PRIMING THE INNOVATION PUMP: AMERICA NEEDS MORE SCIENTISTS, ENGINEERS, AND BASIC RESEARCH

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Downward trends in the number of U.S. born scientists and engineers, and basic research and development are threatening U.S. national security and economic prosperity. Leadership in science and technology has long been an unrivaled U.S. advantage; however, the United States has lost and is continuing to lose ground in critical technology metrics. In today's knowledge-based economy, scientific innovation is more important to U.S. economic growth and national security than ever before. Accordingly, the United States must rebuild its foundation of competitiveness—its supply of talented scientists, engineers, and basic research and development resources—that has served Americans so well over the past 50 years. In the 21st century, U.S. success lies at the leading edge of the scientific frontier.

Keywords: *Scientists, Engineers, Research, Economic Growth, National Security*

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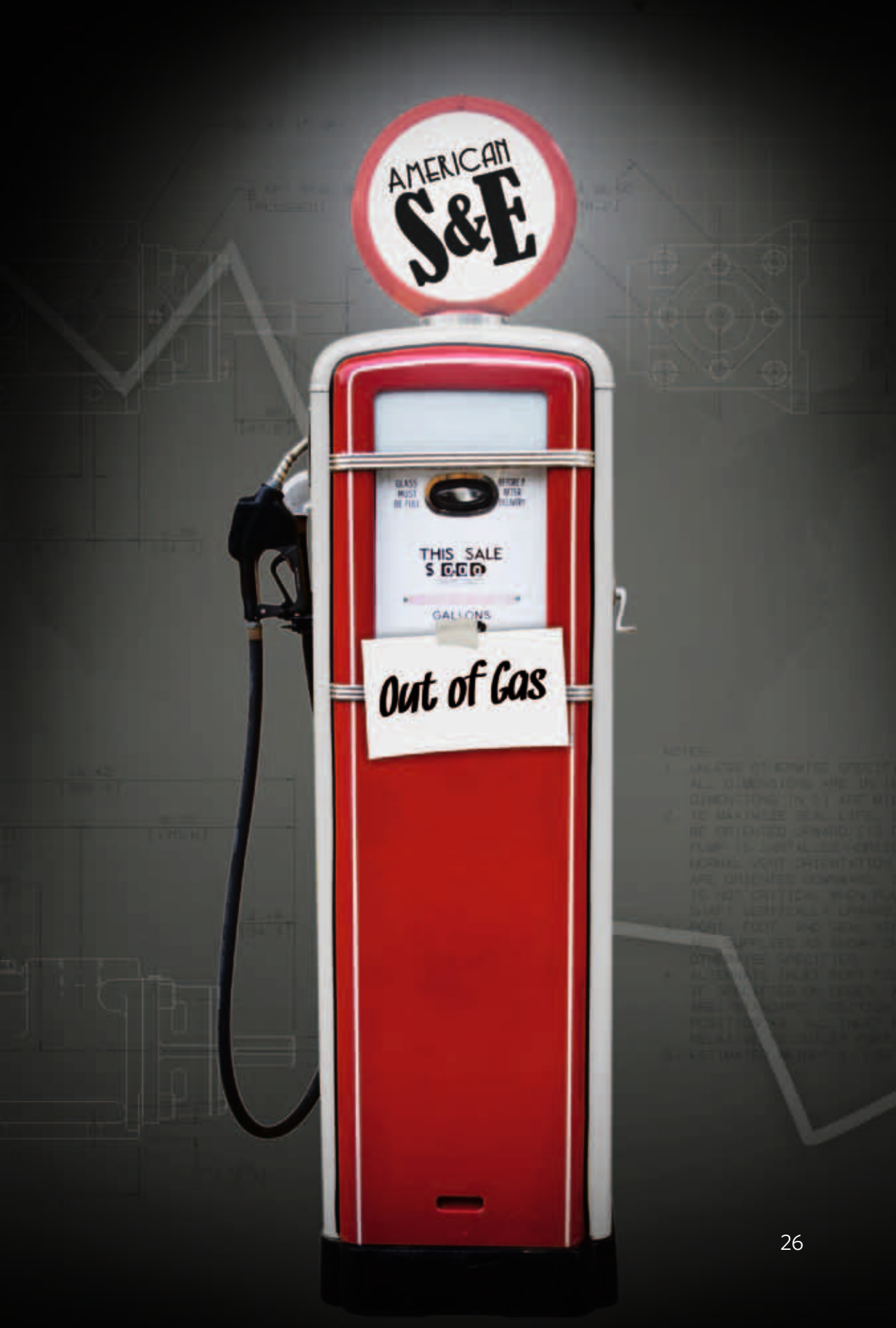

