerging economies have coupled education-abroad programs with strategic investments in S&E infrastructure — in essence pushing students away to gain skills and creating jobs to draw them back. Other countries, particularly in Europe, are tr\ ing to retain their best .students and also to increase quality and open international access to their own higher educational institutions.

\'isa and Inimignition Policy

A grow ing challenge for policymakers is to reconcile the flow of people and infomiation with security needs. Policies and regulations, particularly those governing visas and immigration, can dismpt the global movement of individuals and therefore the producti\'ity of scientists and engineers. In turn, this can affect a nation's economic capabilities.

The repercussions of the terror attacks of September 1 1. 2001, have included security-related changes in federal visa and immigration policy. (Xher immigration-related policies relevant to international student flows are international reciprocity agreements and deemed e.xport policies. Policy changes intended to restrict the illegal movements of an e.xlremely small population have had a substantial eff'ect on international graduate students and postdoctoral scholars already in the Ignited States or contemplating a period of study here.

** W. I. Cohen 2001 East Asia atthi Center: Four Thousand Years of Engagement widi the World New York: Columbia University Press

^ D. E. Stokes 1 997, Pasteur 's Quadrant: Basic Science and Technological Innovation, U'ashington DC : Brookings Institution, pp. 38-41 . Stokes e.xplains the elTect of this e.xport and re-importation of S&E talent on US universities: '^This tide, which was at a flood in the 1 880's, reflected the lack of an /\mchcan system of advanced studies adequate to the needs of a rising industnal nation, and was a standing challenge to create one. The cflbrts to fill this gap in Amencan higher education were generously supported by Amcnca's econcHnic e.xpansion,

particularly by the fM'ivate mdividuals who had acquired great wealth in the decades aher the Civil War. many of whom had gamed a vision of what might be done fiom their studies in the German universities."

^ Shanghai's Jiao Tong University Institute of Higher E(iucalk>TU Academic Ranking of World Universities. 2004. Available at; hllp://cd.sjlaedu.ca''rank''2004.'2004Nfam.htm. The ranking emphasizes prizes, publications, and citations attnbuted to faculty and staff, as well as the size of institutions. The Times Higher Education supplement also provides international compansons of universities.

** The Conference Board of Canada 1 999, The Economic Implications of International Education for Canada and Nine Comparator Countries: A Comparison of International Education Activities and Economic Performance. Ottawa, ON: Department of Foreign Affairs and International Trade. Also see AnnaLec Saxenian 1999. Silicon Valley 's Nen' Immigrant Entrepreneurs. San Francisco: Public Polic>' Institute. Available at. http.//www.ccis-ucsd.org/PUBLICAT10NS/wrkgl5.PDF.

Changes in visa and immigration policies and structures had a rapid and adverse elTect on student mobility. Nonimmigrant*\isa issuance rates decreased, particularly for students (see Figure IS-5). Implementation of the student-tracking system, the Student and KKchange Visitor Information System (SEMS), and enhanced Visas Mantis securiw screening led to closer scrutiny and longer limes for visa processing, in some cases caasing students to miss classes or to turn to other countries for tlieir graduate training."* .After intense discussions between the university community and government agencies. ^ ' some of Utese policies have been adjusted to reduce eft'ects on student mobility (sec Figure IS-6), However, unfavorable perceptions remain, and international sentiment regarding the L'nited States and its visa and immigration processes is a lingering problem for the recruitment of international students and scholars.

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To maintain its leadership in S&E research, ilic United States mu.si be able to recruit tlie most talented people worldwide for positions in academe. induslr>, and go\ emment.^* ITie United Slates Uierefore must work to attract the best international talent while seeking to improve the mentoring, education, and training of its ow n S&E students, including women and members of underrepresented minority groups. Ibis dual goal is especially important in light of increasing global competition for the best S&E students and scholars.

Federal actions that have been recommended include the following;

• Create new nonimmigrant-visa categories for doctoral-level graduate students and postdoctoral scholars, whether they are coming to the L'nited States for formal educational or training programs or for short-term research collaborations or scientific meetings.*® The categories should be exempted from the 214b provision whereby applicants mast show that they have a residence in a foreign countr>' that they have no intention of abandoning.

• Allow- international students, scholars, scientists, and engineers to renew their visas in the l'nited Slates.*®

• Negotiate visa reciprocity agreements between the L’nited Stales and key sending countries, such as China, to extend visa duration and to pennit multiple entries." "

• In the case of deemed e.xport controls, clear students and scholars to conduct research and use equipment required for such research through the visa process.*’

^ See. among many examples "A Visa System Tangled in Red Tape and Misconceived Security Rules is Hurting America” The Economist, May 6, 2004, Caroline Alphonso, ‘'Facing Security Hurdles. Top Students Flock to Canada”. Vu Globe and Mail. February 22. 2005

^ “Statement and Recommendaticms on Visa R-oblems Harming Amenca's Sdcntific. Economic, and Secunty

Interests." February 1 1. 2004, signed b>' 22 scientific, engineenng. and academic leaders.

* Committee on ScieiKe, Engineenng. and Public Policy. 2005, Policy Implications of International Graduate Students and Postdoctoral Scholars tn the United States. Washington DC; National Academies ft-css.

"lbid

^ "Reccmtmendations for Enhancing the US Visa System to Ad\'ance Amenca's Scientific and EcoiKimic Competitiveness and National Security Interests". May 18. 2005. signed by the National Academics presidents and 38 higher education and business aganizations.

** Association of American Universities. "Revision and Clarificaticm of Deemed Export Regulatory- Requirements." submitted to the Bureau of Industry and Sccunty. US Department of Ccmimerce, June 27, 2005

• Implement a points-based immigration policy, similar to that of Canada or the I nited Kingdom, in which US graduate education and S&E skills count toward obtaining US citizenship.^^

Appi'ndix I: Figures and Tables

Enrollments for International Graduate Students between 2002 and 2003 Academic ^'ear.

Figure IS-4. l‘S Doctorate Production Ls Stagnating hile Production in Other C ountries, Particularly China, Is Increasing.

Figure IS-5: N'isa Issuance Rates for .Students and F'xchange Msitors are Back to Pre'9-1 1 Levels.

Figure lS-6: The \'lsas Mantis System Overload Has Been Overcome, and Oxer 80% of Clearance Decisions .Are Now Made in I’nder 30 Days.

Appendix 2: Existing High-Skilled Immigration Policies in OECD Cmintries

(1) Points-Based ImmigratiiHi for Iligh-SkilliHl Workers

(2) Busiiu’ss Tnivel

(3) Student \'isas

(4) \\ ork Penults for International Students and Spouses

(5) Pennit to Stay After Ctraduatioii to Find a Job

OECD, Trends m International Mtgratton: 2004 Annual Report, Pans: Organisation for Economic Co-opcral ion and Develofsnent, 2005- See appendix for information on existing immigration policies.

Appendix 1
Figures and Tables

Figure IS-1: Full-Time Science and Kngineering (*raduate Knrollments Increasing Anion Domestic Students; First-Time Enrollments Stable or Decreasing for International Students.

National Science Foundation Survey of Graduate Students and Postdoctorates in Science and Engineering 2002. Arlington. VA; National Science Foundation 3004 Enrollment numbers include medical fields.

Figure IS-2: International (vraduate Students F^nroUed Predonimantly at Research 1 I'niversities.

♦ Public

• ' Pnvate
-A-RI

■ w ■ ■ Doctorate-Granting

« \ Kis t oi'-s-c a an t D>g

Source. The Council of Graduate Schools. CGS/GRE Graduate Enrollment and Degrees: Annual surveys from

1992-2002. Washington. DC. Available at; http .'/www.cgsnet.cwg/VirtualCentcrResearch-'graduateenrollment.hlm.
The CGS enrollment numbers include all major S&E fields, as business, education, humanities and arts, and pubbc
admmistralion and services. Thenon-S&E fields have 3 and 17% enrollment of international students CGS states.
“Institution type was a major differentiating vanable in the enrollment of non-US students, reflecting the
concenlralicn of international students in doctoral programs in science and engineering.”

Figure IS-3: Over Half of Academic Postdoctoral Scholars .Are Temporant Residents.

Total Postdoctoral Pool

3 Citizens and
Permanent
Residents
I Teir^oraiy
Residents

—A— T en^oraiy
Residents as
% ofTotal

Year

National Science Foundation. Survey of Graduate Students and Postdoctorates in Science and Engineering 2002.
Arlington. VA: National ScieiKe Foundation 2004. Medical fields are included, but postdoctoral scholars with
medical degrees (presumably actir^ as physicians) are excluded from the analysis.

IS-10

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Table lS-1: Forelgn-B<>m Play a Large Role in TS S&L Knterprise as Measured by Those
Hold S&K Positions; Most Foreign-Bom in Mathematics or (oniputer-Science Jobs
Requiring a Bachelor's or Master's Degree.

Number of Foreign- born in USS&K Occupations 2000

AIIS&E

KngirKering

Life Sciences

Mathematics

and

Computer

Physical

Sciences

Social

Sciences

All collegr-educuted

816.000

265.000

52.000

Sciences

370,000

92.000

37.000

Bachelor’s

degree

365,000

132.000

6.000

197.000

21,000

9.000

Master’s

degree

291,000

100.000

10,000

146.000

21.000

14,000

Profe.ssional degree

25.000

5,000

8,000

6,000

4,000

2.000

Doctoral

degree^

135,000

28,000

28.000

21,000

46,000

1^000

Source: National Science Board 2004 Science anJ Engineenng Imiicators. 2004 (NSB 04-1). Arlington, VA;
National Science Foundation Chapter 3

Note: Data are from US Census 2(XI0 5% Public Use Microdata Samples (PUMS) and include all S&E occupations other than postsecondary teachers, because field instruction was not included in occupation coding for the 2000 census

§ In 2001. 57% of those who were foreign-bom S«&E doctorate holders were US citizens. National Science Board 2004 Science anJ Engineering Incbcaton, 2004 (NSB 04-1). Arlington, VA; National Science Foundation

Table IS-2: Large Decrease in Applications and Admissions but More Limited Decrease In Knrollnirnts for International (vraduate Students bet^^een 2002 and 2<M)3 Academic N'car.

Total

Applications -28®o(-5®o)*

.Admissions •I8?o
Fnrollments -6%

Kngineering Life Sciences Physical Sciences

-36‘'o(-7»o) .24‘*o(-l%) -26«o(-3%)

-24% -I9«o -17®o

-8°o .10°o -6%

Heath Brown Council of Graduate Schools Finds Decline in iVew International Graduate Student Enrollment for
the Third Consecutive Year. Washington. DC; Council of Graduate Schools. November 4. 2004

*Availab]c data ftx the 2005 academic year arc shown in parentheses Heath Brown arxl Maria Doulis. 2005.
Findings from the 200S CGS International Graduate Survey I. Washington DC: CouiKil of Graduate Schools

IS-ll

Figure IS-4. I'S Doctorate Production is Stagnating NMiile Production in Other Countries,
Particular!} ('hina. Is Increasing.

Wars

A - tinted States
— Gemiany
— ®— tilted Kingdom
>— Japan
■ -China
« ' ■ India
W ' ■ South Korea
* Taiwan

Source Nalnxial Science Board Science and F.ngmeehng Indicators 2004 (NSB 04-01) Arlington. V'liginia

National Science Foundation 2004. Table 5-30

Not only are other countries increasing their St&E doctorate production, they are also attracting more international students However, the United States may still be ahead in retaining students and attracting high-skilled w'orkers

• The * cage of foreign students on OECD campuses rose by 34.9^4 <xi average between 1 998 and 2002 and by 50% or more in the Czech Republic. Iceland. Korea. New island. Norway. Spam, and Sweden In absolute tenns. more than 450,000 new individuals crossed borders to study in an OECD country during this shon period, raising the number of foreign students enrolled on OECD campuses to 1.781.000. Karme Tremblay 2004 “Links between academic mobility and immigratKm'* Symposium on International Labour and Academic Mobility': Emerging Trends and Implications for Pid>lic Policy. Toronto. October 22.

• In 2000. the EU was ahead of the United States and Japan m the production of S&E graduates As a proportion of PhDs per 1.000 population aged 25-34 years, the EU-15 had an average of 0.56, the United States had 0.48 and Japan had 0 24 However, the em igration of EU- 1 5 $«&£ graduates is creating a restriction for European R&D In the late 1990s. the Eurc^an Si&E workforce accounted for 5 4 per thousand workers vs 8 1 per thousand in the United States and 9 3m Japan European Commission. 2002. Ton ards a European Research Area Science. Technology, and Innovation, Key' Figures 2002. Brussels. European Commission, pp. 36-38 Available at

ftp 'ftp cordis la pub indicalori.'docyind kn:iXi: pdf

• Two independent estimates indicate that of the 60*/« of academic postdoctoral scholars who hold temporary visas, about four-fifths have r>on-US doctorates, which means that half of all US academic postdoctoral scholars have non-US doctorates ” Of postdoctoral scholars on temporary visas, almost 80^ « had earned their PhDs outside the United States Of those with non-US PhDs, the highest number came from China (25%), followed by India (1 1%), Germany (7%). South Korea (5%), Canada (5%). Japan (5%). the UK (4^ #), France (4®'#). Spiain (2%). and Italy (2%) The United States is benefiting from an inflow of postdoctoral scholars who have received graduate support and training elsewhere

^ Estimates based on the NSF Survey of Doctorate Recipients 2001, the NSF Survey of Graduate Students and Postdocs 2001. and the 2004 Sigma Xi National Postdoctoral Survey Available at http; ''postdoc.sigma.

xi org.

IS- 12

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Figure 18-5: \’isa Issuance Kates for Students and Exchange N'isitors are Back to Pre-9-11 levels.

FI Msas

1999 2000 2001 2002 2003 2004
Mscul Year

J1 N'isas

1999 2000 2001 2002 2003 2004
Msical Year

3Refusab

Overcomcl

3 Total
Revised

-Adjusted

Refusal

Rate

I bsucd

] Refusals
Ov'ercome

] Total
Refused

-Adjusted

Refusal

Rate

Source: United States Department of Slate Bureau of CcMisuIar Affairs Report of the I'tsa Office: Multi Year
Reports (I992~2004l. Washington, DC: US Department of State. Available at http./ lravei state gov/visa/report.html
Note: Report of the risa Office is an annual publication of the US Department of Stale, published by the Bureau of
Consular Affairs. Recent editions are available at http:/<'travel.state.gov/Visa''reporthtm]. The adjusted refasal rate
is calculated with the following formula: (Refusals ' Refusals OvercomeA\'aivedy(Issuance$ + Refusals Refusals
Os'ercomeWaived).

A steep decline in visa issuances began in 2001 and continued through 2003. J-visa issuances, mostly to Europeans,
follcnved roughly the same pattern, with a larger rise in the 1990s and a smaller downturn after 2001 To date, the
dow'ntum has reflected an increased denial rate more than a decreased application rate. As seen in the figure, the
refusal rate for J-visa applicants rose steadily from 2000 through 2003. The adjusted refusal rate for F-visa
applicants peaked in 2002. In 2004, denial rates had decreased considerably and were approaching 1999 levels.

Figure IS-6: The \ lsas Mantis System Overitrad Has Been erconie, and O^er 80% of
Clearance Decisions Are Now Made in Tnder 30 Days.

Source: United States Department of State Bureau of Consular AfTairs, Report of th^ Visa Office.. Washington.

DC: US Department of State Available at http ^'travel. stale gov/visa^repon.html.

In 2002, a new antiterrorist screening process called Visas Condor was added for nationals of I’S-designated state sponsors of terrorism^ that initially overloaded the Security Advisory Opini<m (SAO) interageiKy process and slowed N'lantis clearances^* The problem of extended waiting times for clearance of ncHiimmigrant visas flagged by \4anlis has for the most part been addressed successfully ^ By August 2004. the proportion of Visas Mantis visitors cleared w'lthin 30 days hasd risen substantially, and fewer than 15% took more than 30 days. The VTsas Mantis process*' is triggered when a student or exchange-visitor applicant intends to study a subject covered by the Technology Alert List (TAL). The express purpose of the TAL, originally drawn up as a tool for pre\'cnting proliferation of weapons technology, is to prevent the e>TK)rt of “goods, technology, or sensitive information" through such activities as “graduate-level studies, teaching, conducting research, participating in exchange programs, receiving training or cmploymcnl"” Initially, Mantis iM’ocedurcs were applied on entr>' and each re-entry to the Ignited States for persons studying or working in sensitive fields. In 2004, SAO clearance was extended to 1 year for those who were returning to a US government-sponsored program or activity and performing the same duties or functions at the same facilit>' or organization that was the basis for the onginal N^tis authorization.*’ In 2005. the US Department of State extended the validity of Marais clearances for F. J. H. L. and B visa categones

’^Countries designated sectiwi 306 in 2005: Iran. S>Tia, Libya. Cuba. North Korea, and Sudan. See http /'travel siate.gov /visa’temp‘'mfo/mfo_l 300.html

** Government Accountability OHice. 2004 Border Security: Improvements Needed to Reduce Time Taken to

Ac^udicate lisas for Science Students andSchobrs(GAO-h4-3y\). Washingtoa DC. GAO In April-June 2003. applicants waited an average of 67 days for completicm of secirity checks associated with visa applicatkms

** Government Accountability Office. 2005. Bonder Security: Streamlined 1‘isas Mantis Program has /oMv/vcf burden on science students and scholars, but further refinements needed (GAO^)5-198). Washington DC; GAO.

The Visa Mantis pre^ram was established in 1998 and applies to all nonimmigrant visas, including student (F), exchange-visitor (J). tempewary-worker (H). inlracompany -transferee (L). business (B-1). and tounst (B-2).

** Sec ht^./.travcl.statc.gov ’visa/testimony 1 hlml for an overview of the Visas N'fanlis and Condor programs.

** SeeDcpartmcnt of Slate cable. 04 Stale 153587. No. 22. Revision to Visas Mantis CIcaraiKc Procedure. Available
at: http /'travel slalcgov/visaslatel53587 html

Clearances for F visas are valid for up to 4 years unless the student changes acadcin ic positions. H. J. and L
clearances are valid for up to 2 years unless the visa holder's activiQ' in the United States changes.^

“Extension of validity for science-related interagency visa clearances ” Media Note 2005/1 82. US Dcpanmcnl of
Slate. February 11, 2005,. Available at: htlp;//w'ww.state-gov/r/f»'prs/ps'2005/42212,htin

Appendix 2

Kxisting High-Skilled Immigration Policies in OK('D (ountries^'

Migration for employment particularly for higli skilled workers, remains a core concern for OECD member countries.**' EU countries, especially those witli developed S&E capacity, have implemented strategies to facilitate retention and immigration of the technically skilled. Several OECD countries have rela.xed their immigration laws to attract high-skilled students and workers. Some are increasing growth in their international-student populations and encouraging lliese students to apply for resident status."*^

(1) Points- Hased Immigration for High-Skilled \\'orkers
Points systems, while not widespread, are starting to develop. Canada, .Australia, New Zealand, and the United Kingdom use such systems to recruit highly skilled workers. The Czech Republic set up a pilot project that started in 2004. In 2004, the EU Justice and International .Atfairs council adopted a recommendation to facilitate researchers from non-EU countries, which asks

member states to w aive requirements for residence permits or to issue them automatically or through a fast-track procedure and to set no quotas that would restrict their admission. Pemiits should be renewable and fiimih reunification facilitated, fhe European Commission has adopted a directive for a special admissions procedure for third-world nationals coming to the EU to perfomi research. This procedure will be in force in 2006.

• Canada has put into place a points-based program aimed at fullllling its policy objectives for migration, p<inicularly in relation to the labor-market situation. The admission of skilled w orkers depends more on human capital (language skills and diplomas, professional skills, and adaptability) than on specific abilities.**^ Canada has also instituted a business-immigrant selection program to attract investors, entrepreneurs, and self-employed workers.

• Ciermany instituted a new immigration law on July 9. 2004. .Among its provisions, in the realm of migration for employment, it encourages settlement by high skilled workers, who are eligible immediatelx for permanent residence permits. Family members w ho accompany them or subsequently join them have access to the labor market. Like Canada. (lennany encourages the immigration of self-employed persons, who are granted temporarx residence permits if they invest a minimum of I million euros and create at least 10 jobs. Issuance of w ork pemiits and residence pemiits has been consolidated. The OITice for Foreigners w ill issue both permits concurrently, and the Labor .Administration subsequently approves the work permit.

■*' Unless otherwise noted, policies listed arc from an overview presented in. OECD. 2005. Trends w I nternational Migration: 2004 Annual Report Paris: Organisatiwi for Economic Co-operation and Development
^ OECD members countries include Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France. Germany. Greece. Hungar\\ Iceland, Ireland, Italy, Japan. Korea. Laxembourg, Mexico. Netherlands. New Zealand. Norway. Poland. Portugal, the Slovak Repi^lic. Spain. Sweden. Switzerland. Turkey, the United Kingdom, and the United States.

Karine Tremblay. 2004. Links between academic mobility and immigralion. Symposium on International Labour and Academic Mobility: Emerging Trends and Implications for Public Policy, Toronto. Oct<d?er22.

^ Applicants can check online their chances to qualify formigrauon to Canada as skilled workers. A points score is automatically calculated to determine entr>' to Canada under the Skilled Worker category. See. Canadian Immigration Points Calculator Web site at http A'www workpermitcom/canada/points_calculator.htm.

• The UK Highly Skilled Migrant Programme (HSMP) is an immigration category for entiy to the UK for successful people with sought-after skills. It is in some ways similar to the skilled migration programs for entry' to .Australia and Canada. Tlie l^K has added an MB.A provision to the HSMP. Eligibility for HSMP visas is assessed on a points system with more points awarded in the following situations:

o Preference for applicants under 28 years old.

o Skilled migrants with tertiary' qualifications.

o High-level work experience.

O Past earnings.

O In a few rare cases, HSMP points are also awarded if one has an achievement in one's chosen field.

o One may also score bonus points if one is a skilled migrant seeking to bring a spouse or partner who also has high-level skills and work experience.

• Australia encourages immigration of skilled migrants, who are assessed on a points system with points awarded for work experience, qualifications, and language proficiency^ .Applicants must demonstrate skills in specific job categories.

(2) Business Tnnel

• Asia-Pacific Economic Cooperation (APEC) has instituted the Business Travel Card Scheme designed to liberalize trade and stimulate economic grow th. I'he scheme facilitates travel for business people traveling for short periods to participating countries (in 2004, .APEC had 16 member countries, including China). Travel is possible between participating countries after submission of a single application, w hich is filtered by the applicant's home country and fonvarded to all the participating countries for precertification. Cardholders are checked against police records in their own country as well as against warning lists in participating countries. .Approved travelers get cards valid for .3 years that provide special access to fast-track lanes at airports. In 2(X)4, there were over 5,000 cards in circulation.

(3) Student M.sns Many OECD countries are determined to attract a larger number of international students. In addition to developing special programs and streamlining application processes, some countries have signed bilateral agreements while others have decided to offer job opportunities to graduates.

• Canada Students no longer require study pennits for stay's of less than 6 months.

• France Since 1999, it has been po.ssible to obtain a 3- to 6-month visa for short-term studies w ithout registration.

(4) ork Penults for Inteniatlonal Students and Spouses

• Canada^ A new off-campus woric program allows international students at public postsecondary institutions to woik off campus, extending the previous policy enacted

UK HighK' Skilled Migrant Programme Web page. Also has a points calculator. See hltp://www-workpcrmit-com/uk/highly_skillcd_migr anl_program.htm
^ See points calculator at http .'.'w’vs'w.workperm it.com 'australia''point_calculator-hlm.

^’OST. "Canada: Immigration Policy Change Widens Door forForeign Students and Scholars.’'Br7t^ej6(July 13.
2005). Available at: http vbndges.ostina o^

earlier in 2005 that allowed students to work on campus while in Canada on a student visa.

• (ierntany Since 2003. international students have been allowed to work 180 haif-daN^ per year w ithoiil a work pennit.

• Austria Since 2003. .students can work half-time to finance their studies.

(5) Fcmiit to Stay after (traduation to Find a Job

• Canatia^^ .As of May 16, 2005» a new policy allows certain students to work in their field of study for up to 2 years after graduation. Previously, international students were allowed to stay only 1 year after graduation to work in Canada.

• (iermany International students may remain in Ciemiany for 1 year after the end of their studies to seek emplo>ment.

• Foreign students at UK universities graduating from specific engineering, physical-science and mathematics courses are now permitted to stay in the UK for 1 year after graduation to take up emplovment.''® The Science and Engineering Oraduate Scheme was launched on October 25, 2004, and is now fully operational. ITiis new immigration categon. allows non-European Economic .Area nationals who have graduated from l^K-higher or further-education establishments in certain mathematics, physical-sciences and engineering subjects w ith a 2.2 degree or higher to remain in the UK for 12 months after their studies to pursue a career. Only those who have studied approved programs are eligible to apply to remain under the scheme, llie scheme was first announced in the UK 2003 Budget as an incentive to encourage foreign students to study in these fields in the l^K and to be an asset to the workplace after gradimtion by relieving the shortages of engineering, plu'sical-science and mathematics graduates in the

UK. .Applicants must

o Have successfully completed a degree course w ith second-class honours (2.2) or higher, a Ma.sters course or Phi) on the relevant list of Department for Education or Skills-approved physical-science, mathematics, iuid engineering courses at a l^K institution of higher or further education,
o Intend to w ork during the period of leave granted under the scheme,
o 13e able to maintain and accommodate themselves and any dependents w ithout recourse to public funds.

o Intend to leave the I'K at the end of their stay (unless granted leave as a w ork-permit holder, high skilled migrant, business person, or innovator).

*OST 2005 Ibid

■** UK Home Office "Working tn the UK" Web p^e. Available at:

http; ''A^'^^'w.worklngmtheuk gov. ukA\'orking_in_the_uk.''ea''hoincpageschenies_and_programmesgradua le_students.
html

The scheme was highlighted in Sir Gareth Roberts' review, "The Supply of People with Science. Technology.
Engineenng and Mathematics Skills" (see http. ' Www kent ac uk/'stm&'research-gc roberts-transferable-
skills/roberts-recommendations doc) that the UK was sulTenng from a shortage of engineering, mathematics and
physical science students at universit)' and skilled wc^-kers in the labor market This shortage could do senous
damage to the UK's future economical growth There is currently a reported shortage in sectors such as research and
development and finarwial scrs'ices for mathematics. scieiKC. and engineenng ^cialists

lliis paper summarizes findings and recommendations from a variety of recently published reports and papers as input to tlie deliberations of the Committee on Prospering in the Global Economy of the 2 1st Centurv . Statements in this paper should not be seen as the conclusioas of the National Academics or the committee.

in Federal Science and Technology Funding

Suniniiiry

llie complementary goals of balance and adequacy in federal funding for science and technology require both diversity and cohesion in the nation's R&D system.

Diversity fosters creativity, creates competition among people and ideas, brings new perspecti\ es to problems, and fosters linkages among sectors. Cohesion helps ensure that basic research is not squeezed out by more immediate needs and that the highest quality research is supported.

Federal actions that could improve the balance of federal .science and technology (FS&T) funding include the following:

- Create a process in Congress that examines the entire FS&T budget before the total federal budget is aggregated into allocations to appropriations committees and subcommittees.

- Establish a stronger coordinating and budgeting role for the Office of Science and Technology Policy to promote cohesion among federal R&D agencies.

- Maintain the diversity of FS&T funding in terms of sources of funding, performers, time horizons, and motivations.

- Balanee funding between basic and applied research and across fields of research to stimulate innovative cross-disciplinary thinking.

- Protect funding for high-risk research by setting aside a portion of the R&D budgets of federal agencies for this purpose.

- Maintain a favorable economic and regulatory environment for capitalizing on research — for example, by using tax incentives to build stronger partnerships among academe, industry, and government.

