Fall 2005

The BRIDGE

LINKING ENGINEERING AND SOCIETY

NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES

Promoting the technological welfare of the nation by marshalling the knowledge and insights of eminent members of the engineering profession.

The
BRIDGE

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Erratum
Richard Schwartz, chair of the Committee on Engineering Studies at Tribal Colleges, was incorrectly identified in the June issue. Dr. Schwartz is co-director of the Birck Nanotechnology Center and former dean of engineering, Purdue University.

A complete copy of each issue of *The Bridge* is available in PDF format at *http://www.nae.edu/TheBridge*. Some of the articles in this issue are also available as HTML documents and may contain links to related sources of information, multimedia files, or other content.

The BRIDGE

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LINKING ENGINEERING AND SOCIETY

Editor's Note

Features

NAE News and Notes

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Editor's Note

George Bugliarello is President Emeritus and University Professor at Polytechnic University in Brooklyn, New York, and foreign secretary of NAE.

Globalization and Engineering

Globalization is not a new phenomenon. Carthage, Rome, the Ottomans, several European powers, and mercantile city-states had multicontinental trading networks made possible by a combination of economic power, military power, and the latest technology. At certain stages in their history, they all outsourced elements of production, education, and even armies. Eventually, however, these globalizations collapsed, often because of the political and economic consequences of war.

The globalization we are experiencing today is unprecedented in its magnitude and reach. The whole world has become a market for the economies of many countries, and globalization is transforming not only the location and organization of production and services, but also social and economic patterns. The long-term consequences are still unfathomable, and the debate rages on, not only in the United States, but also in Europe and elsewhere. In our country, there are growing concerns about the impact of globalization on our technological prowess, the long-term maintenance of our manufacturing capability as critical technological skills migrate abroad, our energy supplies, our research capacity, and our ability to stay on the cutting edge of engineering and science, which is essential to preserving our strength and freedom.

These concerns are aggravated by the anemic production of engineers in the United States, where enrollments in engineering colleges have remained practically static for the past 20 years. The 70,000 or so engineers we graduate each year, including foreign students, represent a decreasing percentage of the worldwide total. Even if 70,000 seems to be in balance with job opportunities at this moment, it is worrisome that less than 5 percent of U.S. college students go into engineering, far fewer than the 12 percent in Europe and the 40 percent in China. While other countries are setting very high targets for the number of engineering Ph.D.'s as a key to future success, the number in the United States has increased very little. Combined with similar declines in the sciences, the United States is becoming less technologically literate, although the country is bound to depend more and more on science and technology for its future security, prosperity, and health.

Clearly, for the United States to hold its own in technology and prosper in a globalized world, we must rethink engineering education and make it more attractive to young Americans. We must also develop a far-sighted science and technology policy and rethink our funding priorities for R&D in the physical sciences and engineering.Dissipating the fog and uncertainties of globalization and taking advantage of the opportunities created by globalization will require cool heads and realistic assessments, rather than knee-jerk reactions. We are moving into uncharted territory, and time is not on our side. But we *are* becoming aware of what needs to be done.

The NAE Engineer of 2020 Project, which has produced two studies on the skills U.S. engineers will need in 2020, is an important first step. A new National Research Council (NRC) report, *Globalization of Materials R&D: Time for a National Strategy*, which will be available shortly after this issue of *The Bridge* goes to press, explores these and many other issues. An upcoming report by the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academies, *Storm Clouds on the Horizon: Setting the Right Course for America's Economic Leadership*, also focuses on what needs to be done for the United States to prosper in the global economy.

In short, globalization can weaken us, or it can offer us, and the world, hope that we can find ways to avoid global conflicts and improve human welfare. But we must act now to ensure that the United States continues to prosper and has the strength and talent to contribute to improvements in the security and quality of life for people everywhere.

The papers in this issue address some of these issues and concerns. Martin Kenney and Rafiq Dossani describe the very rapid increase in offshoring of R&D and engineering design jobs. American companies, they point out, are looking to hire individuals with advanced degrees and workplace experience in India, the Philippines, and elsewhere. To illustrate the challenges of globalization, the authors focus on changes in civil engineering and electronic and computer engineering.

Senator Lamar Alexander addresses broader concerns about our scientific and technological strengths. He also suggests directions for public policies to mitigate the consequences of a looming crisis.

The article by **Peter Bridenbaugh**, chair of the NRC Committee on the Globalization of Materials R&D, and Mike Moloney, senior program officer of the National Materials Advisory Board, provides a summary of the conclusions and recommendations of the new NRC report, which focuses on the consequences of offshoring of materials R&D for U.S. engineering and technological leadership.

Ron Hira's article identifies trends and impacts of offshoring engineering and describes the "adjustments" required of U.S. workers in a globalized marketplace. Hira notes the urgent need for good data and enlightened public policies to help U.S. workers meet the challenges ahead.

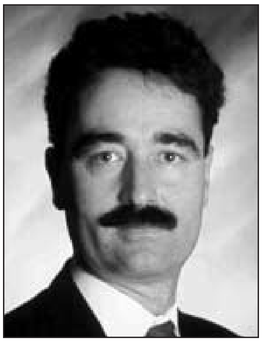
NAE president **Wm. A. Wulf** pieces together a mosaic of disturbing trends that must be reversed. (A statement recommending changes in visa policies, signed by President Wulf and the heads of dozens of major academic and professional organizations, is reprinted on p. 36.)

We hope the articles in this issue and upcoming Academies reports will encourage a discussion—and inspire action—not only in the engineering community, but also among decision makers and concerned citizens.

George Bugliarello

U.S. engineers are now in competition with low-wage engineers in developing countries.

Offshoring and the Future of U.S. Engineering: An Overview



Martin Kenney

Rafiq Dossani

Martin Kenney and
Rafiq Dossani[1]

Engineering as a profession in the United States and other developed nations may soon face a crisis. As a result of sophisticated telecommunications and the digitization of engineering work processes, increasing portions of engineering work can be done without close proximity to particular persons, places, or other processes. In principle at least, this work can be done anywhere in the world that has access to (1) global telecommunications networks and requisite software packages and (2) adequately trained personnel. Undergraduate engineering students in relatively advanced developing nations, such as India and China, follow a curriculum roughly comparable to the one taught in developed nations. Thus, even as barriers to performing conventional engineering work remotely are eroding, a global pool of conventionally trained engineers is growing. This means that U.S. engineers are now in global competition with engineers in developing nations whose wages are 40 to 80 percent lower than ours.

Martin Kenney is a professor in the Department of Human and Community Development, University of California, Davis, and senior project director at the Berkeley Roundtable on the International Economy. Rafiq Dossani is senior research scholar at the Asia/Pacific Research Center, Stanford University.

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[1] The authors' names are in reverse alphabetical order in keeping with their practice of rotating authorship.

In this paper, our discussion is limited to work that is relocated but still services markets in developed countries (rather than work done to meet the needs of local markets in developing countries). Offshoring of this work can not only directly replace existing workers, but can also capture jobs that would have been added to the U.S. economy, especially for fast-growing entrepreneurial ventures that must lower cash expenditures and speed up product development. Recent examples include Silicon Valley high-technology start-up companies that establish offshore subsidiaries very early in their life cycles. In these cases, offshoring does not reflect direct job displacement but redirects job growth to lower cost developing nations, at the same time making the start-up more competitive.

Offshoring not only causes direct job displacement, but also redirects job growth to lower cost nations.

Nearly as important as job displacement is the possibility that offshoring could create significant downward pressure on engineering salaries, which is likely if engineers in developed nations are unable to produce significantly greater value than their much lower paid counterparts in developing nations. We are unable to quantify the downward pressure on wages, but there is ample evidence that offshoring combined with technical changes led to stagnant wages for factory workers during the 1990s, and there is a distinct possibility that engineers might experience similarly stagnant wages.

If offshoring continues or even accelerates during the next few years in response to continued pressure to reduce costs, conventionally trained engineers in both large and smaller firms are likely to face sluggish job markets. As a result of these tight labor markets, engineering as an academic discipline is likely to become less attractive to U.S. college students, unless the engineering curriculum changes to address the new reality.

Offshoring Engineering

Twenty years ago, anyone who advocated the offshoring of engineering jobs to developing nations would have been met with derision. Not only were engineers in developing countries considered incapable of performing the work, but they also had limited access to computers and reliable telecommunications infrastructures. In addition, transporting blueprints and data was time consuming, risky, and expensive. As any executive, manager, or research and development (R&D) director at a large or small firm knows, these things are no longer true.

The McKinsey Global Institute (MGI) (2005) recently examined the potential for offshoring globally from developed nations in 10 industries, three of which—automobiles, software, and information technologies (IT) services—are illustrative of the potential of offshoring engineering. In job categories rich in engineers and scientists, such as IT services, MGI calculated that 59 percent of the work could theoretically be offshored. In automotive engineering and R&D, 42 percent of total employment could possibly be offshored. Interestingly, however, they found that fewer than 2,000 automotive engineering and R&D jobs had actually been offshored. MGI attributed the lag to the conservative nature of the industry. However, given the intense pressures on U.S. automobile firms to cut costs and accelerate development, these small numbers may be the beginning of a much larger trend. Among automobile assemblers alone, MGI estimated that 198,000 jobs in developed nations could be offshored in engineering and R&D. Job losses in the United States could be even greater in percentage terms because our manufacturers are also losing market share. But the U.S. auto industry is not alone. In 2005, the Renault-Nissan alliance outsourced IT services contracts worth approximately $600 million to two U.S. firms, Hewlett Packard and Computer Sciences Corporation, and a French firm, Atos (Ovum, 2005). Some of these jobs will certainly go to India and Eastern Europe.