AMERICAN
S&E
THIS SALE
GALLONS
Out of Gas

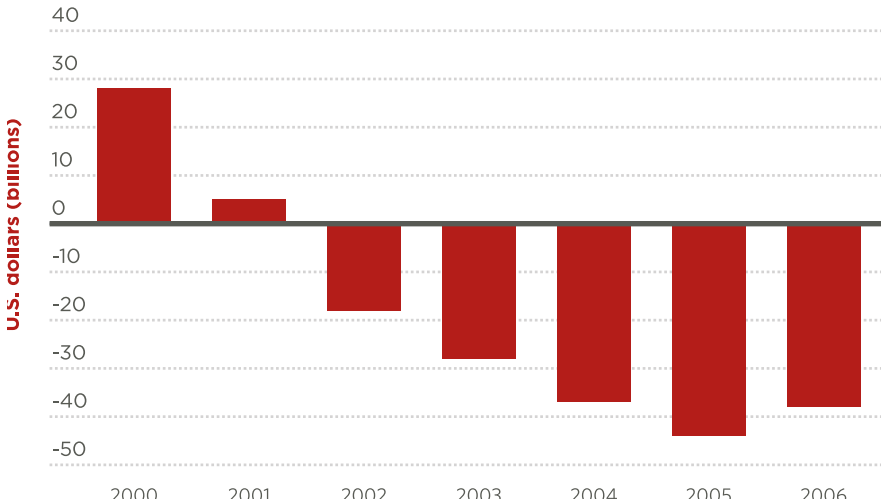
The United States has led the world in science, technology, knowledge generation, and innovation; however, the nation can no longer take its supremacy for granted. Nations fueled by globalization and competitiveness are on a fast track to surpass the United States in scientific excellence and technological innovation. Specifically, downward trends in the number of U.S. scientists and engineers (S&Es), and national basic research and development (R&D) are exacerbating this challenge and have troubling implications for U.S. economic prosperity and national security. Increasing the U.S. supply of quality S&Es and boosting basic R&D resources are essential to national security and economic growth. Continued economic and national security requires effective industry and government action as well as policies to ensure the United States remains at the leading edge of the scientific frontier.

From Producing Stuff to Producing Ideas

The liberal, neo-classical economic doctrine and its principle that capital drives growth has given way to knowledge economics and its principle that innovation drives growth (Atkinson, 2009, slides 40–41). During the industrial revolution, physical capital was the competitive advantage and growth was the product of land, labor, and capital—in other words, how much "stuff" was produced. In 1930, Joseph Schumpeter, an Austrian economist, first pointed out that innovation is the key to economic growth (Schumpeter, 1930). Today, Paul Romer's **new growth theory** builds on Schumpeter's premise by stressing that information leads to knowledge and then knowledge leads to innovation (*The Knowledge Economy*, 2009, pp. 4–5). Value is created by combining information and knowledge into new combinations—what Romer calls recipes. A recipe is more valuable than its parts; and new combinations are limited only by a person's, a corporation's, or a nation's ability to innovate (Romer, 2007).

Knowledge quickly becomes obsolete in a globalized environment, so competitive advantage—based on knowledge—requires the continuous creation of more knowledge into innovative products and processes. This framework applies to both economic and national security. The pendulum has swung such that poor countries of the future will have no ideas, whereas poor countries of the past had no natural resources. Taiwan, for example, started with essentially no natural resources but grew rapidly because of its ability to innovate. The U.S. innovation engine—fueled by the supply of S&Es and basic R&D resources—is quickly losing ground to international competitors that are rapidly accumulating intellectual capital and R&D capacity. Of specific concern is the general lack of interest

FIGURE 1. U.S. TRADE BALANCE IN HIGH-TECHNOLOGY GOODS: 2000–2006



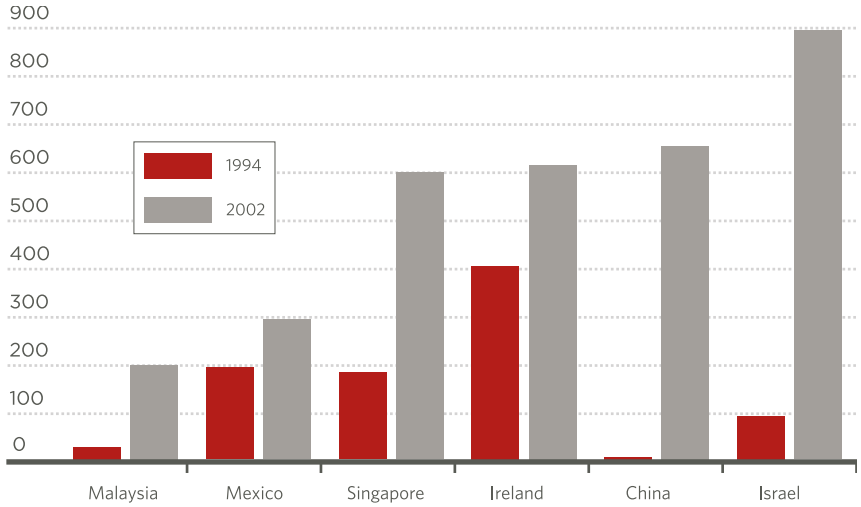
Note. Adapted from *Science and Engineering Indicators 2008,* by National Science Board, 2008, NSB Report No. 08-01.

among American-born youth in pursuing careers in the science, technology, engineering, and math (STEM) fields; and the long-term decline in the national investment in basic R&D (Marshall, Coffey, Saalfeld, & Colwell, 2004, p. 1). If these trends continue, the United States will find itself at a severe disadvantage.