- Encourage industry to boost its support of research conducted in colleges and universities from 7% to 20"o of total academic research over the ne.xt 1 0 years.

Two important goals can help policymakers judge the adequacy of federal funding for FS&T, First, the United States should be among the world leaders in all major areas of science. Second, the United States should maintain clear leadership in some areas of science. The recent doubling of the budget of the National Institutes of Health and other recent increases in R&D funding acknowledge the tremendous

opportunities and national needs tliat can be addressed tliroiigli science and technology. Similar opportunities e.\ist in the physical sciences, engineering, mathematics, computer science, environmental science, and tlie social and behavioral seiences — fields in which federal funding has been essentially flat for the last 15 years.

.■\mong the steps that the federal government could take to ensure that funding for seience and technology' is adequate across fields are these:

• Increase the budget for mathematics, the physical sciences, and engineering research by 1 2“ o a year for the next 7 years w ithin the research accounts of the IX'partment of Knergy. the National Science I-oundation. the National Institute for Standards and Technology, and the Department of Defense.

• Return federal R&D fiuiding to at lea.st l“o of US gross domestic prirduct.

• Make the R&D tax credit pennanent to promote private support for research and development, as requested by the .Administration in the FV 2006 budget proposal.

Support for a new interdisciplinary field of quantitative science and technology policy studies could shed light on the complex effects tliat scientific and technologic advances have on economic activities and social change.

.V Century of .Science and Technology

In 1945, in his report Science— The Endless Frontier, Vannevar Bush proposed an idea that struck many people as far-fetched,' He wrote that the federal government should fund the research of scientists w ithout know ing exactly w hat results the research would yield an idea that flatly eonlr.avcned the IIS government's historical practice.^

IX’spite tlie misgivings of many policymakers, the US go\ emment eventually adopted Bush's idea, file resulting expansion of scientific and technological knowledge helped produce a half-century of unprecedented technologic progress and economic growth. New teclinologies based on increased scientific understanding have enhanced our security, created new industries, advanced the fight agaiast disease, and produced new insights into ourselves and our relationship with the world. If the 20th eentury was .America's eentury, it also was the century of science and technology.

Since 1 950, the federal government's annual support for research iuid de\elopment (R&D) has grown from less than S3 billion to more than S130 billion more than a 10-fold expansion in real terms.’ Today, about I in every 7 dollars in the federal discretionary budget goes for R&D, Performers of federal R&D include hundreds of colleges and uni\'ersities and many thousands of private companies, federal laboratories, and other nonprofit institutions and laboratories, 'nie.se institutions produce not only new know ledge but also the new generations of scientists and engineers who are

' Office of Scientific Research and fXvcIopnienl, Science -The Endless Frontier, Washinglon. DC: US Govemmenl Printing Office. 1945

^ A Hunter Dupree. Science in the Fede ml Government: A History of Policies and Activities. 2nded., Baltimore. MD. Johns Hopkins Universily Press. 1986.

’ National Science Foundation. National Science Board. Science and Engineering Indicators 2000, Arlington, VA: National Science Foundation, 2000.

responsible for a substantial portion of the innovation that drives changes in our economy and society.

Major priorities within tlie federal R&D budget have shifted from the spaee raee in the 1960s to energy independence in the 1970s to the defense buildup of the 1980s to biomedical research in the 1990s. In the 1990s. the nation’s R&D system also began to eneounter ehallenges that it had not faeed before. Ilie end of the Cold War, an aeceleration of eeonomie globalization, the rapid grovMh of informat ion technologies, new ways of conducting research, and very tight federal budgets led to thorough re-evaluations of tile goals of federal R&D. Tliough Vannevar Hush’s vision remains intact, the R&D system today is much more comple.x, diversified, iuid integrated into society than would have been imagined 60 years ago.

In this decade, the challenges to the R&D system have intensified. Inteniational competitors are now targeting service sectors, including R&D. just as they have targeted manufacturing sectors in the past. Global development and internationalization, new trade agreements, and the rapid flow of capital arc reshaping indirstrics so quickly that policymakers barely have lime to respond. Similarly, workplace technologies and demands change so quickly that workers must be periodically retrained to remain competitive, niroughout modem economies, advantages accrue to individuals, governments, and companies that are adaptable, forward-looking, knowledgeable, and innovative.

.At the beginning of the 21st century, the I'nited States stands at a crossroads, llie only way for this nation to remain a high-wage, high-technology country is to remain .it the forefront of innovation. .Achieving this goal will require that the nation remain a leader in the seientific and technological research that contributes so heavily to innovation.

.Achieving Balance in federal Science and Techiiulugy funding

Federal funding for science and technology in the United States historically hxs been balanced along several dimensioas — between research and development, between defense and nondefense R&D, between academic and nonacademic R&D perfomters, and so on. Much of this balance arises in a de facto manner from the independent actions of a wide range of array supporters and performers. But some is the consequence of explicit policy decisions by the executive and legislative branches.

In the 1995 report Allocating Federal Funds for Science and Technolog)', a committee of the National Research Council laid out five broad principles designed in part to help the federal government achieve the proper balance of R&D funding:''

• Make the allocation process more coherent, systematic, and comprehensive.

• Detennine total federal spending for federal science and technology based on a clear commitment to ensuring US leadership.

• .Allocate funds to the best projects and people.

• Ensure that somtd .scientillc and tecluiical advice guides allocation decisions.

* National Research Council. Commitlec on Criteria for Federal Support of Research and Development, Athcaling Federal Funds for Science and Technology. Washington. DC: National Academy Press, 1995.

• Improve federal management of R&D activities.

'llie report recommended that

• file President present an annual comprehensive FS&T budget, including areas of increased and reduced emphasis. The budget should be sufficient to serv e national priorities and foster a world-class scientiilc and technical enterprise.

• Departments and agencies make FS&T allocations based on clearly articulated criteria that arc congruent witli those used by the Executive Office of the President and by Congress.

• Congress create a process that examines the entire FS&T budget before the total federal budget is disaggregated into allocations to appropriations committees and subcommittees.

• llie President ;md Congress ensure tliat the FS&T budget is sufficient to allow the United States to achieve pre eminence in a select number of fields and perform at a world-cla.ss level in other major fields.

ITie Executive Branch responded by providing, as part of the President’s budget submission, an analysis of tlie FS&T budget that encompasses federal fluids spent specifically on scientific and technological research programs, the development and maintenance of tlie necessary research infrastructure, and the education and training of scientists and engineers. In addition, the White House Office of .Management and Budget (OMB) and Office of Science and Technology Policy (OS fP) issue a joint budget memorandum that articulates the President's goals for the upcoming budget year to aid them in the preparation of agency budgets before submission to OMB.

.Analysis of this budget reveals trends in the support of scientific and technologic research that the broader category of R&D obsewes. For e.xample. in the president’s FV 2006 budget request, federal R&D would be up l“ci from SOI. 5 billion to S132.3 billion. But FS&T would be down 1%, from $61.7 billion to $60.8 billion (see Figures R&D-l and R&D-2).' (The director of OSTP has pointed out that it can be misleading to compare proposed budgets w ith enacted budgets because the latter can contain funds specified by Congress for research projects that were not included in tlic President’s budget.^)

Congress has not yet adopted a process that entails an overall consideration of the scientific ;md technological research supported by the federal government.’ Subcommittees in both the House and Senate still consider portions of the federal R&D budget separately without deliberations or hearings on the broad objectives of S&’f spending. At a minimum, the use of a common budget classification code could allow Congress more easily to address science and tecluiology programs in a unified manner.

* Office of Management and Budget. Budget of the United Stales Government, Fiscal Year 2006. Washington, DC: US Government Printing Office, 2005.

* John Marburger. speech to the 20th Annual AAAS Forum on Science and Technology Policy. April 21. 2005.

’ Jeff Bingaman, Robert M. Simon, and .Adam L Rosenberg, "Needed A Revitalized National S&T Policy". Issues in Science and Technology, Spnng 2004. pp 21-25.

C)\crall consideration of the FS&T budget could reiterate the importance of basic research and of diversity among research supporters and performers. Kspecially when budgets are tiglit. basic research can be displaced by the more immediate needs of applied researeh and technologs' development. In fact, less than half of all federal R&D funding is allocated for basic and applied research (see Figure R&D-.F). The FS&T budget has increased since 2000. but these increases are primarily due to increases in funding of the

National Institutes of Health (NTH). Non-defense related R&D funding has been stagnant in recent years (see Figure R&D-4). Recently, the FS&T budget has been declining since the charge to double NIH funding has been completed (sec Figure R&D-5). Recent Department of Defense (DOD) budgets ofTer another example — ever the last decade, the resources prosided for basic research by the IX)D have declined substantially.* Recent trends show that while defense R&D budgets have been increasing overall, the amount of resources allocated to science research in IX)D is decreasing (see Figure R&D-6). This lack of support for basic research could have major consequences for the development of necessarx' future military capabilities.

Allocating Federal Funds for Science and Technology also recommended that:

• R&D condueted in federal laboratories foeus on the objeetives of the sponsoring ageney and not expand beyond the assigned missions of the laboratories. The size and activities of each laboratory should correspond to changes in mission requirements.

• FS&T funding generally faxor academic institutions because of their flexibility and inlierent quality eontrol and beeause they link researeh to edueation and training in science and engineering.

• FS&T budget decisions give preference to funding projects and people rather than institutions. Tliat appro.ach will increase the flexibility in responding to new opportunities and changing conditions.

• C'ompetitix'c merit review, especially that invoix ing c.xtemal reviewers, be the preferred way to make awards, becau.se competition for fimding is vital to maintain the higli quality of FS&T programs.

• Evaluations of R&D programs and of those performing and sponsoring the work also ineorporate tlie views of outside evaluators.

• R&D be well managed and accountable but not micromanaged or hobbled by rules and regulations that have little social benefit.

Diversity cannot be an e.xeuse for mediocrity. People, projects, and institutions need to be reviewed to ensure that they are meeting national needs in science and technology. Open competition invoixing exaluation of merit by peers is the best-knoxvn mechanism to maintain support for the highest-qualitx’ projects and people. Quality also can be maintained by knowledgeable program managers xvho have established external scientific and technical advisory groups to help assess quality ,'uid to help monitor xvhether agency needs are being met.

* National Research Council. Committee on Department of Defense Basic Research. Assessment of Department of Defense Basic Research, Washington. DC: National Academy Press. 2005.

Possible actions for the federal government to maintain tlie dix ersity and balance of federal funding for science and technology include the following:

• Create a process in Congress that examines the entire FS&T budget before the total federal budget is aggregated into allocations to appropriations committees and subcommittees.’

• Establish a stronger coordinating and budgeting role for tlie OS'l'P to promote cohesion among federal R&D agencies.'"

• Maintain the diversity of FS&T funding in tenns of sources of funding, performers, time horizons, and motivations."

• Balance funding between basic and applied research and across fields of research to stimulate innovative cross-disciplinary thinking.'^

• Protect funding for high-risk research by setting aside a portion of the R&D budgets of federal agencies for this purpose.”

• Maintain a favorable economic and regulators' ens ironment for capitalizing on research — for example, by asing tax incentives to build stronger partnerships among academe, industn,-, and government.''*

• Encourage industry to boost its support of research conducted in colleges and universities from 7“o to 20“o of total academic research over the next 10 years.'*

.Vehieving .Vdequacy in Federal Science and Technology Funding

Given the importance of maintaining balance and diversity in the FS&T budget, the nexi logical question is. What is the appropriate magnitude of federal support for science and technology?

In 199.1. the Committee on Science. Engineering, and Public Policy of the National .Academy of Sciences, the National .Academy of Engineering, and the Institute

’ Committee on Critena for Federal Support of Research and Development. 1995,

National Research Council, Board on Science, Technology, and Economic Policy, Trends in Federal Support of Research andGradaate Education, Washington. DC: National Academy Press. 2001.

” National Academy of Sciences. National Academy of Engineenng, Institute of Medicme. Committee on Science. Engineering, and Public Policy, Capitalizing on Imvstments in Science and Technology, Washington, DC: National Academy ftess, 1999

“ National Academy of Engmeering, Committee on the Impact of Academic Research on Industrial Performance, The Impact cf .Academic Research on Industrial Performance, Washington, DC: National Academy Press, 2003

Council on Competitiveness, Irmovate America: Nahonal Irmovation Initiative and Report, Washington. DC: Council on Competitiveness, 2004

National Academy of Sciences, National Academy of Engineering, Institute of Medicine, Committee on Science, Engineering, and Public Policy, Capitalizing on Investments in Science and Teclmology, Washington. DC: National Academy I^ess, 1999.

" National Research Council. Office of Special Projects, Harnessing Science and Technology for America 's Economic Future: National and Regional Priorities, Washmgton. DC: National Academy Press, 1999.

of Medicine established two broad goals to guide federal investments in science and technology:'*

• file I'nitcd States should be among the world leaders in all major areas of science. .Vehieving this goal would allow this nation quickls' to apply ;uid extend advances in science wherever the>’ occur.

• Tlie United States should maintain clear leadership in some areas of science. Tlie decision to select a field for leadership would be based on national objectives and other criteria exlemal to the field of research.

lliesc goals provide a way of assessing the adequacx’ of federal fimding for science and technology. Being world class across fields requires that the United States have the funding, infrastructure, and human resources for researchers to work at the frontiers of research. Hre eminence in fields relevant to national priorities requires that poliexmakers choose specific areas in which to invest additional resources.

.\n important way of measuring leadership and pre eminence in fields and subfields of research is benchmarking of US research elTorts against those in other countries. Experiments with benchmarking have demonstrated that data can be gathered fairly readily for anabsis.” Benchmarking analyses then can be converted into funding guidance that takes into account the activities of other research performers (including industry and other countries) and the inherent imcertainties of research.

Responding to abundant opportunities and national priorities in science and technology, the federal govcniment has inerea.sed R&D funding substantially in recent years. From 1990 to 2002, inflation-adjusted investment by the federal goxemment in academic research went up 66“o.'* Increases in total R&D have been especially dramatic in the last few years because of increases for defense w eapons dex elopment. the creation of homekand-security R&D programs, and the effort to double the budget of NIH.

However, as a percentage of GDP, R&D has fallen from 1.25'^o in 1985 to about 0.75®o today, and a continuation of current trends will cMcnd this decline into tlie future (see Figure R&D-7). Compared witli the European Union, the Organisation for Economic Co-operation ;uid Deielopment. and Japan, US federal R&D expenditures as a share of GDP are declining (see Figure R&D-8). Sweden. Finland. Japan, and Korea all invest a larger percentage of their GDP in R&D than the United States (see Figure R&D-9). In the president's FV 2006 budget request, most R&D progriuns would drop in real terms, and overall e.xpenditures for R&D would fail to keep pace w ith inflation for the first time in more tluui a decade.” Funding for all three multiagency R&D initiatives —

National Academy of Sciences, National .Academy of Engineering, and Institute of Medicine, Committee on Science. Engineering, and Public Policy, Science, Technology', and the Federal Government: National Goals for a New Era, Washinglon, DC: National Academy Press, 1993.

‘’National Academy of Sciences. National Academy of Engmeenng. and Institute of Medicine, Committee on Science, Engineenng, and Public Policy, Experiments in International Benchmarking of US Research Fields, Washinglon, DC: National Academy Press, 2000.

National Science Board Science and Engineering Indicators 20M (NSB M-OI). Arlingtoa Virginia National Science Foundation, 2004

Amencan Association for the Advancement of Science. AA.4S .■Inalysis of R&D in die FY 2006 Budget, VVashingtoa D.C.: AAAS. 2006.

Networking and Intbmiation Technology R&D, the National Nanotechnology Initiative, and the Climate Change Science Program — would drop in FY 2006, Furthermore, with record-breaking budget deficits .and new federal obligations ranging from the war in Iraq to the expansion of Niedicare to pay for prescription drugs, prospects for outyear increases in R&D are dim.

Tlie doubling of the NIM budget from 1998 to 2003 implicitly acknowledged that the rate of return on additional federal investments in science and technology is ver\ high. Similar opportunities exist in the physical sciences, engineering, mathematics, computer science, environmental science, and the social and behavioral sciences — fields in which federal funding has been essentially fiat for the last 1 5 years (see Figure R&D-

10). Mieroelectronies, biotechnology, information teclmolog)', systems analysis, alternative fuels, robotics, nanotechnology, and many other research areas all have the potential to transform entire industries. Even such seemingly esoteric fields as cosmology’ and elementary particle physics could rey eal neyv aspects of matter that not only could have practical implicatioits but will inspire future generations of scientists, engineers, and mathematicians.

In addition, incrc.'tses in funding of fields outside the biomedical sciences can pay dividends by complementing the tremendous advances occurring in molecular biology. .Much of the recent progress in the health sciences hits been under|)inncd by earlier achievements in mathematics, the physical sciences, iuid engineering. Deciphering the human genome, for example, yvas heavily dependent on advancements in robotics and computers, nie development of modem imaging machines yvas made possible to a great e.xlent by advances in engineering and mathematics.

Tlie federal govemment could take several steps to ensure that funding for science and technology is adequate across fields:

- Increase the budget for mathematics, the physical sciences, and engineering research by 12°o a year for the next 7 years in the researeh aceoimts of the IX'partment of Finergy, the National Science Foundation, the National Institute for Standards and Technology, and the Depiirtment of Defense.^*’

- Return federal R&D funding to at le.a.st 1*^ 6 of the US GDP.^'

- Minimize eamiarks in seienee and technology funding because tliese types of research requests diminish the funding available for competitive merit-revieyved research.^^

- Provide a tax credit to corporations that fund basic research in science and technology .at our nation’s universities.

- Make the R&D tax credit pennanent to promote private support of R&D, as requested by the .Administration in the FY 2006 budget proposal.

“ Alliance for Science & Technology Research in America, "Basic Research. Investing in America's Innovation Future", a presentation for the House Republican High Tech Working Group, March 31, 2004.

Council on Competitiveness, Imaraie America. Washington. DC: Council on Competitiveness, 2004
“ Committee on Science. Engmeenng. and Public Policy, 2003.

Innovation has become more important than capital or labor in boosting economic productivity, but the course and cITecLs of innovation arc much harder to predict and understand. New technologies can spread rapidly througli a society, transfonning multiple areas of economic activity and in turn triggering further inno\ ations. fhe prime example is infonnation technology, which has had a dramatic and accelerating influence on manufacturing, the provision of services, and other economic activities.

Intensive study of innovation as an engine of economic growth and social change in an e.xtremely complex social contexl could provide guidance for policymakers and other leaders. For e.xample. is the current federal support of science and technology appropriately balanced across fields? What would be the elTects if federal R&D were returned to its historical high as a share of GDP?

.Another important topic for research is the organization of the federal agencies that support R&D. New organiztitional models could be explored, pcrfonnance metrics developed, and approaches tested.

Options for the federal govcnimcnt include the following:

• Support the development of a new interdisciplinary field of quantitative science and technology policy studies that could work to predict the cITect of specific science and tecluiology projects on the world’s economics and workforces,"^

• Support research to examine the organization models of R&D agencies and potential changes in practices .and structures.

“ Marburger, 2005.

Achieving Balance and Adequacy
in Federal Science and Technulog> Funding
Appendix 1
Figures and Tables

Figure R&D-l: Funds for Basic Research Are Declining at Most Federal Research Agencies.

Figure R&l)-2: Funds for Applied Research, as M'eU as for Facilities and Kquipinent, Are Declining at Most Federal Research Agencies.

Figure R&D-3: Less Than Half All Federal Research and Development Funding Is

AlhK'ated for Science and Research.

Figure R&D-4: Nondefense-Related R&D Funding Has Been Stagnant In Recent Years.

Figure R&D-5: The Federal Science And Technology (FS&T) Budget Has Increased Since 20(NK but These Increases .\re Due Priniaiily to Increases in NTH. The FS&T Budget Is Declining Since NTH Budget Doubling Has C'eased.

Figure R&D-6: Recent Trends in Funding Have Shown That YY hile Defense R&D Budgets Have Been Increiising Overall, the Amount of Resources Allocated to Science Research in the Department of Defense Is Decreasing.

Figure R&D-7: Federal R&D Funding as a Share of (tDP Has Been Declining, w hile Industry Funding Has Recently Begun to Decrease.

Figure R&D-8: C ompared with the Furopean ITilon, the OKCT), and .Japan, I S R&D Expenditures as a Share of CH)P Are Declining.

Figure R&D-9: Sweden, Finland, .lapan, and Korea Are Investing a Larger Percentage of I'heir GDP in R&D than the I'liited States.

Figure R&D-IO: Recent Federal Research Funding for All Fields Is Stagnant. Although Funding for the Life Sciences Increased C»reatly in the Past, for Many Fields the Level of Funding Has Remained Roughly the Same, in C'onstant Dollars, for 30 Years.

Figure R&D-l: Funds for Basic Research are Declining at Most Federal Research Agencies.

Table S-2. FEDERAL RESEARCH AND DEVELOPMENT SPENDING

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SOURCE; Executive Office of the President. 2005. Budget of the United States Government. Fiscal Year 2006, Part Two: Analytical Perspectives. Washington. DC: U.S. Government Printing Office, pp. 66*67. (httpv'/www.gpoaccess.gov/usfcudget/fyOd.'browse.hlml)

R&D-l 1

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Figure R&D-2: Funds for Applied Research, as Well as for Facilities and Equipment, Are Declining at Most Federal Research Agencies.

SOURCE: Executive Office of the President. 2005. Budget of the United States Goveniment, Fiscal Year 2006. Part Two; Analytical Perspectives. Washington. DC; U.S. Government Printing Office, pp. 66*67. (httpy/www.gpoaccess.gov/u^udget/fy06/browse.html)

R&D-12

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Figure R&D-3: Less Than Half All Federal Research and Development Funding Is Aliocated for Science and Research.

Rgure4-12

Funding concepts In FY 2P04 budget propoeal

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An alternative method of calculating technology investment uses the federal science and technology (FS&T) budget. It encompasses the funds spent specifically on research programs, research infrastructure, education, and scientific training but excludes funds for development of technologies.

Source: National Science Board. Science and Engineering Indicators 2004 (NSB 044)1). Arlington, Virginia National Science Foundation. 2004. Figure 4-12.

Figure R&D-4: Nondefense^Related R&D Funding Has Been Stagnant in Recent Years.

Selected Trends in Nondefense R&D, FY 1976-2006

In billions of constant FY 2005 dollars

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Source: American Association for the Advancement of Science. Chart: Selected Trends mNond^ense R&D: FY 1976^2006 . " Washington. DC. 2005. Available at: htlp://www.8aas.oi)g/spp/rd/tnion06c.p(lf

Figure R&D-5: The Federal Science And Technologv’ (FS&T) Budget Has
Increased Since 2000, but These Increases Are Due Primarily’ to Increases in NIH.
The FS&T Budget Is Declining Since NIH Budget Doubling Has Ceased.

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SOURCE; Executive Office of the Presidenl. 2005. But^LCl of the United Stales Government. Fiscal Year

2006. Part Two: Analytical Perspectives. Washington. DC: U.S. Government Printing OBlce. pp.68. (http://www.gpoacccss.gov/u8budgel/fy06/brow8e.html)

Figure K&D-6: Recent Trends in Funding Have Shown That ^^'hile Defense R&D
Budgets Have Been Increasing Overall, the Amount of Resources Allocated to
Science Research in the Department of Defense Is I>ecreasing.

Trends in Defense R&D, PY 1976*2006

m billions of constant FY 200S dollars

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Source; American Association for the Advancement of Science. Chart: Trends in Defense R&D: FY I976* 2006" Washington. DC. Febniaiy. 2005. Available at; http;//www,aaas.oig;/spp/rd/trdef06c.pdf

Yaar

Source; National Science Board 2004. S&E Indicators. 2004. Arlin^on. VA; National Science Foundation.

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Figure R&D-7: Federal R&D Funding as a Share of GDP Has Been Declining, while Industry' Funding Has Recently Begun to Decrease.

Figure 4-5

R&D share of GDP: 1963-2002

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Source; Nafional Science Board. Science and Engineering Indicators 2004 (NSB 04-01). Arlington, Virginia. National Science Foundation. 2004. Figures 4-3 and 4-5.

R&D- 17

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Figure R&D-8: Compared with the European Union, the OECD, and Japan, US

R&D Expenditures as a Share of GDP Are Declining.

Figure 1.2. Trends in R&D intensity. 1995*2003
GERD as a percentage of GDP

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cun: OECD. MSTl cMsbsse. Jurw 2004.

O OECD 2004

Source; Oi^aiisition for Economic Cooperation and Development. Mam Science and Technology Indicators 2004. Paris. France: OECD. Jine 2004.

Figure R&D-9: Sweden, Finland, Japan, and Korea Are Investing a Larger Percentage of Their GDP in R&D than the United States.

R&D investments: US, Asia-Pacific and EU

Gross expenditure on R&D as % GDP

Sot4rc0. OECD Mam Science & Technologs* Indicators. June 2005

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Source: Organistlion for Economic Cooperation and Development. Mam Science and Technology fndtcalon. 2005. Paris. France: OECD. June 200S. Available at: htlp://www.oecd.org/document/^6^0.2340.en_2649_34451_1901082_l_I_I_l,00.hlml

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Figure R&D-IO: Recent Federal Research Funding for All Fields Is Stagnant. Although Funding for the Life Sciences Increased Greatly in the Past« for Many Fields the Level of Funding Has Remained Roughly the Same, in Constant Dollars, for 30 Years.

Source: American Association for the Advancement of Science. Chart: Trends in Federal Research by Discipline: FY 1970’7004" Washington. DC. February. 200S. Avail^le at; http : //www.aaas. org/spp/rd/discip04 . pdf

Tliis paper summarizes findings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 2 1st Centuiy . Statements in this paper should not be seen as the eonelusions of the National Academies or the eomniittee.

The Productivity of Scientific and Technological Research

Suiiiiiiary

Innovation the process of converting inventions, ideas, or concepts into commercial products or processes — has always been a convoluted process, but today it is becoming even more dillicult to understand and predict. Seemingly minor de\ elopnients can have major consequences, producing a nonlinearity that defies forecasting. Developments in one field can heavily illuence other fields, creating multidisciplinary networks of cause and effect. New ideas can come from anywhere in the production process, not just from the basic research that traditionally has been seen as the driver of innovation. In such a fluid, interconnected system, policymakers need to create the optimal environment for innovation and then stand back and let the system do its job.

'Hie elTectiveness of scientific and technologic innov ation depends on many factors in research organizations, including the management and review of research programs, the policies and procedures that apply to those programs, and the broader environment and culture of research. Federal options to improve this effectiveness include the following:

The Research Environment and Culture

• Increase the size and duration of project aw ards so that researchers spend more time doing research and less time ensuring that their research is supported.

• Increase the diversity of the individuals and organizations doing research.

• Fund risky projects that could dramatically advance an area of research or open new research frontiers.

• Develop a new digital cyberinfrastructure to make the best use of rapidly expanding databases and multidisciplinary collaborations.

• Expand funding for merit-reviewed, cross-disciplinary, collaborative research centers.

Program Management and Review

• Ensure that federal agencies include research programs in their strategic plans and that the>' e\'aluate the success of those programs in performance reports.

• E\'aluate research in terms of quality, relex ance. ;uid leadership. For basic research, include assessments of the hi.storical value of basic research in contributing to national goals.

• Evaluate how well research programs dev elop human resources and the quality, relevance, and leadership of tlie programs.

• Establish a fonnal process to identify and coordinate areas of research that are supported by multiple agencies, and designate a lead agency for each such field.

Administrative Policies and Procedures

• Develop a new framework for the development of policies, rules, regulations, and laws affecting the partnership between the federal government and the institutions th.at perfonn research.

• Raise the cap on reimbursement of indirect costs to rellect the costs to universities of conducting research.

• E.xpand and enliance the Federal Demonstration Project to enroll more institutions and heighten the visibility of this important initiative.