General Motors (GM) is a leader in relocating R&D and certain elements of design. Its offshore centerpiece is a laboratory in Bangalore that employed approximately 240 professionals in 2005 and is expected to employ 400 in the future. The Bangalore laboratory works in partnership with the GM research laboratory in Warren, Michigan. The sophisticated activities in the Indian laboratory are reflected in the skill levels of the persons being recruited. In July 2005, the laboratory was advertising jobs for individuals with master's degrees or, preferably, Ph.D.'s, in aerospace, computer, industrial, mechanical, and software engineering and computer and materials science. In the materials laboratory, GM is searching for people with master's and Ph.D.'s in metallurgy, polymer science, materials science, materials processing, and math-based analysis of materials. In the material process modeling group, work being done by these newly hired engineers will include validating microstructural models, designing high-performance materials, and molecular modeling of nanocomposite/TPO exfoliation and fuel cell membranes (General Motors, 2005). These job descriptions are indicative of the engineering activities major industrial corporations can offshore to India.

GM is not alone, however. General Electric had 1,600 researchers in its research laboratory in Bangalore, India, in 2003 and 3,500 in 2005. A great many other major industrial firms are also hiring technical talent in low-wage nations in a wide variety of engineering disciplines. Even if this trend does not lead to the loss of existing jobs, it will surely produce significant downward pressure on salaries.

Civil Engineering

In May 2004, according to the Bureau of Labor Statistics (BLS), 218,220 civil engineers and 90,000 civil engineering technicians were employed in the U.S. economy (BLS, 2005). Given the importance of construction to the U.S. economy, the unique nature of structures, the need for customizing buildings for specific sites, and the large number of small (less than 50 persons) civil engineering firms, it might seem that civil engineers would be protected from offshoring. However, giant engineering contractors, such as Bechtel Group, Fluor Corporation, Jacobs Engineering Group, Washington Group International (WGI), and others, are already offshoring civil engineering work to lower cost environments. Bechtel has approximately 800 professionals working for its global operations in India, and Fluor has a large engineering operation in the Philippines (Rubin et al., 2004).

Of course, offshoring is not confined to U.S. firms. European civil engineering firms facing the same pressures are also offshoring. For example, Mott McDonald, a British firm, had a unit in Mumbai in 2004 with 850 employees. As such units mature, they will not only increase in size but will also be able to undertake more sophisticated work.

The traditional view has been that offshoring is a "big company" game, but this view is dated. The offshore outsourcing phenomenon is much more common than many believe. BE&K Engineering, a Birmingham, Alabama, firm, does design work in Mumbai and has a unit in Poland (Rubin et al., 2004). And lower costs are not the only, or even the primary concern, for some firms. Harris and Sloan (H&S), an engineering services firm in Davis, California, that employs 27 professionals and is expanding rapidly, subcontracts the services of five civil engineers in India because of space constraints and a shortage of experienced local engineers. In addition, the company realizes a 50 percent savings in cost.

H&S has experienced difficulties with its Indian firm, however, such as high turnover and the inability to manage directly the Indian engineers it trains. The relative lack of control of the outsourced Indian operation has also created problems in terms of wages and benefits. In fact, the company wants to increase wages to raise morale and improve retention. In addition, H&S is considering adding a subsidiary in Vietnam (Harris, 2005). Currently, H&S plans to configure its offshore employee pool to consist of about three engineers and two drafters managed by a high-level "project manager" in the Davis office. As offshoring increases, every group of about 10 will have an offshore manager. H&S is a pioneer in the offshoring and outsourcing trend, but a number of its competitors are also offshoring a portion of their work to Vietnam or China.

Offshoring is no longer a "big company" game.

At a minimum, offshoring dampens upward pressures on wages. By opening an overseas office or contracting work overseas, firms can limit their high-cost domestic head count. In contrast to electrical engineering (EE) and computer science (CS), for which India and China are the destinations of choice, civil engineering firms can also outsource work to the Philippines, Vietnam, and Latin America. For smaller firms that do not require large numbers of workers, other nations can also offer their services.

Because the construction market is so strong in the United States, civil engineering is globalizing less visibly than other branches of engineering. Although changes in the practice of civil engineering differ in some ways from changes in other areas of engineering, the field is being transformed by a combination of design automation software and globalization. Almost as soon as a civil engineering graduate leaves the university, he or she must be able to operate as a "junior project manager" who can deliver creative, cost-effective solutions that include a global component.

Electrical Engineering and Computer Science and Engineering

More U.S. engineers are employed in EE and CS than any other fields of engineering. According to BLS (2005), more than 1.25 million persons were employed in related fields, not including computer programmers, support specialists, systems analysts, database administrators, network and computer systems administrators, network systems and data communications analysts, and other types of computer specialists, who account for another one million jobs. In terms of employment, software and computer engineering is the most important engineering job category, mirroring the technical strength of the U.S. economy.

Until recently, many scholars and most news reporters thought that the activities being offshored would be routine, low-end work, such as data entry and programming—activities that the United States could afford to lose. Unfortunately, this comforting idea is simply not true. Table 1 shows a compilation of jobs described on the websites of five major U.S. electronics and software firms in February 2005. The table is self-explanatory, but note the remarkable number of Ph.D.'s being sought, nearly all of them with at least five years of experience. The job descriptions read exactly like those for technologists being hired in the United States. For example, Cisco India advertised for a master's degree EE&CS graduate with the following credentials in addition to technical knowledge: "Technical, Industry, Business and

TABLE 1 Highest Degree Required in Job Descriptions of Five Multinational Corporations Operating in India and China, February 2005

	None	Technical	Bachelors	Masters	PhD	Total
CISCO						
Shanghai	0	0	17	19	0	36
Beijing	2	0	7	3	0	12
Bangalore	10	0	28	65	0	103
INTEL						
Shanghai	10	9	61	55	9	144
Beijing	1	0	7	6	1	15
Bangalore	11	7	39	112	10	179
HP						
Shanghai	6	2	7	29	1	45
Beijing	5	0	25	28	0	58
Bangalore	15	3	62	42	34	156
MICROSOFT						
Beijing	2	0	0	1	0	3
Bangalore	2	0	13	5	0	20
Hyderabad	17	3	57	14	3	94
ORACLE						
Beijing	0	0	0	2	0	2
Bangalore	9	1	63	16	0	89
Hyderabad	0	0	62	35	13	110

Sources: Adapted from information on the Cisco, Intel, HP, Microsoft, and Oracle websites.

Cross-Functional Knowledge. Partnership. Solve Problems & Make Decisions. Demonstrate Leadership. Establish Plans. Think Globally. Dedication to Customer Success. Innovation and Learning. Acknowledged technical expert on project." This is not an advertisement for a routine, low-level job.

Anecdotal evidence is confirmed by the MGI report (2005), which finds that 60 to 78 percent of engineering and associated middle-level managerial positions in the packaged software industry in developed nations are theoretically offshoreable. The result for IT services is similar—47 to 56 percent of the software and hardware engineering and associated middle-level management jobs are susceptible to offshoring. Analysts working on software/IT architecture and market research are similarly vulnerable (45 to 55 percent). Whether these estimates are off by 10 or even 40 percent is not important. Even low double-digit percentages are certain to be disruptive.

The collapse of the "Internet bubble" in 2000 had a devastating effect on EE&CS on many fronts. Not only have EE&CS departments experienced a drop in enrollment, but employment has not rebounded as well as it has after previous downturns. Students are aware of the threat of offshoring and the increase in EE&CS employment in low-wage, offshore environments.

Start-ups Going Global

Nearly 70 years ago, Karl Compton and other business and engineering leaders in the Boston area created an economic development model in which technological entrepreneurs supported by venture capital would build new firms. A certain portion of these start-ups would grow large and hire large numbers of workers (Hsu and Kenney, 2005). This model reached its apogee in the development of Silicon Valley, which pioneered technologies that transformed the world in which we live. As venture capital funding recovers from the darkest days of 2001, new firms, such as Google, Salesforce.com, and many others, continue to be spawned in Silicon Valley, and some are growing rapidly.

At a recent conference we organized at Stanford, however, presentations by Silicon Valley-based start-ups suggested that a new, global division of labor is emerging. For example, Ketera, a software start-up company headquartered in Silicon Valley, has 75 workers in its Bangalore operation and 150 workers globally. The vice president for engineering at Ketera noted that almost any function currently done by the U.S. team could be offshored, at least, partly. In his view, only customer-facing functions had to remain in the developed country market. He added, perhaps hyperbolically, "I do not see the need for my role as currently described to be U.S.-located in a year's time!" (Shah, 2005). If large numbers of new jobs in small firms continue to be relocated, there may be other ramifications, such as "the relocation of entrepreneurship" per se.

The relocation of new jobs by small firms could lead to the "relocation of entrepreneurship" per se.

