The Eroding Foundation of National Security

It is relatively common to cite numbers of aircraft, tanks, and ships as a surrogate for military strength. But over the longer term, a better measure is the relative size of a nation's economy, with particular emphasis on those components relating to technology and manufacturing. Examining this point of view and assessing the US outlook, assuming the nation's current trajectory is sustained, the implications are not encouraging.

A few years prior to the attacks of 9/11, the US Congress created a bipartisan commission to propose a national security strategy for the early part of the twenty-first century. This endeavor, led by Senators Gary Hart (D-CO) and Warren Rudman (R-NH), became known simply as the Hart-Rudman Commission. The commission's staff was led by Gen Chuck Boyd, USAF, retired, whose enormous service to the nation included seven years as a resident of the "Hanoi Hilton" and related environs. Senator Hart has since described the effort as perhaps the most important thing he has ever worked on—strong words given his role on the Warren Commission and contributions to resolving many critical national security issues. There were about 15 members of the commission, representing all parts of the political spectrum. The resulting report was unanimously endorsed by the participants.

The first of two major findings in the report—which took almost two years to prepare and was released *prior* to 9/11—stated that Americans were likely to die on our nation's soil by the tens of thousands due to the actions of terrorists. We did not base this unfortunately rather prescient conclusion on any hard intelligence—rather, it stemmed from a few pieces of simple logic. First, there are a large number of people on this planet who harbor intense hatred for the United States and its success. Second, following the end of the Cold War, the US military had such predominant relative strength that it made no sense for an enemy to engage the United States in conventional combat. Third, modern technology had, for the first time in history, made it possible for individuals, or small groups acting alone, to profoundly disrupt the lives of very large groups of people.

The commission made a number of recommendations, including the need to establish a homeland security organization that would involve the elements that now largely form the Department of Homeland Security. Unfortunately, the report was released during a period when the

nation was preoccupied counting chads and butterflies on presidential election ballots and thus was largely ignored. In fact, to this day only one of the 50 recommendations offered by the commission has been implemented: creation of the Department of Homeland Security. Unfortunately, as history progressed, Congress soon had 108 of its committees and subcommittees providing oversight of that department.

A second major finding of the Hart-Rudman Commission warned that "second only to a weapon of mass destruction detonating on an American city, we can think of nothing more dangerous than a failure to manage properly science, technology and education for the common good." This finding seemed to come as somewhat of a surprise to many readers. After all, this was a commission established to examine US *defense* needs—yet its principal findings did not propose that the nation needed more carrier battle groups, more tactical air wings, or more infantry divisions. Rather, the report's findings focused heavily on science, technology, and education; not because the size of the nation's military force is not of the utmost importance, but because the latter was suffering from even greater neglect.

A few years later, a committee was established by the Congress, once again on a bipartisan basis, with the purpose of examining the nation's ability to compete in the evolving global economy. The resulting effort was conducted by the National Academies of Science, Engineering, and Medicine and produced, among other publications, a 500-page book generally referred to as the "Gathering Storm report," after the first line in its title.[1]

This committee, unanimous in 19 of its 20 recommendations (the sole dissenting vote considered it unnecessary for the federal government to fund energy research), was composed of 20 members and included presidents of public and private universities, CEOs of Fortune 100 companies, former presidential appointees, three Nobel Laureates, and the head of a state public school system. Upon completing our work, two members joined the president's cabinet, one as secretary of energy and the other as secretary of defense.

While not specifically focused on national security matters, the committee clearly recognized that without a viable economy there could be no viable defense. The chairman of the Joint Chiefs of Staff more recently echoed this view during congressional testimony, and the experience of the Soviet Union as the Cold War drew to a conclusion served to punctuate his assertion.

The arithmetic is relatively simple. Without a strong economy, there will be modest tax revenues. With modest tax revenues, there will be

modest funds for defense. With modest defense, the nation will be endangered. The question thus becomes, How does the United States maintain a strong economy in this revolutionary age of globalization?