Losing Ground on All Fronts

By most science and technology (S&T) metrics the United States leads the world. However, the nation has already lost and is continuing to lose ground in critical technology output metrics such as its trade balance of high-tech goods (Figure 1), the number of technical articles published, and the number of technical articles cited by others (National Science Board [NSB], 2008, pp. 10–12). In a recent study, 38 of the world's 50 leading research institutions were in the United States; however, other nations are quickly catching up (Freeman, 2006, pp. 2–3). For example, multinational companies are operating 53 state-of-the-art, high-tech industrial parks and 750 R&D centers in China (Berry & Loeb, 2008, p. 6). Growth in overseas R&D infrastructure has increased the off-shoring of U.S. industrial R&D (Figure 2) (Atkinson, 2009, slide 25). In addition, the world's S&T investment increased by 96 percent from 1996 to 2006, with China's growth at 9 percent, dwarfing all other countries, including the United States whose S&T investment decreased by 6 percent

FIGURE 2. BOOM IN RESEARCH AND DEVELOPMENT PERFORMED OVERSEAS BY U.S. COMPANIES

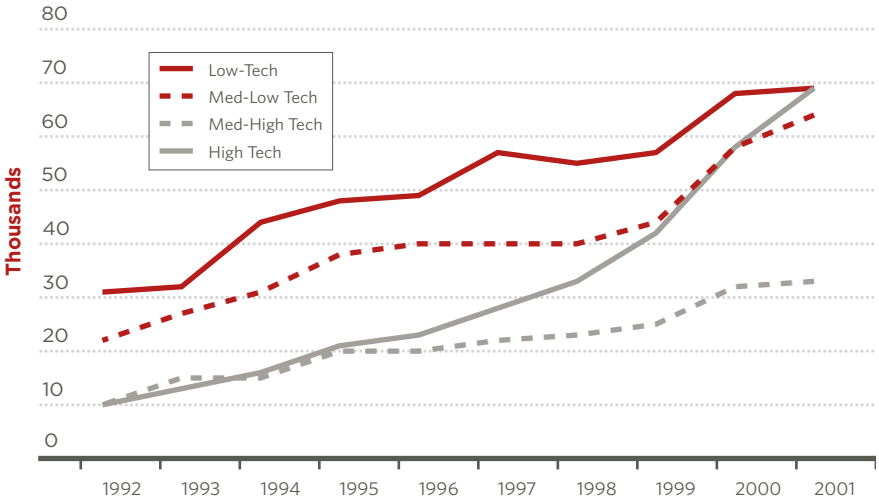


Note. Adapted from *Innovation and U.S. Economic Growth,* by R. D. Atkinson, February 5, 2009, Information Technology and Innovation Foundation presentation to Industrial College of the Armed Forces.

(Berry & Loeb, 2008, p. 2). As a result, China "isn't just making T-shirts anymore," it is producing increasing amounts of medium- to high-tech products for both commercial and military use (Figure 3), and other countries are following suit (Atkinson, 2009, slide 29). The U.S. output of native-born S&Es, however, is just as worrisome.

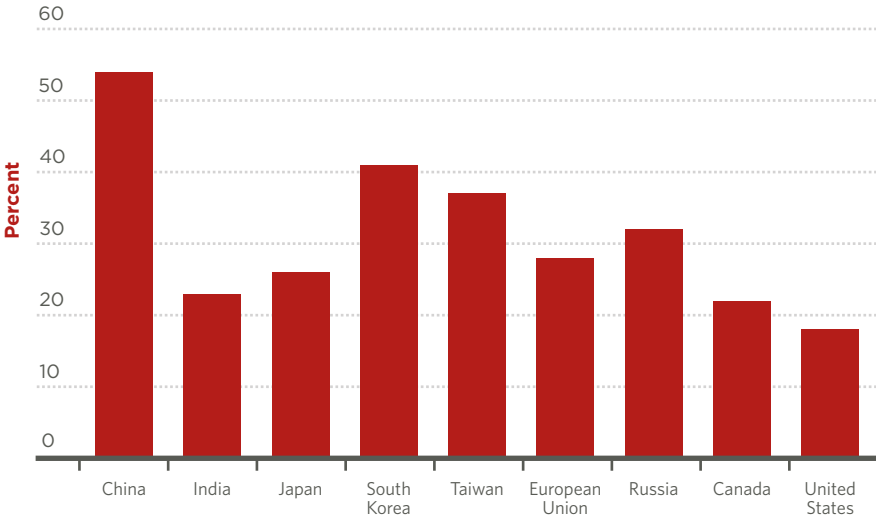
The United States lags behind global competitors in the percentage of undergraduates earning S&E degrees (Figure 4) (Atkinson, 2009, slide 26). In 2002, only 17 percent of U.S. undergraduates earned engineering degrees, as compared to 53 percent in China (National Science Foundation [NSF], 2006, Appendix, Table 2-38). In addition, the U.S. global share of S&E doctorates and undergraduate degrees fell from 40 to 20 percent and from 30 to 14 percent between 1970 and 2000 (Freeman, 2006, pp. 2–3). According to the NSF, 58 percent of engineering doctorates awarded in the United States in 2003 went to noncitizens, while greater than half of the students enrolled in U.S.-taught engineering programs were foreign-born. And in 2004, S&E doctorates awarded to temporary residents increased by 9 percent, compared to 2 percent for U.S. citizens (National Defense Education Program [NDEP], 2009a, p. 2). Also, in a recent survey of more than 270,000 U.S. college freshmen, only 7.5 percent said they intended to major in engineering—the lowest level since the 1970s (Aerospace Industries Association [AIA], 2008, p. 4). While foreign innovations benefit the standard of living in the United States, the government must increase its own supply

FIGURE 3. CHINA ISN'T JUST MAKING T-SHIRTS ANYMORE



Note. Adapted from *Innovation and U.S. Economic Growth,* by R. D. Atkinson, February 5, 2009, Information Technology and Innovation Foundation presentation to Industrial College of the Armed Forces.

FIGURE 4. UNITED STATES LAGS IN PERCENT OF UNIVERSITY STUDENTS RECEIVING DEGREES IN SCIENCE AND ENGINEERING



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of S&Es and basic R&D resources to maintain its edge in economic and national security matters.