A typical start-up company today begins planning for global growth from its inception. In response to pressure from venture capitalists to reduce cash burn rates, start-up companies are creating offshore facilities even before their head counts reach 100. This offshoring decision has two aspects. It lowers the cost of starting a firm and thus encourages entrepreneurship. And, at the very least, it allows a firm to shift mundane work to low-cost locations and reallocate its budgets to new product development.

Take, for example, Tensilica, a Silicon Valley-based start-up firm that relies on intensive, sustained, leading-edge technological innovation by its engineers. During the downturn of 2001 and 2002, even though business prospects slowly improved, the company's engineering budget did not increase because existing products were being improved at the expense of innovation. The solution was to offshore product improvement to India, which the company did in 2004. This change generated savings that enabled more resources to be spent on leading-edge work in the United States (Dixit, 2005).

This example illustrates a second aspect of offshoring—employment growth takes place not only in the United States, but almost immediately offshore as well. In an extreme case, the leadership and marketing team might remain in the United States while most of the employees are located abroad.

Does this extreme represent the future of technology entrepreneurship? This vision may be apocalyptic, but we are convinced that the geographic footprint of start-up firms is in flux. The future cannot be guaranteed, and our mental models of the location of jobs created by the technology entrepreneurship process must be adjusted accordingly.

By creating new value, entrepreneurship can become the antithesis of the zero-sum game.

Responses

Leaders of major U.S. technology firms have cited the appalling state of K–12 education as a major barrier to retaining jobs in the United States. Although we agree that there are serious problems with K–12 education and severe financial difficulties facing publicly supported institutions of higher education, more funding for education will not address the problem of the increasing offshoring of engineering jobs. As the world becomes more globalized, much of the routine, computer-based engineering work can be done remotely, and undergraduate engineering curricula in reputable universities everywhere in the world (many in low-wage nations) are roughly equivalent (and are becoming more so). At the margins, U.S. institutions have more resources and slightly more modern equipment and software, but these amount to no more than a 10 or 20 percent advantage for our undergraduates.

Of course, even within a country, the graduates of the best universities still command a significant premium over graduates from other schools, and this difference crosses borders. At the graduate level, our finest research universities are still superior to universities elsewhere. However, other nations are trying to emulate our success, and they will certainly improve their research capabilities. Thus, simply improving our educational system along the lines of its current operation is not likely to prevent further offshoring.

The career of the engineer of the future is likely to take one of two directions. Engineers employed in organizations will necessarily be required to coordinate projects having global workforces. The critical words in the previous sentence (to which current engineering education pays little attention) are "coordinate" and "global." A typical U.S. engineer will have to become a project manager early in his or her career and will be coordinating the work of people stationed around the world, either within the parent organization or in contractor organizations.

Entrepreneurship will require engineers to move in a different direction. The heart of entrepreneurship is creating new knowledge and actualizing it in the marketplace. Engineer-entrepreneurs must not only understand how to design good products, but also how to design good business ventures (Hargadon, 2005). Entrepreneurial engineers need not only a rigorous engineering education, but also an understanding of the elements of entrepreneurship. There are advantages to being located in a developed country with sophisticated markets that often set the pace for consumers, and young engineer-entrepreneurs must know how to take advantage of the knowledge in our marketplace. By creating new value, increased entrepreneurship is the antithesis of the zero-sum game.

In the future, most engineers will experience midcareer changes. Thus, the existing model of the engineer who necessarily receives all of her or his training while young, usually soon after high school, must give way to a model of engineers who may choose to enter the field much later in life, perhaps after working in related fields, such as the pure sciences, for several years. New curricula must be developed that allow them to complete their educations over a longer period of time, perhaps while working part time. The University of California, Davis, recently launched a program to train Ph.D. students in the basics of entrepreneurship, not to encourage them to leave graduate programs and academic careers for industry, but to equip them to recognize commercially viable projects in their future academic careers. This kind of flexibility will be necessary to increase U.S. competitiveness.

The licensing of an engineer could also be changed. Perhaps it would be better if licensing were based on a system of regular, midcareer renewals; such licensing systems have already been adopted in nonengineering fields, such as accounting and finance. The advantages of such a system are obvious, especially in light of increasing evidence that the engineers most threatened by foreign competition are not those who are freshly out of college, but those in midcareer who may be replaced by newly trained engineers, either in the United States or Asia. The change is worthy of serious consideration.

Finally, Americans must understand that, just as proximity to sophisticated markets conveys advantages to them, the development of low-cost economies conveys advantages to engineers in other countries. In other words, countries like China and India are rapidly developing markets with unique engineering situations, and American engineers could benefit by becoming familiar with those environments so they can capture value from them, rather than assuming that all high value-added new ideas will necessarily emerge in developed countries. This implies that, at the very least, internships (and perhaps early career paths) should be increasingly global. Some universities have already begun to respond to these challenges. The Asia Technology Initiative at Stanford University, for example, places engineering students in summer internships in Bangalore, Beijing, and Tokyo.

Whether U.S. engineers become entrepreneurs or global project managers, they will need an educational system that provides them with the tools to succeed. An educational system that only provides them with the same skills as their colleagues in China and India will equip them to earn comparable wages (i.e., $6,000 per year plus a bonus for being located in the United States). Thus, engineering education cannot continue as usual. As Table 1 indicates, more of the same education, such as lengthening the curriculum by a year to improve students' technical skills, is unlikely to address the problem of offshoring.

Engineering capabilities, though seemingly concentrated in the education-obsessed nations of East and South Asia, are distributed globally. Traditionally, a small, often elite, group migrated to the United States, but the vast majority of engineers or potential engineers remained in their homelands, unable or unwilling to move to where the job opportunities were. This labor mobility barrier protected U.S. engineers from competition and allowed them to demand high wages. Nevertheless, over the last three decades, the internal U.S. engineering workforce has become increasingly internationalized.

Although the labor mobility barrier persists, decreases in the cost of telecommunication, the increase in bandwidth, the ubiquity of the Internet, and the adoption of standardized software, combined with increased comfort with offshoring and outsourcing, is changing the global engineering labor market. Lower cost, similarly skilled engineers are now available worldwide.

For the most highly educated, most brilliant engineers, offshoring is likely to have little, if any impact. There will always be positions for them, they will continue to be rewarded for the enormous value they create, and the nation where they are based will be rewarded in taxes and profits. Our concern is with the 90 percent of engineers who will be pushed into international competition, just as U.S. factory workers were more than two decades ago.

Our concern is with the 90 percent of engineers who will be pushed into international competition.

For engineers being trained today, this new reality is becoming increasingly evident. Their response is difficult to predict, but as the cost-benefit equation shifts, and if engineering education only provides them with the same skills as others in the global economy, many are likely to pursue other fields of learning. This would be unfortunate, however, because enormous opportunities are being created for technically skilled graduates capable of understanding and operating in global

Conclusion

This is not a zero-sum world. If India and China capture more of the engineering value chain, this does not mean the United States must lose. It does mean that we must understand the implications of changed circumstances and experiment with responses. We have focused on the situation in EE&CS and civil engineering, but as GM's Bangalore laboratory demonstrates, all engineering and engineering sciences in the United States may be disrupted. There are ways to address these problems, but fashioning them will require deep study and thought, which are in short supply at the moment.[2] Solutions may vary by industry and discipline, but it would be irresponsible not to prepare for this global shift.

[2] A forthcoming report by the Association of Computing Machinery Job Migration Task Force, which was appointed to examine these issues and recommend responses, will provide a detailed analysis for the changing location of the workforce for software. The report is expected to be published in late 2005.

networks or with the entrepreneurial skills to discover new opportunities and pull together the resources and teams capable of actualizing them.

Protectionism and anti-offshoring agitation are likely to be little more than rearguard actions, which may be justified only if more long-term responses are simultaneously put in place. But given the history of U.S. responses to threats from imports and offshoring, protection is likely to become permanent and a substitute for real change. In the long run, the "protected" industrial sector will eventually collapse anyhow, as happened in consumer electronics, integrated steel production, and, quite possibly, automobiles. Engineering is too important a contributor to our economy to entrust its future solely to market forces in the belief that a positive outcome will result. A more rational, positive response is to try to determine the skills future U.S. engineers will need and then make changes to provide them. Only then will U.S. engineers be capable of creating a new reality.

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The author outlines a national effort to ensure U.S. competitiveness in the global economy.

The Next Big Surprise

Lamar Alexander is U.S. senator from Tennessee.

Lamar Alexander

September 11th came as a big surprise to this country. We weren't expecting what happened, and we weren't prepared for it. As General Carl Stiner, former head of U.S. Special Forces, recently reminded me, we should have seen the warning signs.

In 1992, a U.S. military training mission in Saudi Arabia was bombed, and 43 American soldiers were killed. In 1993, the World Trade Center in New York was targeted; six people were killed and 1,000 were injured. In 1995, a National Guard training mission in Saudi Arabia was bombed, and five soldiers were killed. In 1996, the bombing of the Khobar Towers in the same nation killed 19. Bombings of the U.S. embassies in Kenya and Tanzania killed 224 in 1998. And in 2000, the *USS Cole* was attacked off the coast of Yemen killing 17. Today, our government is mobilized in an unprecedented effort to make sure terrorism never surprises us again.