The Research Knviroiiiiieiit and Culture

Because innovation does not have a single obvious pathway to success, much depends on the environment and culture that make innovation possible. Iliese factors range widely across social, administrative, and technological dimensions. The social factors include such considerations as commitment, collaboration, communication, the tre.atment of multiple viewpoints, workplace diversity, and the willingness to take risks. .Administrative factors include salaries, benefits, workplace conditions, the availability of sabbaticals, and travel funding. Technological factors include technical support, training, access to higli-speed computing and communications. inform,ation serv ices, and so on.

Each of these environmental and cultural dimensions can itself be the subject of innovation. This is most obvious with regard to information technologv'. To take just one example, a Web site called InnoCentive (vvvvvv.innocentive.com) now allows companies to post R&D problems online iuid offer scientists financial rewards for .solutions.

The consequences of innovation extend into the social and administrative spheres. For example, increasing the number of women in the biomedical sciences helped focus attention on women's health issues, with corresponding increases in research in these areas. Similarlv , funding researchers at dilTerent stages in tlieir careers and at different types of institutions can expand the range of viewpoints brought to bear on a problem.

The federal initiatives that could improve the research environment and culture are unlimited. .Among those sugge.sted are the following:'

• Increase the size and duration of project awards so that researchers spend more time doing research and less time ensuring that tlieir research is supported (.see Figures RP-1 and RP-2).

• Increase the diversity of the individuals and organizations doing research.

• Fund risky projects that could dramatically ads ance an area of research or open new research frontiers.

• Develop a new digital cyberinfrastructure to make the best use of rapidly eNpanding databases and multidisciplinaiy eollaborations.

• Fi.vpand funding for merit-reviewed, cross-disciplinary, collaborative research centers.

• Collect the best practices and attributes of federal agencies and research performers and disseminate this infomiation widely.

• Develop a common electronic grant-application system that combines the best features of current systems and can be used by all re.searchers and all federal agencies.

Program Miinagmiciit and Review

In an era of innovation, the innovation process itself needs to be the subject of research and development. Federal policies that influence scientific and technological research ;uid the commercialization of that research need to be continualh' re-examined and improved. Valuable sources of insight include international comparisons, the results of small-scale experiments, lessons from other sectors of the economy, and clear, data-based thinking.

One useful way to improve the effectiveness of research programs is by setting goals for tliose programs and then monitoring the ability of programs to achieve those goals. Tliis was one of the aims of the 1993 Gov ernment Performance and Results .Act (GPR.A), which was designed to encourage greater efficiency, effectiveness, and accountability in federal programs and spending. The act required federal agencies to set strategic goals for at least a 5-year period and then measure their success annuallv' in meeting tliose goals.

For agencies that support research activities, implementing GPR.A has presented many challenges.^ .Applied-research programs, whether conducted by federal agencies or private companies, have desired outcomes that are directly related to agenev' or company missions. F.valuating such programs is therefore relatively straightforward. A series of milestones that should be achieved by particular times can be established, and periodic reporting can indicate progress toward those milestones.

' National Science and Technology Council, Business Models Subcommittee, "Comments from the Request for Information”

^ National .Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Committee on Science, Engineering, and Public Policy, Evaluating Fediral Research Programs: Research and the Government Performance and Results Act, ViashingforcDC Nanonal Academy Press, 1999.

But the usefulness of new basie research is inlierently unpredictable, niough histor>’ abundantly demonstrates the tremendous value of basic research, the practical outcomes of such research can seldom be identified while the research is in progress. Furthermore, misuse of measurements for basic research could lead to strongly negative results. Measuring this research on the basis of short-term relevance, for example, could be veiy destructive to quality work.

For both basic and applied research, there are meaningful measures of quality, relevance to agency goals and intended users, and contributions to world leadership in the relevant fields. 'Iliese measures can be regularly reported, and they represent a sound way to ensiue that the country' is getting a good return on its research investments. A full description of an agency's goals and results should contain an evaluation of all research activities and their relevance to an agency's mission.

Evaluating basic research requires sub.stantial scientific or engineering knowledge. Evaluating applied research requires, in addition, the ability to recognize its potential applicability to practical problems, which typically requires input from potential users. Expert re\ iew should be used to assess both basic-research and applied-research programs. .A balance must be achieved between having the most know ledgeable and the most independent indis iduals serve as reviewers.

Pluralism is a major strength of the US research enterprise. But better communication among agencies would enlianee opportunities for collaboration, keep important questions from being overlooked, and reduce inetficient duplication of cITort. Identifs ing a single agency to serse as the focal point for particular fields of research could bring needed cohesion to the federal research effort. In some cases, it may make sense to adopt the model used at the Defense .Advanced Research Projects .Agency (D.ARP.A), in which the desired end product or technology is defined before research begins, so that research teams can coordinate their efforts to solve the problem.

To improve the etfectiveness of federal research and development programs, the federal government could:

• Ensure tliat federal agencies include research programs in their strategic plans and that the\' evaluate the success of those programs in performance reports.^

• Evaluate research in terms of quality, relevance, and leadership. For basic research, include assessments of the hi.storical value of basic research in contributing to national goals.

• Evaluiite how well research programs develop humtm resources and the quality, relevance, and leadership of the programs. If federal research activities do not continue to produce a flow of well-educated scientists and engineers, the capability of an agency to fulfill its mission w ill be compromised and the know ledge learned and technology developed w ill be lost.

• Establish a formal process to identify lutd coordinate areas of research that are supported by multiple agencies. A lead agency should be identified for each such field, and that agency should be responsible for ensuring that coordination occurs among the agencies.

’ Ibid

• ln\ esligate and experiment with innovative ways of managing researeh. such as establishment of long-term research goals, very Hat management structures, multidisciplinary teams, and a focus on technology transfer (these are some of the approaches that have met with considerable success at O.VRPA).^

.Vdiiiinistralis e Policies and Practices

The performers of research sponsored by the federal government operate under an increasing number and variety of administrative requirements, lixamples include rules for human subjects, animal welfare, conflicts of interest, costing and administration, agency-specific requirements, and indirect costs. While each rule has its own history and justifications, the combination of often porrriy coordinated requirements imposes a significant biuden on research performers.

Two publications from the OITice of Management and Budget (OMB) — Circular .A-21, Cost Principles for F.diicalional Institutions, and Circular .A-1 10. Uniform Admmistruitve Reomrenienls for Grams and Olhei Agreements with Inslitttliom of Higher Education. Hospitals, and Olher Xon-Prof 'il Organizations form the framew ork for current eost and administrative regulations. Both are in need of revision. In 1999, the National Science and Technology Council (NSTC) released a report titled Renewing the Eederal Got’ernment-University Research Partnership for the 21st Century, which laid out a set of guiding principles to provide a framew ork for tlie development of new policies, rules, regulations, and laws. These principles could be used to define acceptable standards for the conduct of research that could identify areas of deficiency and foster an appropriate balance between compliance with regulations and administrative fiexibility.

.A particularly contentious issue for college and university researcher performers has been the 26'’o cap on reimbursement of administrative costs imposed by the federal government in 1991. Currently, about a quarter of federal funds spent on research at universities reimburses indirect costs. Ihe two major components of indirect costs are for the construction, maintenance, and operation of facilities used for research and for supporting administrative expenses, such as financial management, institutional review boards, and environment, health, and safety management.

.As the administrative demands on universities have increased, these institutions have had to pay for an increasing percentage of indirect costs that are not covered under the 26*0 cap. As a result, universities have had to shift funds to cover administrative costs from other sources, including tuition, endowments, or state appropriations. Eventually, this cost shifting w ill be detrimental to the health of these institutions, resulting either in less research, higher tuitions, or reduced serv ices to students.

.A more llexible and responsive relationship between federal agencies and universities could help control the administrative costs of research. In 1986. the program now known as the Federal Demonstration Partnership (FDP) was established to examine.

* LawTcncc H Dubois. "DARPA's Approach to Innovation and Its Reflection in Industry", pp 37-48 m Reducing the Time from Basic Research to Innovation in the Chemical Sciences: A ll'orkshop Report to the Chemical Sciences Roundtable. Washmgton, DC: National Academy Press, 2003
' Office of Science and Technology Policy, Analysis of Facilities and.idministrative Costs at Universities, Washington. DC: Executive Office of the President, 2000.

streamline, and reduce the burdens of grant administration. Tlie goals of the FDP are to standardize terms and conditions across federal agencies. simplif\' the prior-approval proce.ss. and streamline award distribution — for example, the FDP is doing a long-term study of institutional burdens related to the OMB circulars. F,.\tending the FDP to colleges with less involvement in federal research awards would help disseminate best practices among federal agencies and institutions of higher education.

•Among the actions the federal government could take to reduce the administrative burden on the perfomiers of research are the follow ing:

• Use the "Principles of the Federal Partnership with Universities in Research" de\ eloped by the NSTC to provide a framework for the development of new policies, rules, regulations, and laws affecting the government-university partnership.

• Raise the cap on reimbursement of indirect co.sts to reflect the costs to universities of conducting research.

• Expand and enhance the FDP to enroll more institutions and heighten the visibility of this important initiative.

• Streamline and align the grant-administration process across agencies to the e.xtent that is consistent with agency needs: all agencies should use uniform terms and conditions for all research and research-related project grants.

The Productiv ity of Scientific and Tecluiological Research
Appendix KP 1
Figures and Tables

Figure RP-1: The Average Length of an NSF Research Grant Has Increased Recently but Is Still Less Than 3 Years.

The Average Duration of Awards
for Research Grants will be 3.0 Years.

□ Goal □ Result

Source: Nitfional Science Foundation. FY2004 Perfonmnce and Accountability Report. Arlington, Virginia: National Science Foundation. 2004.

RP-8

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Figure RP-2; NSF Reached Its Average Annualized Award Size Goal for 200-<, but
It Is Only $140,000 per Year.

NSF will Increase the Average Annualized Award Size
for Research Grants to $139,000.

□ Goal □ Result

Source: Nalional Science Foundalion. FY2004 Performance andAccountability Report. Arlington. Virginia: National Science Foundation. 2004.

RP-9

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This paper summarizes findings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Kconomy of the 2 1st Centun-. Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

Investing; in High-Risk and Breakthrough Research

Sumniars

If processes for awarding research grants are too risk-averse, innovali\'e research projects that could lead to future breakthroughs in science and technology ma> never be funded. To avoid over-cautious R&D funding, recent reports and new programs have focused on three critical areas: adequate funding for basic, discovers -oriented research; independent research funding for young investigators; and funding for individuals who propose visionars' research.

.Among llie federal actions that have been proposed to encourage high-risk research are the following:

• Reallocate 3® o of all federal-agency R&D budgets toward grants that invest in novel, high-risk. and e.\plorator> research.

• Establish a program at the National Institutes of Health (NIH) to promote the conduct of innovative research by scientists transitioning into their first independent positions.

• Within NIH. continue to e.vpiore programs, such as the Pioneer Awards, to increase funding for high-risk, high-benefit biomedical research.

Suppoil Iligh-Kisk Research

Besides favoring older investigators, the current peer-review sv'stem can tend to drive aw ard decisions toward conservative research that is based on precedent and is consensus-oriented. .As a result, public funding for research can gradually shifi from investments in bold, transformational discoverv’ to much more incremental research.

Hie Council on Competitiveness proposes in tlie 2004 report Innovate America: Thriving in a World of Challenge and Change that the nature of discoverv-focused research creates a need for government support. However, federal research support since the Cold War has become more conservative, focusing on short-tenn. incremental, low-risk goals. Outside the gov eminent. Uie council believ’es that risk-based investments are also needed to promote innovation. Inv'estors tend to focus on short-term profits and are unwilling to accept the risks tliat come with investing in a long-temi research project (see Figure HRR-1).* 'fhe report recommends the following:

’ Council on Competitiveness. Inncn-ate America: Thriving in a World of Challenge andChange, Washingt on. DC:
Council on Competitiveness, 2004.

HRR-1

• Reallocate 3®o of all federal-agency R&D budgets toward grants that invest in novel, high-risk. and e\plorator\' research.

• Provide a 25*^o tax credit for early-stage investments of at least $50,000 through qualitled angel funds. ^

In the Tnited States. NIIl has. tlirough its Roadmap initiative, also begun to seed more innovative, high-risk research. ‘**I1ie past two decades have brought tremendous scientific advances that can greatly bcnent medical research.*' the Roadmap argues. ‘‘While progress will continue into the foreseeable future, human health and well-being would benefit from accelerating the current pace of discovers-. One way to achieve this goal is to support scientists of exceptional creativity who propose highly innovative approaches to major contemporary challenges in biomedical research.

NIIl has traditionally supported research projects, not indiN'idual investigators. However, complementary means might be necessar\- to identify scientists with ideas that have the potential for high impact, but that may be too novel, span too diverse a range of disciplines, or be at a stage too early to fare w ell in the peer review process.” .As part of this initiative. NIH has created the NIH Director's Pioneer .Awards ‘lo encourage creative. ouLside-tlie-box thinkers to pursue exciting and innovative ideas about biomedical research.” Hie first Pioneer .Awards were granted in 2004.'

To revitalize frontier research capable of pro\'iding breakthroughs, the federal government could

• Within NTH. continue to explore programs, such as the Pioneer .Awards, to increase funding for high-risk, high-lx;netll biomedical research.

'Hie National Science Board, at the National Science Foundation (NSF). is also discussing this i.ssue. In 2004. an ad hoc Task Group on Higii-Risk Research was formed, which recommended that a formal Task Force on I'ransformative Research be established under the Committee on Programs and Plans. .Additionally, the ad hoc Ta.sk Group noted that there is no formal definition of “high-risk” or “transfomiative” research, so there is no way to adequately detennine how much support NSF is providing to such projects, but there are several rea.sons to begin doing so. The formal committee is researching these and other questions, and a report is expected w ithin 2 years. ^

'Hie Kuropean Commi.ssion (EC), meanwhile, has focased part of its R&D funding on seeding high-risk research. Under its Si.xth Framework Programme (FP6). the EC has established a New and Emerging Science and Technology (NEST) program at f 2 1 5 million to “support unconventional and visionary research w ith the potential to open new fields for European science and technology. a.s well as research on potential problems uncovered by science.”'

^ Council on Compclrtiveness. 2004

^ National Institutes of Health. NIH Roadmap. “High Risk Research.” 2005 Sec http //nihroadmap nih go\’ highrisk

* National Science Board Committee on lAognims and Plans. Charge to the Task Force on Transformative Research Available at. http '%ww nsf gov/nsb committeeS'Cpptrcharge htm

’ European Commission. Enterprise and Industry Directorate-General “New and Emerging Science and Technology
(NEST) Programme.*' 2005 Available at http -www cordis lu neslhome himl

HRR-2

Foster lnno\atiun through ^’oung Investigators

While peer review provides a high-integrity process sheltered from political forces, evidence suggests that it tends to favor both established investigators and investigators, new or continuing, who build on established research lines.^ .As a result, young investigators have difllculty establishing themselves as independent researchers, w hich can have a variety of negative consequences for establishing careers, ensuring an adequate research workforce, and bringing fresh insights and ideas to the research enterprise. Indeed, recent research indicates that the age at which great innovations are produced has increased by about 6 years over the 20th centurv. and the loss of productivity at earlier ages is not compensated for by increased productivity after early middle age’

(see Figure HRR-2). Ilie risk is that competence and productivity can be honored to the point where they become the “enemies of greatness’*.

'l”he cuirent system tends to emphasize the number of papers published and can overlook w hether important problems are being tackled. ISecause requests for grant funds from new' investigators are evaluated on the basis of “preliminarv' results”, most ftmded research becomes constrained to well-worn research paths, which for new investigators often means the research they previously pursued when they were postdoctoral fellows in established laboratories. In short. innoN ation can become the victim of a system that has become too risk-averse.

Ikcause of the diniculties facing new investigators, the median age at which investigators receive their first research grant from NIIl. for e.xample. had crept up to 42 years in 2002. This raises the concern that new investigators are being driven to pursue more conservative research projects instead of higli-risk. high^reward research that can significantly advance science. .Also, young investigators can end up focusing much of their attention on others’ research, forfeiting the special creativity that they may bring to their own work (sec Figure HRR-3).*

The same consideratioas applv to work funded by the IX'partmenl of IX'fense (DOD). TIte need for new discoveries and innovation argues for substantial involvement of university researchers. Yet some younger university researchers in the expanded fields of interest to tlie IX)D are discouraged by difficulty in acquiring research support from the department.^

To address these needs, the federal government could;

• tlstabiish a program at NTM to promote the conduct of innovative research by scientists transitioning into their first independent positions. These research grants would replace the existing collection of K22 awards and would provide sufficient funding and resources for promising scientists to initiate independent research programs and allow for increa.sed risk-taking during the final phase of these elToits. 'fhe program should make 200 grants annually of $5CX).000 each, payable over 5 years. Each award would provide funding for 2 years of postdoctoral training support while the awardee develops an independent re.search program and 3 years of support as a fully independent researcher.*®

* Nati<xial Research Council Bne^es to /nt4?/vndt?«tv: FosUring die Independence <^New Investigators m
Biomedical Research, Washington. National Academies Press. 2005

^Benjamin Jones 2005. Age and Great Innovation (Wotkiri^ paper 11359). Cambridge. MA National Bureau of
Econcwnic Research Available at http7/^vwwnbeTorg pQpers''w 11359,

* Naticmal Research Council Blitzes to Independence: Fostering the Independence <^New Investigators m

Biomedical Research. Washington. DC Nationel Academies lAess. 2005

* NatKMial Research Council Assessment of Department of Defense Basic Research. Washington. DC National
Academies Press. 2005.

National Research Council Bruges to Independence. 2005.

Establish aiid implement uniformly across all the NIH institutes a New Investigator ROl grant. Tlie “preliminary results*’ section of the application should be replaced with “previous e.Kperience” to be appropriate for new investigators and to encourage higher-risk proposals or scientists branching out into new areas. This award should include a full budget and have a 5-ycar term. NTH should track New Investigator ROl awardees in a unifonn manner, including their success on future ROl applications.

Encourage, tlirougii IX)D funding and policies for university research, participation by younger researchers as principal investigators.*^

" Ibid

National Research Council Assessment of Departmunt c^Def<insii Basic Research, 2005

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Investing in High-Kisk ;inil Breakthrough Research
Appendix lIRR 1
Figures and Tables

Table ofC ontents

HRR.5

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Figure HRR-l: There Is a Growing Gap in Available Risk Capital for Entrepreneurs to Use in Working on New Ideas and Innovations.

Funding Gap in Risk Capital

Funilef/Staqe Pre-Seed Seed Start-Up/Eaity Mid later tn^ei^MofWFMls

VrntvtfMds

VMtireFwMb

li¥e$baMllml

jspMkSneoo) I sm.Hoi>$sii.ao wmssoeaiiea ysiiaiiaip

SSiBartmeii)

Tiv IrxMioAiduMlmggapivBPafflkfttKMSMdaxlcartT stagemmtiiwntsaltttSSOOOOOtoSZwIwnraiigt. ahrreMdMrtfw ltmnlorscannolontcraMkt
MtstMrtv BKtddiy liWfiftusMtABidtniigA VCImansMhngNmtwtttcfMvtofl aert iwtiftinin «tAlargrrcapit4MHi (ntnprmwn np«rt
•ffkutv ill nraag m«tn Mmw* S2 mHiwi »4 SS iiHlfgn
AngclnebtMts.atMChaqofcgattagdimtsUHMi proit* a uMiOA

SuMnt Prnlgn<Vqpn««n(p<Groi(&Nrlwari(i««r(n0saGudan:aroCtriinx>iO^rRi7(Angr<Oiwwttnlxi'ciirC(vrm/Mk.KaKlh^

Source; Council on Competitiveness. Innovate America: Thriving in a Worid of Challenge and Change. Washington.
DC: Council on Competitiveness, 2004. Figure 6, p 36.

HRR-6

Figure HRR2A: Innovation Window Is Becoming Compressed. More People Seek Education
to Keep Abreast of New Knowledge, Delaying the Onset of Productivity.

Figure 1 : The Age Distribution of Great Innovation

Figure 2: Shifts in the Age Distribution of Great Innovation

- Before 1935 193S-1965

. After 1965

Source: Benjamin Jones. Age and Oreat Innovation. NBER Working paper 11359, Cambridge. MA: National Bure»j of Economic Research. 2005 Available at http://vvww.nber.org/papers/wT 1359.

HRR-7

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Figure HRR2B: But Delayed Onset of Innovation Is Not Compensated for by Increased Lifetime Productivity.

Figure 7; Maximiuu Likelihood Estimates for the Potential to Produce Great Innovations as a Function of Age

Source: Benjamin Jouts-Ageand Oreat Innovation. NBER Working paper 11359, Cambridge, MA: National Bureau of Economic Research. 2005 Available at http://w\vw.nber.org/papersAvl 1359.

HRR-8

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Figure HRR-3A: Number of Young (<35 Years Old) In>estigators Receiving Federal Funding Is Decreasing.

Awards 35 and Under

93 94 95 96 97 98 99 0 1

SMphan Gtorgia SUlft Unrvftfsiry

Source; Paula Stephan. Preseniaiion at Bridges to Irtdependence Workshop Board on Life Sciences. The Ntf ional Academies. June 16. 2004. A\'ailable at: hitp:/.‘dels.nas.edu14s/l>ii(^es/Siephan.pdf. Dtfa are drawn from National Scicrtce PourKlaiion's Sur%'ey of Doctorate Recipents.

HRR-9

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Figure IIRR-3B: While Uie Success Rule for Receiving an XI!] Grant Is Highest Among Young Researchers, the Number of Young Researchers Applying for Nil ! Grants Has Decreased Dramatically in Recent Years.

Success rate of competing nen ROl and R29 grant application by age of principal investigator.

40%

35%

1 30%

I

I 25%

s

I

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8

I '5^

10 %

S%

Source; Office of Extramural Research. NIH.

Num

20.000

18.000

16.000

a '«■«»

i 12.000

■B.

.? 10.000

0

1 8.000
^ 6.000

4.000

2.000

0

1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002

Fiscal Year

Source; National Research Council. Bridges to Jrkiepertdertce. Washington. DC; National Academies Pre
ss. 2005
Note: Data is from The National Institutes of Health, Office of Extramural Research. See;
http; //grants. nih.gov/grants/oer .him

ber of ROl, R23, R29, or RJ7 applicants b>’ age cohort.

3610 40

1960 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002

Pisc^ Year

HRR-IO

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Figure 11RR-3C: Success Rates and Proportion of Young Investigators Applying for Grants Are Higher at NSF, \\'hich Has C.AREER— A Special Grants Program for Early-Career Researchers, as \\'ell as Specific Program Guidance and Portfolio Balance Measures.

PERCENT OF FY03 AWARDS TO NEW Pis
versus YEARS SINCE PHD

U

I

45%

40%

35%

30%

25%

20%

15%

10%

5%

0 %

to%-

LessthanS 5-10Years 11-15Yaars OvarlSYears

Years

Years Since PhD Granted

PERCENT OF FY03 AWARDS TO NEW Pis
vefsus FIELD divided into YEARS SINCE PHD
60 00%

50 00%

40 00%

3000%

20 . 00 %

10 00%

000 %

Source: Mary Clutter. Presentation at Bridges to IndeperKlence Workshop. Board on Life Sciences, The National Academies. June 16, 2004. Available at: http://del$.nas.edu/bls''bri(^es^Ch[tter.pdf

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BIO CSE Er« ENG GEO ».f>S S8E

Directorate

HRR-11

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Iliis paper summarizes findings and recommendations from a variety of recently published reports and papers as input to tlie deliberations of the Committee on Prospering in the Global Economy of the 21st Century . Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

En-suring That the United States Is at the Forefront in Critical Fields of Science and Technology

.Summary

.As concerns over the declining competitiveness of some US industries emerged in the 1980s, policies and programs were put into place with tlie goal of enabling new ideas particularly those created through federal support to be commercialized more quickly.

These policies and programs have taken a number of forms. Tliey have included support for R&I9 partnerships among companies and between industry and government, support for R&D activities in small companies, programs to support academic research in areas of interest to industry, policies to encourage commercialization of in\ cntions made by federal laboratories and those made by academic researchers w ith federal support, initiatives to coordinate federal R&l) in areas of interest to several agencies, and the creation of private-sector advisory committees concerned w ith the future international competitiveness of particular industries.

Some of these programs have attracted controversy. For e.sample. the .Advanced Technology Program (.ATP), having survived several attempts to eliminate it. was not appropriated funds for new aw ards in FY 2005. ' Others have continued and expanded or have made a variety of transitions for example, from government-supported to privately funded.

Federal actions that have been proposed include the following:

New Policies and Initiatives

• C'reate interdi.sciplinary discovery-innovation institutes to bring together research, education, and practice around the solution of major societal problems.

• Create a program of “Innovation .Acceleration"’ grants to stimulate high-risk research through a set aside of 3 “ b of agency R&D budgets.

• Create a National Institute of Innovation to provide \ enture capital for innovative startups.

• Expiuid industry-led roadmaps for R&D priorities.

' See the ATP Web site's “Update for 2005". www atpnist gov/atp'05coniphtni

EL-1

- launch a large new initiative to develop the computational science base and the necessary' broad infrastructure (such as networks) and domain-specific tools for research and education enabled by information technology across the various fields of science, engineering, and medicine.

- Establish centers for production e.veellcnce and Innovation Extension Centers to improve the capabilities of small and medium-sized enterprises.

Modifications of Existing Policies and Programs

- Make improvements to the Small Business Innovation Research program, including bridges between phase 1 and phase 11 funding, increased phase II funding relative to phase I funding, and regular assessments across agencies.

- Restore .VfP funding including die ability to support new .awards to die average level of recent years.

- Make improvements in .ATP, including streamlining the application process and widening the window for funding, better integrating .ATP w ith other programs, and focusing some funding in thematic areas.

- Have such agencies as the Securities and Exchange Commission, the Federal Communications Commission, and the Intenial Revenue Service consider launching industry-university collaborative research centers to benefit the services industries.

- Re-examine and amend the Bayh-Dole .Act to encourage collaboration among university licensing offices, thereby promoting economic development.

I'he Krdrral Ctovoninirnt us \'rnluro Capitalist

Ilic Small Business Innovation Research (SBIR) .and Small Business Technology Transfer (SITR) programs have sought to encourage the innovative activities of small businesses. SBIR was established in 1982 and sets aside 2.5 “ b of the exlramural R&D budgets of the largest federal science agencies for funding R&D by small businesses; it currently runs at over $1 billion per year.^ Table EL-1 shows the overall trend. SBIR encompasses three phases: feasibility, development, and commercialization. SBIR has been review ed and evaluated a number of times over the course of its existence.’ The National Research Council is currently undertaking a new assessment of the program.'*

STlTt was established in 1992 to encourage small businesses to piirtner w ith research institutions in R&D ;uid commercialization.’

* National Research Council, SBIR: Program Diversity and Assessment Challenges, Report of a Symposium. Washington. DC National Academies Press. 2004

’ National Research Council. SBIR: An Assessment of the Department of Defense 's Fait Track Initiative. Washington, DC: National Academy Press. 2000 National Research Council. SBIR: Challenges and Opportunities, Washington. DC National Academy Pre.ss. 1999

* National Research Council. .An .Assessment of the Small Busmess Innovation Research Program: Project Methodology, Washington. DC: National Academies Press, 2004,

* US General Accountmg Office. Xontributions to and Results of the Small Business Technology Transfer Program", statement by Jim Wells (GAO-01-867T). Washington. DC: GAO, 2001.

Allliough there has been debate over the years about the impaeLs of these programs and the appropriate evaluation metrics, past assessments have been positive overall. Political support also has been very strong, with a number of teclmical changes having been recommended and enacted over the years.