But it is not only a failure of the nation's *overall* economy that could undermine US national security. The ability to conduct modern warfare is also heavily dependent upon two particular elements of the economy. The first of these is science and technology, and the second is manufacturing.

For more than a half century, secretaries of defense have pointed to the importance of maintaining technologically superior forces as an offset against larger forces maintained by other nations. Technological advantages have been known to have decisive impacts throughout the history of warfare. Pivotal advancements include gunpowder, the stirrup, longbow, machine gun, tank, aircraft, atomic bomb, ballistic missile, nuclear submarine, precision-guided ordnance, space systems, night vision, stealth, and more.

Importantly, unlike during the Cold War era, the leading edge of the state of the art in most technological disciplines no longer resides within the Department of Defense or the "defense industry." Increasingly, the nation's defense will depend upon adapting innovations that have their roots in the commercial sector. Thus, the extent to which the nation maintains a military lead will increasingly be a function of the global competitiveness of the United States.

But with a heavily service-oriented economy (with the service sector gradually increasing from 31 to 73 percent of overall output since 1850) and a declining manufacturing sector (declining from 23 to 12 percent of GDP in the past 40 years), it becomes highly problematic how the nation's military can be provided the equipment it needs to ensure success in times of conflict or crisis. Recall that during the peak of production in World War II, the United States manufactured 13 aircraft *per hour,* 24 hours a day, seven days a week. This is certainly not to neglect other important aspects of modern warfare, but manufacturing still counts—as does technology.

The two highest-priority recommendations included in the Gathering Storm report were, first, that the United States must repair its failing K–12 public education system, particularly in math and science; and, second, that it must substantially increase its investment in scientific research. The two US presidents who held office since the report was released, one a Republican and one a Democrat, both strongly embraced these findings. But implementation has, once again, been sporadic—at best.

The fundamental issue is not how the United States is faring in comparison to itself in previous eras, but how it will fare in the burgeoning world of globalization. Arguably, globalization has been prompted by two technological advancements. The first is the advent of modern jet aircraft that make it possible to move objects, including people, around the planet at nearly the speed of sound. The second is the development of information systems that move ideas and knowledge around the world literally at the speed of light. Significantly, both these advancements trace their roots to work sponsored by the US Department of Defense. The result, as pronounced in the words of Frances Cairncross of *The Economist,* is that "distance is dead."

Yes, distance *is* dead. In fact, Nobel Laureate Arthur Compton forecast as long ago as 1927 that "communication by printed and spoken word and television [will be] much more common . . . so that the whole earth will be one great neighborhood." The author of the bestseller *The World is Flat*, Tom Friedman, stated, "Globalization has accidentally made Beijing, Bangalore and Bethesda next-door neighbors."

One of the more profound consequences of globalization is that individuals will no longer compete for jobs simply with their neighbors across town; rather, they must compete with their neighbors across the planet in such places as Tianjin, Taiwan, Toulouse, Tokyo, and Trivandrum.

Concurrently, the business neighborhood is also internationalizing at an unprecedented rate, with some three billion new would-be capitalists having entered the global job market following restructuring of the world's geopolitical system just prior to the beginning of the current century. These individuals are increasingly well-educated, particularly in science and technology; highly motivated; and willing to work for a fraction of the wage to which the average US worker has become accustomed.

Ironically, in this new world disorder we can expect that the "established" nations will be the most challenged. One reason is that past success desensitizes the ability to recognize and respond to needed change. Why would anyone change the very things that have put one in first place?—a question that might have been asked by the leaders of Spain in the sixteenth century, France in the eighteenth century, England in the nineteenth century, and even the United States in the twentieth century. It might also have been asked by the leaders of such businesses as Kodak, Pan Am World Airways, and Blockbuster. As Wall Street lawyers are fond of reminding, past performance does not assure future results.