Since over half the American-born S&E workforce is over 40 and will retire in the next 20–30 years, the increasing number of foreign-born versus U.S.-born S&E students exacerbates the economic and national security dilemma (Marshall et al., 2004, p. 3). The Department of Defense (DoD) alone is expected to lose more

How can the United States stop this downward spiral in S&E and basic R&D capacity?

than 13,000 S&Es in the next decade (NDEP, 2009b, p. 2). Industry is not immune either. Sixty percent of the aerospace industry workforce is 45 or older, and 27 percent of its engineering workforce is qualified for retirement (AIA, 2008, pp. 3–4). Foreign-born S&Es are earning the lion's share of undergraduate and graduate S&E degrees, but security concerns with foreign-born S&Es limit their opportunities within the DoD and its supporting contractors as well as other federal agencies (Marshall et al., 2004). How can the United States stop this downward spiral in S&E and basic R&D capacity?

The U.S. Innovation Engine... Running Lean on S&Es and Basic R&D

U.S. investment in the physical sciences, engineering, and R&D has not kept pace with demands of the global economy and national security threats. September 11, 2001, and its continuing aftermath underlie the need for a powerful U.S. S&T effort; however, the number of U.S. citizens enrolling in graduate math, engineering, and physical science programs—the fields of broadest DoD application—fell by 25, 21, and 17 percent (National Science Foundation [NSF], 2001). In addition, 70 percent of the world's R&D is now conducted outside the United States (Rees, 2008a, slide 5). How can this be considering 96 percent of Americans believe S&T plays a significant role in national security, 80 percent believe S&T is very important to meeting future terrorist threats, and 90 percent are concerned that low S&T performance will impact the nation's future economic prosperity (Bayer Corporation, 2003)? Actions need to match sentiment for a shift to occur.

S&T innovation fuels the product development cycle. However, the DoD, particularly over the last 20 years, is expending extraordinary energy attempting to incrementally improve existing capabilities, resulting in diminishing gains in capability at excessive cost (Chao, 2009, slide 7). This shortsighted approach places the

U.S. military dominance and economic competitiveness, particularly in the defense sector, at risk. "Current military dominance derives from S&T investments made in the 1950s through the 1970s by DoD and other federal agencies"; therefore, shortsightedness today may concede U.S. military dominance 10, 20, and up to 30 years or more in the future (Marshall et al., 2004, p. 3). It is "akin to a farmer who wishes only to harvest and not to sow" (Frosch, 1996, p. 22). To sow the seeds of technology, and to increase the opportunity for greater capability gains, the United States must focus more effort on the earliest stages of the product development cycle, researching and experimenting with new and innovative technologies. "If we do not invest heavily and wisely in rebuilding these two core strengths"—S&Es and basic R&D—"America will be incapable of maintaining its global position long into the 21st century" (U.S. Commission on National Security, 2001, p. ix).

Scientists and Engineers

The productive power of the U.S. economy and its national security lies primarily with its people. The Office of Management and Budget (OMB) estimates that privately owned capital in the United States is worth $13 trillion, while its human, intellectual capital is worth $48 trillion (OMB, 2007, p. 195). According to Alan Greenspan, "If we are to remain preeminent in transforming knowledge into economic value, the U.S. system of higher education must remain the world's leader in generating scientific and technological breakthroughs and in preparing workers to meet the evolving demands for skilled labor" (Greenspan, 2000, p. 4). But this system is being challenged from abroad.

Foreign students, particularly Asian students, are less likely to study in the United States for several reasons. First, foreign countries are growing their own higher education capabilities. From 1994 to 1998, the number of Chinese, South Korean, and Taiwanese doctoral students at U.S. universities dropped by 19 percent, while their enrollment at institutions in their native countries doubled (Task Force, 2005, p. 5). In 2006, five Chinese universities ranked in the top 100 universities for science, with Peking University ranking 12th (Berry & Loeb, 2008, p. 7). Second, foreign countries are developing their own high-tech industries and research capacity. As a result, increasing numbers of U.S.-educated doctoral S&E graduates are returning to their native countries to pursue research opportunities. And finally, tighter visa restrictions post-9/11 deter foreign students from studying in the United States. The cap on H-1B visas for high-skilled specialties decreased from 115,000 in 2000 to only 65,000 in 2007 (Bordoff, Deich, Kahane, & Orszag, 2006, p. 6). Due to security restraints, the United States can no longer rely on a steady influx

of foreign S&E talent to supplement innovation, and must produce more homegrown STEM talent to maintain its economic and national security edge.

Since 1980, S&E positions in the United States have grown by five times the rate of other professions; however, the number of S&E degrees earned by U.S. citizens is decreasing (Task Force, 2005, p. 5). This is especially critical to DoD laboratories and agencies like the National Security Agency, where U.S. citizenship is a security requirement (Bordoff et al., 2006, p. 6). Additionally, the time and cost to pursue S&E graduate degrees have increased while the compensation in S&E fields has declined relative to other high-level occupations (Freeman, 2005, p. 10). These trends clearly signal the need to create incentives—such as higher wages, fellowships, and employment guarantees—to maintain the pipeline of quality S&E talent that our nation's economy and national security structure sorely need. Unless more U.S. students choose S&E fields, the U.S. public and private innovation sectors will experience a significant "brain drain."