Possible federal actions to improve and extend these programs include the following:

• Bridge the funding gap between phase 1 and phase II awards provided by the SBIR program.*

• Increase tlie number of phase II SBIR awards at the e.xpense of phase I awards,^

• Regularly a.ssess SBIR program results and compare with the Department of Defense (DOD) Fast Track results, and assess the costs and benefits of better integrating SBIR awards in the development of “clusters” around universities and technology parks.®

• Create a National Institute of Innovation that would provide venture capital for innovative startup companies to smooth the peaks and valleys of private-sector venture-capital flows.’ A similar idea, called the Civilian Technology Corporation, was proposed by a National .Academies committee some years ago.”

The .Vdvanced Technology Program and Other Consortia

Partly as a response to Japan's success in benefiting from industrial consortia in such areas as steel and semiconductors. Congress passed the National Cooperative Research .Act in 1984. lliis legislation limited potential antitrust liabilities in order to encourage corporate R&D consortia.

With the launch of SEM.ATECH in 1987, the US government moved to actual financial support for collaborative industrial R&D. SEM.ATECH was founded as a partnership between US semieonductor companies and the DOD. In the succeeding years, as the US semiconductor industry regained competitive strength, the federal contribution to SEM.ATECH was gradually reduced and then eliminated.'' Tlie consortium, now named Inteniational SEM.ATECH. includes countries based in Europe. Korea, and Taiwan in addition to those based in the United States.

.ATP was established in 1988 as a program of the National Institute of Standards and Technology (NIST). .ATP supports collaborative research among companies. Tlie program has operated at a level of $150 million to $200 million per year in recent years.

* National Research Council. The Small Business Innovation Research Program: Challenges and Opportunities, Washington. DC: National Academy Press. 1999

Ubid

* National Research Council. 2000.

’ Kent Hughes. “Facing the Global Competitiveness Challenge". Issues in Science and Technology 2I(Summer 2005).

National Academy of Sciences, National Academy of Engineering, Institute of Medicine, The Government Role in Civilian Technology, Washii^ton. DC.: National Academy Press, 1992.

*' National Research Council Securing the Future: Regional and National Programs to Support the Semiconductor Industry. Washington. DC: National .Academies Press. 2003 See also the "History" page on the International SEMATECH web site, www sematcch org'corporate/history.htm

As mentioned above, the FV 2005 budget ineluded funds to eontinue existing projeets but no money to fund new proposals. Figure EL-2 shows how .ATP funding has fluetuated over the years. .ATP also supports an exiensive program of evaluation and researeh. whieh has supported work at the National .Aeademies and the National Bureau of Eeonomie Researeh.'^

Possible federal aetions to derive advantage from govemment-industn, partnerships and industrial eonsortia inelude the following:

• Create “Innot ation .Acceleration” grants to stimulate high-risk research.'* These grants w ould be supported througli a set aside of .3 of agency R&D budgets.

• Restore the support of .A'fP and its abilitx’ to fund new projects to the level of recent years.

• Streamline and shorten the .AIT application process and timeline.'*

• Give applications from single companies parits’ w ith those from Joint ventures or consortia.**

• E.xtend tlie window for .ATP award applications, accelerate the decision-making process for awards, and extend Ute period in which awards can be made.'*

• Retain the debriefing process for unsuccessful .ATP applicants.'*

• Concentrate a significant portion of .ATP aw ards in selected thematic areas.'*

• Coordinate .ATP with SBIR and national initiatives.'*

• Establish a regular outreach program within NIST to coordinate .ATP awards witli matching grants by states.**

• Pass legislation that would allow industries to form self-organizing investment boards that would raise funds through a ‘lax” on sales of their products in order to support R&D on common problems.*'

I'niversity-Biiscd Centers

Federally supported university-based centers constitute a category of programs that support collaborative (usually interdisciplin.'uy) research between unis ersities and

See the ATP web site, www.alp.nist gov/faclsheets/l-a-l hlm

Council on Competitiveness, Innovau America: National innovatiem Initiative anti Report. Washington. DC; Council on Competitiveness, 2004,

National Research Council, The .Advanced Technology Program: Challenges and Opportunities. Washingtcn. DC: National Academies Press. 1999.

” Ibid

“National Research Council. The Advanced Technology Program: Assessing Outcomes. Washington. DC:

National Academies Press, 2001

” Ibid

'• Ibid

“ Ibid

“Ibid

Paul Romer, “Implementing a National Technology Strategy with SelfOrganizing Industrv' Investment Boards." pp 345-399 m Martin Neil Baily, Peter C. Reiss, and Clifford W'inston (cds,), Brookings Papers on Economic Activity: Microeconomics 0). Washington, DC. Brookings Institution, 1993,

industries, nicse include such programs as the lingincering Research Centers (ERCs). Science and Teclmologv’ Centers (STCs). and Industr>'-University Cooperative Research Centers (I/L'CRCs) of the National Science Foundation (NSF). Other agencies, such as the Department of Transportation and the Department of Energ>' (DOE), also support university-based centers. These programs are generally awarded on a continuing basis with renewal reviews at fi.xed periods. NSF support for individual STCs phases out after 1 1 years, while other center programs are funded longer. I,everaged support from industiy is generally required, the level of w hich varies by program.

Tbe NSF elTorts have the longest track record. For e.xample, the ERCs program was established in 1985.^^ 'llie program itself is occasionally evaluated internally and by an external contractor using surveys, bibliomctric analysis, and other methods.^^ 'ITicsc cvahuitions generally show that a large percentage of industry participants derive benefits from participation, including know ledge transfer and the ability to hire students, .-kt the time when the STCs program was being considered for renewal, a National .Academies eommittee recommended that the program continue."^ Figure EL-3 shows how the various NSF centers programs fit into the overall funding picture.

Options for federal action include the following:

• Establish a new, large, multiagency centers program. In a preliminary report released for public comment earlier this year, a eommittee of the National

•Academy of Engineering proposed to create a program of interdisciplinary discovery-innovation institutes on research-university campuses. The institutes would bring together research, education, and practice around the solution of major societal problems.^* Multiagency federal support for the institutes would build to several billion dollars per year, to be supplemented by support from industry , states, and nonprofits.

• Establish centers in agencies that have not supported centers in the past. Federal mission and regulatory agencies w ith primary responsibility for the serx iccs industries — such as the Securities ;md Exchange Commission, the Internal Revenue Service, the Federal Communications Commission, and the Department of Health and Human Services (DHHS) — should consider funding academic research in ways that encourage greater participation by the services industries.^*’

“ Linda Parker. The Engineering Research Centers (ERC) Program: An Assessment of Benefits and Outcomes, Arlington, Va,: National Science Foundation, 1997.

(www.nsf.gov/pubs/ 1 998/nsl9840.:ns(9840. htm).

^ J. David Roessner, ITavid C'hcney, and H.R. Coward, Impact of Industry Interactions with Engineering Research Centers- Repeat Stiufy', SRJ International, 2004.

^ National Academy of Sciences, National Academy of Engineering, Institute of Medicine, An Assessment of the National Science Foundation 's Science and Technology^ Centers Program, Washington, DC: National Academy Press, 1996.

” National Academy of Engineering, Assessing the Capacity of the US Research Enterprise (preliminary report for public comment/, Washington, DC: National Academies Press, 2005.

“ National Academy of Engineering, The Impact of Academic Research on Industrial Performance, Washington, DC: National Academies Press, 2003.

C'oilaboraln e Research and Development Agreements

Another mechanism for govemment-industrv’ collaboration is a collaborative and dexelopment agreement (CRADA), 'Ilie Stevenson-Wydler Teclmology Innovation Act of 1986 allowed federal laboratories to enter into CRAlJ.As with private companies, llie legislation has been amended several times and covers most agencies.Hie National •Aeronautics and Space .Administration has a separate authority under the 1958 Space .Act and the 1989 National Space Policy.^’

As of FY 2001, there were 3,603 active CR.AD.As, 80 “o of w hich involved the IX)1), DOE. or D1111S.“

CR.AD.As can range from focused collaboration on a specific tecltnology to large programs, such as FrecdomC.AR. a successor to the Partnership for a New Generation of Vehicles (PNG\') CR.AD.A between the IX3E and the big three automakers.^’ PNGV was reviewed by a standing National .Academies committee.™ .Although the research made impressive teclmological progress, only w ith the recent rapid rise in gasoline prices are advanced technologies for high-fuel-economy vehicles becoming a competitive factor in the marketplace.

The Bayh-Dole .Vet

The Bav'h-Dole .Act of 1980. which allowed universities to own and license patents of university inventions (even inventions supported by federal funds), ushered in an e.vpiosion of university patenting and licensing activity.” Tliere is broad recognition that Bayh-lX)le has encouraged a variety of luiiversity-induslrv- collaborations and small-finn startups. Figures E1.-4 and EE-5 show how industry support for university research and university licensing income has gone up. fliere has been continuing research and debate on the ultimate impacts.’’

Calls to amend or rethink 13ayh-Dolc have come from several quarters in recent years. Some companies and universities have found it dilTicult to work out tlie intellectual-property aspects of collaboration.” There also have been cases in w hich

^’NASA. Space AcI Manual, Washington, DC: NASA, 1998 Available al nodis3 gsfc nasa gov/1050-1 html

“ National Science Board, Science and Engineering Indicators 2004, Arlington, VA: NaUonal Science Foundation, 2004. See summaiy points for Chapter 4 at www,nsfgov/sbe/srs/seind04/c4/c4h htm)

® US General Accounting Office. “Lessons Learned from Previous Research could Benefit FreedoraCAR Initiative”, statement of Jim Wells (GAO-02-810T). Washington, DC: GAO, 2002.

* National Research Council, Review of the Research Program of the Partnership for a Slew Generation of Vehicles, Washington. DC National Academies Press. 2001

” Council on Government Relations, The Bayh-Dole Act: A Guide to the Law and Implementing Regulations, Washington, DC: CGR, 1999. Avialable at wwve ucop edu'ott/bayh html)

David C. Mowery and Arvids A Ziedonis, “Numbers, Quality and Entry How Has the Bayh-Dole Act Affected US University Patenting and Licensing?" in Adam B. Jaffe, Josh Lerner, and Scott Stem (eds.). Innovation Policy and the Econont}-, Volume I, Cambridge, MA : The MIT Press, 2001

” Susan Butts and Robert Killoran. "Industry-Univeisity Research in Our Times: A White Paper,” 2003

Available al: htlp://www7 nalionalacademies orgguirr/IP_background html)

university intellectual-propcrlN rights might have impeded the flow of a superior medical treatment to the market, to the detriment of public health.^

Possible options for federal action include the following;

• Evaluate and amend the Bayh-Dole Act to promote collaborations between

university technology-transfer offices, local community colleges, local economic-development planning agencies, federal laboratories, select managers of venture funds, and industr\ leaders. This would respond to the increasing pressure on university technology-transfer specialists to become stewards of their regional economic development. Cooperative Economic Development Agreements (CED.As)can accomplish this goal.^^

(omniissions and Councils on Specific Industries and Technologies

Over the years, a number of national advisor^' bodies have been set up to develop policy ideas and recommendations afiecting specific industries. These bt)dies have sometimes taken on science and engineering issues as a central part of their work. The National Advisor\' Committee on Semiconductors, which operated in the late 1980s and early 1990s. is one example. A more recent example is the Commission on the future of the United States .Aerospace Induslrs.^^ .A followup elTort. the National .Aerospace Initiative, has sought to involve the relevant agencies in the development of technology roadmaps for the inditslrv .^’

'Ilie President's Infonnation Technology .Advisorx' Committee, which was disbanded in June 2005, issued a final report recommending that federal agencies change the way they fund computational science and calling on the National .Academies to lead a roadmapping effort.^* Several years ago. an advisor)' committee to NSF recommended the launch of an effort to boost c\ berinfraslructure for research enabled by information technology.^’

Possible options for federal action include the following:

• Make coordinated, fundamental, structural changes that alTinn the integral role of computational science in addressing the 21st cenlurx 's most important problems, which are predominantly multidisciplinar>’. multiagenc)', multisector, and collaborative. To initiate the required transformation, the federal government, in partnership with academe and industr>', must create and execute a multidecade

” Avital Bar Shalom and Robert Cook-Deegan, "Patents and Innovation in Cancer Therapeutics: Lessons from CellPro,” The Kiilbank Quarterly ^0(X><ccmhcx 2002);637-76, iii-iv.

Clovia Hamilton. "University Technology Transfer and Economic Development: Proposed Cooperative Economic Development .Agreements Under the Bayh-Dolc Act", John Mortal! Law Review, Winter 2003.
^ Commission on the Future of the United States Aero^cc Indusu>’. Final Report. Arlington. VA 2002 Available at www.ila.doc.gov ul''acrospace/3erospacecommissic»i;'AcroCommissionKinalRcpon-pdf
National Research Council. Evaluation of the National Aerospace Initiative. Washington. DC : National

Academies Press, 2004

” President's Information Technology Advisory Committee, Computational Science: Ensuring America ’s Competitiveness, Washington, DC: 2005.

^ BKic-Ribbon Advisor)’ Panel cm Cy'berinfrastructure, Revolutionizing Science and Engineering Throug h
Cybehnfrasiructure, Arlington, VA.. National Science Foundaticm, 2003

roadmap directing coordinated advances in computational science and its applications in science and engineering disciplines.

• Commission the National Academies to convene one or more task forces to develop and maintain a nniltidecade roadmap for computational science and the fields that require it with a goal of ensuring continuing ItS leadership in science, engineering, the social sciences, .and the humanities.

• Direct the NSF to establish and lead a large-scale, interagency, and internationally e(X)rdinated .Advanced Cyberinfrastnielure Program to create, deploy, and apply csberinfrastrueture in ways that radiealls' empower all scientific and engineering research and allied education. Sustained new NSF funding of SI billion per year is required to achieve “critical mass” and to leverage the necessary coordinated coinvestment from other feder.al agencies, universities, industrv , ;md international sources required to empow er a revolution.''''

Manufurturing and Innosatiun Kxlension

Tlic Manufacturing Extension Partnership (MEP) program of NIST was established in 1989 and now comprises about 350 nonprofit MEP centers that collectively receive a little over SlOO million annually from NIS f." 'I'he centers have been successful in attracting support from states, industry, and other entities.

Several recent recommendations for federal action are related to manufacturing technology and extension seix iees:

• E.stablish a program of Innos ation E.xtension Centers to enable small and medium-sized enterprises to become first-tier manufacturing partners.'^

• Create centers for production excellence that include shared facilities and consortia.'**

* Ibid

Sec the NIST web site, www mep nislgov about-mep/aboul hlml.

■** Council on Competitiveness, /nnova/e America: National Innovation Initiative and Report, Washingt on,

DC: Council on Competitiveness, 2004

®Ibid

Knsuring That the rnited States Is at the Forefront
ill Critical Fields of Science and Technolog>
Appendix
Figures and Tables

EL-5: License Income to North American Cni>erslties and Research Institutes. Licensing Income Has Grown.

EL-9

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Ficrurc KL-1: Small-Business Innovation Research .Ward Funding, by Type of .Wal’d: FV 1983-2001. .\s a Fixed Percentage of Large Research-.\gency Budgets, SBIR has Grown Steadily over the ^'ears.

All agencies

FY Total Phase I Phase II

(feasibility) (main phase)

1983

45

45

0

1984

108

48

60

1985

199

69

130

1986

298

99

199

1987

351

110

241

1988

389

102

285

1989

432

108

322

1990

461

118

342

1991

483

128

336

1992

508

128

371

1993

698

154

491

1994

718

220

474

1995

835

232

602

1996

916

229

646

1997

1.107

278

789

1998

1.067

262

804

1999

1.097

300

797

2000

1,190

302

888

2001

1.294

317

977

Source: National Science Board Science and Engineering Indicators 200^ (NSB 04-01) Arlington, Virginia. National Science Foundation. 2004. Appendix Table 4-39.

EL-10

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Figure EL-2: Suraiiiar>' of ATP Awards, by Source of Funding: 1990-2004. The ATP

Program Has Been Controversial and Has Fhirtuated In Size as a ResulL

Source: Advaiced Techtiolocy Program. ^ 47 ^ Factsheet: 3A.3: ATPA^x : • Summary Data- ($

MUlionj). September 2004. Available at http://www.atp.ntst.gov /factsheets;3'a>3.htm

Figure EL-3: Centers as a Percentage of the NSF Research and Related .Account.

m Fundamental
Science &
Engineering

■ Centers

□ Capability
Enhancements

Source: Ndional Based on data in the National Science Foundation. 200S.FY 2005 Performance and Accountability Report. Arlington. VA: National Science Foundation.

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Figure EL-^: Industry Support of Science and Engineering Research at US Colleges and Universities. Industry Support Has Increased Steadily since Bayh-Dole.

Source: Robert Killoren and Susan Butts. Industry-lMiversity Research in Our Times. Background paper for Re-Engineenng Intellectual Property Rights Agreements in Industry-Uniyersity Collaborations. Govemment'University-Industiy Research Roundtable. National Academies. June 26. 2003. Available at: http://vvww7.nationalacademies.org/guiir/IP_backgroundhtinl

Figure EL-5: License Income to North American Universities and Research Institutes. Licensing Income Has Grown.

Fiscal Year

Source: Robert Killoren and Susan Butts. Industry-lMiversity Research, in Our Times. Background paper

for Re-Engineenng Intellectual Property Rights Agreements m Industry-University Collaborations. Goveniment*Universfty*Indistiy Research Roundt^le, National Academies. June 26. 2003. Available at: http://www7.nationalacademies.org/guiir/TP_backgroundhtmI

EL- 12

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Undcrstundin^ Trends in Seicncc and Technologv' Critical to US Prosperitj’

Suniniari

Sound policies rest on a solid foundation of infomiation and analysis. The collection and analysis of data have become key components of the innovation system.

During the late 1980s and early 1990s. policy-makers expressed a growing interest in assessments and international comparisons of critical technologies, litis interest was prompted by the rapid (and unexpected) emergence during the 1980s of Japanese companies in high-technology fields, such as microelectronics, robotics, and advanced materials. Policy-makers proposed that regular elTorts to identity the technologies likely to underlie future economic growth and to assess the relative international standing of the United States in those technologies would yield infomiation useful for making investment decisions.

Today, a number of government and private groups undertake a variety of technology assessments that enltancc our imdcrstanding of .Vmcrica's relative standing in specific science and engineering fields. More detailed and imiovative measures could provide important additional infomiation on the status and effects of scientific and technological research.

Recommendatioas for federal actions in these areas include the following:

International Benchmarking of US Research Fields

• Establish a system to conduct regular international benchmarking assessments of US research to provide information on the w orld leadership status of key of fields and subfields of scientific and technologic research.

Critical Technologies

• Establish a federal office that would coordinate ongoing prii ate and public assessments of critical technologies and initiate additional assessments where needed.

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Data Collection and Dissemination

• Mandate that the White House OlTice of Science and Teclinologj' Policy prepare a regular report on innovation that would be linked to the federal budget cycle.

• Provide the National Science Foundation (NSF) Division of Science Resources Statistics (SRS) w ith resources to launch a program of innovation surv'eys.

• Ensure that research and innovation survey programs, such as the NSF R&D sursey, incorporate emerging, high-growth, tecimology-intensivc industries, such as telecommiuiications and biotechnology, and industries across the sen ice sector — llnancial services, transportation, and retailing, among others.

Scieiirr and Terhnology Iteiirhiiiarking

As part of the technology and intcniational-competiti\ eness debates of the 1980s and 1990s, several initiatives were launched to assess national capabilities in specific fields of science and engineering. Many of the early assessments looked at Japanese capabilities and were perfonned by US or international panels.’ In the late 1980s. the Japan Technology Evaluation Center started as an interagency federal initiative managed by S.AIC; it evolved into an NSF-contracted center at Ixtvola College of Mary land and is now an independent nonprofit know n as the WTEC, Inc.^ WTEC assessments cover a variety of countries and fields and are undertaken on an ad hoc basis. Ihcy are funded by the federal agencies most interested in the specific field being assessed.

A 1993 National .Academies report recommended that the world leadership status of research fields be evaluated through international benclimarking.^ A follow up report that reviewed three benchmarking e.vperiments (mathematics, immunology, and materials science and engineering) concluded that the approach of using e.xpert panels could yield timely, accurate “snapshots” of specific fields. ' The report also suggested that benchmarking assessments be conducted every 3-5 years to capture changes in the subject fields. Figure lT-1 illustrates one such assessment.

llie factors considered most important in determining LIS leadership status, on the basis of all the international benclimarking e.xperiments, were human resources and graduate education, funding, innovation process and industry, and infrastructure.

In addition, the Bureau of Industry and Security of the US Department of Commerce undertakes assessments of the US industrial and technology base in areas considered important for national defense.* These assessments often take into account international competitiveness.

' National Research Council, National Ktatcrials Advisoiy Board, High-Technology Ceramics in Japatv Washington, DC: National Academy Press, 1984.

^ Sec the WTEC. Inc., website. www.wtcc.org''wclcomc.hun.

^ National Academy of Sciences, National Academy of Engineering, and institute of Medicine, Committee

on Science, Engineering, and Public Policy, Science, Technology, and the Federal Government Washington, DC: National Academy Press, 1993.

■* National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Committee on Science, Engineering, and Public Policy, Experiments in International Benchmarking of U.S. Research Fields, Washington, DC: National Academy Press, 2000.

’ See www.bis doc gov/defenseindustrialbaseprograms/osies.T)efkJaiketRescarchRpts'Default htm

Possible federal action includes the following:

• Establish a system to conduct regular international benchmarking assessments of US research to provide information on tlie world leadership status of key fields and subfields of scientific and technological research.

■Vn e.vample of the potential utility of this information is shown in Figures UT-2 to 1lT-5 which show funding and innovation process metrics for nanoteclinology.

Critiml Trchiiologirs

In 1990. Congrc.ss mandated that a biennial review be conducted of .Vmcrica’s commitment to critical tcclmologies deemed essential for "maintaining economic prosperity and enhancing the competitis eness of the US research enterprise”. The legislation required that tlie number of technologies identified in the report not exceed .^0 and include the most economically important civilian technologies expected after the decade following the report’s release with the estimated current and future size of the domestic and intemational markets for products derix ed from the identified technologies.

However, the e.xact definition of critical technologies was not included in the legislation.

Tlie Office of Science and Technology Policy ((9STP) prepared National Critical Technologies Reports (NCTR)to Congress in 1991,'^ 199.1.^ 1995,* and 1998.’ The content of and methixis used to prepare the NCTRs varied throughout the decade.'* The 1995 report, for example, identified seven ‘leehnology categories” (energy, environmental quality, infonnation and communic.ation. living systems, m,anufacturing. materials, and transportation), which were divided into 27 "technology areas”. Figure l'T-6 illustrates the NCTR an.alyses for materials research. Each of the 27 areas was identified on a competitive scale ranging from lagging to leading, and each area was then compared w ith Europe and Jap.-ui."

Over the 1990s. the R.-VND Corporation played an increasingly important role in the preparation of the NX’TRs. R.VN’D assisted with the background research for the 1993 report .and was a co-author of the 1995 report with OSTP.'^ The 1998 critical-technologies report was prepared by R.AND w ith little involvement of OSTP." This report, which refocased the study specifically on input from the private sector, identified five critical sectors of technology: software, microelectronics and telecommunications

® Nauonal Critical Technologies Panel, Report of the National Critical Technologies Panel, Washington. DC U S Government Prinung Office. 1991

^NaUonal Critical Technologies Panel, The Second Biennial Report of the National Critical Technologies Panel, Washington. DC: US, Government Prmting Office. 1993

* NaUonal Critical Technologies Panel. The National Critical Technologies Report, Washington. DC: U S, Government Pnntmg Office. 1995

’ Steven W Popper. Caroline S Wagner, and Eric V Larson. New Forces at it'ork: Industry I 'lews Critical Technologies, ^nta Monica. CA: RAND. 1998

'“Carolme S. Wagner and .Steven W Popper. "Idenufying Critical Technologies in the VSA~, Journal of Forecasting. 22(2003): 113-128,

" National Critical Technologies Panel 1995
W'agnerand Popper. 2003. p, 120
“ibid

technologies, advanced maniifacliiring. materials, and sensor and imaging technologies.'^
. Vfter the release of the 1 998 report, the legal requirement for OSTP to prepare the NCTR was remox ed.

Those invoix ed in the NCTR process point out that federal agencies and state and local governments ased the reports as a basis for policy-making. I loxvever, the NCres do not appear to have had a formal effect on L'S federal policy toward technology development.'’ For example, the NCTRs did not lead to the creation of anx’ large cross-agency technology initiative. Nanotechnology xvas not a focus of the final 1998 NC'I'R. but OSTP started xvork around that time on discussions that would culminate in the creation of the National Nanotechnology Initiative sex eral years later.'*

In addition to the NC'f Rs. .several other public and private efforts to identify critical technologies in both the defease and cix ilian arenas xxere luidertaken during the 1990s by such groups as the US Department of Defense'’ and the Council on Competitiveness.'* More recently, several government agencies have e.xpressed interest in assessing international capabilities in militarilx critical technologies.'* .Also, a mmiber of countries are engaged in periodic assessments of critical technologies and international capabilities.

Possible federal actions include the following:

• Kstablish a federal olTice that would coordinate ongoing private and public assessments of critical technologies and initiate additional assessments xvhere needed.

• .Analyze the technology forecasting and foresight activities of other countries to identify xvhere such activities c:ui provide useful input to policy processes.

Data on Kesrarch and Innuxaliun

llie adequacy of measures and statistical data to inform policy-making remains a concern of the science and technology policy community. For example, during the 1990s, information technologies xvere widely deployed throughout the US economy and played a major role in a surge of US imiovation. yet this process xvas captured poorly, if at all. by traditional indicators of research and innovation. E.xcept for statistics on fotTnal R&D spending, patents, and some aspects of science and engineering education, innovation-related data are extremely limited.’'’

Popper, Wagner, and Larson, 1998.

Wagner and Popper. 2003. p, 123.

Neal Lane and Thomas Kalil, “The National Nanotechnology Initiative Present at the Creation". Issues in Saence anti Technology 21(Summer 2005): 49-54
’’ See the Militanly Critical Technologies website, wxvw dlic mil'mcll

** Council on Competitiveness, Gaming New Ground: Technology Priorities for America 's Future. Washington, DC Council on Competiuvencss, 1991

National Research Council Division on Engineering and Physical Sciences, .^voiding Surprise in an Era

^Global Technology. Advances, Washington, DC: National Academies Press. 2005
“ National Research Council Committee on National Statistics, Measuring Research and Development Expenditures in the U.S. Economy. Washington. DC: NaUonal Academies Press. 2004,

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•Among the steps the federal government could lake to improve data collection and analysis are the following:

• Miuidate that OSTP prepare a regular report on innovation that would be linked to the federal budget cycle.^' The goal of the report w ould be to give the government and the publie a clear sense of how federal support for R&D fits into the larger national economic system and how both are linked to an increasingly international process of innovation.

• Provide the NSF SRS w ith resources to launch a program of inno\ ation surxeys.^^ SRS should work with e.vpcrts in universities and public institutions that have expertise in a broad spectrum of related issues. In some cases, it may be judicious to commission case studies. NSF also should build im internal capacity to resolve the melhodologic issues related to collecting inno\ ation-related data.

• Ensure the collection of information needed to construct data series of federal science and technology (FS&T).’^ NSF needs to continue to collect tire additional data items that are readily available in the defense agencies and e.xptmd collection of civilian data that would permit users to constnict data scries on FS&T e.xpenditures in the same maimer as the FS&T presentation in the president's budget documentation.

• Oi erhaul the field-of-science classification system to take aecoimt of changes in academic research, including interdisciplinary and multidisciplinary research.^'* It has been some 3 decades since the field-of-science classification system has been updated, and the current classification structure no longer adequately reflects the state of science and engineering fields. OMB needs to initiate a review of the Classification of Fields of Science and Engineering, last published as Directive 16 in 1978. file SRS could serv e as the lead agency for tin effort that must be conducted on a govemmentw ide basis. NSF should engage in a program of outreach to the disciplines to begin to develop a standard concept of interdisciplinary and multidisciplinary research, and on an e.xperimental basis it should initiate a program to collect information from a subset of academic and research institutions.