Another reason why today's industrialized nations may be the most challenged in the emerging era is an economic one: nine factory workers can be hired in Mexico for the cost of one in the United States; in Viet-

nam, 20 assembly workers can be hired for the cost of one in the United States; five chemists can be employed in China for the cost of one in the United States; and eight engineers can be hired in India for the cost of one in the United States. Productivity rates of course differ from country to country but not nearly enough to offset differences of such magnitudes. Over time, wages will of course rise in the developing countries, as they already have in China, but because of the sheer size of the world's potential workforce, it will take decades to approach equilibrium, particularly for the less-skilled portion of the workforce.

Adding to the employment challenge in developed countries is that many low-end skills can now be performed by robots. Indeed, technology can destroy jobs just as it can create them—all part of the chaos of the marketplace. During the recent economic downturn, one-third of US manufacturing jobs—5.5 million jobs—disappeared. Forty-two thousand factories closed. A few of these are now reopening—but with smaller, less-well-paid workforces that produce the same output as before. It should be emphasized that it is not simply factory workers whose jobs are being affected by this trend; it is increasingly a "full-spectrum" problem, impacting accountants, dentists, radiologists, architects, professors, scientists, lawyers, and engineers—even basketball and baseball players. Further, it is no longer simply factories that are moving abroad; the list now includes research laboratories, logistics depots, administrative offices, financial centers, and prototype shops.

A strong economy is in part propelled by a citizenry with significant purchasing power. In this regard it is estimated that within a decade, 80 percent of the world's middle class will reside in what are now categorized as developing nations. In less than two decades, more middle-class consumers are projected to live in China than in all the rest of the world combined. There are already 80 million people in China who can reasonably be characterized as middle class. Globally, it is estimated that by the mid 2020s, there will be two billion such consumers—with the number in China exceeding the total population of the United States at that time by a factor of two.

One consequence of this global restructuring is, forecasters say, by 2050 less than 20 percent of the world's gross "domestic" product will be generated by the United States and Europe *combined*—further suggesting the magnitude of the shift that is engulfing the planet. Of course, the possibility exists that some other nations could implode; however, it has never been a particularly sound business strategy to assume that one's competition will simply "implode."

Various studies, one of which led to a Nobel Prize, have demonstrated that during the past half-century, 50–85 percent of the increase in the nation's GDP is attributable to advancements in science and technology, as is two-thirds of the increase in productivity. Scientists and engineers comprise less than 5 percent of the nation's workforce, but, importantly, the work performed by that 5 percent disproportionately creates jobs for much of the other 95 percent.

Given these figures, each 1 percent of the population that is composed of scientists and engineers underpins about 15 percent of the growth in GDP. Over the long term, each percentage point of growth in GDP is accompanied by about 0.6 percentage point's increase in overall employment. Hence, one might conclude that, within limits, each 1 percent of the workforce engaged in science and engineering accounts for on the order of 10 percent of the increase in jobs—a substantial multiplier.

For example, the invention of the iPad, the Blackberry, and the iPhone—all rooted in much earlier research performed in solid state physics—created jobs not only for scientists and engineers, but also for factory workers, truck drivers, salespersons, and advertisers. The *Journal of International Commerce and Economics* notes that in 2006 the 700 engineers working on Apple's iPod were accompanied by 14,000 other workers in the United States and nearly 25,000 abroad.

Floyd Kvamme, a highly successful entrepreneur and former chair of the President's Council of Advisors on Science and Technology, has said that "venture capital is the search for good engineers." Steve Jobs told the president of the United States that the reason Apple employs 700,000 workers abroad is because it couldn't find 30,000 engineers in the United States. Microsoft is currently establishing a software facility across the border in Canada because US immigration policy precludes it from hiring the talent it needs from around the world.

Other than its democracy, free enterprise system, and rule of law, perhaps the greatest competitive advantage the United States has enjoyed in recent decades has been its array of great universities. According to *The Times* of London, the top five universities in the world—and 18 of the top 25—are located in the United States. The highest-ranking Chinese institution currently holds 17th place, although massive efforts are underway to enhance China's higher-education system. Rankings by China's Shanghai Jiao Tong University place US institutions in five of the top six places and 18 of the top 25.