In the meantime, we have been ignoring the next big surprise—that in 10 or 20 years other countries may close the economic gap between themselves and the United States. As there were with 9/11, there are warning signs. Indian cities like Bangalore have become magnets for companies that once were found only in Silicon Valley. Last year, when I was in Japan, Tokyo

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was abuzz because China had surpassed Japan as the second largest oil-guzzling nation in the world. (The United States is first.) In 2003, China launched its first man into space. The U.S. share of worldwide high-tech exports has been in a 20-year decline; from 1980 to 2001, our share fell from 31 percent to 18 percent. At the same time, the global share for China, South Korea, and other emerging Asian countries increased from just 7 percent to 25 percent. China graduates almost four times as many engineers as the United States and offers lucrative tax breaks to companies that conduct research and development (R&D) there. India is pouring money into technology parks to lure Indian citizens who attended American graduate schools. South Korea graduates nearly the same number of engineers as the United States, even though it has only one-sixth the population and one-twentieth the GDP. These are sobering statistics.

South Korea graduates almost as many engineers as the United States.

When I was in Europe in March 2004, I heard that British Prime Minister Tony Blair and German Chancellor Gerhard Schroeder were working to model their universities on American institutions. In 1998, Europe graduated more Ph.D.'s than the United States; the goal is for Europe to graduate five times as many Ph.D.'s as the United States in the next five years. In February, the European Union affirmed that its economic development strategy is directly linked to reforms in higher education.

The United States, with only 5 percent of the world's population, has 30 percent of the world's wealth. That's an astounding figure. The people of China, India, Brazil, and other countries around the world have noticed, and they don't see any reason for the United States to continue to hold such a lead over them. They are undertaking calculated, concerted efforts to improve their competitiveness in the global marketplace, especially when it comes to science and technology.

America prospered during the latter part of the twentieth century like no other country had before, and at least part of that success reflected our commitment to educating and supporting several generations of American innovators. According to Nobel laureate economist Robert Solow, nearly half of our nation's economic growth since World War II can be attributed to advances in science and technology. So, what must America do to maintain leadership in the global economy? How can we succeed in an increasingly competitive marketplace?

If we are to continue to enjoy our prosperity, we will have to make new, strategic investments in science and technology and education in the twenty-first century. Here are a few ways we can maintain our competitive edge.

Increased Funding for Research in the Physical Sciences

As I noted earlier, nearly half of our nation's economic growth since World War II can be attributed to advances in science and technology. If we want that growth to continue, we must invest in the research that fuels those advances at national laboratories and universities. This means a stronger investment in fundamental research in the physical sciences and a sustained commitment to regaining international leadership in areas such as advanced scientific computing at dedicated national user facilities.

In recent years, investment has shifted away from research in the physical sciences and engineering to the life sciences. Product development and applied research now attract more than 80 percent of the $240 billion spent annually on R&D by the public and private sectors. Only 18 percent is devoted to basic research—a number we need to increase if we are to remain competitive in the long run.

Many proposals have been made about how to do this. Last year, Senator Carl Levin and I sponsored a bill to double the funding for the U.S. Department of Energy (DOE) Office of Science over the next five years. In April 2005, 67 senators joined with me to ask Congress for a 7 percent increase over the President's funding request for the DOE Office of Science. Not many proposals in the Senate attract that level of support during tight budget times, and our request was honored. On the House side, Congressman Frank Wolf of Virginia recently proposed that funding be tripled for federal basic science programs and that the government pay the interest on undergraduate loans for students who agree to work in science, math, or engineering for a five-year period after graduation.

Coordinated Federal Programs to Optimize Innovation

Unfortunately, the need for more investment in research isn't our only problem. According to a recent report issued by the National Commission on Energy Policy, an "insufficiency in investment [in energy-related R&D] is compounded by shortcomings in the government's management of its energy-technology innovation portfolio." The commission also noted that "Recommendations for strengthening the organization and management of the government's energy research, development, demonstration, and deployment programs have emerged from every major recent study."

Let me give you an example of why the commission may be right. From 1993 to 2001, we poured billions of dollars into the Partnership for Next Generation Vehicles (PNGV), which was supposed to result in American leadership in the deployment of hybrid vehicles. PNGV was led by a consortium of the Big Three automakers, while domestic manufacturers like Toyota, Honda, and Nissan, that wanted to participate in the program, were left out. Yet on America's roads today you see lots of Toyota and Honda hybrids but not many hybrids from the Big Three. That approach simply didn't work.

The recently passed Energy Bill took a different approach that I hope will be more successful. In that bill, we provide grants to domestic automobile manufacturers to encourage the production of hybrid and advanced diesel vehicles; these grants apply to all domestic producers, regardless of where their company headquarters are located. I think that's a better approach in this specific case, and it illustrates a larger point—that we must ensure that our incentives for R&D are geared to producing the maximum benefit to American producers and consumers.

Implementing best management practices in research programs will also be key to success in the future. I recently spoke about R& D management with Dr. Tony Tether, director of the Defense Advanced Research Projects Agency (DARPA), a successful U.S. Department of Defense organization that invented the Internet, stealth technology, and some aspects of global positioning system (GPS) technology. DARPA is generally recognized as a success in terms of its ability to bridge the "innovation gap" between scientific discovery and technology implementation.

Dr. Tether believes that the key to DARPA's success is people. To maintain an entrepreneurial atmosphere and the flow of new ideas, DARPA steadily rotates in and empowers very highly qualified program managers based on "Experimental Personnel Authority"; most program managers serve only four years. The practice is based on the belief that new ideas come from new people. New program managers are also able to redirect the work of their predecessors—and even undo it if necessary. The combination of new people, a flat organizational structure in which expert program managers are empowered to make decisions, and the fact that DARPA has no dedicated laboratories or facilities to support and maintain, have ensured that DARPA has very few institutional interests other than innovation. I hope we can apply some of these same practices in other federal organizations that manage R&D portfolios aimed at bridging the innovation gap.

Reform of U.S. Immigration and Visa Policies

Getting the "people question" right requires more than good management policies. It also requires attracting the best and brightest minds to study and work in our country. That's why our immigration policy must not only preserve American security but must also welcome talented individuals from around the world. Since September 11, 2001, we have clamped down on entry into our country, and our policies have become stricter. As a result, international applications to American graduate schools declined by 28 percent from 2003 to 2004. Applications from China fell by 45 percent and from India by 28 percent. Scientific conferences are increasingly being held outside the United States. We must reverse this trend.

Our incentives for R&D must be geared to provide maximum benefit to American producers and consumers.

Much of the trouble has arisen from the Visa Mantis clearance process for students and researchers who might be studying sensitive technology. Early this year, the State Department took an important step in the right direction by announcing a change in that process that will extend the validity of clearance for the duration of study (up to four years) for students who remain enrolled in the same program here in the United States. The average time for Visa Mantis clearance has dropped from 77 days to 14 days, and our embassy in Beijing reports that Chinese student visa applications this year are up 15 percent. These are dramatic improvements.

Yet more can be done. I recently co-chaired a roundtable with key senators and senior administration officials, including the Deputy Secretary of Homeland Security, to see what additional steps can be taken to improve our visa policy so that we attract, rather than discourage, the best and brightest foreign students and researchers to study here, work here, and even eventually live here as American citizens.

One idea that was suggested was making comparable changes for researchers by making the Visa Mantis clearance last for the duration of a given research project. Another idea was to find a way to eliminate the requirement that talented students and researchers demonstrate an intent to leave the United States after studying or working here. Study visas serve that purpose now for students, and H-1B visas serve that purpose for skilled workers. But we need to do more.

Enabling States to Pay for Higher Education

In addition to our commitment to attracting talented students, we must also maintain our overall commitment to higher education. When I was governor of Tennessee, 50 cents of every dollar we spent went toward education. Today that number is down to 40 cents. Why? Because states are bearing an increasingly large burden for Medicaid—Tennessee's program is called TennCare. Tennessee now spends 31 cents of every dollar on health and social services; when I was governor it was only 15 cents. Much of that increase is the result of ongoing, unsustainable growth in Medicaid spending.

As a senator, I hope to be a Paul Revere for federalism and wake people up to the fact that what we do in Washington, D.C., can have significant effects on state spending. States are significantly restrained by federal regulations and the federal courts. We must make sure that when we pass laws in Washington, we are not sending the bill for implementing those laws to governors and mayors back home. Those are unfunded mandates, which the Republican Congress made a commitment to curbing 10 years ago when it passed the Unfunded Mandate Reform Act.

The other significant pressure on state funding decisions comes from the federal courts. The courts protect our rights, and it's important that they do so, but they should not be making policy decisions we elect our local leaders to make. I have introduced the Federal Consent Decree Fairness Act to slow down what two New York Law School professors have called "democracy by court decree"—the judicial management of state and local policies. Passage of this bill would level the playing field for state and local governments trying to regain control over programs that have been taken over by the federal courts.

States have traditionally paid a certain cost for universities located within their borders. But as state budgets are being "crunched," states are contributing less overall to education. To compensate, universities have been raising tuition. Only by getting the federal government off the backs of state and local governments can states hope to continue providing significant funding to universities.