The DoD is taking action to avoid this "brain drain" through NDEP. The objective of NDEP is to bring more S&Es into the national security enterprise by supporting local educational initiatives. NDEP has an aggressive congressional mandate to award 1,000 innovative scholarships by 2013; to demonstrate DoD's involvement in K–12 education programs; and to award 50 five-year research fellowships by 2013. NDEP's primary focus is on middle school students that are "at a game-changing age where they will need to embrace math and science, or likely vanish as potential STEM employees"; however, NDEP also focuses on university students through its Science, Mathematics, and Research for Transformation (SMART) program. SMART funds U.S. S&E students' education costs in exchange for a 1-year payback in a DoD laboratory for each year of educational support. While NDEP programs have shown success, more has to be done at a national level because the DoD has 83,000 S&Es (70 percent engineers) and replenishing this resource does not occur overnight (NDEP, 2009b, pp. 1, 3). The challenge is even greater in industry.

Industry has been working this issue for some time, but is still struggling to hire the talent it needs. For example, 13 percent of the overall aerospace and defense workforce is qualified for retirement, and within 10 years this figure will grow to 50 percent. Of the 70,000 engineering bachelor's degrees awarded in the United States annually, most disciplines are not in high demand by DoD contractors (AIA, 2008, p. 3). Industry's viability depends on a skilled workforce, so industry is seizing ownership of the issue. Lockheed Martin (LM), the top recruiter of new engineers (5 percent

of all undergraduates in its majors of interest), is particularly concerned because 70 percent of its workforce is over 40 (McPherson, 2008a, slide 5). Through its Engineers in the Classroom program, LM is building school partnerships to create a pipeline of future S&E employees. From high school down to elementary school, LM engineers are participating in curriculum development, teacher training, and science and mathematics extracurricular activities with the objective of building excitement and enthusiasm for science, math, and engineering among America's youth (McPherson, 2008a, slides 7–10). With an aerospace and defense workforce that is half its size at the end of the Cold War, efforts like LM's Engineers in the Classroom need to expand in size and numbers, because it can take 22–25 years to grow an experienced engineer from entry-level talent. Meanwhile, the experienced workforce is retiring at accelerating rates (McPherson, 2008b). While not as severe, the same issues apply to commercial industry. A possible source of increased S&E talent is women and minorities.

A POSSIBLE SOURCE OF INCREASED S&E TALENT IS WOMEN AND MINORITIES.

As hard as it is to attract young Americans to pursue STEM, it is even harder to attract women and minorities. "The proportions of women, blacks, and Hispanics in S&E occupations have continued to grow over time, but are still less than their proportions of the population" (NSB, 2008, pp. 3–6). While women make up 46 percent of the overall U.S. workforce, they are significantly underrepresented in the S&E professions (Marshall et al., 2004, p. 4). Similarly, "African Americans and Hispanics combined make up 25 percent of the U.S. population, but account for only 11 percent of the engineering bachelor's degrees awarded to U.S. students" (NDEP, 2009a, p. 6). Women make up 48.6 percent of the college-degreed workforce, but only 24.7 percent of the S&E workforce. African Americans constitute 7.4 percent of the degreed workforce and only 6.9 percent of the S&E workforce; while Hispanics, the largest growing population in the United States, only constitute 4.3 percent of the college-educated workforce and 3.2 percent of the S&E workforce (Marshall et al., 2004, p. 4). The significance of these figures is magnified because the majority of women and minority S&Es are relatively young; therefore, enticing more into the S&E professions could significantly help with America's "brain drain" of S&E talent (Marshall et al., 2004, p. 4). The basic R&D "budget drain" is just as impacting.

Basic Research and Development

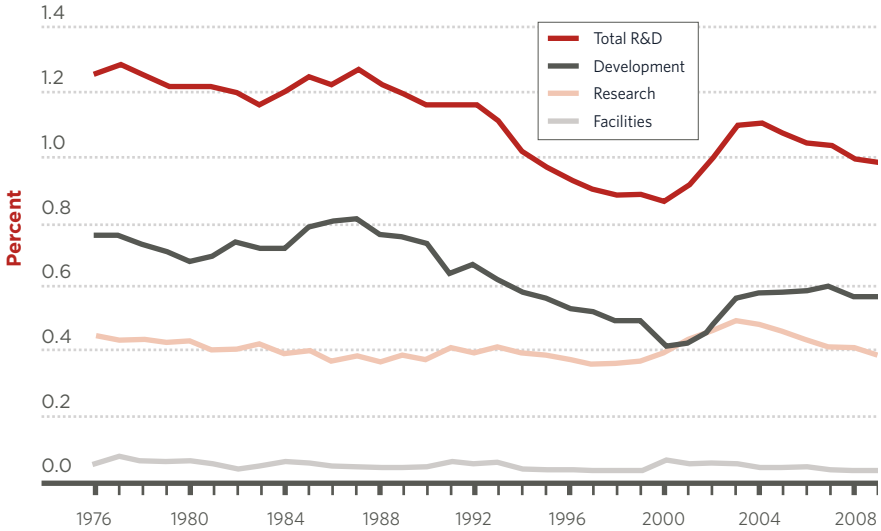
> *As changes in this century's threat environment create strategic challenges—irregular warfare, weapons of mass destruction, disruptive technologies—this request places greater emphasis on basic research, which in recent years has not kept pace with other parts of the budget.*
>
> *- Robert M. Gates, Secretary of Defense*

Secretary Gates' emphasis on basic R&D in his Fiscal Year 2009 Posture Statement is encouraging; however, much more is required at a national level (Rees, 2008a, slide 7). In a global comparison of the basic research share of total R&D expenditures, the United States ranks 16th (NSB, 2008, Figures 4-20, 4-41). DoD's $271 million basic R&D increase in the Fiscal Year 2009 budget is a step in the right direction; however, it may do little to overcome years of declining and flat budgets (Rees, 2008a, slide 17). In the post-9/11 world, where security and economic threats can appear from anywhere, a diverse and vibrant national basic R&D program is a necessity for economic and national security.