Recently, however, as US state and local tax revenues declined precipitously due to the economic downturn, the nation's public institutions of higher learning found themselves facing severe budget shortfalls—some

requiring Draconian corrective measures, such as the 65 percent tuition and fee increase imposed by the State of California during a single three-year period. During the past decade, the state universities that educate 70 percent of the nation's students have on average suffered a 24 percent budget reduction, not including the effect of inflation. State funding for colleges and universities per student is now at a 25-year low. To partially offset this shortfall, average net (after financial aid, much of it provided by taxpayers) tuition has increased at a rate that far exceeds either the inflation rate or the growth in family income. In short, many states have simply decided to disinvest in higher education, de facto privatizing their research universities but without the commensurate endowments.

The US scientific enterprise would barely function today were it not for the larger number of immigrants who came to the United States, most in search of an education, and remained to contribute upon completing their academic work. However, fewer of the very best foreign minds are now coming to the United States for their education, and of those who do, fewer are remaining. Worse yet, US immigration policy seems designed to drive such individuals out of the country after they receive their degrees.

And that brings one to the presumptive source of much of America's future science and engineering talent, particularly in the national defense arena: the US public K–12 system—or, more accurately, system of systems—with its 14,000 independent school districts, 99,000 schools, 49 million students, and 3.2 million teachers. Were one to give this system a grade, it would be generous to assign a C-minus—which is not a formula for continued success by a nation whose citizens are accustomed to a lifestyle supported by a GDP-per-capita that is six times that of the average for the rest of the world.

The domestic K–12 pipeline for college graduates includes, of course, some outstanding schools, some exceptional teachers, and some extraordinary students. Further, the proliferation of charter schools, albeit at a rather glacial pace, is having a net positive effect. So too are such private initiatives as Teach for America, Math for America, the National Math and Science Initiative, FIRST, and numerous other such endeavors, but each on a small relative scale. Whatever the case, in international tests in math and science, US students are firmly ensconced near the bottom of the global class.

In international standardized tests involving 15-year-olds from 34 OECD countries, US students now rank 21st in science and 26th in mathematics—a further decline of four places in science and one in math during the past three years alone. Writing scores are the lowest ever

recorded by US students, and a report by the Hartland Program on Education Policy and Governance ranked the US high school class of 2011 as 32nd in overall performance among the 34 OECD nations. Others have noted that math scores of the children of janitors in Shanghai are markedly superior to those of the children of professional workers in the United States.

In US standardized tests, sometimes referred to as the Nation's Report Card, 67 percent of US fourth graders scored "not proficient" (the lowest ranking) in science. By eighth grade that fraction had grown to 70 percent, and by twelfth grade it reached 79 percent. Seemingly, the longer young people are exposed to the US public K–12 education system, the worse they perform. In contrast, when the head of a large US city's public school system visiting Finland asked her counterpart if she knew what percent of their students were performing below grade-level, the reply was, "Why, I can tell you their names."

A little analysis reveals additional disconcerting trends. During the 40 years the US National Assessment of Education Progress test has been administered, real spending per student increased by 140 percent and staffing per student increased by 75 percent. Meanwhile, scores in reading and science were basically unchanged, and math scores declined slightly.

Mathematics scores among nine-year-olds, the so-called bright spot in recent tests, did improve slightly. But overlooking the fact that few firms or the US military employ nine-year-olds, at the evidenced rate of improvement it will take about 150 years for these public school students to catch up with their private school counterparts, even in this country, assuming the latter also continue to improve at their historic rate. And this has little to do with catching up with the youth of Finland, Hong Kong, Taiwan, India, Singapore, and China.

Perhaps most disheartening of all is the epidemic of self-delusion now permeating the nation that might be referred to as the "Race to the Bottom." This is a race wherein some states lower their standards to obscure the poor absolute performance of the students for whose education they bear responsibility. The Vital Signs Report issued by Change the Equation notes that "Across the nation, only 38 percent of U.S. 4th graders were proficient or advanced in math in 2009. Yet states, on average, reported proficiency rates that (based on the state's own tests) were a full 37 percentage points higher."