• Redesign NSF's indirstrial R&D survey.^* file redesign should begin by assessing the IIS survey against the international ‘'standard" — the definitions promulgated through the Frascati Manual from the Organisation for Economic Co-operation and Development. The redesign also should update the industry questionnaire to facilitate an understanding of new and emerging R&D issues, enliance the program of data analysis .and public<ation. revise the sample to enliance coverage of grow ing sectors, and improve the collection procedures to better involve and educate the respondents.

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Kent Hughes, “Facing the Global Competitiveness Challenge,” Issues in Science ami Technology, 21(Sunimer 2005):72-7S
“ National Research Council, 2004.

“ Ibid
“Ibid
“ Ibid

• Ensure that research and innovation survey programs, such as NSF's R&D survey, incorporate emerging. high-gro\Mh. technologv -intcnsive industries, such as telecommunications and biotechnology, and industries across the service sector — financial services, transportation, and retailing, and others.^* .Also, survey programs should collect information at the business-unit level of corporate activity rather than on a firm as a whole, and geographic location detail should be collected.

• NSF should increase the analytic value of its data by improving comparability and linkages among its data sets and between its data and data from other sources, such as the US census.^’

• SRS should develop a long-temi plan for its Science and Engineering Indicators publication so that it is smaller, more policy focused, and less duplicative of other SRS publications.^ SRS also should substantially reduce the time between the reference date and data release of each of its surveys to improve the relevance and usefulness of its data.

^ National Research Council. Board on Science, Technology, and Hconomic Policy, Indusirial Research and Innovation Indicators, Washington. DC. National Academy Press. 1997.

Comm ittee on National Statistics, 2004.

“Ibid

L'iiclei*staii(liiig Trends in Science and Technology
C ritical to US Prosperity
Appendix
Figures and Tables

Figure t'T-1

Fxample of International Benchmarking for Several Materials Science
and Kngineering Subfields

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Source: National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Committee on Science, Engineering, and Public Policy, Experiments in International Benchmarking of US

Research Fields Washing,ton, DC; National Academy Press 2000

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Figure UT-2

Nanotecholog>' Funding by the US Government Investment Has Been Declining as
a Share of Global Government Investment.

Share of total gowrnment mwiunent, totals m Sbilhons

1.5 2.4 3.1 3.7

Mfc* Rooo. RAD II Wwt^hop Pumii^Suh. NmoBwngt* ^Ownot

Sean Murdock. Testimony before the Research Subcommittee of the Committee on Science of the United States House of Representative. Hearing on: '‘Nanotechnology: Where Does the US Stand?" June 29th, 2005.

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Figure UT-3

Nanotechologj' Funding; Government and Corporate Funding Dwarf Venture

$ Billions

VC

Nanotech

Funding

1998-2004

C'apilal Funding.

Global

Corporate

Funding

2004

Global

Government

Funding

2004

Sean Murdock. Testimony before the Research Subcommittee of the Committee on Science of the United States House of Representative. Hearing on: “Nanotechnology: Where Does the US Stand?” June 29th, 2005.

Figure llT-4

Nanoteciioiogy Innovation Process: The Number of US sTartups Is Stagnating.

Sean Murdock. Testimony before the Research Subcommittee of the Committee on Science of the United States House of Representative. Hearing on: “Nanotechnology: Where Does the US Stand?” June 29th, 2005.

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Figure UT-5

Nanotecholog>' Innovation Process: Patenting by US Inventors Is Growing Rapidly.

S«an Murdock. Testimony before the Research Subcommittee of tlie Committee on Science of theUnked States House of Representative. Hearkig on: '"Nanotechnology; Where Does the US StandT' June 29th.

2005.

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Figure l'T-6

Kxaniple of Critical Technologies last for Materials

Materials

Technology

Technology

Sample Applications to

Aren

Sob-Area

Specilic Technologies

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ns Which Specilic Techs Contribute

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(EP “ Economic Prosperity; NS - National Security)

Source: Office of Science and Technology Polic)' S'ahonai Critical Technologies List, March 1995. Available at: http:-/clintonl nara gov.'White_House'EOP.'OSTP.''CTIformatted'AppA'appa hlml

This paper summarizes rmdings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 21st Centurs'. Statements in this paper should not be seen as the conclusions of the National Academies or tlie committee.

Ensuring That the United States Has the Best Environment for Innovation

Suiiiiiiars

A number of recent reports have raised concerns about the United States' long-term ability to sustain its global science and engineering (S&E) leadership.' 'fhey argue that erosion of this leadership threatens our ability to reap the rewards of innovation in the form of higher incomes and living standards, better health, a cleaner environment, and other societal benelits.

Certainly, tlie leadership position the United States has maintained in research and the creation of new know ledge since World War 11 has been an important contributor to economic growth and other societal rewards. However, a look at US history and some contemporary international examples shows that leadership in research is not a sufTicient condition for gaining the lion's share of benefits from innovation. .A fas orable environment for innovation is also necessary. The enviroiunent for iimovation includes such elements as the market and regulators' environment, trade policy, intellectual-property policies, policies that affect the accimiulation of hunuui c.apital. and policies alfecting innovation environments in specific regions. In addition, grand challenges issued by the president (such as the reaction to Sputnik and the call for the .Apollo project) can mobilize resources and the national imagination in pursuit of important innovation-related goals.

How can the United States sustain and improx e the environment for innovation even in a future where its relative share of global S&E inputs to the innovation process (such as R&l) spending. S&E persoimcl, and the quantity and quality of scientific literature) declines?

Many approaches to improving the innovation ens ironment have been suggested. On some issues, including the offshoring of serxiee-industiy jobs, contradictory' diagnoses and prescriptions have emerged on the basis of interests and political outlook

' American Electronics Association, Losing the Competitive Aih'antage? The Challenge forSaence and Technology in the United States. Washington. DC: Amencan Electronics Association, 2004. Council on Compcliliveness, Innovate America. Washington, DC: Council on Competitiveness, 2004. Richard B. Freeman, "Does Globalization of the Scicntitic/Engmcenng Workforce Threaten US Economic Leadership?" NBER Working Paper 1 1 457, Cambridge, MA. : National Bureau of Economic Research, 2005. Task Force on the Future of American Innovation The Knowledge Economy: Is. America Losing Its Competitive Edge? Washington DC: 2005-

of the anaij'sis. On other issues, such as patent-system reform, similar suggestions have emerged from several different reports. The approaches suggested include the following:

Market. Regulatory, and Legal Environment

• Establish a public-private body to assess the impact of new regulations on innovation.

• Reduce the costs of tort litigation for the economy.

• Reform Section 404 of the Sarbanes-Oxley Act.

• Drop current efforts to e.xpense stock options.

• Create best practices for collaborative standard-setting.

• Undertake market and regulatory reforms in the telecommimications industry with the goal of accelerating the speed and accessibility of networks.

Trade

• Increase focus on enforcement of the prevailing global rules for intellectual-property protection, particularb' in China and in other countries where significant problems remain.

• Make completion of the Doha Round of world-trade talks a priority.

Intellectual Property

• Harmonize the US, European, and Japanese patent systems.

• Institute a postgrant open-review procedure for US patents.

• Stop diverting patent application fees to general revenue to provide the US Patent and Trademark Office (USP'fO) w ith sufficient resources to modernize and improve performance.

• Shield some research uses of patented inventions from liability for infringement.

• I-everage the patent databa.se as an iiuiovation tool.

Tax Policy

• Make the R&D tax credit permanent, and extend coverage to research conducted in university-industn. consortia.

• Provide new tax incentives for early-stage investments in innovative startups.

• Provide more favorable tax treatment (expensing and accelerated depreciation) for the purchase of high-technology manufacturing equipment to encourage industry to keep manufacturing in the United States.

Human Capital

• Create incentives for im estments by employers and employees in lifelong learning, including the creation of ta.\-protected accounts.

• Restructure and expand worker-assistance programs like tlic Trade .Adjustment .Assistance .Act so that they are more flexible and cover workers displaced by reasons other than trade.

• Expedite the immigration process, including issuance of permanent residence status (green cards) to all master's and doctoral graduates of US institutions in science and engineering.

• Make Hl-B visas “portable" to reduce the possibility of visa holder's being exploited and to reduce the negative impacts on L'S workers in those fields.

• Fund new programs that promote entrepreneurship at all levels of education.

• Reform policies toward health and pension benefits.

• Require companies operating in the United States to be transparent in reporting ofl'shoring decisioas.

• Use procurement policies to discourage government contractors from ofl'shoring by requiring that certain tasks be perl'ormed by US workers.

New "Apollo”

• Gain presidential-level commitment to the proposition tliat sustaining and enhancing US ability to innovate is a key national priority.

• Have the President issue a major challenge encompassing federal research and all aspects of the innovation process to mobilize resources in pursuit of a critical national goal. The candidate fields for such a challenge include energy, space, and health care.

Support for Regional Innovation

• Establish a program of national innovation centers, or "hot spots”, w ith matching funds from states and educational institutions.

• Designate a lead agency to coordinate regional economic-development programs to ensure that there is a common focus on innovation-based growth.

Innosation and the Economy

Wm. .A. Wulf points out that ‘there is no simple formula for innovation. Tliere is, instead, a-multi-component ‘environment’ that collectively encourages, or discourages, innovation.”* Tliis environment includes research funding, an educated workforce, a

* Wm. A. Wulf. 2005, "Review and Renewal of the Environment for Innovation”, unpublished paper.

culture that encourages risk-taking, a I'lnancial system that provides patient capital for entrepreneurial activity, intellectual-property protection, and other elements.

The significance of this innovation environment has long been a subject of stud\'. .As far back as .Adam Smith, economists have been interested in technologie innovation and its impact on economic growth.’ Early in the 20th century, Joseph Schumpeter argued that innovation w as the most important feature of the capitalist economy. Starting in the 1 950s, Robert Solow and others developed methods of accounting for the sources of growth, leading to the obsen ation that technologic change is responsible for over half the observed growth in labor productivity and national income. Tliese methods are subject to continued debate and refinement. For e.vample, over long periods the contributions of technologic change and other causes of growth such as worker skills, capital deepening, and institutional change — are highly interactive and difiicult to separate.

Otlier economists have focused on a more qualitative study of the institutions and practices underlying innovation in individual industries and entire economies. The elTort to understand “national innovations systems” has been one focus of recent studies.’

Others have e.vamined the performance of particular industries.’ The Sloan Foundation has given understanding innovation a high priority in its funding.'

Tliis literature underscores the importance of the environment for innovation and points to several lessons from recent history. Japan's growth trajectory' in various S&E inputs and outputs (such as R&D investments, S&E personnel, and patents) since the early 1990s has been similar to what it was before,’ Yet the .lapanese economy's ability to reap the rewards of innovation in the form of higher productivity and incomes was much higher in the earlier period. This can be explained partly by the dual nature of the Japanese economy, where world-class manufacturing industries sert ing a global market exist side by side with ineffieient industries, such as construction.* Economic mismanagement and a lack of llexibility in factor markets (labor and capital) also have played an important role.

In contrast, in the mid-1990s the United States saw a jump in productivity grovMh from the levels that had prevailed since the first oil shock of the early 1970s.’ In addition to gains in information technology (IT) manufacturing productivity, productivity gains from IT u.se and the creation of new business methods that take ads antage of IT were w idespread througliout the economy (see Figure EI-1).

’ Joel MokjT, “Innovation in an Historical Perspective: Talcs of Technology and Evolution", in Berm S tcil, David G. Victor, and Richard R Nelson (cds). Technological Innovation and Economic Performance, Princeton, NJ: Princeton University Press, 2002

’ Richard R. Nelson, ed . national Innovation Systems: .4 Comparative .4nalysis. New York; Oxford University Press, 1993

’ National Research Council, US Industry in 2000: Studies in Competitive Performance, Washington, DC; National Academics Press. 1999,

* Sec the Alfred P Sloan Foundation web site at wivw, sIoan.org,

’ Adam S. Posea “Japan" in Steil, Victor, and Nelsoa 2002

* Dale W Jorgenson and Masahiro Kuroda, “Technology, Productivity, and the Competitiveness of US and Japanese Industries", in Thomas /Vrrisoa C. Fred Bergslca Edward M. Graham, and Martha Caldwell Harris (eds.), Japan 's Growing Technological Capability: Implications for the US Economy, Washingtoa DC; National Academy Press, 1992.

’ William Nordhaus, The Sources of die Productivity Rebomd and the Klanufacturing Employment Puzzle, NBER Working Paper 1 1 354. 2005.

It is important to note that science and teclinology and the innovation process are not zero-sum games in the international context.'* The L'nited States has proved adept in the pa.st at taking advantage of breakthroughs and inventions from abroad, such as the jet engine and monoclonal antibodies."

Groups and individuals have made numerous recommendations for change in tlie US environment for innovation.

Market, Rcgulatuiy , and Legal F.nsinmment

.\l.any anaivses of iraiovation focus on the supply side of the equation, such as the size and composition of R&D spending, the number of S&E graduates, .and so forth. Ihe importance of the demand side is sometimes neglected. Ilie imperative of meeting the needs of deniiutding bu\ ers and consiuners plays a key role in driving the creation and dilTusion of innovations. .Un open dynamic market is the source of LIS competitive strength in a range of industries. Even under the “Dell model" — in which development, manufacturing, and other functions are sourced and performed around the globe — contact with customers and knowledge of their needs is a critical capability that Dell keeps inhouse."

In contrast, industries and economies where markets are closed, competition is limited, or consumer rights are not protected tend to act as a drag on iimovation and growth. McKinsey and Company’s intcmation.al studies on sector productivity during the 1990s showed th.at competitive markets were the key factor separating successes and failures."

A w ide variety of policies and practices inlluence the market, regulatory, and legal environment for innovation. These include financial regulations, where the Sarbanes-Oxley .Act has produced a number of changes in recent years. In addition, the costs of I'S approaches to litigation alTecting product liability and securities fraud are a perennial target of industry groups.

Given the fact that the I ’nited States has lagged behind a number of other countries in broadband aceess (see Figure EI-2) and the potential positive impact of better and cheaper netw ork access for the economy and the research enterprise in particular, the complex regulations governing telecommunications, the broadcast spcctnrm. and related areas would seem a promising target of reform.

Possible federal actions include the following:

• "The impact of new regulations on market investments in innovation should be

more carefully and collaboratively assessed by a public-private Financial Markets

'* Wm. A Wulf, “Observauons on Science and Technology Trends: Their Potential Impact on C)ur Future”,

in y\nne G.K Solomon (ed). Technology Futures and Global ITeallh, Power and Conjhct, Washmgton,
DC; Center for Strategic and International Studies, 2005.

" National Academy of Sciences, National Academy of Engineenng, Institute of Medicine, Capitalizing on
Investments in Science and Technology, Washington. DC; National Academy Press, 1999.

" Thomas L. Friedman, The iVorld is Flat: A Bnef History of the 2 1st Century, New York: Farrar, Straus
and Giroux, 2005, p dia-dlO

" William W. Lewis, The Power of Productivity: Health, Poverty, and die Threat to Global Stability,
Chicago: The University of Chicago Press, 2004

Inlemicdiars' Committee, where periodic meetings can score existing and proposed legislation. This committee would follow the model of the Foreign Exchange Committee and Trea.sur>' Borrowing Committee.”''*

• "The countrx’ should set a goal to reduce the costs of tort litigation from the current level of two percent of GDP some S200 billion down to one percent.””

• Reform Section 404 of the Sarbancs-Oxlcy Act. which requires an internal control report in the company's amuial report. “Many small and medium-sized companies have serious concern « ith Section 404 and the expense of the internal control reporting requirements. Small and medium-sized companies are disproportionately burdened by Section 404. and these provisions need to be examined to ensure a proper balance between accountability and bureaucracy.”

• Drop elTorts to expense stock options. “No industry has benefited more than the high-tech industry from the use of stock options. Stock options provide employees w ith a direct link to the growth and profitability of companies. They also are an essential tool for attracting and retaining the best workforce, especially for small businesses and start-ups who do not always have the capital to compete on salary-alone. .Already China and India have learned from tlie successful use of stock optioas in Silicon Valley and are using it to attract and retain businesses and employees.”

• “The Federal govemment. througli the Internal Revenue Service or Treasury-

Department. should establish clear guidelines in the Internal Revenue Code on the acceptability of investment of foundation assets in start-up ventures.””

• “The Federal government should encourage best practices and processes for standards bodies to align incentives for collaborative standard setting, and to encourage broad participation.””

• 'Bie Congress should “use the D'lA' transition to encourage both licensed and unlicensed wireless broadband networks as competitive alteniativcs to wireline cable and DSL olTerings.”'*

• “Provide indu.slry- the incentives to promote broadband and eellular penetration. Countries like South Korea and Italy- have realized enormous competitive advantages by- investing heavily- in broadband and cellular deploy ment. Just as the interstate higliw-ay system dramatically- increased the efficiency- and prixluctivity of the US economy half a century- ago. so too can en'tcient communications networks have the same positive elTect today. Broadband and cellular dilTusion also foster competitive advantages by creating demand for eutting edge products and services.”''’

Trade-

'^Council on Competitiveness 2004, p 65
” Council on Competitiveness 2004, p 65
"* Council on Competitiveness 2004, p 62
” Council on Competitiveness 2004, p 70

'* Michael Calabrese, testimony to the Committee on Commerce. Science and Transportation, United States Senate. Hearing on Broadcast to Broadband, July 12, 2005.

American Electronics Association, 2005, p 26

Multilateral trade liberalization has been a goal of US policvinakers of both politieal parties since the end of World War II. Ilic renewal of large US trade deficits in recent years has spurred debate over how to correct it and other global imbalances, 'ITie very large US deficit with China has produced calls for exchange-rate adjastment and other measures. In many important respects. China's industrial-development strategy has followed tlie export-led "playbook” developed by Japan, Korea and other high-growth .Vsian economies during the 1960s. 1970s. and I980s.“

Improving the protection of intellectual property worldw ide. and especially in such large countries as China where piracy rates are higli. has been a policy focus of indastrs groups (see Figure FI-3). It is important to note that China's laws and policies have come into line w ith international standards as a result of its accession to the W'orld Trade Organization, so tile main issue is enforcement.

Possible federal actions include the following:

• "Promote stronger enforcement of intellectual property protection worldw ide. Intellectual property is typically the core asset of any high-tech company. From patents and copyrights to software and trade secrets, intellectual property forms the basis of the knowledge economy. Far too often, foreign legal systems do not adequately protect tlie owner of these valuable creations, resulting in the loss of literally billions of dollars. Hie Biusiness Softw are .-Mliance estimated that 36 percent of software w orldw ide was illegalls' pirated in 2003. litis translates to a $29 billion loss in revenue. In China, this figure is 92 percent and the revenue loss is estimated at $3.8 billion. Digital technology has made intellectual property theft that much easier on a w ide scale. When foreign companies and consumers can steal this hard-eanied property, the profitability and. ultimately, the competitiveness of US companies sull'er.'”'

• Make conclusions of the Doha Round a top priority. “The United States economy has gained greatly from liberalization of tr.ide worldwide and from the rules based system facilitated by the World Trade Organization (WTO), flie IX)ha round of trade talks broke dow n in the summer of 2003 as negotiations on agriculture and certain sers ice sectors reached an impasse. .As a result, the United States risks losing momentum in further opening global markets to US products and services."

Intellectual Property

With the rise of knowledge-based industries and a number of legislative, judicial, and administrative actions, intellectual-propcrts protection in the United States has been significantlv’ strengthened over the last 25 years.“ With the increase in the \ alue of a US patent have come an increase in patenting and greater focus by companies and other inventors on the management of intellectual-property as an a.sset. In this environment.

“ Robert Samuelson. "China's Devalued Concession" The ITashingion Post July 26. 2005, p. AI9
American Electronics Association, 2005, p 25

“ Wesley M Cohen and Stephen A Merrill (eds), Patents m the Know ledge-Based Economy, Washington, DC: National Academies Press, 2003.

debate eontinues on how to tweak US intellectual property policies so that they maximize incentives for the generation and broad dilTasion of innovations.

Possible federal actions include the following:

• “Reduce redundancies and inconsistencies among national patent systems. 'ITie United States. Europe, and Japan should further harmonize patent examination procedures tutd standards to reduce redundancy in search and examination and eventually achieve mutual recognition of results. DitTcrenccs that need reconciling include application priority (first-to-invent versus first-inventor-to-fiile). the grace period for filing an application after publication, tlie best mode reqiiirentent of US law , and the US exception to the rule of publication of patent applications .after 1 8 months. This objective should continue to be pursued on a trilateral or even bilateral basis if multilateral negotiations are not progressing.”®

• "Strengthen USPTO capabilities. To improve its performance the USPTO needs additional resources to hire and train additional examiners and fully implement a robust electronic processing capability. Further, the I'SPTO should create a strong multidisciplinarx anaivtical capability to a.ssess management practices and proposed changes, provide an early w anting of new technologies being proposed for patenting, and conduct reliable. consi.stent. reputable qualits' reviews that address olfice-w ide and individual examiner performance. 'Ilie current USPTO budget is not adequate to aceomplish these objectives.”"

• “Institute an t)pen Review procedure. Congress should seriously consider legislation creating a procedure for third parties to challenge patents after their issuance in a proceeding before administrative patent judges of the USPTO. The grounds for a challenge could be any of the statutory standards novelty, utility, non-obviousness, disclosure, or enablement or even the case law proscription in patenting abstract ideas and natural phenomena. Tlie time, cost, and other characteristics of this proceeding should m.ike it ;ui attractive alternative to litigation to resolve patent validity questions both for private disputants and for federal district courts. Ilie courts could more productively focus their attention on patent infringement issues if they were able to refer validity questions to an Open Review proceeding.”®

• “Leverage the patent database as an innovation tool. Develop pilot projects (jointly funded by industry, universities and government) to highlight techniques for leveraging patent data for discovery.""

Tax Policj

® National Research Council. A Patient System for the 2Ist Century. Washington. DC; National Academie
s
Press, 2004, p 8

" Ibid . p 7 Similar recommendations appear m CouiKil on Competitiveness, 2004, and American Hlectronics Association, 200S. The latter two reports recommend stopping diversion of patent-application fees to general revenue.

® National Research Council. 2004, p. 6. A similar recommendation appears m Council on Competiuveness, 2004.

" Council on Competitiveness, 2004, p 70

Tax policy is another element of the environment for innovation. The research and experimentation tax credit (popularly known as the R&D tax credit) is a longstanding feature of the tax code, although it is generally renewed year to year. The tax treatment of investments in startup companies and purchases of high-technology manufacturing equipment have also been the focus of recent recommendations.

Possible federal actions include the following:

• ‘■'nic federal gox eniment should provide a 25 percent tax credit for early stage investments when made through quiiliTied angel funds. Ihe individiuls participating in these funds would need to make a minimum investment of S50.000 each year in order to receive the tax credit. .Acceptable investments would be restricted to those that meet requirements for revenue size and age of firm."'’’

• “Enact a permanent, restructured R&E tax credit and extend the credit to research conducted in university-indastrv’ consortia."”

• .Allow more favorable tax treatment of purchases of high-technology manufacturing equipment. “.-Accelerated depreciation or expeasing of high technology equipment would have a particularly positive investment impact.

Many of our economic competitors who actively seek to lure investment in semiconductor manufacturing overseas offer far more favoriible tax treatment th.an that offered in the United States. .As part of the discussion of fundamental reforms of the tax code to promote investment and manufacturing in the US, the Congress should consider allow ing companies to expense higli technology equipment."”

• “Else the required repeal of the Foreign Sales Corporation exemption to fund a revenue-neutral lax credit for investment in information-processing equipment, software, and industrial equipment. In response to WTO rulings. Congress passed a reduction of the corporate lax rate, which really does little to encourage companies to be more competitive iind innovative. .An investment tax credit would help companies increase inve.sinieni which would in turn boost productivity. Moreover, it would make EIS companies more likely to invest in equipment in tlie I nites States and not overseas."”

liiinian Capital

.A highly skilled, flexible labor force is an essential component of this nation’s ability to reap the benefits of imiovation. Recent debates over workforce issues have revolved around several issues.

” Ibid. p 62.

” Ibid , p 59 There are sanilar recommendations in numerous other reports, including National Academy of Engineering, Mastering a Wen- Role: Prospenng in a Global Economy, Washington, DC NaUonal Academies Press, 1993. and American Electronics Association, 2005.

” Semiconductor Industry Association web site, www.sia-onltne.org backgrounders_ta\.cfm.

* Robert Atkinsoa Meeting the Offshoring Challenge. W'ashingtop DC, Progressive Policy Institute. 2004

Tlie first trend is that growing numbers of service industries and their labor forces are becoming subject to global competition, a condition with which manufacturing industries have long familiarity. OITshore outsourcing of business process and IT jobs, or “offshoring”, is growing rapidly (see Figure EI-4). Aspects of research and education arc included. Tliere are strong disagreements about what outsourcing means, the ultimate impacts, and policy prescriptions.^' In any case, the trend reinforces the imperative for the promotion of lifelong learning in the Ignited States. As illustrated by Figure EI-5, working adults and other nontraditional students are of grow ing importance in fields like computer science. Calls to rethink approaches to incentives for continuing education and trade-displacement assistance programs have come from several quarters.

A second element focuses on the immigration of scientists, engineers, and other skilled professionals who contribute to the inno\ ation process. Several recent reports have suggested ways to encourage skilled foreigners to continue immigrating. US openness to people and ideas from around the w orld is a longstanding strength of the .American environment for innovation.” In particular, immigrant scientist-engineer-entrepreneurs Irom Ale.xander Ciraham Bell and .Andrew Carnegie to .Andrew Grove have played key roles in the creation of leading US companies and entire indastries.

A third human-capital issue is the reform of health insurance, pensions, and other public and private benefits infra-stnictures. The goals here are to make these systems sustainable from a long-term cost perspective and to help them support a workforce that is increasingly mobile and less likely to be employed by large organizations for extended periods.

A fourth issue is the promotion of education about entrepreneurship at various educational levels, including S&E education. .Among the recommendations that have been suggested are these:

• "Create the human capital investment tax credit to promote continuous education. Companies often lack incentives to invest in educating and retraining workers as they risk losing that return on investment if the woricer subsequently leaves the firm. By providing human-capital investment tax credits, the US government can encourage companies to retrain w orkers by reducing or eliminating out-of-pocket costs. .At the forefront of technology innovation, companies are often the best predictor of what skills will be most valuable in the future. Continuous retraining, education, and skills acquisition ensure that fewer teclmologv' workers will find themselves suddenly displaced w ith no skills to participate in the constantly shirting high-tech industr> . Furthermore, society w ould benefit from the continuous education of workers, which also increases productivit>' and decreases downtime betw een jobs.""

• Create lifelong learning accounts for employees that allow ta.\-exemj)t contributions by workers and tax credits for employer contributions. ^

For a point-counterpoint see Ron Hira and Anil Hira, Outsourcing America: M hat 's Behind Our National Crisis and How IVe Can Reclaim American J(A>s. Washington, DC; AMACOM Books, 2005, and Diana Farrell, Martha Laboissiere. Robert Pascal, Jaeson Rosenfeld, Charles de S^undo. Sascha Sturze. and Fusayo Umezawa. The Emerging Global Labor Market. New York: McKmsey Global Institute, 2005.

National Academy of Sciences. National Academy of Engineenng, Institute of Medicine, 1 999.

" Amencan Electronics Association. 2005. p, 26.

^ Council on Competitiveness, 2004, p. 54.