Direct contribution of R&D investment to economic growth in real Gross Domestic Product (GDP) was 6.7 percent during 1995–2002, up from 4.3 percent during 1974–1994 (Bureau of Economic Analysis, 2006). Although R&D contributes significantly to economic growth, the private sector invests less in basic R&D than is justified by societal benefits, because private innovators receive only a small fraction of the benefits their inventions generate. Surveys show that private return on investment (ROI) of basic R&D typically ranges between 7–15 percent, while the social benefit ranges between 30–50 percent (Popp, 2004). While society benefits tremendously, private industry's incentive to conduct basic R&D is low so industry concentrates on short-term, incremental R&D, similar to DoD. This is a significant innovation loss, because the private sector accounts for nearly two-thirds of total R&D (Bordoff et al., 2006, p. 2). Because the private sector invests less than it could in basic R&D, the United States is not realizing its full economic, or for that matter, national security potential. The world's fastest growing economies are on track to catch up to the U.S. basic R&D investment. China, South Korea, and Taiwan increased their R&D investment by 140 percent from 1995–2001, while the United States increased its investment by only 34 percent (Task Force, 2005, p. 9). To compensate for this shortage in private basic R&D, the United States must increase its public investment to maintain its innovative edge.

"Much of the strength of the United States is attributable to its technological prowess, much of which developed out of gov-

FIGURE 5. DECREASING TREND IN RESEARCH AND DEVELOPMENT (R&D) AS PERCENT OF GROSS DOMESTIC PRODUCT, FY 1976–2009*



* FY 2009 figures are the latest American Association for the Advancement of Science (AAAS) estimates of FY 2009 request. R&D includes conduct of R&D and R&D facilities. Data to 1994 are obligations from the National Science Foundation Federal Funds Survey. The 2009 Gross Domestic Product figures are from the United States Government, Office of Management and Budget.

Note. Adapted from AAAS analyses of R&D in annual AAAS R&D reports.

ernment-funded science research" (NDEP, 2009a, p. 3). Publicly funded basic R&D typically yields a high ROI of 30 percent or more (Mansfield, 1991, p. 3). However, "federal basic research in the physical sciences and engineering is flat or has declined as a percentage of GDP over the past 30 years" (Figure 5) (NDEP, 2009a, p. 3; Advancing Science, Serving Society [ASSS], 2009, Figure 1). Yet in times of crisis, public basic R&D has paid off. Basic R&D—conducted by the NSF, the National Aeronautics and Space Administration, and DoD for example—has provided innovations with huge societal payoffs, such as the World Wide Web, portable communications, the Internet, computer graphics, and broadband capabilities to name just a few, some of which have led to multibillion-dollar industries (National Research Council, 2003). The range of potential security and economic threats is increasing; therefore, the United States must increase its investment in basic R&D across the board. While DoD has been and is currently the largest benefactor and contributor to public basic research, it is losing ground fast (Rees, 2008b, p. iv).

Recent trends raise questions about the U.S. public funding of basic R&D. First, basic R&D has shifted from long-term, blue-sky research, which will most likely yield significant technological break-

FIGURE 6. INNOVATION CURVE: BASIC R&D PROVIDES GREATER CAPABILITY GAINS AT LESS COST

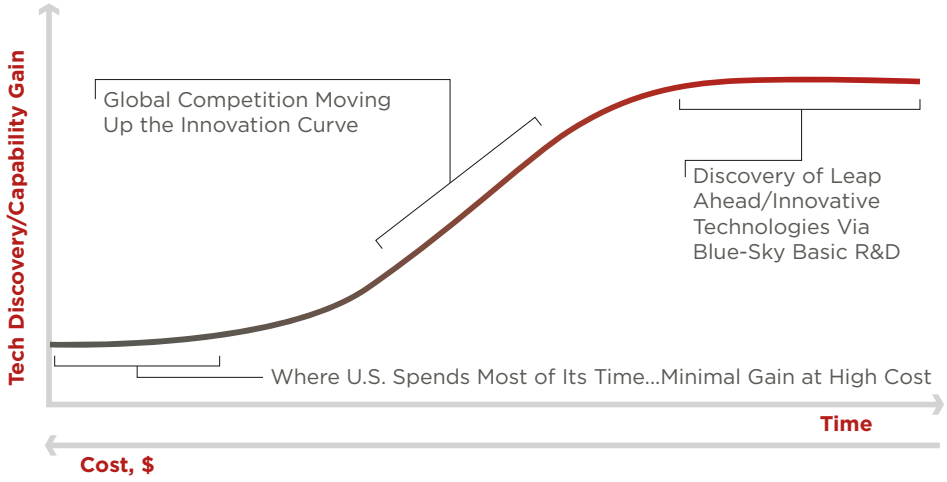
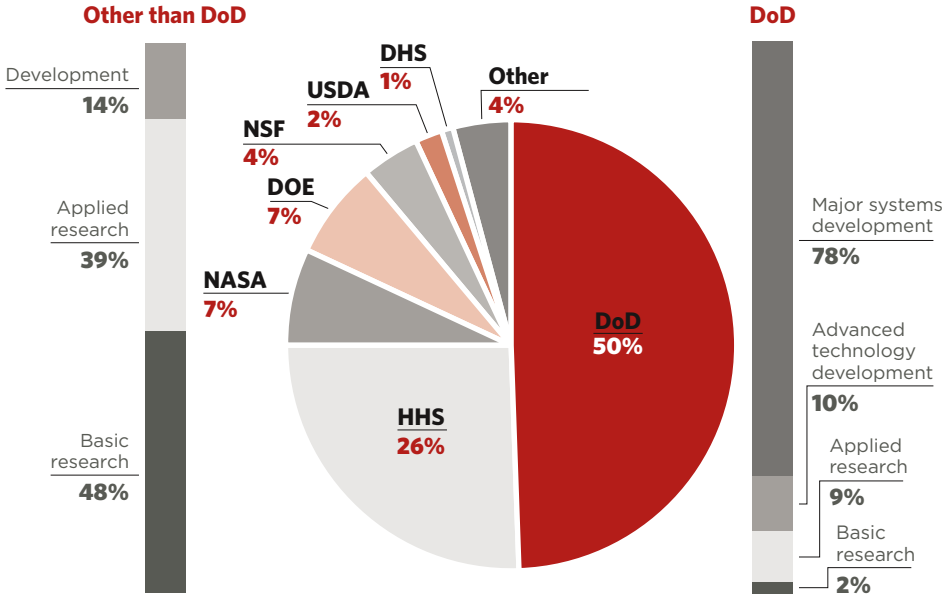