Recently, some parents, school systems, and even states have begun holding their children out of class on the day standardized tests are administered in an ostrich-like response to the K–12 dilemma. Yes, there

is considerable pressure in taking standardized tests, and, yes, there is considerable pressure out there in the global job market as well. And, no, the Common Core standards being used in math and reading are not a federal government takeover of elementary and secondary education; the standards were instituted by the governors of 45 states and the District of Columbia as guidelines for what a youth must learn to survive and prosper in the global economy.

It is also occasionally argued that the United States seeks to educate a larger proportion of its youth than other nations; however, an analysis conducted under the auspices of Harvard's Kennedy School of Government indicates that the fraction of US students scoring at the highest of three levels of performance in a standardized mathematics test was "*significantly exceeded*" by students in 30 of the 56 participating nations. Similarly, highly accomplished US students with at least one college-educated parent ranked behind overall highly accomplished students in 16 countries, no matter the educational level of the latter's parents.

One may recall how strongly Americans reacted a few years ago when it was discovered that our nation's Olympic basketball team no longer ranked first in the world. Yet, at the same time, the populace seemed remarkably complacent that our nation ranked 6th in innovation-based competitiveness, 12th in percent of adults with college degrees, 15th in science literacy among top students, 16th in college completion rate, 20th in high school completion rate, 23rd in the state of physical infrastructure, 27th in life expectancy, 28th in mathematics literacy among top students, 40th in improvement of innovation-based competitiveness in the decade, and 48th in the quality of overall K–12 math and science education. Worse yet, the nation's position has generally deteriorated since these rankings were collected.

It is worthy of note how quickly a leadership position in science or engineering can vanish in the face of the rapid rate of change in these particular fields. Craig Barrett, former CEO of Intel and a member of the committee that prepared the Gathering Storm report, points out that more than 90 percent of the revenues Intel realizes on the last day of any given year is derived from products that did not even exist on the first day of that same year.

According to the College Board, only 43 percent of all college-bound US high school seniors meet "college-ready" benchmarks. ACT, another organization that administers college entrance examinations, concludes that the figure is only 24 percent, and this of course excludes the nearly one-third of students who either never began or dropped out of high school. Nor does it reflect the one-third of those who do graduate high

school but do not enter college. In the case of potentially pursuing an education in engineering, the college-ready proportion is found to be about 15 percent.

A root cause of this dilemma is that 69 percent of 5th–8th grade students in US public schools are taught math by teachers who possess neither a degree nor a certificate in math. Fully 93 percent of these students are taught physical sciences by teachers with neither a degree nor a certificate in the physical sciences. In fact, more than half of the nation's science teachers have not had a single college course in the field they teach.

There are a plethora of reasons why the United States suffers a shortage of qualified teachers, among which are lack of prestige assigned by the public to the teaching profession, lack of discipline in the classroom, demanding work, and inadequate pay for the best teachers.

The latter tells a great deal about the nation's priorities. *US News and World Report* observed a few years ago that a high school teacher in the United States needed to work 43 hours to make $1,000. But a corporate CEO could, on average, do so in two hours and 55 minutes, Kobe Bryant took five minutes and 30 seconds, and Howard Stern needed to labor only 24 seconds in his chosen profession. In 40 of the 50 states, the highest-paid public employee is a college football or basketball coach.

When Americans are willing to pay more to ensure their city's professional football team has a good quarterback than to ensure their children have good teachers, it should not be a surprise that 53 percent of the nation's teachers abandon the classroom within five years to pursue other careers. For once, the problem is *not* a lack of funds. The United States spends more per K–12 student, totaling 7.4 percent of GDP, than any other country with the exception of Switzerland. The worst-performing schools in the nation are in Washington, DC—which just happens to be where the most highly funded public schools are found. Based on the writer's travels in 112 countries, it appears not to be without justification that Bill Gates has remarked, "When I compare our high schools to what I see when I'm traveling abroad, I'm terrified for our workforce of tomorrow."