• "Reform and rename the Trade Adjustment Assistance Program to cover workers displaced for reasons other than trade, including service sector workers."^*

• "Oiler more flexibility and focus under federal-state employment and training programs. States and the federal government should have more discretion to devote employ ment and training resources tow ard high-performance programs, high-growlh skills and skills in demand by local firms.""

• "E.xpand temporary wage supplements that help move workers more quickly oft' unemployment insurance and into new jobs and on-the-job training, nte .Alternative Trade .Adjastment for (^Ider Workers Program should be expanded to include younger workers and should not be linked exclusively to trade dislocation."''

• "Re-institute Hl-U training grants to ensure that .Americans are trained in the skills and fields for which companies now bring in foreign nationals.""

• "Establish an expedited inunigration process, including automatic work pennits and residency status for foreign students who: a) hold graduate degrees in S&E from .American universities, b) have been oft'ered jobs by US-based employers and w ho have passed security screening tests.""

• "Give green cards to all US trained master and doctoral students. .Accredited L'S colleges and universities award 8,000 doctoral and 56,000 master's degrees in S&E to foreign nationals per year. Instead of sending these people back to their countries, they should be given a Green Card to stay in the United States, 'nicsc people will make significant contributions to the economy and workforce, file United States benefits by keeping them here.""

• "Hl-B visas should be made 'portable' so that a foreign temporary nonimmigrant worker can more easily change jobs in the United States.""

• Tlie National Science Foundation should take a significant role in funding pilot efl'orts to create innovation-oriented learning ens ironments in K-12 and higlier education. It also should sponsor research into the processes involved in teaching creativity, inventiveness, luid commercialization in technical en\ ironments,'"

• 'I1ie federal government should create legal certainty for cash-balance pension plans to ensure that employers can continue to ofl'er tliem. These plans are popular w ith many employees and have significant advantages over many defined-contribution plans."

" Ibid., p 56.

" Ibid
''Ibid
'* Ibid
" Ibid , p 51

" .American Electronics Association, 2005, p. 25. A similar recommendation appears in Council on

Competitiveness. 2004

■“ National Research Council. Building a IVoriforce for the Information Economy, W'ashington, 1X2: National Academics Press, 2001.

Council on Competitiveness. 2004, p 53
" Ibid . p 55

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• Have the states and tlie federal goventment eneourage the widespread availability of Health Savings Aceounts. including affordable options for low-ineome workers, as a health-insurance option that prox ides portability for employees."

• “States and the federal goventment should define a role for government re-insurance of higher-cost healthcare c.vpenses. so as to reduce the cost of employer-provided coverage and reduce the cost of healtlieare to employees,'’*’

• "Goventment procurement niles should favor work done in the I'nited States and should restrict the oll'shoring of w ork in any instance where there is not a clear long-term economic lienefit to the nation or where the work supports technologies that are critical to our national economic or military security.”**

• Kei|uire transparent disclosure of offshoring, " nic publicly ow ned firms that engage in olTshoring ouglrt to at least he transparent in their business dealings, offering layolT notices and providing clear accounting of the employment in their various units, both domestic and abroad.”*’

Supporting C lusters and Regions

Tlie tendency of innovative capabilities (such as research, manufacturing, educational institutions, and the w orkforee) to conglomerate in specific regions has heen a subject of economic inquirv for some time.** Tlie Council on Competitiveness sponsored a multiyear initiative to study the phenomenon in the US context.** One recent anah’sis postulates that regions need to draw a “creative class” human-resource base to compete etTeetively in know ledge-intensix e industries.’* . Vlthougli mam' of the poliev' levers to promote regional innovation are in the hands of state and local govemmenLs. the federal government could play a larger role through such actions as the following:

• "'nie federal government should create at least ten Innovation Hot Spots over the next five years. State and local economic development entities and educational in.stitutions should raise matching funds and develop proposals to operate these pilot national innovation centers.””

• “Innovation Partnerships need to be created to bridge the traditional gap that has existed between tite long-term discovery process and commercialization. These

"Ibid
*’ Ibid

** IEEE- 2004, Position Statement on Off^ore Outsourcing. Washington. 1X2. Available at

WWW leeeusa org policy/positionsJoffshoring asp A similar recommendation appears on the Economic

Policy Institute web site

*’ Economic Policy lasUtute. EPI Issue Guide: Offshoring, Wa.shington. IX: 2004

** Michael J Piore and Giarles F Sahel. TTie Second Industrial Dmde: Possibilities for Prosperity, New

York Ba.sic Books, 1984

** Council on Competitiveness. Clusters of Innovation: Regional Foundations of US Competitiveness. Washington. EX: Council on Competitiveness. 2001

’’’Richard Flonda. The Rise of the Creative Class ..and how it's tranfforming work, leisure, community'. & everyday life. New York: Basic Books. 2002.

” Council on Competitiveness. 2004, p 62,

new partnerships would involve academia, business and govemnient, and they would be tailored to capture regional interests iuid economic clu-sters.””

• "Tlie federal government should establish a lead agency for economic

development programs to coordinate regional elTorts and ensure tliat a common focus on innovation-based grovMh is being implemented.”’’

New “.Vpollo”, “Sputnik”, or “Manhattan Project"

.As part of the 2004-2005 debate over the sustainability of US S&E leadership, some individuals and groups have called for a presidential-level challenge to mobilize resources and national imagination in an effort that also would grow the S&E enterprise. Somewhat related is the call for the President to identify innovation as having a major national priority. Specific recommendations include the following:

• L.aunch an e.xplicit national innovation strategy and agenda led by the President, "innovation is the critical pathway to building prosperity and competitive advantage for advanced economies. Yet no single institution in government or the private sector has the horizontal responsibility for strengthening the innovation ecosystem at the national level — it is and always will be a shared responsibility. The United States should establish an e.xplicit national innovation strategy mid agenda, including an aggressive public policy strategy tliat energizes the environment for national innovation."”

• “Establish a focal point w ithin tlie E.xecutive Office of the President to frame, assess and coordinate strategically the future direction of the nation's innovation policies. Tliis could be either a Cabinet-level interagency group, or a new, distinct mission assigned to tlie National Economic Council."”

• “Establish an explicit innovation agenda. Direct the President's economic advisors to analyze the impact of current economic policies on US innovation capabilities and identify opportunities for immediate improvement."*’

• “Direct the Cabinet officers to undertake a policy, program mid budget review and propose initiatives designed to foster innovation within and across departments. This is an opportunity to break dow n ‘stovepipes' and foster closer collaboration among the agencies to meet clear national needs."”

• "The United States should build an integrated healthcare capabilitv bv the end of the decade.'”*

• .Apply information technology, research, and systems-engineering tools to US health-care delivery.”

’’Ibid .p. 53
” Ibid. p. 63.

” Ibid., p- 66-
” Ibid
’* Ibid
’’Ibid

’'Ibid.p. 74

” National Academy of Engmeenng'InsUtule of Mcdicmc. Building a Better Delivery System: A New Engineering Heallhcare Partnerdtip, Washington. DC: National Academics Press. 3005.

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• launch a LiS-China crash program to develop alternative energies*

“ Friedman. 2005, p 413

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Knsuring Thai thr I'nitrd States Has
the Best Kns ironnient for Innovathai
Appendix
Figures and Tables

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Figure EI-1: Contribution of Different Industries to the Productivity Rebound, 1998-2003, by Broad Industry' Group.

AverAge

shAre

Co)\tiibutio)\ to Aggregate productivity' groH-th

1998-2002

1999

2000

2001

2002

2003

100.00

2Si7

2.05

1.71

2.90

3.72

2.49

87 .S 0

1.96

2.08

2.00

2.97

3.43

2.49

FuMnc«. inniTAnce. r«Al est<ile. etc.

19.74

0.60

1.36

0.92

0.33

0.38

0.72

Coaiputef And eteclionic piodttcts

1.66

0.47

0.64

0.09

0.37

0.58

0.43

Retul tiAde

6.91

0.12

0.31

0.45

0,37

0.43

0.33

IntonnAbon

4.62

0.22

0.14

0.21

0.34

0.56

0.30

PioieMionAl aikI bustneM services

11 .S 3

0.13

- 0.18

0.41

0.42

0.47

0-25

DuiAble goods other thAir computers

6.78

0.01

0.30

0.01

0.49

0.26

0.21

WholesAle txAde

6.08

0.31

• 0.19

0.52

0.27

^.07

0.17

N'ondtuAble goods

5.75

0.12

0.04

0.00

0.51

0.39

0.21

TiAnsportAtion Atul wAiehousing

3.01

0.06

0.15

0.02

0.16

0.19

0.11

Utilities

1.97

0.07

0.17

- 0.06

0.18

0.17

0.10

Arts, enterlAinmenl, recreAtion. etc.

334

0.03

0.00

• 0.03

0.02

o.<»

0.01

Agriculture, forestry, otc.

1.03

0.00

0.10

• 0.12

006

0.09

0.03

Govemorent

12.44

0.06

0.04

• 0.07

• 0.04

0.14

0.03

Nlixung

1.04

0.12

- 0.04

• 0.09

0.08

- 0.07

0.00

EducAtionAl services, IvaIiIi CAre, etc.

7.09

- 0.01

001

- 0.05

0.01

003

0.00

Other services, except government

2.40

- 0.07

- 0.05

- 0.07

- 0.08

004

- 0.05

Cofutniction

4.42

-0 18

- 0.13

0.03

- 0.03

000

- 0.06

Source: William Nordhaus. 2005. The Source of the Productivity Rebound and ifte Manufacturing Employment Puzzle. NBER Working Paper 11354. Table 4. p. 24. Available al: hUp;//www.nber.org/pq>crs/ w 1 1 354 .

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Figure EI<2: The United Stales Has Tagged Other Countries in Broadband Adoption.

Rank	Country	
1	South Korea	24.9
2	Hong Kong	20.9
3	The Netherlarxis	19.4
4	Denmark	19.3
5	Canada	17.6
16	United States	11.4

Source; Michael Calabrese. "Broadcast to Broadband; Completing the Digital Television Transition Can Jumpstart Affordable Wireless Broadband" House Testimony. July 12, 2005.

Figure EI-3: China Has a High Piracy Rate, hut Because of Market Size Software Piracy Losses Are Actually Higher In the United States.

Ranking by S004 Software Piracy Loesee .i

PInMv of SIOO MWlon or Mer*

SM

United States

S6.64S

China

3.S65

France

2.928

Germany

2.286

United Kingdom

1.963

Japan

1.787

Italy

I.SOO

Russia

1.362

Canada

889

Brazil

659

Spain

634

Netherlands

628

India

SI9

Korea

S06

Australia

409

Mexico

407

Poland

379

Belgium

309

Switzerland

309

■M

Sweden

S 304

Denmark

226

South Africa

196

Norway

184

Indonesia

183

Thailand

183

Turkey

182

Finland

177

Taiwan

161

Malaysia

134

Czech Republic

132

Austria

128

Hungary

126

Saudi Arabia

I2S

Hong Kong

116

Argentina

108

Ukraine

107

Greece

106

Source; Business Software Alliance and IDC. 2005. Second Armual BSA and IDC Global Software Piracy Study. Washif^ton, DC. Available at; http://www.b6aorg.''globalstudy/upload/2005-GIobal-Stu(ty-EngUsh.pdf

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Figure EI-4: Even in the Rapidly Growing Category Of Global Service Exports, Offshoring of Business Process and IT Work from Rich to Poor Countries Will Constitute a Larger Share, Grow ing at a 30% Compound Annual Rate Between Now and 2008.

BPO/IT offshoring to low-wage locations as a percent of total global service exports

SBillion

Project

CAGR

%

CD

* Estimated at 6% arviual growth from 2002 hgure
Source WTO, McKinsey Global ir>$Utute analysts

Source: McKinsey & Company. “The Emerging Global Labor Maricel". June 2005. Executive Summary, p 19.

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Figure EI-5: Nontnulitioiiiil Students and lligher-Kducation Providers Are Increasingly Important in Such Fields as Computer Science.

TABLE 1.2 Top Producers of Computer Science Bachelor’s Degrees, 2001

Academic Institution		Number of 2001 Bachelor’s Degrees Awarded
1.	Strayer University	840
2.	DeVry Institute of Technology (Addison, IL)	477

3 -

CUNY Bernard Baruch College

465

4 -

University of Maryland Baltimore County

463

5 -

DeVry Institute of Technology (Phoenix, AZ)

440

6.

DeVry Institute of Technology (Cty of Industry, CA) 349

7 -

Rutgers the State University of New jersey

336

8.

DeVry Institute of Technology (Kansas City, MO)

316

9 -

DeVry Institute of Technology (Long Beach, CA)

301

10. James Madison University

393

Source: CPST; data were derived from the National Science
Foundation, WebCASPAR Database, and NCES.

Source American Association for the Advancement of Science Preparing Women and Minorities for the IT Worfforce: The Role of Nontraditional Educational Pathways. Washington. DC, 2005. Available at http //WWW aaas org/publication8/books_reports/lTW/PDFs/Complete_book.pdf

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Iliis summarizes findings and recommendations from a variety of recently published reports and papers as input to the deliberations of the Committee on Prospering in the Global Economy of the 2 1st Century . Statements in this paper should not be seen as the conclusions of the National Academies or the committee.

Issue Brief:

Scientific Communication and Security

Summun

Among the fundamental tenets of science is openness minimizing restrictions on communication among scientists is considered essential to progress. Ilie Ignited States has achieved and maintained its pre eminence in science and technology’ (S&T) in part by embracing the values of scientific openness. .And this openness has no natural, and certainly no national, boundaries in an increasingly international scientific enterprise.

Openness may pose risks, however. .Adversaries may take advantage of ready access to information to acquire knowledge with which to do harm. Economic competitors may use open communication to pursue their ow n interests at the expense of the I 'nited States.

Ilie I'nited States has souglit to limit these potential negative consequences by setting some limits on scientific communication. A system to protect intellectual property seeks to ensure that the applications of discoveries initially benefit those who make the breakthroughs. In the realm of national and homeland security, the I'S goi emment carries out some research and development in secret and restricts access to certain types of information to keep it away from those who may have hostile intent.

llie scientific and technical community recognizes that it has a responsibility to help protect the I ’nited States, as it has in the past, by harnessing the best S&T to help counter

terrorism ;uid other national-security threats, even though tliis may mean accepting some limitations on its work. However, there is concern that some of llie policies on scientific communication enacted in tlie w ake of the September 1 1 terrorist attacks and the anthrax mailings and others under consideration will undermine the strength of science in the United States w ithout genuinely advancing security. Various organizatioas. including the National .Academies, have olTcred recommendations to address these concerns:

• Continue to support the principle set forth in National Security Decision Directive 189 that federally funded fundamental researclu such as that conducted in universities and laboratories, should “to the maximum extent possible*’ be unrestricted.

• Create a clearly defined regulatory "safe harbor" for fundamental research so that universities in particular can have confidence that activities w ithin the safe harbor are in compliance, thus pennilting a focus on w hate\‘er occurred outside the safe harbor.

• Regularly review and update the lists of information and technologies subject to controls maintained by federal agencies w ith the goal of restricting the focus of the controls ;uid removing controls on readily available technologies. Carry out the priK'ess across as well as within agencies, and include input from the S&T community.

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• With regard to the specific issue of “deemed exports", do not change the current system of license requirements for ase of export-controlled equipment in university basic research until the follouing steps have been implemented:

o Oreatly narrow the scope of controlled teclmologies requiring deemed-e\-port licenses, and ensure that Uie list remains narrow going forward.

o IX'lctc all controlled technology from the list whose manuals are available in the public domain, in libraries, on the Internet, or from the manufacturers.

o Delete all equipment from the list that is available for purchase on Uie open market overseas from foreign or l*S companies.

o Clear international students and postdoctoral fellows for access to controlled equipment when their visas are issued or shortly therealler so that their admission to a university academic program is coupled with their access to use of export-controlled equipment.

• I 'ndertake a systematic review to determine the number and provisions of all existing types of “sensitive but unclassified”’ information in Uie federal government, t'sing Uiat baseline, require a further review and justification for the maintenance of any category .

Tie remaining categories to an explicit statirton, or regulatory framework that includes procedures to request access to information and appeal decisions.

• In implementing federal security policies for S&'I” personnel:

o Engage S&T personnel in the development and implementation plans for security measures.

o Continue to accept non-L'S citizens as visitors and in some cases stafi'. expedite security reviews for visitors, and more generally work to avoid prejudice against foreigners.

o Focus and limit security elTorts to address the most importiuit security situations.

• Create new or exp;uid exi.sting mechanisms to engage the S&T community in advisory capacities and to improve communication channels.

o Encourage communication among the diverse communities involved in security issues -policy. S&T. national and homeland security, law enforcement, and intelligence -so that policies regarding scientific communication are both elTective and broadly accepted.

o Build bridges among these communities, particularly in areas of S&T, such as the life sciences, where there is little history of working with the government on security issues.

Secret Research and Classification of Infonnation

Tlie US government handles issues of secrecy througli a complex mix of statutes, regulations, and procedures that govern the control of classified information, public access to go\ emment inlomiation. and the maintenance of government records. With two exceptions, the government has no authority to designate information produced outside this legal framework as classified. ‘ In the wake of September 1 1, President Bush exiended classification authority to

' The first exception is through the Atomic Energy Act. information related to nuclear weapons may be “bom classified" without any prior involvement of the government in its generation The second exception, under the

several departments and ageneies that had not previously been involved in such matters, such as the Department of Agriculture, the Environmental Protection Agency, and the Department of Health and Human Ser\ ices.

Controversies over whether are«is of scientific research should be restricted in the name of national security recurred throughout the Cold W;ir. During the early 1980s. the Reagan administration sought to restrict scientific communication in a number of fields. Tlial controversy eventually led to a presidential directive in 1985, influenced in part by a report from the National Academy of Sciences.^ National Security Decision Directive 189 (NSDD-189) states that federally funded fundamental research, such as tliat conducted in universities and laboratories, should ‘"to the maximum e.xtent possible*’ be unrestricted.^ Where restriction is deemed necessarv", the control mechanism is formal classification. "No restrictions may be placed upon the conduct or reporting of federally-funded fundamental research that has not received national security classification, except as provided in applicable US statutes." Hie policy set out in NSDD-189 is still in force and has been realTimied by several senior George W. Bush administration officials.'*

Over the years, reports and statements from the National Academies and other organizations have strongly supported the principle set forth in NSDD- 1 89 as essential to maintaining the vitality of fundamental research in the United States.^ Some have suggested that President Bush should reissue the directive as a signal of its continuing importance and his administration’s commitment to scientific openness. Others are concerned that, given current conlro% ersies and security concerns, the interagenc\ process necessarx for such an action could result in a weaker presidential statement. At a minimum, tlie federal government could:

• Continue to support the principle set forth in National Security Decision Directive 189 that federally funded fundamental research, such as that conducted in universities and laboratories, should “to the maximum exient possible” be unrestricted.

“Sensitive” Research and Controls on liifomiation

Serious concerns can arise over whether information is properly cla.ssified, whether too much infonnation is classified, and how such decisions are made, but these debates over the classification of scientific research take place within a system of reasonably well-specified and

Invention Sccrcc 7 Act of 1951. permits infonnation received as part of the patent-application process to be classified

^ National Research Council. Saentific Communication and S'ational Security, Washington. DC: National Academy Press, 1982.

’ “Fundamenlar research is defined as "basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from propnelary research and from industrial development, design, production and product utilization, the results of which ordinarily are restricted fw proprietar>' or national security reasons" (National Security’ Decision Directive 1

89. September 21,
1985),

* Letter to Dr. Harold Brown from Ccmdoleczza Rise. Assistant to the President for National Security Affairs.
November 1 . 2001 . John Marbuiger. Director of the Office of S&T Policy. Executive Office of the President,
reaffirmed NSDD 1 89 in a speech to a workshop on "Scientific Openness and National Sccunty” at The National
Academies on Januarj’ 9, 2003.

* Receiu examples include National Research Council, Assessment of Department of Defense Basic Research,
Washington. 1X2 National Academics Press. 2005. p.6; Center for Strategic and International Studies. Security
Controls on Scientific Information and die Conduct of Scientific Research.^O^IoshiTi^xoru DC: CSIS, June 2005

understood rules. Far more problematic is the interest in designating certain areas of research and certain tvpes of knowledge- wherever they are prtxiuced and however they are funded as “sensitive but unclassified" (SBU).

Tlie problem of “sensitive information" is not new. Classification is only one of the ways in which the US government controls public access to information. .Across the federal government, there are dozens of categories that apply narrowly or broadly to specific types of infonnation (see Figure SCS*1).* Some of the categories are defined in statute, some through regulation, and some only through administrative practices. In addition, diflerent agencies may assign a varieU’ of civil and even criminal penalties for violation of their restrictions.^

Here, the fund;uiiental issue is the scope of restrictions that is. how much should the government liy to control? W'hen the primar\' US opponent was another tecivioiogically sophisticated state, the Soviet Union, the case could be made that one should focus on S&T areas that could tnily make a difference in terms of adding to Soviet capabilities or undermining those of the United Slates. With the fall of the Soviet Union, some argue that the range of less technologically sophisticated opponents, including terrorists, now confronting the United States means that the government should lr\' to deny access to the much w ider range of information and technologies that could be useful to them.

While recognizing the legitimate concerns that others may take adN antage of open access to infonnation. technologies, and materials for malicious purposes, past e.xaminations of the potential tradeoffs between openness and security ha\e concluded that the Ignited Stales is best ser\ ed by focusing its efforts on protecting few er, ver\ -high- value areas of S&T.® ITiis is particular!) tnie in fields where knowledge is advancing quickly and diflusing rapidly; otherwise, the United States may e.xpend its efforts in attempts to control knowledge and technology that are readily available elsew here. In addition, many of the existing mid proposed lists of “sensitive" information and materials tend to consist of broad and general categories, making it potentially difficult for researchers to know whether their activities are in or out of bounds.

Hiese considerations suggest two general principles and a number of specific recommendations :

• Principle 1: Construct “high fences" around narrow areas — that is, maintain stringent security around sharply defined and narrow ly circumscribed areas, but reduce or eliminate controls over less sensitive material.

* The CSIS Cofnmission on Science and Security m the 21st Century identified at least 20 tyf>es of information that could be considered “sensitive” wilhm the Department of Energy, most without consistent departmcnl-widc definitions or application (Center fcH* Strategic and International Studies. Science anti Secunly in the 2 1st Century: A Report to the Secretary of Energy on the Department of Energy Laboratories^ Washington, DC: CSIS, 2002,

J Knezo, “ ‘Sensitive But UiKlassified’ and Other Federal Security Controls on Scientific and Technical Information History and Current Controversy”, Washington. DC; Congressional Research Service. Apnl 2,2003, p.lO.

* This ts a fimcUmental conclusion of the Corson report and is echoed in other repeals, such as National Research Council, .4 Review of the Department of Energy Classification Policy anJ Practice, Washington, DC: National Academy Press. 1995. Commission on Protecting and Reducing Government Secrecy (the Mo>’nihan Commission), Secrecy, Washington. DC: US Government Printing Office, 1997; Center for Strategic and International Studies, Security Controls on Scientific Information and the Conduct of Scientific Research. WashmgfiOn, DC: CSIS. June 2005.

o Regularly review and update the lists maintained by federal agencies of information and technologies subject to controls with the goal of restricting their focus and removing controls on readily available technologies,
o Carr\’ out the process across as well as within agencies, and include input from the S&T community.

• Principle 2: Avoid the creation of categories of SBU information and consolidate e.xisting ones.

o Undertake a systematic review to determine the number and provisions of all existing types of SBl ' in the federal government,
o Using that baseline, require a further review and justification for the maintenance of any category . Tie remaining categories to an e.xplicit statutoiA or regulator\ framework that includes procedures to request access to information and appeal decisions.

“Deemed F'xports'': A Special Current C'ase

The controls governed by the Export Administration Act and its implementing regulations extend to the transfer of “technologx Technology is considered **specific

information necessary for the 'development,' 'production,' or 'use' of a product”, and providing such information to a foreign national w ithin the Ignited States may be considered a “deemed export'’ whose transfer requires an export license’ (italics added). Ilie primary responsibility for administering deemed exports lies w ith the Department of Commerce (DOC), but other agencies may have regulations to address the issue. Deemed exports are currently the subject of significant controversy.

In 2000, Congress mandated iuinual reports by agency oflices of inspector general (IG) on the transfer of militarily sensitive technology to countries and entities of concern; the 2004 reports focused on deemed exports. Ilie individual agency IG reports and a joint interagencx report concluded that enforcement of deemed-export regulations had been ineffective; most of the agency reports recommended particular regulatory remedies.*’

The IXK' sought comments from the public about the recommendations from its IG before proposing any changes. The department earned praise for this effort to reach out to

’ “Generally, technologies subject to the Export Administration Regulations (EAR) are those which are in the United States or of US origin, in whole or in part. Most are propHietaix'. Technologies which tend to require licensir^ for transfer to foreign nationals are also dual-use (i.e., have both civil and military applications) and are subject to one

or more control regimes, such as National Security, Nuclear Proliferation, Missile Technology, or Chemical and
Biological Warfare ^ “ Deemed Exports" Questions and Ans\s'ers . Bureau of Industi)' and Security', Department of
Commcrcc-

The International Traffic m /\rms Rcgulaticms (ITAR), administered by the Department of Stale, control the export
of technology, including technical information, related to items on the US Munitions List Unlike the EAR,
however, “publicly available scientific and technical information and academic exchanges and information
presented at scienufic meetings are not treated as controlled technical data ”

® Reports were produced b\' the DOC, DOD, The Department of Energj' (DOE), and the Department of Stale,
Department of Homeland Secunty', and the Central Intelligence Agencies. Only the interagency report and the
reports from DOC, DOD, and DOE are publicly available.

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potentially atTccled groups and is currently reviewing the 300 plus comments it received, including those from the leaders of the National Academies.*’

On July 12. 2005, the Department of I>?fense (1X)D) issued a notice in the Federal Register seeking comments on a proposal to amend the Defense Federal .Acquisition Regulation Supplement (DF.ARS) to address requirements for preventing unauthorized disclosure of export-controlled information and technology under IX)D contracts that follow the recommendations in its IG report. 'Die proposed regulation includes a requirement for access-control plans covering unique badging requirements for foreign \n oricers and segregated work areas for export-controlled intbrmation and technologx , and it makes no mention of the fundamental-research exemption.’" Comments are due by September 12. 2005.

Many of the comments in response to the IXK' expressed concern that the proposed changes were not based on systematic data or analysis and could have a significant negative impact on the conduct of research in both universities and the private sector, especially in companies with a substantial number of employees who are not US citizeas. Similar comments are expected in response to the 1X)D proposals. .Among the recommendations that have been offered to date to address these concerns are the following:

• Create a clearly defined regulator\ "safe harbor" for fundamental research so that universities can have confidence that activities within the sate harbor are in compliance with security restrictions, thus pemiilting a focus on whatever occurred outside the safe harbor.’^

• Do not change the current sx'stem of license requirements for use of expi^rt-controlled equipment in university basic research until the following steps have been implemented:

o Greatly narrow the scope of controlled technologies requiring deemed e.xport licenses, and ensure that the list remains narrow going forward,
o Delete all controlled technology from the list whose manuals are available in the public domain, in libraries, on the Internet, or from the manufacturers,
o Delete all equipment from the list Utat is available for purchase on the open market overseas from foreign or US companies,
o Clear international students and postdoctoral fellows for acce.ss to controlled equipment when tlieir visas are issued or shortly thereaffer so that tlieir admission to a university academic program is coupled w ith their access to use of export controlled equipment.’*’

Fiigaging the S&T Community in the Challenges of .\ehie>ing Security

In the wake of September 1 1 and the anthrax mailings, the S&T community, as in past times of crisis and along w ith other .Americans, responded to the new challenges to US security. This response has occurred on main levels, from helping to analyze current and potential threats

The letter from the Residents of the National Academies may be found at
http://www7.nationalacadcmies-orgTscansAcadcmv_Presidcnts_Ccsnmcnts_to_DOC,PDF-
Federal Register 70(132XJuly 2005) 39976– 78. Available at
http ://a257.g akamailech.nct7/257/2422^1jan20051800'edocketaccess.gpo-gov/2005/05-13305-hlm
See footnote 1 1 .