FIGURE 7. FEDERAL OBLIGATIONS FOR R&D BY AGENCY AND TYPE OF R&D: FISCAL YEAR 2007



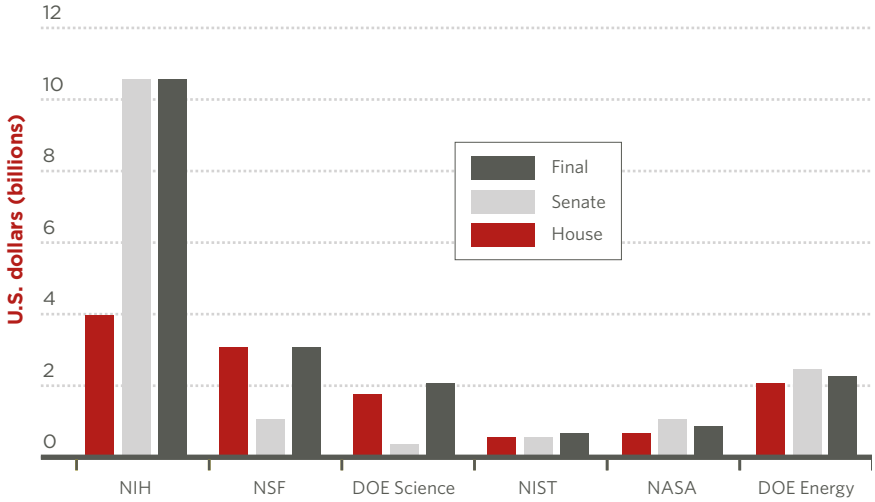
Note. DoD = Department of Defense; DOE = Department of Energy; DHS = Department of Homeland Security; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture. Detail may not add to total because of rounding. Adapted from *Science and Engineering Indicators 2008,* by National Science Board, 2008, Appendix, Table 4-30; and National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007. Due to rounding issues in the source from which the data were adapted, not all percentages add up to 100 percent.

throughs to R&D designed to reach more specific findings in shorter time horizons and at greater cost, such as applied and developmental R&D (Figure 6). Of note is the Defense Advanced Research Project Agency's (DARPA) shortening of go/no-go reviews for projects that are from projects of 12- to 18-month intervals versus prior 36-month intervals. This type of short-term focus hamstrings researchers and reduces the possibility of groundbreaking innovations like the Internet, global positioning technology, and Stealth that DARPA-funded, blue-sky research has produced in the past (Bordoff et al., 2006, p. 9). Similarly, the Services own 80 percent of the defense basic R&D; however, they are primarily interested in mission-focused research, not blue-sky research (Rees, 2008a, slide 22). Figure 7 shows the federal R&D obligations for Fiscal Year 2007. What is most telling is DoD's lack of interest in basic R&D—only 2 percent (NSB, 2008, p. 4–25, Figure 4-6). If DoD wants to

If DoD wants to continue its long-held strategy of "quality over quantity" via high-technology and modernization, it must continue to expand its basic R&D investment.

continue its long-held strategy of "quality over quantity" via high-technology and modernization, it must continue to expand its basic R&D investment. Second, the public basic R&D portfolio reflects a growing imbalance. Between 1995 and 2005, biomedical basic R&D increased by 115 percent—four times the rate of increase in basic R&D in the physical sciences, mathematics, and engineering, which are the disciplines most applicable to DoD initiatives (AAAS, 2006). In the $789 billion American Recovery and Reinvestment Act signed into law on February 17, 2009, $21.5 billion is for federal R&D with the majority—$10.4 billion or 48.4 percent—going to the National Institutes of Health (NIH) for medical research, of which $6.5 billion alone is for biomedical R&D. The next largest share at $3 billion—a factor of 3.5 times less than the NIH share—went to the NSF (Figure 8) (AAAS, 2006). While advances in medicine are worthy, limiting research—particularly research in the physical and engineering sciences that apply to a broad array of scientific fields, including biomedical—limits innovation potential (National Research Council, 2001). And finally, basic R&D does more than just generate new discoveries and knowledge; it also prevents technological surprise, educates S&Es so that they can be more effective, and sustains the human talent and research infrastructure so critical to national security and economic growth (Rees, 2008b, p. 2). To stop and reverse this innovation implosion, new policies are needed to

FIGURE 8. 2009 ECONOMIC RECOVERY BILL FEDERAL R&D FUNDING—HOUSE, SENATE, AND FINAL BILLS



Note. NIH = National Institutes of Health; NSF = National Science Foundation; DOE = Department of Energy; NIST = National Institute of Standards and Technology; NASA = National Aeronautics and Space Administration. Adapted from *Final Stimulus Bill Provides $21.5 Billion for Federal R&D,* by American Association for the Advancement of Science, 2009.

increase public and private R&D as well as incentives to increase the number of quality American-born S&Es.