He might also have been terrified by what he has seen as it affects recruiting future US armed forces. The nation's K–12 system is not only the source of future scientists and engineers who will build the economy that underpins national defense and produces leading-edge military capabilities, it is also a source of military manpower. The modern war fighter requires technical skills to operate and maintain sophisticated military systems, including the latest devices of cyber warfare. Discon-

certingly, 75 percent of today's military-age youth are deemed unqualified to serve in the US armed forces at all, because of mental shortcomings, physical inadequacies, moral failings, or all three.

Ironically, as many former school board members have learned, the fastest way to be voted out of office is to propose that the length of the school day be extended. But in 2011, 292 school districts did in fact change the length of the school week: *shortening* it to four days—largely a consequence of mounting budgetary pressures. Even before this trend began, the US school year averaged 180 days, while the school year in China was 220 days—a 22 percent difference. The short school year in the United States was of course intended to free students so they could help with the harvest, something that relatively few students do today. No business could survive if it closed its plants for three months a year.

Management consultants McKinsey & Company sought to link GDP—not an unreasonable surrogate for the standard of living in a country with a relatively stable population—with K–12 educational achievement. It concluded that if US youth could match the academic performance of students in Finland, the size of the US economy would increase between 9 and 16 percent; that is, about two trillion dollars.

In the face of such statistics, an interesting but largely unknown experiment in education has been taking place in New York City, where the Harlem Success Academy has been selecting students from the local neighborhood by lottery. Yet, in standardized tests, six nearby public schools have only 31 percent of their students proficient in reading and 39 percent in math while the Harlem Success Academy has 88 percent of its students proficient in reading and 95 percent in math. To be sure, not all charter schools have been as successful—but the overall evidence in their favor is compelling.

The American Dream simply does not work without quality education for *all*. Between 1979 and 2004, the real after-tax income of the poorest one-fifth of Americans rose by 9 percent; that of the richest one-fifth by 69 percent; and that of the top 1 percent by 176 percent. Further, children in the highest quartile of academic performance but with parents in the lowest economic quartile have a lower probability of graduating from college than children in the lowest academic quartile with parents in the highest economic quartile. This is not the American Dream. Today's younger generation is the first in US history to be less-well-educated than their parents. They are almost certain to be less healthy than their parents. And surveys indicate that two-thirds of today's parents believe their children are likely to enjoy a lower standard of living than they themselves enjoyed. According to the Hamilton

Institute, the median income of men between 25 and 64 years of age fell 28 percent over the 40-year period ending in 2009. In the case of high school graduates who did not attend college, the decline in income was 47 percent.

Given the situation that exists in grades K–12, it is not surprising that the nation's supply of engineers and physical scientists has become a major concern to many US corporate executives. It is an even greater concern among those who bear responsibilities for national security and cannot simply shift engineering and manufacturing offshore and for whom the requirement for security clearances largely limits the employee pool to US citizens. Nearly two-thirds of the students who receive doctorates in engineering from US universities today are foreign born.

The Gathering Storm report, among numerous other assessments, concluded that if the United States is to create jobs for its citizens, leading in innovation is a necessary but not sufficient condition, as mathematicians like to say. To maintain a leading position will require that a cadre of citizens be produced who excel in science and engineering and also that the citizenry as a whole be equipped to hold jobs in a hi-tech world. Yet, today, only 16 percent of US baccalaureate degrees are awarded in science and engineering. In China, the corresponding share is 47 percent, and in Singapore even more. In the singular case of engineering degrees, the share in Asia is 21 percent; in Europe, 12 percent; and in the United States, 4.5 percent. By almost all of these measures the United States was ranked first, or near-first, only a few decades ago, a time when the foundation was being laid for the technological advancements that are the basis of much of today's economy.

In terms of the fraction of baccalaureate degrees that are awarded within the discipline of engineering, the United States ranks 79th among the 93 nations considered in one recent study. The only countries ranked behind the United States in this respect were Bangladesh, Brunei, Burundi, Cambodia, Cameroon, Cuba, Zambia, Guyana, Lesotho, Luxembourg, Madagascar, Namibia, Saudi Arabia, and Swaziland. The United States most closely matches Mozambique in the fraction of graduates studying science and engineering.