Unintended Consequences of Federal K–12 Education Standards

A lot of thought has been focused on what can be done in higher education and research investments to improve the competitiveness of the United States, but we also need to take a step back and address problems where creative thinking starts, in young children in their most formative years. As the federal government sets standards and encourages states to ensure that all children succeed, we must make sure that K–12 schools also continue to challenge and inspire students who are high achievers, particularly students who excel in math and science. K–12 schools must provide them with experiential, in-depth learning, which is essential for innovation.

Conclusion

I have focused on just five of many areas where we can launch a national effort to ensure that the United States remains competitive in the global economy. The rest of the world is no longer content to allow 5 percent of its population to have 30 percent of its wealth. If we don't begin to adapt quickly to global changes, the next big surprise for the United States will come 10 or 20 years from now when we wake up and realize our standard of living is slipping. The challenge before us is complex and urgent. We all need to work together to ensure that our current prosperity is passed on to the next generation.

Globalization could threaten U.S. access to advances in materials science and engineering.

Globalization of Materials Research and Development

Peter Bridenbaugh and Michael Moloney

Peter Bridenbaugh

Michael Moloney

The media these days are filled with talk of offshoring and outsourcing. The continued globalization of research and development (R&D) and the proliferation of information technology and global communications are being driven by large trends, such as the impact of twenty-first century technology and increased international and transnational industrial and economic activity. Under the auspices of the National Research Council National Materials Advisory Board, and sponsored by the U.S. Department of Defense, a new study, *Globalization of Materials R&D: Time for a National Strategy*, was conducted to examine these issues and assess how they might affect continued U.S. access to the best of materials science and engineering (MSE) R&D. The study committee defined globalization as the worldwide expansion of MSE knowledge-creation centers as a result of U.S. and non-U.S. industry and government investments, as well as worldwide collaboration facilitated by information technology.

The study had four goals: (1) to assess the current status of MSE R&D from a global perspective; (2) to identify the drivers of U.S. companies' decisions to locate materials research in the United States or abroad; (3) to assess

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the impact of the globalization of MSE R&D on the U.S. economy and national security; and (4) to recommend actions to ensure continued U.S. access to critical MSE R&D.

Globalizing Trends

Information from the National Science Foundation (2004), the results of a survey of industrial R&D by the Economist Intelligence Unit (2004), and the results of a poll of MSE practitioners carried out for this study all show that globalization has led to an increase in both transnational, academia-led R&D with international academic and industrial collaborators and transnational, corporation-led R&D with foreign affiliates of U.S. corporations, foreign academics, or foreign corporations. The data show that companies are being driven to globalize R&D activity for a number of reasons: (1) access to expertise; (2) mitigating the impacts of regulatory regimes; (3) proximity to new international customers; and (4) cost savings. The risks of investing in overseas corporate R&D vary but can include concerns about the ownership of intellectual property and the security of trade secrets, as well as concerns about the rule of law and democratic institutions. Academic researchers are also participating in global MSE R&D by seeking out domestic or international partners that can advance their research priorities, by participating in international conferences, and by adopting information technology for sharing R&D results on a global scale.

Our strategic lead in materials-related technology, and perhaps other technologies, is clearly threatened.

The effects of globalization on U.S. leadership in MSE R&D vary by field or subfield. For instance, in composites, U.S. leadership has declined to the point that we may no longer be able to exploit the promise of new composites. Leadership in the subfield of magnetic materials is mixed; the United States leads in some critical areas and is among the leaders in other areas. In metallurgy R&D, the United States appears to be losing its leadership role, and all indications are that this trend will continue. The situation in electronic and optical-photonic materials is mixed, with the United States leading in some areas but not in others. Currently, U.S. scientists working on superconducting materials are at the cutting edge of R&D on nearly all fronts; however, other countries share the lead or have surpassed us in applications. In catalyst technology, there has been a continued decline in U.S. leadership. In nanomaterials and nanotechnology, as measured by the number of corporations engaged in the subfield, the United States leads, but it is too early to say which, if any, region of the world will emerge as a clear leader as this field matures. Because nanotechnology is essential to many electronic and photonic materials and devices, the U.S. position in these subfields is interconnected.

Surveys of patents and recent literature suggest that, even though MSE R&D is emerging at an accelerating rate in countries not previously known as centers of materials expertise, the United States remains either the world leader or among the world leaders in most MSE subfields. But the European Union and the Asia-Pacific region, notably Japan and, recently, China, are challenging traditional U.S. leadership. Global activity in all areas of MSE is increasing significantly in Asian countries that were not active in these fields before. Although it is difficult to say how the situation will evolve, the overall trend is clear. In keeping with broad trends toward globalization, the globalization of MSE R&D is proceeding rapidly and the technological lead of the United States is narrowing. The loss of U.S. leadership in several areas of materials research where it has traditionally been dominant is a real possibility.

Impacts for the United States

The proliferation of technologies and capabilities, at the very least, will complicate the analysis of potential threats and challenges to the United States and, at worst, will allow potential adversaries to gain the advantage in strategic fields. Although the United States might also gain some advantages from exploiting new technologies that might emerge as a result of increased global activity, the strategic one- to two-generation lead in materials-related technology, and perhaps other technologies, is clearly threatened.

Economic Impact

The overall economic impact of the globalization of MSE R&D has been limited so far, although analysis is difficult because of a lack of data and the absence of a robust, analytical framework. The economic impact is also likely to differ by subfield. For example, the United States has already lost its competitive advantage in catalysts but so far maintains its lead in semiconductor research. The overall economic impact of globalization will depend on how these trends evolve and on the future relative contributions of materials subfields to the U.S. economy.

On balance, the United States could gain from the globalization of MSE R&D, but only if the country positions itself strategically in the new R&D environment and U.S. companies can gain new advantages by integrating domestic and global R&D results into final products. This outcome requires creating conditions at the private and public levels that enable U.S. firms to increase their productivity, efficiency, and innovative capacity. U.S. companies will then be able to take advantage of foreign R&D and international R&D relationships by integrating them fully and effectively into their domestic R&D programs—assuming they have maintained these capabilities.

Impact on National Security

Globalization of MSE R&D will also affect our national security. U.S. security forces in the twenty-first century will have to communicate faster, more reliably, and on a global scale. New threats to national and homeland security will require new detection methods, and new tasks will require new weapons and new materials for new and better delivery platforms. New systems will have to be multifunctional, self-diagnostic, self-healing, low cost, low maintenance, environmentally acceptable, and highly reliable. MSE R&D that meets those needs will certainly improve our national security and homeland defense.

The evolution of materials research in the United States and abroad will affect the nation's ability not only to defend against emerging threats, but also to ensure that the economic underpinnings of national security remain healthy. As knowledge and the intellectual capacity to generate new knowledge proliferate across the world, as innovation and development cycles become shorter, and as U.S. dependence on foreign sources of innovation increases, the lead in critical technologies enjoyed thus far by U.S. defense and intelligence communities will be seriously eroded unless mitigating actions are taken.

The emergence of new centers of high-value research across the globe has created an international market-like demand for the best and brightest students and experts, challenging the ability of the United States to attract top researchers. Any decrease in the supply of non-U.S. experts directly involved in U.S. research and innovation, combined with the acknowledged difficulty of attracting U.S. students to MSE, will put a strain on the supply of top scientists and engineers capable of conducting R&D necessary for economic growth and national security. A loss of expertise will diminish not only the value of the U.S. research output, but also, in the long term, the nation's capacity to recognize, understand, and exploit research results from elsewhere.

Increasing dependence on foreign sources of innovation could jeopardize the U.S. lead in defense and intelligence technologies.

Recommended Actions

The globalization of MSE R&D could have a significant positive impact for the United States, but the risks of a negative impact remain substantial. Even if great efforts are made to maintain control of U.S.-generated technologies, knowledge, and capabilities, investments by other governments in their own MSE R&D will challenge the United States' technological lead. The loss of national capacity for MSE research or a decline in the ability of U.S. manufacturing to take advantage of and motivate MSE research or a diminished U.S. military, homeland defense, or intelligence capability would not only damage our national pride or our international image. In a knowledge-based future, the United States will retain its current world economic leadership and its strong national defense and security only if it continues to have access to, and in many cases generate, cutting-edge science and technology. The United States must maintain access to the global output of critical MSE R&D.

Access is only part of the story, however. Integration must also be a priority. But integrating R&D is not easy.

If current trends continue, there is a risk that some of the knowledge generated in MSE R&D abroad will not be absorbed in the United States and that the United States may not have the domestic expertise to recognize foreign innovation and maximize its integration. Maintaining access to current MSE R&D will require active management, which in turn will require a national strategy that allows the United States to take advantage of the benefits of the globalization of MSE R&D.

A protectionist approach might result in the U.S. losing access to superior technologies developed elsewhere.

Developing a National Strategy

A national strategy for the effective development and use of MSE R&D must include several elements. First, there must be a coordinated approach to exploring critical questions in the various subfields of MSE. This will require identifying programmatic linkages among R&D programs of the defense services and national security agencies, assessing the readiness of these R&D programs to provide critical MSE capabilities, and recommending how international and transnational MSE R&D should be integrated into these domestic efforts. Second, there must be a road map that defines immediate priorities and next steps. Third, stakeholders and decision makers from the defense, homeland security, and intelligence communities should coordinate and find synergies with the wider federal science and engineering agencies (including the National Science Foundation [NSF], U.S. Department of Energy [DOE], National Aeronautics and Space Administration [NASA], etc.). Fourth, advice from academia, industry, and other experts should be solicited, as required—perhaps with the participation of the Defense Science Board; and industry should be asked to suggest policies and incentives that would encourage proactive strategies for retaining a strong MSE R&D base in the United States.