Policy Recommendations

U.S. technological leadership requires effective government policies to keep the nation at the leading edge of the scientific frontier. "The attack [September 11, 2001] was sort of like when Sputnik went up and created the National Defense Authorization Act in 1958"; however, Americans need to once again find the excitement and urgency of 50 years ago that led to technological achievements such as the Apollo moon landings (NDEP, 2009a, p. 2). Time is of the essence because the Apollo generation is ripe for retirement. U.S. leadership should create and pass a National Security Education Act for the 21st Century to provide a strategic framework for national security and economic policies. The following policies, while not an exhaustive list, would be a step in the right direction.

National Innovation Policy Recommendation

Simply funding more basic research and educating more S&Es is not enough. The United States must create national innovation policies to provide focus, to avoid excessive duplication with

limited research dollars, to promote the diffusion of innovative ideas across private and public lines, to advocate for innovative projects, to ensure a continuous supply of quality S&Es and basic R&D resources, and to tie innovation to U.S. economic and national security. In addition, the developer, owner, and executor of innovation policy should be the Office of Science and Technology Policy headed by the Science Advisor to the President, thus providing clout to innovation policy.

S&E Policy Recommendations

Increase the number and value of S&E graduate research fellowships (GRFs). At a minimum, the NSF should triple its GRFs to restore the ratio of GRFs to undergraduate engineering degrees to the ratio that existed in the early 1960s, following Sputnik (Freeman, 2006, pp. 2–3). Increasing GRFs will incentivize the most talented S&E students to continue on to graduate work versus pursuing more lucrative fields (Bordoff et al., 2006, p. 7).

Continue to attract the best and brightest S&Es from abroad. Highly skilled immigrant S&Es contribute significantly to U.S. economic growth. For example, a third of all businesses founded in the Silicon Valley in the 1990s were started by foreign-born S&E entrepreneurs. The Russian-born Sergei Brin started Google; and eBay was started by Pierre Omidyar, an Iranian born in Paris. Also, one-half of U.S. Nobel laureates in science are foreign-born (Bordoff et al., 2006, p. 7). And finally, foreign-born competition will drive U.S.-born S&Es to achieve greater educational heights and innovation to compete.

Increase the H-1B visa caps to pre-9/11 levels. "The U.S. is failing to take full advantage of the global talent pool" (Bordoff et al., 2006, p. 8). The number of international S&E students in U.S. graduate programs declined by 20 percent between 2001 and 2004 (Bordoff et al., 2006, p. 8). The United States must reverse this trend to maintain its innovative edge.

Improve STEM education. By developing programs that demonstrate the practical uses of math and science, the government can generate interest in STEM careers and support students interested in these programs through government-funded fellowship, thus providing a steady stream of S&E talent.

Basic R&D Policy Recommendations

Increase public basic R&D resources (funding and facilities) and apply them based on overall effectiveness. This will help balance basic R&D investment over all scientific fields, particularly the physical sciences,

mathematics, and engineering that have broad applications, to avoid overinvestment in particular areas such as biomedical, at the expense of others.

Incentivize private basic R&D through R&D tax credits. Tax credits would incentivize private firms to conduct basic R&D in areas that reflect public interest, in addition to increasing innovation and spin-off commercial opportunities that increase economic growth (Atkinson & Wial, 2008, pp. 8, 11).

Employ prizes when applicable. Prizes, particularly in the multimillion-dollar range, could entice researchers that would otherwise not do business with the government due to bureaucratic red tape. In addition to bringing in fresh ideas, prize strategies increase the resources brought to bear on a problem because research teams apply their own funds in the hope of winning (Bordoff et al., 2006, p. 10).

Regulate intellectual property rights such that innovation is maximized while protecting innovator's rights. The number of patents granted increased from a rate of less than 1 percent a year from 1930 to 1982 to 5.7 percent a year from 1983 to 2002. In addition, the intellectual rigor required to receive a patent also decreased (Jaffe & Lerner, 2004, p. 25). As a result, excessive and inappropriate patents keep innovation out of the public realm (Nelson & Romer, 1996, p. 19).

Conclusions

Innovation is more important to the U.S. economy and national security now than in the past. Since World War II, the United States has been the leader in innovation; however, international competition is posing a growing challenge to U.S. technological supremacy. The United States has the best market environment in the world to support innovation, but arguably weak innovation policies. Effective government innovation policies are critical to keeping the nation at the leading edge of the scientific frontier. "What makes knowledge, innovation, and technology such powerful drivers of economic growth is that, unlike capital and labor, they do not suffer from diminishing returns"; therefore, America must rebuild its foundation of competitiveness—its supply of S&E talent and basic R&D resources—that have served the country so well for the past 50 years (Atkinson & Wial, 2008, p. 19). The challenges are real and growing, so knowledge generation and innovation must become a national priority. Sir Isaac Newton captured this continuation of

innovation best when he said, "If I have seen further, it is by standing on the shoulders of giants" (Atkinson & Wial, 2008, p. 11).

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