During the past two decades—part of an era that has been described as technology's greatest period of accomplishment—the number of engineers, mathematicians, and physical scientists graduating in the United States with bachelor's degrees actually *fell* by more than 20 percent, until a very recent up-tick as the shine on careers in law and on Wall Street began to tarnish. This contrasts with a *growth* during the above time

period in the production of lawyers of 20 percent and masters in business administration of 120 percent.

The number of engineering *doctorates* awarded by US universities to US citizens actually *dropped* 34 percent in the decade prior to the release of the Gathering Storm report. Reflective of this is a full-page article that appeared in the *Washington Post* that bore the headline "How to Get Good Grades in College." A sub-headline advised, "Don't Study Engineering." Apparently many young people read the *Washington Post*. Speaking to a group of political leaders in the nation's capital, Jeff Immelt, CEO of General Electric, forthrightly shared his opinion on the topic: "We had more sports-exercise majors graduate than electrical engineering graduates last year. If you want to become the massage capital of the world, you're well on your way." And this is in spite of the fact that 43 percent of the grades awarded by US colleges and universities are now A's, the grade most commonly granted. In 1970, 27 percent of grades were A's. Yet, the average full-time student at a four-year college now spends 12 hours a week in class and 14 hours studying outside of class for a 26-hour workweek. Not surprisingly, employers state that three-fourths of the college graduates *that they actually hire* are not prepared to enter the work force, educationally, culturally, or both.

A popular misconception is that STEM (science, technology, engineering, mathematics) professions do not pay well—a conclusion sometimes based on comparisons with the extraordinary compensation received by a few individuals working on Wall Street, in entertainment, or sports, particularly prior to the "dot.com bubble" period. One study has shown that on average, STEM workers earn 26 percent more than their non-STEM counterparts who possess comparable levels of education. The most common undergraduate degree among Fortune 500 CEOs is an engineering degree. Furthermore, following the 2008 financial crisis when overall unemployment exceeded 10 percent, it peaked at 5.5 percent in STEM fields. Exacerbating the dilemma in producing scientists and engineers is the enormous "leakage" in the talent pipeline. If, in the year 2030, the United States needs one additional engineering researcher with a PhD, we must begin with a pool of about 3,000 students in 8th grade today.

Another major problem is that in the United States, engineers are all too seldom a woman or a member of a minority group. Women, comprising half the nation's population and 58 percent of its undergraduate degree recipients, receive only 20 percent of the engineering bachelor's degrees and 19 percent of the engineering doctorates awarded by US universities. In contrast, women now receive a majority of the degrees

in law and medicine and represent an extraordinary 72 percent of high school valedictorians.

Members of minority groups also receive a disproportionately small share of science and engineering degrees. For example, African Americans and Hispanics, each comprising about 13 percent of the US population, receive fewer than five percent each of the bachelor's and doctoral degrees awarded in these fields. There have been recent encouraging signs of gains; however, the improvement to date has been on the margin. This is a particular concern for the long term since demographic results indicate that within about three decades, minorities will make up the majority within the United States, and that is already the case among those younger than 18 years of age.

Ironically, there will probably never again be a shortage of engineers in the United States in terms of overall numbers. The reason is that US firms can now readily ship much of their engineering work overseas if there are insufficient numbers of engineers at home. One problem, of course, is that most of the jobs those engineers create will also be located overseas.

One periodically reads that there are too many engineers in the United States. There are several reasons why this claim deserves scrutiny. The first is that although the nation graduates more individuals with engineering degrees than there are engineering jobs, many of those receiving such degrees plan to continue their careers in other fields, including business, medicine, and law. Engineering degrees are broadly considered an excellent undergraduate foundation for studies in a variety of other disciplines. Another factor is that the pace at which new knowledge is being developed is so rapid that engineers who do not keep up with the state of the art very quickly find themselves irrelevant and members of the so-called "excess" of engineers.