A robust national strategy that ensures U.S. access to the results of MSE R&D will require a thorough understanding of current trends in MSE R&D worldwide; the identification of the questions and challenges that must be addressed to meet national economic, defense, and homeland security needs; and a fresh approach to managing regulatory regimes, improving education, and strengthening the infrastructure for U.S. MSE R&D. This will require sufficient information on global MSE R&D activities and effective monitoring, as well as regular benchmarking of the relative status of U.S. MSE R&D.

Currently, data on the global flow of investments in R&D generally, and in MSE R&D specifically, are insufficient. Building a national strategy that ensures U.S. access to MSE R&D will require the collective efforts of various federal agencies to provide better data and new analytical tools to understand the complexities of the R&D globalization phenomenon. Maintaining continuous access to global R&D will require improving U.S. Department of Defense (DOD) forecasting and monitoring systems and expanding capabilities of identifying the development of critical technologies worldwide.

Of course, predicting what new capabilities might be developed from yesterday's research or the particular challenges tomorrow's adversaries might present may be difficult, at best (DSB, 2005; NRC, 2002, 2003). Moreover, the acquisition of technology from another country in the past does not guarantee that the same can be done in the future. Addressing these and other national security concerns will require coordination and cooperation among DOD, NSF, DOE, NASA, the U.S. Department of State, the U.S. Department of Commerce, and others to assess lists of existing critical technologies, contractual arrangements, and R&D funding procedures and to define longer term goals for MSE R&D.

Regulatory regimes can have a significant impact on national policy. They can affect where R&D is performed, determine how intellectual property developed abroad is treated, define export licensing processes that affect the execution of R&D programs, affect the availability of skilled researchers, and provide tax incentives. As MSE R&D becomes increasingly global, public policy makers must ensure that U.S. regulatory regimes do not unreasonably impede the participation of U.S. researchers in international R&D of national importance or the participation of foreign researchers in U.S. research. A review of the nation's regulatory system should include how the system of export controls would be affected by identifying important technologies to which the nation must have access but not necessarily control.

It may be tempting to consider protecting U.S. interests by retreating from the world stage in areas considered critical to national or economic security. A protectionist approach, however, might result in the United States not having access to superior technologies developed elsewhere. The best way to ensure access to cutting-edge knowledge and technology and protect long-term U.S. interests would be for the United States to participate in international partnerships and become an active player in global MSE R&D.

Maintaining a world-class domestic capacity to engage in international MSE R&D, to integrate non-U.S. R&D into U.S. systems, and to monitor and understand global MSE R&D and its impact on U.S. technological leadership will require significant changes in the U.S. MSE educational system. The challenges facing the system include the expanding curricula in MSE departments; the difficulty of attracting high school and university graduates to pursue careers in MSE; and the continuing dependence of graduate programs on foreign students, who are now the objects of intense global competition. The Organisation for Economic Co-operation and Development reports that in 2000 about 40 percent of students in China graduated with engineering degrees, whereas in the United States the figure was about 5 percent (OECD, 2002).

For the United States to maintain its leadership in innovation and a robust national research infrastructure, these trends must be turned around. Efforts could include: promoting MSE as a career choice; helping students overcome deficiencies in K-12 education; meeting the needs of U.S. industry and other actors; providing financial support to encourage U.S. citizens to study materials science; setting minimum competencies for graduate students working on master's degrees in MSE; and improving the balance between large and small MSE departments.

Maintaining U.S. expertise and leadership must be based on a robust research infrastructure wherein materials problems can be addressed and solved and the solutions verified, from laboratory scale through pilot scale. However, the loss of once-dominant industry materials laboratories raises serious questions about where future MSE R&D will take place. The United States can no longer count on the ongoing exploration of new technical areas that could be of interest to business and ongoing monitoring of developments in university and government laboratories. Clearly, this is a serious problem that must be addressed.

Conclusion

Formulating a national strategy in response to the globalization of MSE R&D will present policy makers with multidimensional challenges. Coordinating the activities of so many federal agencies and mobilizing the resources of industry and academia may require the involvement of the Executive Office of the President. The recommendations in the new NRC report (2005) provide a framework for a robust national strategy that could ensure a positive impact for the United States and continued access to current MSE R&D. The framework is based on a series of initiatives to benchmark MSE R&D in the United States; define MSE R&D requirements for twenty-first century national security needs; outline a regulatory framework that supports U.S. MSE innovation in a globalized environment; and maintain a national infrastructure that supports a global role for the United States.

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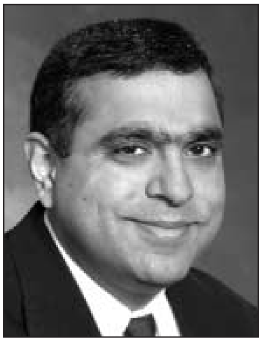
Engineers need better data and government help to "adjust" to offshoring.

Impacts and Trends of Offshoring Engineering Tasks and Jobs



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Many companies are transferring tasks and jobs that have traditionally been done by American engineers to lower cost countries where engineers earn as little as 10 percent of the salaries Americans earn. Company managers, making rational decisions, hope to save up to 70 percent in net costs by offshoring work. Although no government organization has reliable figures on exactly how many engineering tasks and jobs have been moved to low-cost countries in recent years, observable trends indicate that offshoring is accelerating in scale and scope. No doubt these changes have important implications for American engineers and the U.S. national innovation system; but engineers have little objective information to help them adapt to these changes, and, in spite of widespread media attention, policy makers have so far chosen to do nothing in response to these structural changes to our innovation system.

On the macroeconomic level, economists are debating whether offshoring is good for America. In a recent article in the *Journal of Economic Perspectives*, for example, Nobel laureate Paul Samuelson describes some very plausible scenarios in which offshoring would actually leave America worse off.

[1] The opinions expressed in this paper are those of the author and do not represent the official position of IEEE-USA. For more information on the subjects discussed here, see *Outsourcing America: What's Behind Our National Crisis and How We Can Reclaim American Jobs* by Ron Hira and Anil Hira (AMACOM, 2005).

Ralph Gomory and William Baumol (2001) demonstrate that standard trade theory shows multiple outcomes for trading partners. In some outcomes, both partners benefit; in others, one country gains and the other loses.

The net effects of offshoring on the U.S. economy are uncertain, but engineers and the engineering community can begin adapting if they understand the anticipated impacts on the labor market and begin tracking observable trends. This information can also help policy makers explore feasible policy responses.

Impacts of Offshoring on Employment[2]

Most economists believe that offshoring will have little or no long-term impact on the overall number of jobs or the unemployment rate in the United States. According to their models, the total number of jobs in the United States is a function of the size of the labor force (primarily influenced by population), and the unemployment rate is a function of monetary and fiscal policies. They argue that individual jobs may indeed disappear at the microeconomic level as they are moved overseas, but the displaced workers will find jobs elsewhere in the economy as new opportunities arise or are created.

In the short term, offshoring is expected to have the following impacts on employment: (1) job displacement for U.S. workers; (2) a change in the mix of U.S. occupations; and (3) downward pressure on wages for jobs that are newly tradable across borders.

Job Displacement

Some U.S. workers will lose their jobs as their work is shifted to overseas locations. In July, for example, Wachovia Corporation announced plans to move many of its information technology (IT) jobs to India and told its 3,000 U.S. IT workers to prepare for lay-offs. The assumption is that these about-to-be displaced workers will be reemployed rapidly, and at substantially the same wages, as they "adjust," as economists say, to structural changes in the economy.

In reality, the adjustment process—workers seeking and finding opportunities at other companies, in other geographic regions, and/or in other occupations—is difficult. The data on reemployment outcomes are limited, but we can get an indication from the Bureau of Labor Statistics *Displaced Workers Survey* (2004). The survey shows that, of workers who were displaced between 2001 and 2003, 35 percent were still unemployed in January 2004, and, of the 65 percent who were employed, only 43 percent earned as much as they did before displacement. Thus, the empirical data show that displaced workers are not reemployed rapidly (one in three remains unemployed) or at the same or higher wages (three in five took pay cuts).

These outcomes are largely consistent with results of surveys of displaced workers conducted since 1979. Significant numbers of displaced workers are likely to remain unemployed for extended periods of time, and many of those who find work take substantial pay cuts.

Macroeconomic job creation is an important factor in the rate and quality of reemployment. If many new jobs are being created, a worker's chances of successful reemployment increase. Unfortunately, levels of job creation in the most recent economic expansion of the U.S. economy have been unusually low. Although most macroeconomic indicators, such as robust expansion of the gross domestic product (GDP), have been favorable, job creation has been far weaker than during any other recent recovery from recession.

Job creation during the latest economic recovery has been weaker than during any other recovery from recession.