These recommendations were made hy Dan Mote, j^csidcnl of the Unb ersity of Maryland, at a May 6, 2005.
workshop at the National Academies and cited m the letter from the National Academies' prcsidenls

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to working on ways in which advances in S&T can improve national and homeland security.*^ Iliis has required active engagement by the S&T community with policymakers, particularly in national and homeland security, in law enforcement, and in intelligence, w here many of the parlies at Ihe table are likely to lack experience dealing w ith one another. It also involves continuing efforts to ensure that highly qualified S&T personnel are attracted to working on problems related to national and homeland security.

Press reports since September 1 1 have suggested tliai olTicials in the 1X)D and DHS are concerned about attracting eligible w orkers, especially those w itii specialties in demand in open piuls of the private sector. Since a significant portion of the work may be restricted or classified,

this issue is largely a subset of the wider problem addressed in other background papers of ensuring that sutTicicnt qualified US citizens are available to do the work. It also involves ensuring that restrictions on non*US citizeas as employees arc appropriate.

In addition, attracting personnel requires tlie creation of a work environment that w ill enable R&D in particular to be “cutting-edge'*. For example, scientists working in a restricted or classified en*ironment. especially at federal laboratories, still need to interact w ith the wider scientific community, including foreign visitors and collaborators, w here much of the innovation most relevant to their work is taking place. In the w ake of a series of scandals over alleged security lapses in the IX)I‘ nuclear-weapons complex in the late 1990s, the department imposed a number of new and expanded security restrictions. This sparked substantial concern about ensuring that the scientific qiuility of the laboratories could be siLstained. imd several organizations made proposals they believed would provide an appropriate balance between openness iuid security, these including*^

• Engage S&T personnel in the development and implementation plans for security measures.

• Continue to accept non-l^S citizens as visitors and in some cases staff, expedite security reviews for visitors, and more generally work to avoid prejudice against foreigners;

• As with recommendations for other situations, focus and limit security eft'orts to address the most important security situations.

Beyond attracting S&T personnel, it is essential to engage the broader S&T community in efforts to bring the latest S&T to bear on security problems. Much of the relevant research and many of the best ideas seem likely to come from outside the government and its own network of laboratories. Tapping these resources involves meeting several needs. One is ensuring an attractive climate for undertaking security-related R&D in universities and the private sector. .Another is engaging the S&T community in a variety of advisor)' capacities and communication channels. Some observers have recommended a variety of new mechanisms or expanded and revised roles for existing mechanisms, including the follow ing:

For a comprehensive examination of the potential contributions of S&T. see National Research Council. Mc^ng /he Nation Safer: The Role of S&T in Countering Terrorism. Washington. DC National Academies Press. 3002

Guides to additional reports and current projects of The National Academies related to homeland security may be found at http://www.nalionalacademies.org'subjecundex/'sec.html

NaUonal Research Council. Balancing Scientific Openness and NaUonal Sectinty Controls at the Nuclear Weapons Laboratories, Washington, DC: National Academy FVess. 1999, Center for Strategic and International Studies, Science and Security in the 21st Century; A Report to the Secretary of Energ)' on the Department of Energy Laboratories. Washingtoa DC: CSIS. 2002.

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• Encourage communication among the diverse communities involved in security issues policy, S&T, national and homeland security, law enforcement, and intelligence — so that policies regarding scientific communication are both effective and broadly accepted.

• Build bridges among these communities, particularly in areas of S&T, such as the life sciences, where there is little histor>‘ of working w ith the government on security issues.*’

Sec the recommendations, for example, m National Research Council. in an Age of

Terrorism. Washington. DC: the National Academies Press. 2004.

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Scientific Communication and Security
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Figures

Figure SC&S-I: F.xamples of“Sensilixe but I'nclassifled” aud Other Controlled Information.

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Figure SC&S-l: Examples of “Sensitive but Unclassified” and Other Controlled Information.

Data Categon-

Desciiption

FOIA Exenjpted

Any mfonuation that is exempted from mandator\' disclosure under the
Fre^m of luformauou Act

Intelligence Actnities

Information that mvoh*es or is related m mteUigence acUMUes.
uKludiufi collection methods personnel, and uuclassifred mfonnation

Cn.'ptologic ActiMties

Information that im olves encryption deciyption of information:
couummications secunt>' eqiupment leer's, algonthius. processes,
mfonuation mvohing methods and mtemal workmgs of
crsptoloffic eouipment

Command and Control

Infonuation in\ oImm the command and control of forces troop
movements

\\>apon and W'eapon
Swiems

Infonuation that deals with the design, functionaliti*. and capabilities
of weapons and weapon svstems both frelded and im*helded

RD&E

Research, development, and engineenug data on un-fielded products,
projects, systems, and programs that are m the develi^ment or
acQuismon phase

Logiscics

Informatiou dealing with logistics, sillies matenals. parts and parts
reoiusitions mcludins quantities and numbers

Medical Care HIPAA

Infonuation dealmg with personal medical care, patient treatment,
prescriptions ph*sician notes, paneut charts x-ra^^. diasuosis. etc

Personnel Management

Information dealmg with personnel, includmg evaluations mdi\idual salanes assieumeuts and mtemal personnel manaeemeut

Information covered bv the Pnvaev Act of 1974 (5 U S C $ 552A)

Contractual Data

Information and reccnxls pertaining to contracts bids, proposals, and
other data mvobine sovemment contracts

Insestigative Data

Infonuation and data pertaiumg to official cnminal and ci\il

ms esiigatious such as mvestigator notes and attomey-cheut pnxileged

information

Source: Congressional Research Service. "Sensitive But Urwlamfied” and Other Federal Security Controls on
Scientific and Technical Information: History and Oirrent Controversy. (CKS Report for Congress. Order Code
RL31845.) Februar>-20,20(M.

Iliis paper summarizes findings and reeommendations from a variety of recently published reports and papers as input to llie deliberations of the Committee on Prospering in the Global Economy of the 21st Century. Statements in this paper should not be seen as the conclusions of the National .Academies or the committee.

Science and Technology Issues in National and Homeland Security

Summars

Keeping a technological edge over adversaries of the United States has long been a key component of our national seciuity strategy. US preeminence in science iuid technology (S&T) is considered essential to achieving that goal, so throughout the Cold War tlie United States generously funded research and development, including basic research, that could contribute to national security. Since 1950. “defense’’ funding has been the largest component of the overall federal R&D budget, and it ha.s been a majority of that funding since FV 1981 (see Figure N'HS-1). Tliat investment has provided substantial spinolTs to the private sector, adding to the knowledge base and innot ation that have fueled US productivity and prosperity.

In the wake of Ute September 1 1 attacks and the anthra.x mailings, tlie nation has looked to S&T to help meet the new challenges of homeland security. Meanw hile. the US militaiy is in the midst of a ■'transfonnation" that depends on taking advantage of new and emerging technologies to respond to the dilfuse and uncertain threats that characterize the 2 1 st centuiy.

The current pursuit of national and homeland securits is taking place in a profoundly different environment, how ever, llie end of the Cold War and tlie increasing commercialization and globalization of the traditional .sources of S&T innovation for security have produced significant challenges for US national mid homeland security policies. Many proposals to ensure continuing US S&T leadership see defense funding as essential to supporting this goal, requiring policies that would be able to serve both economic and national and homeland security objectives.

Federal actions that have been proposed include the follow ing:

• Raise the level of S&T spending to .T’ o of Department of Defense (1X9D) spending and restore DOD’s historical commitment to basic research by directing 20“o of its S&T budget to long-temi research.

o Increase the budget for mathematics, the plw sical sciences, and engineering research by a year for the iie.vt 7 years w ithin the research accounts of the Department of Energy (DGE). the National

Science Foundation (NSF). the National Institute of Standards mid Technology (NIST), and the DGD.

o Within the 1X9D. set the balance of support for 6. 1 basic research more in favor of unfettered exploration than of research related to short-term needs.

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• For homeland security R&D:

o Commit to increase the portion of support that the IX-partment of

Homeland Security (DHS) devotes to basic research, perhaps by setting targets to be achieved within 5-10 years as the most immediate needs arc .satisfied.

o I ndertake a comprehensive review to identify opportunities across the entire federal homeland security R&D budget to support increased investments in basic and applied research,
o On the applied R&D side, search for technologies that can reduce costs or provide ancillary benefits to civil society to ensure a sustainable eflbrt against terrorist threats.

• Conduct a review of the current military and dual-use export-control systenvs to identify policies that narrow ly target exports of concern w ithout needlessly burdening peaceful commerce; .strengthen the multilateral cooperation essential to any effective export-control regime; streamline export cla.ssification. licensing, and reporting processes; and afford the President the authority and flexibility needed to advance US interests.

• Establish a new framew ork for coordinating multilateral export controls based on harmonized export-control policies and enhanced defense cooperation with close allies and friends.

• .Assess w hether the current system of the national laboratories that carry out defense-related research has tlie structure, personnel, and resources to provide the eutting-edge work and iraiovation to support national and homeland security R&D needs.

• Create a new National Defense Education .Act (XDE.A) for the 21st century.

ITie new NDE.A would include portable graduate fellowships, institutional traineeships, incentives to create professional science and engineering (S&E) masters programs, undergradiuite loan forgiveness, grants to support new and innovative undergraduate curricula, grants to c.xpand K-12 education outreach, summer training and research opportunities for K-12 teachers, employer S&E and foreign-language educational tax breaks, national laboratory and federal service professional incentives, and additional funds for program evaluation.

The National and llomrland Security R&D Portfolio

With the end of the Cold War, US defense investment, already declining in the wake of the Reagan .Administration's massive buildup, entered the longest periixl of sustained decline since the end of World War II. with deep cuts in funding for weapons procurement and R&D. September 1 1 and the wars in .Afghanistan :md Iraq have more than restored overall funding levels, but serious concents remain about the size and even more the mix of tlic R&D portfolio. In recent years, more and more emphasis has gone to development as opposed to research (see Figure NHS-2). Ihe portion of die IX)D R&D budget devoted to basie research (the “6. 1” aceount) has declined in constant dollars from

.\HS-2

3.3“o in F^' 1994 lo an estimated 1.9“o in FY 2005 (see Figure NHS-3).' In addition, within that account there has been increasing emphasis on research that appears more likely to yield short-term pay-olTs rather than the more open exploration that has been so important to past advances. Tlie President's budget request for F^’ 2006 called for a 13“o cut in the 6. 1 account, which by July 2005 the House of Representatives had partially restored to a 4“o decrease. I'he House also called for a 4.2 ®o gain in applied research (the “6.2" account) rather than the 15®o reduction called for by the President’s budget request, althougli the gain would come largely in the fonn of earmarks.^

Heyond meeting Uie immediate perceived R&I3 needs of the US militarvy broad service policy documents, such as Joint Vision 20/0 and 2020, look toward substantial expansions in the breadth and depth of S&T to support US strategy.^ The transfonnation goals set forth in fX JD’s 200 1 Qu.adrennial Defense Review (QDR) also depend on continuing to exploit the enhanced capabilities that can emerge from advances in S&T; the report called for significantly increasing S&T spending w ithin the DOD budget.'*

.Achieving these goals will require a return to the traditional strong support for basic and applied research, in particular in the physical sciences and engineering. These goals also will demand initiatives in new ;uid emerging areas of S&T, such as those called for by the QDR and a recent Defense Science Bo.ard study.’ In addition, tliesc chimges are considered essential to sustaining the role that defense research has played in improving the broader he.alth of the US S&T enterprise.

.Among the actions that have been proposed for the federal government are these:

• Raise the level of S&T spending to 3“b of IX)D spending* and restore IXJD’s historical commitment to basic research by directing 20'’o of its S&T budget to long-term research.^

• Increase the budget for mathematics, the physical sciences, and engineering research bv 1 2“o a vear for the next 7 years w ithin the research accounts of IXJE, NSF, NIST, boD.

• Within DOD, set the balance of support for 6. 1 basic research more in favor of unfettered exploration than of research related to short-term needs.

Funding for R&D for homeland security is a much more recent enterprise. Ilie majority of US homeland securits’ R&D funding actually occurs outside DHS (see Table NHS- 1).* .After annual increases of more than $200 million in each of its first 3 years.

* Funding for the 6.2 “applied research" account has gone up and down but now is 5.5 % in FY 2005 compared with 7 6 •/« in FY1994 Constant dollar and Percentage calculations by the Council on Competitiveness based on AAAS. “Historical Tabic: Trends in DOD 'S&T.' 1994-2005"

* AAAS. “Update on R&D in FY 2006 DOD House Appropnations". July 2005

* National Research Coxmeii Assessment of Department of Defense Basic Research, Washington. DC: National Academies Press. 2005

‘ Department of Defense. Quadrennial Defense Review Report, Washington. DC: Department of Defense. 2001

* Defense Science Board. The Defense Science Board 2001 Summer Study on Defense Saence and Technology, Washington. DC: DSB. 2001

‘p41.

Council on Competitiveness, Innovale America: National Innovation Initiative Summit and Report: Thriving in a Worldof Challenge and Change, Washington. IX): Council on Competitiveness. 2004

* AAAS. “Table 4: Federal Homeland Sccunty-Rclated R&D by Agency’*. N'brch 2005.

the FY 2006 budget request for DHS R&D slowed to a 3.6°o increase, or S44 million, for a total of $1.3 billion. To date, both the House and the Senate have essentially retained the requested levels, but each has made changes in how the funds would be allocated. F,fforts to consolidate all DHS R&D programs into tlie department's Directorate for S&T are scheduled to be completed in F Y 2006.’

Basic research is at present a relatively small portion of the federal homeland security R&D portfolio. The priority is instead on elTorts to use S&T to develop and field new methods and measures to increase security as quickly as possible.” Ihe primars exception is the biodefense program, in particular the very large National Institutes of Health research program.

The question of the baUuice across the homeland security R&D portfolio is an open issue. If more funding for basic research is a goal, options for the federal government include the following:

• Commit to inerca.se the portion of support that DHS devotes to basic research, perhaps by setting targets to be achieved w ithin 5-10 years as the most immediate needs are satisfied.

• Undertake a comprehensive review to identify opportunities across the entire federal homeland security R&D budget to support increased investments in basic and applied research.

• (>i the applied R&D side, search for technologies that can reduce costs or provide ancillars benefits to civil society to eitsure a sustainable elTort against terrorist threats.

New Sources of Innovation for Security: The fechnology Transfer Dileiiinia

Traditionally, I'S government programs were the primary driver for research into new defense-related teclinologies. The IX)D relied on a dedicated domestic industrial base, supported largely by the results of generous DOD-funded R&D in the commercial sector and universities.

That Cold War model no longer exists because of the deep cuts in US defense research investment already discussed and the dranutic increa,ses in private sector R&D investment, particularly in the high-teclmology areas such as infonnation and communications teclutologies essential to transfomiation. Hie US government has attempted to come to tenns with this new situation througli a variety of initiatives to enable it to take advantage of innovation from the commercial .sector that could "spin on” to enhance military capabilities.

The dramatic consolidation and increasing globalization of many sectors of the traditional defense industrial base also have encouraged US efi'orts to find ways to enhance technology cooperation w ith close friends and allies. In the decade following

9 AAAS. "RAO Flli(lif« L'pdUe on RAD in Die FY 2006 DHS Biiifccl". 200.'

For a comprehensive e.samination of the potential contributions of science and technology, sec Nation

al
Research Coimcil, Making tfie Nation Safer: The Role of Science and Technology in Countering Terrorism. Washington. DC The National Academies Press. 2002. Guides to the additional reports and current projects of the National Academies related to homeland security may be found at http WWW nationalacademies org;'subiectinde.x'sec html

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the end of the Cold War, the 15 major US defense contraetors shrank to four huge firms (see Figure NHS-4)." Many US defense firms have embraced a global business model, and non-US firms, primarily from Europe, have gained access to the US defense market on their own or in cooperation with US companies.'^

Tliese fundamental changes in the sources and structures of innovation for national security have also made it easier for US adversaries to gain access to knowledge and technologs' that could improve their capabilities. Policies to draw on innovation from firms in the commercial sector w ith global markets and inteniational workforces or to enhance inteniational technology cooperation potentially clash with longstanding US efforts to control the leakage of teclmology. September 1 1 and increasing concerns for terrorism especially using nuclear, chemical, or biologic — agents, have e.vacerbated these tensions. Faced with adversaries who are far less technologically sophisticated or who are relying on technology to make rapid advances in their capabilities -and for whom a much broader range of US technologies is thus potentially relevant than for a technologically advanced opponent like the Soviet I'nion there is a natural inclination to broaden the scope of I'S control elTorts to cover as much as possible that could be of use.

■flierc is increasing concent that current policy initiatives serve neither technology transfer and cooperation on the one hand nor proliferation prevention on the otlier.'^ In part, this is because technology-transfer policj' is being pursued largely through a polic\' apparatus constructed during the Cold War that critics from mans' quarters charge has never genuinely adjusted to the new tlireats facing the L'nited States. .According to critics, continued reliance on this apparatus — in particular, tlie current e.vport-control regime for militars' and so-called dual-ase goods and technologies — might do relatively little to prevent others from gaining access to US prixiucts and know-how while damaging the capacity of the United States to draw on imiovation in the commercial sector for both economic and national and homeland security objectives.

While erities generally share profound dissatisfaetion with the current system, tliere is little coasensas within or among the federal government. Congress, and the affected communities about remedies for the situation. These disputes are not new, but the\' take on particular force now because of tlie depth and extent of the disputes and because of their potential impact on elTorts to promote the health and capacity of the US S&T enterprise.

" A R Markusen and S S Costigaa “The ktilitary’ Industrial Challenge”, in Markusen and Costigan (ed s.).
Arming the Future: A Defense Industry for the 21st Century. New York: Council on Foreign Relations. 1999. p 8

‘ “Transformed? A Survey of the Defence Industry", The Economist, July 20, 2002; and K Ha>'ward, “The Globalization of Defence Industries". Survival. Summer 2001
See, for example. National Intelligence Council, Mapping the Global Future: Report of the National Intelligence Council’s 2020 Project, Washington, DC NIC, December 2<X)4, and Defense Science Board Task Force on Globalization and Security. Final Report, Washington, DC Office of the Under Secretary’

of Defense fcH' Acquisition and Technology. 1999

See, for example. Defense Science Board Task Force on Globalization and Security. Final Report: CSIS.

Tecimolog^' and Security in the 21st Century: USMilitafy Export Control Reform: Government Accountability Office, Defense Trade: Arms Export Control System in the Post-9/1 1 Environment, GAO-05-234, February 1 6, 2005; and GAO, Defense Trade: Arms Export Control Vulnerabilities and Inefficiencies in the Post-9/11 Seaihty Emironment, GAO-05-468R, April 7, 2005.

For the federal government, there are a number of possible options, including

these:

• Conduct a review of the current US militarx’ and dual-use export control systems to identify policies that narrowly target exports of concern without needlessly burdening peaceful commerce; strengthen the multilateral cooperation essential to any elYective export-control regime; streamline export classification, licensing, and reporting processes; and afi'ord the President the authority and flexibility needed to advance US interests.'^

• Establish a new framework for coordinating multilateral export controls based on harmonized export-control policies and enhanced defense cooperation with close allies and friends.*®

The Role of the National Laboratories in National and Homeland Security

Over the course of the Cold War, the United States created a system of national and federal laboratories, some devoted exclusively to research related to national security and some serving multiple roles. 'ITie DOE. for example, maintains 10 national laboratories that are managed through contracts with universities and private firms.*’ ilie DOD maintains a much larger system. Other laboratories maintained by such agencies as National Aeronautics and Space .Administration may also conduct defense-related work.

DIIS has turned to some of the existing DOE laboratories to support its new R&D enterprise;** it also is creating the National Bioterrorism .Analysis and Countenneasures Center to handle its large biodefense-research portfolio. Some of these laboratories do a mix of classified and unclassified research, and others carrv' out only unclassified work, in some cases to ensure the maximal openness for their basic-research programs.

Since the end of the Cold War, questions have arisen periodically about the continuing relevance of the national-laboratorv' system. Periodic reviews of the DOE laboratories, for example, have proposed substantial changes, including consolidation of the laboratories and significant changes in management structures.” More general concerns include how to ensure the quality of scientific personnel in the laboratories and whether measures should introduce greater competition to increase the incentives for the laboratories to draw on the best personnel and ideas in the private sector.^®

Center for Strategic and Inlcmalional Studies, Technology and Security in the 21st Centufy\' US Milit ary'
Export Control Reform. Washington, DC: CSIS, 2001-

** lienrv' L. Stimson Center and Center for Strategic and International Studies, Enhancing Multilater al
Export Cwtrols for VS National Security, Washington, DC: The Ilenr)' L Stimson Center, 2001,

See. for example. http:/M'\^'w.energy.gov/engine 'content.do?BT_CODE*ST_SS16.

** See ht^D;//ww>^'.dhs,gov/dhspublic/d>splay?theme=27&content=3000.

See, for example. Department of Energy, Task Force on Alternatives Futures for the Department of Energy National Laboratories (Galv in Comm ission), 1 995; General Accounting Office, Department of Energy National Laboratories Need Clearer Vision and Better Management, GAO/RCED -95- 1 0, Januaiy 1995; National Research Council, Maintaining High Scientific Quality at Los Alamos and Livermore National Laboratories. Washington, DC: National Academies Press, 2004.

“ See. for e.xample. National Research Council, National Laboratories: Building Neve fVays to Work Together — Report of a Workshop. Washii^ton. DC: National Academies Press. 2005. and the suggestions about personnel in Defense Science Board. The Defense Science Board 2001 Summer Stutfy on Defense Science and Technology. Washington, DC : DSB, 200 1 .

Options for the federal government to address these issues include an initial effort to:

• .Assess whether the current system of the national laboratories that carry out defense-related research has the structure, personnel, and resources to provide the cutting-edge work and innovation to support national and homeland security R&D needs.

National Defense Education Act

Adopted by Congress in 1958. Uic original NDE.A was intended to boost education and training in security and national-defense related fields. NDE.A was a response to the laimch of Sputnik and the emerging tlireat to the United States posed by the Soviet l^nion. 'ITie NDEA was funded with approximately S400 million to $500 million (in constant 2004 dollars). NDE.A provided funding to enhance research facilities: fellowships to thousands of graduate students pursuing degrees in science, mathematics, engineering, and foreign languages: and low-interest loans for undergraduates in these areas.

Hy the 1970s, the act had been largely superseded by other programs, but its legacy remains in the form of several federal student-loan programs.^* Tlie legislation ultimately benefited all of higher education as the notion of defense was expanded to include most disciplines and fields of study.

Ilie IX)D workforce is critical to our nation's security planning. Iliis workforce, however* has experienced a real attrition of more than 13.000 personnel over the la.st 10 years. .At the same lime. DOD projects that its workforce demands will increase by more than 10°o (by 2010). Indeed, several major studies*^ since 1999 argue that the number of US graduates in critical areas is not meeting national, homeland, and economic security needs (see Figure NHS-5). Science, engineering, and language skills continue ha\'e ver\’ high priority across government and industrial sectors.

Many positions in critical-skills areas require security clearances, moaning that only US citizens may apply. While over 95*^0 of undergraduates are US citizens, in many of the S&E fields less than 50°o of those earning PhDs are l^S citizens. Retirements also loom on the horizon: over 60®o of the federal S&E workforce is over 45, a large proportion of whom are employed by DOD (see Table NIIS-2). DOD and other federal agencies face increased competition from domestic and global commercial interests for top-of-lheir-class, security-clearance-eligible scientists and engineers.

To ensure adequate human resources in fields important for homeland security, the National Research Council in the report Making the Nation Safer recommended that

Association of American Universities. A National Defense Education Act for the 2lst Century’. Renewing
Our Commitment to US Students, Science. Scholarship. andSocie^^, Washington DC: AAU, 2005
Available at; http://wwi** a au ed u^'educatiorv’NDEAOP pdf

Michael Parsons. 2005. “Higher Education Is Just Another Special Interest". The Chronicle of Higher Education B20 Available at; http: ’/chronicle com/pnn/weekly/v51/i22/22b02001 him
** See, for example, the National Science Board's companion paper \o Science and Engpieenng Indicator s,
2004. Arlingtoa VA. National Science Foundatioa 2004.

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there be a himian-resource development program similar to the NDEA.^'* National weapons laboratories have instituted specific programs to recruit and hire critically skilled people to slalTnuclear-stcKkpile stewardship programs — for which US citizenship is a primary^ consideration- -including graduate and postdoctoral internship programs, programs involving local high schools and universities, and support for current employees to gain additional training (see Table NHS-3). Human-resources ofYices are attempting to solve workforce problems through a number of independent actions. Many agencies now have direct-hire authorities and can offer significant signing bonuses in special cases. A recent Government Accountability Office report indicates these multiapproach programs arc a major reason that 1X)D laboratories currenth do not have significant problems locating the necessar\^ people to fill critical-skills positions.^^

DOD has proposed, as part of the department’s 2006 appropriations,^*^ to create and fund NDEA 2005 (see Figure NHS-6). This program would eMend a 2004 pilot SMART program and, as with the original NDE.A, would provide scholarships and fellowships to students in critical fields of science, mathematics, engineering, and foreign languages. It would expand on the original act in providing scholarships to undergraduates, including those pursuing associate degrees. ITie program would cover tuition, room and board, internships, tutors, and travel for all students. DOD requires a ser\ ice commitment on completion of studies.

DOD has requested $10.3 million in its FY 2006 budget request for this program. SMART was initiated in 2005 as a pilot program and funded at $2.5 million. The program has generated considerable interest among students: SMART currently funds 25 students, but DOD vetted over 600 applications.^’

Possible actions include:

• Create a new NDEA for the 21 si centurv' to promote the education and training of students in science, technology, engineering, mathematics, and foreign languages. Tlie new NDE.A would include portable graduate fellowships, institutional traineeships, incentives to create professional S&E masters programs, undergraduate loan forgiveness, grants to support innovative undergraduate curricula, grants to expand K-12 education outreach, summer training and research opportunities for K-12 teachers, employer S&E and foreign-language

^ National Research Council, Making the Nation Safer: The Role of Science and Technology in Countering
Terrorism, Washington, DC; National Academy Press. 2001.

Government Accountability Office, National Nuclear Security Administration: Contractors' Strategies to
Recruit and Retain and Critically Skilled Workforce Are Generally Effective (GAO-05-164), Washington DC: GAO, 2005,

" See H.R. 1815, National Defense .Authonzation .Act for Fiscal Year 2006 § Sec, 1105. Science, Mathematics, and Research for Transformation (SMART) Defense Education Program— National Defense Education Act (NDEA). Phase I. Introduced to the House on 4/26/2005; on 6/6/2005 referred to Senate committee, status as of 7/26/2005: received in the Senate and read twice and referred to the Committee on
Armed Services

^ Jeffrey Brainard. . "Defense Department Hopes to Revive Sputnik-Era Science-Education Programs".

The Chronicle of Higher Education 51(36X2005); A18. Available at:
http:/, chronicle, com/pmi/weekly/v51/i36/36a01 802.htm,

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educational lax breaks. national-laborator\' and federal-ser*ice professional
incentives, and additional funds for program evaluation.**

" National Research Council. 2001 Making the Nation Safer: The Role of Science and Technology in Countering Terrorism. Washington, DC: National Academy ftcss, Ronald M Sega. Director of Defense Research and Engineering, DoD, Testimony Before the Subcommittee on Emerging Threats and Capabilities of the Senate Armed Services Committee, March 9, 2005. Available at http //armed-services senate gov'statcmnL'2005 'March/Scga"/o2003*09-05 pdf . and Association of Amencan Universities 2005. A National Defense Education Act for die 21" Century. Renewing Our Commitment to US Students, Science. Scholarship, and Society (White paper) Washington DC: AAU. Available at
http Vw ww aau edu/educalion/NDE AOP. pdf.