The issue is not that the nation may have too many engineers and scientists; the issue is that the nation may have too many engineers and scientists *relative to what the nation chooses to invest in what engineers and scientists do*—such as build modern infrastructure, create jobs for others, support national security, produce clean forms of energy, and help counter disease. With regard to the latter, the field of biomedical research, a discipline strongly supported in public surveys, has witnessed a decline in government funding of 23 percent in real terms during the past decade after a significant "catch-up" period a few years earlier. Overall, the United States has sunk from first to tenth place in the fraction of GDP devoted to R&D and to 26th in the world in the share of national R&D funding provided by government. China is projected to surpass

the United States in R&D investment in both absolute terms and as a fraction of economic output within a decade.

One might reasonably argue that investing in research should be the province of the nation's industrial sector, since industry is a major beneficiary of the results of research. But a survey conducted by the US National Bureau of Economic Research reveals that 80 percent of the senior corporate financial executives questioned said they would be willing to forgo funding research and development to meet near-term profitability projections. Constructive or not, the reality of the "next-quarter-oriented" financial markets is to greatly emphasize near-term results at the expense of long-term, high-risk endeavors—such as research and development. Today, shareholders of Fortune 500 firms hold their stock in a particular company on average only four months, thereby having little interest in investing in research. Thus, to an ever increasing extent, America's future resides upon our federal government providing the funds needed to support research that will largely be conducted in the nation's universities. The great industrial research institutions such as the iconic Bell Laboratories seem to have seen their best days.

Intel's Howard High's comments are fairly representative of the demands placed on US industry: "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 in the next ten years." Or, in the words of DuPont's then-CEO, Chad Holliday, "If the U.S. doesn't get its act together, DuPont is going to go to the countries that do." Bill Gates says, "We are all going where the high I.Q.'s are." Why do they do this? Because it is what their shareholders demand.

An analysis of the most recent Standard & Poor's index of the 500 largest publicly traded US corporations shows that 47 percent of their corporate revenue already comes from *outside* the United States. Under this scenario "American" firms and their shareholders can still prosper and CEOs can still receive their bonuses, but there will be fewer jobs for the average US worker, a greatly diminished defense industrial base, and reduced funding available for the nation's armed forces. Furthermore, US corporate tax policy is designed to keep US firms from investing at home the profits they earn overseas. Today, more than a trillion such dollars are sitting abroad looking for investment opportunities there.

But if we must rely on the federal government to support a greater share of research, the government's own Congressional Budget Office projects that if established practices continue, by the year 2043 "entitlements" (mostly social programs) and interest on the national debt will entirely consume federal revenues—leaving no money whatsoever for

research (or education or defense). Interestingly, that is the year a child born today would nominally receive a PhD in science or engineering.

It is popular among politicians to blame China for this predicament in which the United States finds itself. But is it China that runs our public schools? Does China decide how many Americans will study science and engineering? Does China train the nation's teachers? Does China decide how much the United States should invest in research?

The bottom line, even as the United States today faces a major debt crisis, is that its leaders need to understand the difference between spending for investment and spending for consumption. While the nation will need to do a lot less of the latter, it will need to do a lot more of the former. US national defense depends on maintaining a strong economy, and a strong economy in this age demands prowess in science and engineering. Prowess in science and engineering depends on an educated citizenry and investment in research—and in both of these foundational areas, the United States is failing.

While testifying before a committee of the Congress in support of funding for education and research, I was asked by a member, "Mr. Augustine, do you not understand that we have a budget crisis in this country?" I responded by saying that I am an aeronautical engineer and in my career worked on a number of airplanes that during their development programs were too heavy to fly. Never once did we solve the problem by removing an engine. In the case of creating jobs for Americans, it is research, education, and entrepreneurism that are the engines of innovation, the creators of jobs, and therefore the underpinning of the nation's defense capability. I was flattered when President Obama used this analogy during his State of the Union Address. SSQ

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Note

1. Institute of Medicine, National Academy of Sciences, and National Academy of Engineering, *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington: National Academies Press, 2007), available for free download at http://www.utsystem.edu/competitive/files/rags-fullreport.pdf.

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