There are a few good explanations for why the economic expansion has not generated jobs up to historical norms. In the 44 months since the recession ended in November 2001, the economy has created 2.907 million new jobs, or an average of 793,000 jobs per year. Job creation for the 44 months after the previous recession, which ended in July 1991, was 8.575 million jobs, an average of 2.339 million per year. Just to keep up with new entrants in the labor force from demographic changes, the economy must create about 1.8 million jobs per year. Therefore, adjustment is more difficult than usual for displaced workers trying to find employment in their own or other occupations.

[2] The term offshoring as used in this paper encompasses offshore outsourcing.

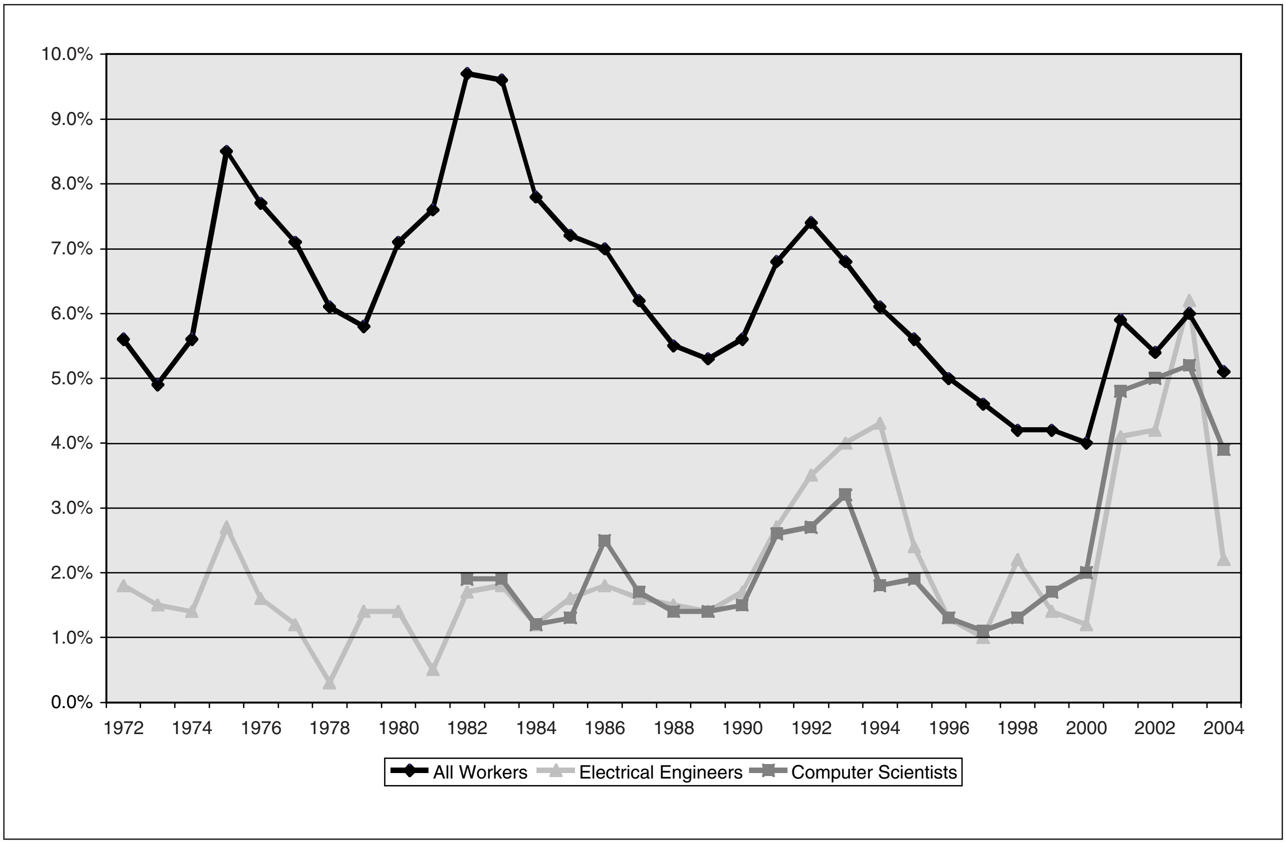

FIGURE 1 Unemployment rates for U.S. electrical and electronics engineers. Source: IEEE-USA, adapted from BLS, 2004.

As Figure 1 shows, U.S. electrical and electronics engineers and computer scientists experienced higher levels of unemployment in the past four years than during any other four-year period since 1972. In 2003, for the first time, the unemployment rate for electrical and electronics engineers (6.2 percent) exceeded the national unemployment rate (6 percent). To put this in historical perspective, throughout the whole decade of the 1980s, unemployment among electrical and electronics engineers never rose above 2 percent, despite national unemployment rates that peaked at 9.7 percent.

In addition, because of the slack labor market, wages of those who are employed fell slightly. For the first time in the 31 years that IEEE-USA has been surveying its members, median compensation declined in 2003. Although unemployment rates improved markedly among electrical and electronics engineering in 2004, this was partly due to increased hiring and partly due to engineers dropping out of the profession and looking for work in other occupations. Electrical and electronics job creation has not been robust enough to make up for earlier losses.

Many factors, such as the telecommunications bust, have contributed to the slack market for electrical and electronics engineers. But, understandably, they have expressed greater concerns about offshoring than some other professionals, such as accountants, who have benefited from high demand generated by the Sarbanes-Oxley regulations. In addition, engineers who are unemployed for an extended period of time may face higher burdens than the average U.S. worker. If it's true that "the half-life of an engineer is three to five years," engineers who are out of work for a year or more risk losing cutting-edge skills much more rapidly than displaced workers in other occupations.

Mix of U.S. Occupations

The second effect of offshoring predicted by economists is a change in the mix of U.S. occupations, as some jobs migrate to more efficient (lower cost) overseas locations. As some sectors are lost, the United States will specialize in sectors in which it has a comparative advantage. However, there is no guarantee that the new mix of U.S. occupations will be better. In fact, economists cannot predict what types of new jobs will be created. This is a key policy question that no one can answer at this point. It is also a practical question. At every IEEE meeting I attend, I am invariably asked, "What new jobs should I be training for? What new skill sets will I need?"

Educators are grappling with the same questions. Engineering educators want to adjust curricula to help immunize their students against offshoring. But because most companies are reluctant to reveal their plans for offshoring, and because the government is not collecting data, we are all left to speculate about what kinds of jobs will go and what kinds will stay.

If the United States relinquishes many engineering and technology jobs, will we be able to replace them with better jobs? If the replacements are nontechnology jobs, how will that affect our ability to drive technological innovation? Conventional economic theories do not explicitly account for the impacts of offshoring on technological innovation and national security.

Wage Suppression

The third predicted effect on employment is wage suppression in jobs that are newly tradable across borders. Workers in these occupations are suddenly facing much more competition, which means they have less bargaining power. As some try to shift into nontradable tasks in the same or new occupations, competition for these jobs will also increase. Some observers believe that wage suppression, rather than job loss per se, will be the most significant effect of offshoring on U.S. employment.

Observable Trends in Offshoring

The types of jobs moving offshore do not follow a simple pattern, such as tasks requiring lower education levels moving offshore and higher level tasks remaining in the United States. Clearly, at least some high-level engineering design tasks are being moved offshore, and the primary driver is lower wages. Many top technology firms, such as Microsoft, General Electric, Google, and others, are building research and development centers in low-cost countries, and job openings posted on the websites of technology companies indicate that overseas engineering hires often require advanced degrees and experience. And the trend is not limited to established or mature companies. Many venture capital firms now require that the start-up firms they fund have offshoring plans.

IT services is the first-mover sector in the current, nonmanufacturing wave of offshoring. Thus, IT may be an indicator of things to come for other sectors. Because many of the larger IT firms are publicly traded, we can understand how offshoring is unfolding in IT services by examining their financial reports. Table 1 shows comparative basic financial data for the largest IT services firms with traditional business models and for firms that started with an offshore outsourcing model. As you can see from the table, two of the major offshore outsourcing companies, Infosys and Wipro (both based in India), have higher market valuations than their U.S.-based competitors, Electronic Data Systems (EDS), Computer Sciences Corporation (CSC), and Affiliated Computer Services (ACS). In 2004, for example, EDS had $21 billion in revenue and a $10.3 billion market valuation; Infosys, with only $1.6 billion in sales, had a $20.5 billion market valuation. In other words, Infosys has twice the market capitalization of EDS with one-twelfth the sales.

Indian offshore outsourcing firms have significantly higher profit margins than their U.S. counterparts.

Profit Margins

The reason for the high valuation of offshore outsourcers is quite simple. They have significantly higher profit margins, also shown in the table. In 2004, Infosys and Wipro had net profit margins of 31 percent and 20 percent, respectively, while EDS and CSC had net margins of 0.8 percent and 5.8 percent. And these differentials have been sustained for the past five years.

These comparisons demonstrate that IT offshore outsourcers are hardly small players. In fact, they are actually the market leaders. Rapid sales growth (39 percent for Wipro) results in rapid job growth (45 percent, or 14,500 new workers). Infosys added as many employees in the last quarter, approximately 5,000, as it did in its entire preceding fiscal year.