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Figures and Tabies

Figure NHS-1; Since 1950, Defense Funding Has Been the Largest Component of the Overall Federal R&D Fudget, and It Has Been a Majoritv' of That Funding since F\^ 1981.

Source: American Association for Ihe Advancement of Science. Chart: Federal Spending on Defense and Nondefense R&D. " Washington. DC. Febniaiy, 2005. Available at: ttp://www. aaas.org/spp/rd/histdc06.p df

Figure lSHS-2: In Recent Years,Mmore and .More Empliasis Has Gone to
Develonnient as Opposed to Re.search.

2006" Washington. DC. Febmaiy. 2005. Available at: http://www.aaas.org/spp/rd/trdef06c.pdf

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Figure NHS-3: I'lie Portion of the DOD K&U Budget Devoted to Basic Research
(The “6.1” Account) Has Declined in Constant Dollars.

National Science Board. Science and Engineering IndicaSors 2004 (NSB 04-01). Arlington, Virginia.
National Science Foundation. 2004.

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Table NHS'l: The Majority of I'S Ilmneland Security R&D Funding Actually
Occurs Outside the Department of Homeland Security.

<budget authority m mlbons of dollars)

FY 2002

Actual

FY 2003

Actual

FY2004

Actual

FY 2005

Esbmata

FY2006

Budget

Change FY 05*06

Amount %

Agricutture

175

155

40

161

172

11

68%

Commerce

20

16

23

73

82

9

11.9%

Department of Defense

259

212

267

362

394

32

8 7%

Department of Energy

SO

48

47

92

81

-12

•12.5%

Department of Homeland Secunty

266

737

1.028

1,243

1,287

44

36%

Environmental Protection Agency

95

70

52

33

94

61

1851%

Health and Human Services

177

1.653

1.724

1.796

1,802

6

04%

• Mafionel /rutitules of Health

f62

J,633

1.703

f.774

1,781

6

04%

National Aeronautics and Space Adm

73

73

68

88

92

4

4.5%

National Science Foundation

229

271

321

326

329

3

10%

Transportation

106

7

3

0

0

0

Another

46

47

32

42

92

50

118 8%

Total Homeland Security R&D

1.499

3 290

3.626

4.216

4.425

208

49%

(Total Homeland Secwity Spending)

32.681

42.447

40.834

48.015

49,943

3.928

85%

AAAS. based on Office of Management and Budget data from QMS's 2003 Report to Congress on Combating Termnsm and BmigetoftheUS Government FY 2000 Figures ac^usted from OMB data by AAAS to include conduct of R&D and R&D facilities, and revised estimates of DHS R&D Figures do not include non*R&D homeland security activities, nor do they include DOD R&O investments in overseas combabng terronsm

Funding for all years includes regular appropnations and emergency supplemental appropriations
REVISED February 17, 2005

Source: American Assoctaticm for the Advancement of Science. Guide to R<iD Funding Data: Historical Data. Washington. DC. 2005. Available at. http. /www-aaas.org.'spp.'rd'guihisl him

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Figure NHS-4: In The Decade Following the End of the Cold War, the 15 Major US Defense Contractors Shrank to Four Huge Finns.

Figure U,S. Oefemc Mcrgm in th« 1990i

SoNKT; AfldAUur fraaillwD(partiMnlo<Ddemepubbc«tion(mi. lOOGnu^unnKminivtirLdfjnt AitUr VWanirt^Pnmr Contrail Awtnh frm At ftial Yran «f 1993 mid 19M.

Source; Ann R. Markusen and Scan S. Costigaa Arming Tite Future. New Yoik: CouiKil on Foreign Relations Press. 1999. Figure 1-1, p 8.

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Figure NHS-5: The Number of US Graduates in Critical Areas Is Not Meeting National, Homeland, and Economic .Securits' Needs.

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Industry Demand Data

1200 00"

Overwhelming consensus

000.00-

Thousands of unfilled science &

800.00-

engineering positions for US

600.00-

citizens

400.00-

Getting worse

200,00-

1 ••NOIAQiack Look Survey

•Small random sample

-Spring 2004 data only

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Today Today

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UNFILLED REQUISITIONS for

uscrriZEN sciences

ENGINEERING SPECIALISTS
by DEGREE*

Bs MS pro

Source; Edw’ard Sw*allow. OiairNDIA Space Division and Chair. Industry Study on Oritica) Workforce Issues. Presentation at the National Defense Industry Association meeting. April 2005. Available at: hltp;//procecdings.ndia.org/434(Vswallcnv.pdr

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Table NnS-2; 0>er 60 % of the Federal S&K Workforce Is Over 45, a Large Proportion of \Mioni Are Fniployed by IK)I).

1999 2000 2001 2002

1 43.5% 1

i 43.1%

43.4%

1 All sci

26.1%

25.4% 1

25.6%

26.9%

45.5%

I 44.0%

45.3%

Life sci

11.4%

1 11.2% 1

11.0%

10.9%

Physical sci

26.1%

26.2%

Social sci

19.7%

19.6%

All eng

66.2%

66.7%

Aerospace

1 44.7% 1

1 43.6% 1

43.0%

42.8%

Chemical

65.7%

67.6%

Civil

61.8%

1 61.3% 1

60.6%

60.1%

EE&Comp

79.3%

78.5%

79.1%

Industrial

81.1%

80.2%

79.4%

79.4%

Mechanical

88.2%

88.2%

88.4%

89.2%

Other eng

54.6%

55.1%

55.5%

55.9%'

Source: Pre-rclcasc - OPM dala for NSF SJfeE Indicators 2005. Table B-I4 Federal scientists and engineers, by agenc>' and major occupational group. I999'2002

Table .N'HS-3: National \>'eapons Laboratories Have Instituti'd Specific Programs to Recruit and Hire C ritically Skilled People to Staff Nuclear-Stockpile Stewardship Programs, for >Miicli I S (iti/enship Is a Prinian Consideration.

ProKraai

.Sponiior

Pre (:ollef!t(kl2)

Materials World Modules

Armv

STARBASE

OSD-RA

eCybcrmission

Army

Undergraduate

Awards to Stimulate and Support Undergraduate Research Education

—

Research Assistantships in Microelectronics

.AFOSR with NSF

DARPA with Semiconductor
Industries Association

Science. Mathematics, and Research for
Transformation (S\L\RT)

AFOSR

Graduate

National Defense Science and Engineering
Graduate Fellowships

NDSEG

Naval Research – S&T for Americas
Readiness (N-STAR)

Navy with NSF

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SNfART

AFOSR

Source Bill Berry. Acting [>epuly Undersecretary (or Laboratories artd Basic Science. "STEM Education

Act" Presentation at STARBASE Directors* Conference. Apnl 7, 2005. Available at
http ' WWW starhasedod com/resources/SME®«20Briefing-STARBASE%20Directors®o20ConPi»204-7-05v5%20wo* o20Backup.ppt

Figure NHS-6: DOD Strategj' for NDEA VVilhin Its Current Portfolio of Workforce
Programs.

Notional NDEA 2006 Strategy

1 EIrmrntan

1 School

Middle

School

.. . ' 1 Ddci-

Ilisti School:

1 1 sraduaif

I Graduate ^

1 School j

GovernmcDl aod
Industn' EmployiDfoi

Tlmr

NDEA 2006 recommendations reflect a strategy which
sets preconditions for an adequate S&E workforce pipeline based
upon providing S&E-related educational opportunities

Source; Edward Swallow. Chair NDIA Space Division and Chair. Industry Study on Qritical Workforce Issues. FYesentation at the National Defense Industry Association meeting. April 2005. Available at; http://proceedings.ndia.org/4340/swaltow.pdr

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APPENDIX F

K-12 EDUCATION RECOMMENDATIONS SUPPLEMENTARY
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Jl 'STIFICATION FOR NLMnKRS OF TI* ACHFRS AND STl DENTS
IN THE AP-IB AND PRE AP-IB PROGRAMS RECOMMENDED ACTION A-2.

Students

The goal is to have 1,500,000 high school students taking at least one advanced placement (AP) or Inlemalional Baccalaureate (IB) mathematics or science exam by 2010, an increase to 23®o from of I'S higli school juniors and seniors who took at least one AP math or science exam in 2004. with 700.000 piissing the exam* (see Exhibit 1). AP-IB classes must be open to all students.

Exhibit 1: US Public School Enrollment and AP Participation

I'rojccted 2004* Projected 201(t'

Total aradc 9-12 enrollment

14.700,000

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Total ftrade 11-12 enrollment

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Actual 2004'

Injected 2010

Number of high school Jr./Sr. taking
at least one AP mathemattes or

science exam

380,000

1.500,000

Percent of Jr ./Sr. taking at least one
AP mathemattes or science exam

65%

23%

./\P mathematics or science teachers

33.000

100.000

Students per /\P teacher

11.5

15

llie proposed .AP incentive program (APIP) has increased the number of students taking AP exams. To measure AP participation in a school, district, state or nation, we calculated the number of students taking AP exams per 1000 juniors and seniors. In 2005, the number of students taking AP exams in all math, science or engii.sh in the Dallas 10 districts was 2.3 limes that of the national level (see E.xhibit 2).

' AP passing score IS 3-S; note that some colleges do not allow credit Tor APeoureework unless a score ^*5 is achieved IB scores on a 7-potnl scale. and5 or higha is cemadered passing.

^ The College Board

'Statistical Abstnet ofthe United States' 3004. 200S. T^c 303
* The College Board

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Exhibit 2: Students taking AP Exams Per 1000' Juniors and Seniors Enrolled

Dallas 10 APIP schools	325 students
Texas public schools	170 students
US public schools	1 39 students

Teachers — AP-IB

Tlie AP and Pre-AP programs as proposed would provide professional development for 150,000 teachers now in the classroom to teach rigorous math and science courses in middle and high schools. Of these. 70.000 will teach Advanced Placement or International Baccalaureate courses in mathematics and science.^ In addition. 80.000 teachers in grades 6- 1 1 who are now in the classroom will receive training, teachers guides and assessments instruments, such as those available in the Laying the Foundation program, to prepare them to teach pre-AP mathematics and science courses that lead up to AP or IB courses. The proposed professional des elopment program for AP-IB teachers is 7 days a year for four years; for Laying the Foundation teachers it is 8 days a year for four years.

Assuming 10 percent attrition among the current 33.000 AP mathematics and science teachers and by training an additional 70,000 teachers, public high schools would have an estimated 100,000 mathematics and science teachers capable of teaching AP or IB courses in place by 2010. This number is based on a realistic goal w ith the capacity to provide quality professional training for teachers on a large scale. .'Xs they become more productive and confident as teachers, they will recruit more students into demanding mathematics and science courses. We then realistically can e.xpect steady increases in the numbers of junior and senior students who will take .AP-IB mathematics and science exams to 1.5 million students by 2010, with increases well beyond 2010.

Teachers — Pre AP-W

'I1iis proposal will provide pre-AP math and science training in content and pedagogy for 80.000 teachers who are currentU' in grades 6-1 1 classrooms, flie 4-year training program includes 8 days of training each year for four years and the classroom materials (vertically aligned curriculum, lesson plans, laboratory' exercises and diagnostics) needed to teach the more demanding math and science courses. By 2010, these teachers will help an estimated 5 million students each year develop critical thinking and problem solving skills in order to enlarge the .AP pipeline in math and science. This represents an estimated 20®o of US students who w ill be enrolled in grades 6-11 in 2010 (sec Exhibit 3).

^ "Per 1000" is alculatcd on the best ovollmoit data avulable at thetme.

* Including AP calculus, computer science, sttfistics. biology, chemistry, physics and environmental science.

Exhibit y. K-12 Students, Teachers, and Salaries'

	# students	ft teachers	Average salary	ft science and math teachers
K-5	29.627.634	1.781,900	$46,408	

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(191 K in science.

160K in mathematics)

9-12

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High School Grads
f2003-4)

2,771,781

Total (Fall 2003)

48.132,518

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NOTES: In 2003. there were
revenue sources was $8,248

15.397 US school

districts and the average amount spent per K-1 2 student from all

’ Unles otherwise noted figures, excerpts, and dials ire for the 2003>4 school year, as repotted b>' Kaltonal Education Assocnlion. 2005.
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' For the 1999*2000 sdiool year.

* From Glenn conunission report 2000. Includes ALL primary school teachers, as well as specialty teachers in middle and upper grades.

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Appendix G

Rising Abo%e The Gathering Storm:
Energizing and Employing America for a
Brighter Economic Future

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C ommittee on Science, Engineering, and Public Policy
Division on Policy and (»lobal AfTairs
The National Academies

before the

C'ommittee on Energy and Natural Resources
I’.S. Senate

October 18, 2(M15

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Mr. Chairman and members of the Committee.

Thank you for this opportunity to appear before you on behalf of the National .Academies' Committee on Prospering in the Cilobal Economy of the 21“ Century. .As you know, our effort was sponsored by tlie National .Academy of Sciences. National .Academy of Engineering and Institute of Medicine (colleetively known as the National .Academies). The National .Academies were chartered by Congress in 1863 to advise the government on matters of science and teclinologs'.

llie study had as its origin a conversation which took place at the National .Academies w ith Senator Lamar .Ale.vander several months ago. .As a result of that discussion, the .Academies were requested by Senator .Alexander and Senator Jeff Bingaman. members of the Senate Committee on Energy and Natural Resources, to conduct an assessment of .America’s ability to compete and prosper in the 2l“ century and to propose appropriate actions to enhance the likelihood of success in that endeavor. This request was endorsed by the House Committee on Science.

To respond to that request the .Academies assembled twenty individuals with diverse backgrounds, including university presidents. CEOs. Nobel Laureates and fomier presidential appointees. 'Ilic result of our committee's w ork w as examined by over forty highly qiialitled reviewers who were also designated by the .Academies. In undertaking oiu assignment w e considered the results of a number of prior studies which w ere conducted on varioas aspects of .America's future prosperity. We also gathered si.xty subject-matter experts w ith whom we consulted for a weekend here in Washington and who provided recommendations related to their fields of specialty.

It is the unanimous view of our committee that .America today faces a serious and intensifying challenge w ith regard to its future competitiveness and standard of living. Further, we appear to be on a losing path. We are here today hoping both to elevate the nation's awareness of this developing situation and to propose constructive solutions.

The thrust of our findings is straightforward. The standard of living of .Americans in the years ahead will depend to a very large degree on the quality of the jobs that they are able to hold. Without quality jobs our citizens w ill not have the purchasing pow er to support the standard of living which they seek, and to which many have become accustomed', tax revenues will not be generated to provide for strong national securitv' and healthcare; and the lack of a vibrant domestic consumer market w ill provide a disincentive for either LLS. or foreign companies to invest in jobs in .America

What has brought about the current situation? Hie answer is that the prosperity equation has a new ingredient, an ingredient that some have referred to as "The IX-ath of Distance”. In the last century, breakthroughs in as iation created the opportunity to move people and goods rapidls and elficientls' over very great distances. Bill Gates has referred to aviation as the "World Wide Web of tlie twentieth century". In the earls part of the present century, we are approaching the point w here the communication, storage and processing of infonnation are nearly free, fliat is. we can now mo\ e not only physical items efficientls' over great distances, we can also transport information in large volumes and at little co.st.

The consequences of tliese developments are profound. Soon, only tliose jobs that require near-phssical contact among the parties to a transaction will not be opened for competition from job seekers around the world. Further, with the end of the Cold War and the evaporation of many of the political barriers that previously existed tliroughout the world, nearly three billion new, highly motivated, ofien well educated, new capitalists entered the job market.

Suddenly, .Americans find themselves in competition for their jobs not just with their neighbors but with individuals around the world. The impact of this was initially felt in manufacturing, but soon extended to the development of software and the conduct of design activities. Next to be aftected were administrative and support ser\’ices.

Today, ‘liigli end ' jobs, such as professional ser\ ices, research and management, are impacted. In short, few jobs seem “safe”:

• U.S. companies each morning receive software that was written in India overnight in time to be tested in the U.S. and returned to India for further production that same evening making the 24-hour workday a practicality.

• Back-offices of U.S. firms operate in such places as Costa Rica, Ireland and Switzerland.

• Drawings for American architectural firms are produced in Brazil.

• U.S. firm's call centers are based in India where employees are now being taught to speak with a mid-western accent.

• U.S. hospitals have x-rays and C.AT scans read by radiologists in Australia and India.

• At some McDonald's drive-in windows orders are transmitted to a processing center a thousand miles away (currently in the U.S.), where tliey are processed and returned to the worker who actually prepares the order.

• .Accounting firms in the U.S. have clients tax returns prepared by e.xperts in India.

• Visitors to an office not far from the White House are greeted by a receptionist on a fiat screen display who controls access to the building and arranges contacts she is in Pakistan.

• Surgeons sit on the opposite side of the operating room and control robots which perform the procedures. It is not a huge leap of imagination to have highly-specialized. world-class surgeons located not just across the operating room but across the ocean.

.As Tom Friedman concluded in The World is Flat, globalization has “accidentally made Beijing, Ikingalore and liethesda next door neiglibors”. .And the neigliborhood is one w herein candidates for many jobs w hich currently reside in the U.S. are now just a “mouse-click” away.

How will .America compete in this rough and tumble global environment that is approaching faster than many had expected? The answ er appears to be, “not very w ell” — unless w e do a number of things differently from the way we have been doing them in the past.

>\Tiy do we reach this conclusion? One need only e.xamine the principal ingredients of competitiveness to discern that not only is the world fiat, but in fact it may be tipping against us.

One major element of competitiveness is, of course, the cost of labor. I recently traveled to Vietnam, where the wrap rate for low-skilled w orkers is about twenty-five cents per hour, about one-tw entieth of the U.S. minimum wage. .And the problem is not confined to the so-called “low er-end” of the emplovment spectrum. For example, five qualified chemists can be hired in India for the cost of just one in .America. Ciiven such enormous disadvantages in labor cost, we cannot be satisfied merely to match other economies in those other areas where w e do enjoy strength: rather we must excel . . . markedly.

Tlic existence of a vibrant domestic market for products and serv ices is another important factor in determining our nation's competitiveness, since such a market helps attract business to our shores. Hut here. too. there are wanting signs: Goldman Sachs anaivsts project that w ithin about a decade, fully 80"o of tlie world's middle-income consumers will live in nations outside the currently industrialized world.

Tile availability of financial capital has in the past represented a significant competitive advantage for .America. But the mobilitv’ of financial capital is legion, as evidenced by the willingness of U.S. firms to move factories to Mexico. Vietnam and China if a competitive advantage can be derived by doing so. Capital, as we have observed, crosses geopolitical borders at the speed of light.

Human capital – the quality of our work force – is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally w ith tliose of other developed and even developing nations . . . p.articularly in the fields which underpin most innovation: science, mathematics and technology.

Of tlie utmost importance to competitiveness is the availability of know ledge capital -"ideas”. .And once again, scientific research and engineering applications are crucial. But knowledge capital, like financial capital, is highly mobile. Tliere is one m.ijor difference: being first-to-market. by virtue of access to new know ledge, can be immenselv valuable, even if by only a few months. Craig Barrett, a member of our committee and Chainnan of Intel, points out that ninety percent of the products his company delivers on December 31® did not even exist on January I® of tliat same year. Such is the dependence of hi-tech firms on being at the leading edge of scientific and technological progress.

nicre are of course many other factors influencing our nation's competitiveness, riiese include patent processes, tax policy and overhead costs such .^s healthcare, regulation and litigation all of which tend to work against us today. On the other hand. •America's version of the Free Enterprise System has proven to be a pow erful asset, w ith its inherent aggressiveness and discipline in introducing new ide.is and flushing out the obsolescent. But others have now recognized these virtues and are seeking to emulate our system.

But is it not a good thing that others are prospering? Our committee's answ er to that question is a resounding “yes”. Broadly based prosperity can make the world more stable and safer for all; it can make less costly products available for .American consumers; it can provide new customers for tire prixlucts we produce here. Yet it is inevitable that there will be relative w inners and relative losers and as the world prospers, we should seek to assure that .America does not fall behind in the race.

Hie enigma is that in spite of all these factors. .America seems to be doing quite well Just now . Our luation has the highest R&D ins estment intensity in the world. We ha\ e indisputably the finest research universities in the world. California alone has more venture capital than any nation in the world other than the I'nited States. Two million jobs were created in .America in the pxst year alone, and citizens of other natious continue to invest their savings in .America at a remarkahle rate. Total household net worth is now approaching $50 trillion.

'Ilie reason for this prosperity is that we arc reaping the benefits of p.ist investments — many of them in the fields of science and technology. But the early indicators of future prosperity are generally heading in the wrong direction. Consider the following:

• For the cost of one engineer in the United States, a company can hire eleven in India.

• .\mcrica has been depending heavily on forcign-l>om talent, niirty-cight percent of the scientists and engineers in .America holding doctorates were bom abroad. Yet. when asked in the spring of 2005, what are the most attraetix e places in the world in which to live, respondents in onlv one of the countries polled indicated the U.S.,A.

• Chemical companies closed seventy facilities in the U.S. in 2004, and have tagged forty more for shutdown. Of 120 new chemical plants being built around the world w ith price tags of SI billion or more, one is in the LfS. Fifty are in China.

• In 1997 China had fewer than lltty research centers managed by multinational corporations. By 2004 there were over six-hundred.

• Two years from now, for the first time, the most capable higli-energy particle accelerator on earth w ill reside outside the United States.

• nie United States today is a net importer of higli technology products. Ihe U.S. share of global high tech e.xports has fallen in the last two decades from 30“o to 17“o. while .America’s trade balance in higli tech manufactured goods shifted from a positive S3.3B in 1990 to a negative S24B in 2004.

• In a recent international test involving mathematical understanding. U.S. students finished in 27th place among the nations participating.

• .About tw o-thirds of the students studying chemistrv' and physics in U.S. high schools are taught by teachers w ith no major or certificate in the subject. In the case of math taught in grades five through twelve, the fraction is one-half Many such students are being taught math by graduates in physical education.

• In one recent period, low-wage employers like Wal-Mart (now the nation’s largest employer) and McDonald’s created 44®o of all new jobs. Iligli-wage employers created only 29® o.

• In 2003 foreign students earned 59*^0 of the engineering doctorates aw arded in U.S. universities.

• In 2003 only three .American companies ranked among the top ten recipients of patents granted by the U.S. Patent Office.

• In Germany, 36® o of undergraduates receive tlieir degrees in science and engineering. In China, the corresponding figure is 59® o, and in Japan it is 66®o.

In the U.S., the share is 32® o. In the case of engineering, the IIS. shiire is 5®o. as compared with 50®o in China.

• Ihe Lhiited States is said to have over ten million illegal immigrants, but the number of legal visas set-aside anmuilly for 'highly qimlified foreign w orkers" w as recently dropped from 195,000 per year dow n to 65,000.

• In 2001 (the most recent yeiu for which data arc available). IkS. industrv spent more on tort litigation and related costs than on research and development.

As important as jobs are. the impact of these circuntstances on our nation’s .security could be even more profound. In the view of the bipiulisan Hart-Rudman Commission on National Security. “. . . the inadequacies of our system of research and education pose a greater threat to U.S. national security over the ne.xt quarter century than an\' potential conventional war that we might imagine.”

The got>d news is that there are tilings we can do to assure that .America does in fact share in the prosperity that science and technology are bringing the world. In this regard, our committee has made four broad recommendations as the biisis of a prosperity initiative- -and offers 20 specific actions to make these recommendations a reality. Iliey include:

o “Ten ITiotLsand feachers. Ten Million Minds " — which addresses .America's K- 1 2 education system. We recommend that .America’s talent pool in science, math and tcchnolog\’ be increased by vastly improving K-12 education. .Among the specific steps we propose are:

■ Recruitment of 1 0,000 new science and math teachers each year through the aw ard of competitive scholarships in math, science and engineering that lead to a bachelor's degree accompanied by a teaching certificate — and a 5-year commitment to teach in a public school.

• Strengthening the skills of 250.000 current teachers through funded training and education in part-time master’s programs, summer institutes and .Advanced Placement training programs.

• Increasing the number of students who take .Advanced Placement science and mathematics courses.

o “ Sowing the Seeds ’’ — which addresses .America’s research base. We recommend strengthening the nation’s traditional commitment to long-tenn basic research through:

• Increasing federal investment in research by 10®6 per year over the next seven years, with primaiy attention devoted to the physieal seiences, engineering, mathematic's, and information sciences — without disinvesting in the health iuid biological sciences.

• Providing research grants to early career researchers

• Instituting a National Coordination Office for Research Infrastructure to oversee the investment of an additional S500M per year for five years for advanced research facilities and equipment.

• .Allocating at least 8®o of the existing budgets of federal research agencies to discretionaiy funding under the control of local laboratoiy directors.

• Creation of an .Advanced Research Projects .Agency — Energy (.ARP.A-E), modeled after D.ARPA in the Department of Defense, reporting to the Department of Emergy Undersecretaiy for Science. I'he purpose is to support the conduct of out-of-the-box, transfomiational. generic, energy research by universities, industry and government laboratories.

• Establish a Presidential Innosation .Award to recognize and stimulate scientific and engineering advances in the national interest.

o “ Pest and Drightesf ’ which addresses higher education. In this area we recommend:

■ Establishing 25,000 competitive science, mathematics, engineering, and

technology undergraduate scholarships and 5,000 graduate fellowships in areas of national need for US citizens pursuing study at US universities.

• Providing a federal lax credit to employers to encourage their support of continuing education.

• Providing a one-year automatic visa extension to international students who receive a science or engineering doctorate at a U.S. university, and providing

automatic work pemiits and expedited residence status if these students are olfered employment in the US.

■ Instituting a skill-based, preferential immigration option

• Reforming the ciurent system of “deemed exports” so that international students and researchers have access to necessary non-classificd information or research equipment while studying and working in the US.

o • incentives for Innovation ” — in which we address the innovation environment itself

We recommend:

• linhancements to intellectual propertj protection, such as the adoption of a first-to-filc system.

• Increasing the R&D tax credit from the current 20® b to 40® o, and making the credit permanent.

• Providing permanent tax incentives for US-based innovation so that the United States is one of the most attractive places in the world for long-term innovation-related investments.

■ Ensuring ubiquitous broadband Internet access to enable U.S. fmns and researchers to operate at the state of the art in this important technology.

It should be noted that we are not confronting a so-called "t\ pical" crisis, in the sense that there is no 9 1 1, Sputnik or Pearl Harbor to alert us as a nation. Our situation is more akin to that of the proverbial frog being slowly boiled. Nonetheless, while our committee believes the problem we coniront is both real and serious, the good news is that we may well have time to do something about it —if we start now.

.•\mericans. with only 5®o of the world's population but with nearly 30®o of the world's wealth, tend to believe that scientific and technological leadership and the high standard of living it underpins is somehow the natural state of al'fairs. But such good fortune is not a birtliriglit. If we w ish our children and grandchildren to enjoy the standard of living most .Americans have come to expect, there is only one answer: We must get out and compete.

I would like to close my remarks w ith a perceptive and very releviuit poem. It was written by Richard Hodgetts. and eloquently summarizes the essence of innovation in the highly competitive, global enviroiunent. 'fhe poem goes as follows:

Every morning in Africa a gazelle wakes up.

Il knows it must outrun the fastest lion or it
will be killed.

Every morning in Africa a lion wakes up.

It knows it must outrun the slowest gazelle
or it will starve.

It doesn 't matter whether you 're a lion or a
gazelle - when the sun comes up. you 'd
better be running.

.And indeed we should.

Tliank you for providing me w ith this opportunity to testify before the committee. I would be pleased to answer any questions you have about the report

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Appendix H

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