Rapid growth has enabled offshore outsourcing firms to raise extraordinary sums from public offerings on stock markets. At the same time last year that Google

TABLE 1 Comparative Financial Data for Traditional IT Firms and Offshoring IT Firms

	Traditional Model			Offshore Outsourcing Model		
	EDS	CSC	ACS	WIPRO	INFOSYS	COGNIZANT
Market Valuation (billions)	$10.3	$8.1	$6.2	$15.3	$20.5	$6.5
Employees	117,000	90,000	43,000	46,500	36,800	15,300
Sales (millions)	$20,669	$14,059	$4,106	$1,865	$1,592	$587
Net Profit Margin	0.8%	5.8%	12.9%	19.5%	30.8%	17.1%
Employee Growth	–11%	0%	8%	45%	43%	66%
Sales Growth	0%	–5%	8%	39%	50%	59%
Profit Growth	–109%	56%	73%	58%	53%	75%

Source: 2004 annual reports submitted to the U.S. Securities and Exchange Commission.

was raising $1 billion in an initial public offering (IPO) on Wall Street, Tata Consultancy Services, the largest Indian IT firm, raised a similar amount with an IPO on the Indian stock exchanges.

Indian offshore outsourcing firms have significantly higher profit margins than their U.S. counterparts for three reasons. First, and most important, profit margins on work performed offshore are higher than work done on site in the United States. Because a larger share of the staffs of offshore outsourcers is located overseas, these companies have higher profit margins than firms with traditional business models.

Second, the Indian government grants tax holidays on software and business process outsourcing exports. This advantage translates into much lower effective tax rates for Infosys and Wipro (between 13 and 14 percent) than for most U.S. companies, which had effective tax rates of approximately 35 percent.

Finally, many offshore outsourcing firms, based in India and the United States, are using the U.S. government-administered H-1B specialty occupation and L-1 intracompany transfer temporary visa programs to gain competitive advantages. The vast majority of the employees of these companies in the United States are H-1B or L-1 visa holders. Very few American citizens or permanent residents are hired and, in general, H-1B holders are not sponsored for permanent residence.

This serves two purposes. First, it enables companies to pay their on-site workers lower wages than comparable U.S. workers. Second, it facilitates the transfer of work overseas by providing a training ground for key employees. Foreign workers on site in the U.S. for extended periods of time gain critical experience with the most sophisticated customers.

In many cases, workers are part of a formal process known as “knowledge transfer,” whereby U.S. workers are asked to train their foreign replacements. In some cases, this is a condition for the U.S. worker to receive severance pay and unemployment insurance. The foreign workers then return to the offshore location where they effectively act as liaisons to customers; in addition, they train additional offshore workers.

Companies with traditional business models are responding to these market leaders by moving more of their labor overseas. IBM will reportedly increase its head count in India from 6,000 in 2002 to 38,000 by the end of 2005. Accenture recently announced plans to increase its head count by 30,000 in India, China, and the Philippines over the next three years. EDS has announced that 20,000 jobs are being moved from high-cost to low-cost countries.

The robust hiring in India has spurred salary increases for some Indian technology workers. For example, Infosys has announced that its offshore salaries have increased 13 to 15 percent. However, salaries are not increasing across the board; most of the increases went to middle-level workers but not to entry-level or senior-level workers. Of course, the increases are on very low salaries, mostly in the range of $12,000 to $15,000, and it is unlikely that offshore wages will approach U.S. levels anytime soon.

In addition, a new labor supply is coming on line to meet demand as Indian universities turn out more graduates, more workers rotate through the United States on H-1B visas, and more developing countries become attractive places for IT services. Indian IT firms, concerned about competition from even lower cost providers in China, are opening operations there. Tata Consultancy Services, for example, recently announced a joint venture with the Chinese government and Microsoft to help China enter the market. Thus, the primary attraction for companies to offshore—large wage differentials between U.S. and foreign workers—is likely to persist even as demand increases.

Policy Responses

There are no easy answers or silver bullets to the complex economic and employment challenges associated with offshore outsourcing. The general areas in which policy changes can help fall into six categories:

1. Collecting better intelligence to improve labor market signals and clarify the impacts of offshoring on technological innovation and national security.
2. Ensuring that government policies, such as tax incentives and visa programs, do not accelerate offshoring.
3. Taking preventive measures to help workers adapt before they are displaced.
4. Providing palliative measures to help workers who are hurt.
5. Providing recuperative measures to help workers obtain better reemployment.
6. Adopting measures to expand technological frontiers and accelerate the creation of high-wage jobs. (The focus should be on solutions that are geographically "sticky" and that help workers rather than companies.)

More than two years ago I dubbed the policy debate on offshoring the "new competitiveness debate" because I think lessons can be learned from the 1980s debate on competitiveness. The old debate has been extensively chronicled by Dr. Kent Hughes in his new book, *Building the Next American Century: The Past and Future of Economic Competitiveness* (2005). The most important lesson to be learned is that it takes time and creativity to generate sound public policy responses to major economic shifts.

The key difference between the new and old debates on competitiveness is that workers today are much more likely than companies to be adversely affected. This difference means that the practical and politically acceptable solutions that were used in the past will not work this time, and I suspect this will make it much more difficult to move forward. Many companies will be able to adapt to the new competitiveness challenge by substituting foreign for U.S. labor. Thus, they may succeed against their competition, but without U.S. workers.

The current competitiveness challenge has companies pitting U.S. workers against foreign workers, and companies are taking the latest technology and capital to the lowest cost labor, thereby eliminating a traditional advantage for U.S. engineers. This creates a practical problem because most of our established policy mechanisms are designed primarily to help companies. For example, increased government spending on R&D may lead to breakthroughs in nanotechnology in the United States, but the bulk of the jobs created from the design, development, and production of the resultant products may be overseas, as companies quickly or virtually transfer the latest tools, technologies, and techniques to low-cost overseas engineers.

Therefore, policy responses proposed by some business groups, such as doubling the number of U.S. engineering graduates, are not likely to be effective unless they are accompanied by substantive changes in engineering education to provide different skills than those of foreign engineers. We need different, not more, scientists and engineers. Achieving this will be much more difficult than most people realize, but it is time we begin to talk about the best ways to respond to offshoring.

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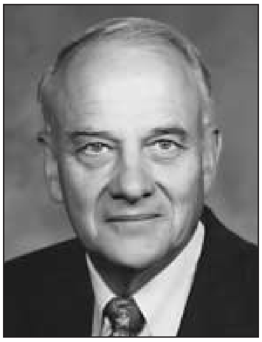
The United States is trading the long-term health of U.S. research and education for the appearance of short-term security.

A Disturbing Mosaic



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Wm. A. Wulf

I assume that all of you have read or heard a discussion of Tom Friedman's book (2005), *The World Is Flat*. But just in case, I'll restate Friedman's premise: the international economic playing field has become flat(ter) and is now "more level" than at any time in the past. This "flattening" is the result of information technology and a glut of inexpensive bandwidth, which has made it possible for American companies to locate call centers in India, coordinate complex supply chains and work flows that enable manufacturing in China, and do "back office" work in India (e.g., Indian radiologists now read x-rays and CAT scans from U.S. hospitals, etc.). Offshoring, outsourcing, and Lou Dobb's "Exporting of America" are all manifestations of this leveling.

Friedman argues that, despite the dangers, a flat world is a *good thing* on the whole—both economically and geopolitically. Lower costs benefit both consumers and shareholders in developed countries, he says, and a rising middle class in India and China will become consumers of their own products and ours. That same rising middle class also has a stake in frictionless international commerce—and hence in stability, peace, and the rule of law. But, Friedman says, there will certainly be problems during the transition, and whether or not global flatness is good for a particular country depends on whether that country is prepared to compete on the rough-and-tumble, level, global playing field.

I was prompted to write this paper by a few lines at the very end of Chapter 6 in which Friedman describes what a country must do to prosper in a flat world:

> *But have we [meaning the United States] really been investing in our future and preparing our children the way we need to for the race ahead? See the next Chapter. But here is a quick hint:*
>
> *The answer is no.*

I am concerned not only about our lack of preparation, but also about a host of related issues. In this paper, I will raise some of these concerns, but I don't pretend to offer solutions to them. Some of these issues are technical and some are not—in fact, some of them are political (not political-party political, but "bringing the rest of the body politic along" political). Engineers tend to shy away from such things—but the stakes are too high, in my view, for us to do that now. My goal is to provoke a conversation in the larger engineering community.

Freidman talks about a "quiet crisis." I have called it a "creeping crisis," but I think we mean the same thing. You all know the storied procedure for boiling a frog. They say that if you drop a frog into 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 incremental rises in temperature are 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—not just outsourcing/offshoring—each one like a tile in a mosaic. No problem by itself creates the sort of crisis that provokes action. But if you stand back and look at the whole 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.

In 2001, the Hart-Rudman Commission, which proposed the establishment of a Department of Homeland Security, 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.*

That report was written before 9/11, but had it been written afterward, I am sure "conventional war" would have been expanded to include the struggle against terrorism. Yet, as a country, we seem to make decision after decision to address problems in ways that trade the *appearance* of near-term security for the reality of long-term damage to our system of research and education—and hence to our *real* security. The problems facing us can be grouped into two clusters: reactions to 9/11 and disinvestment in our future.

We are intent on preserving the status quo rather than reaching for the next big goal.

Cluster 1: Reactions to 9/11

Three of the pieces in my mosaic are reactions to 9/11, clear examples of trading the appearance of security for long-term damage. I am the first to acknowledge that 9/11 *really did* change things and that it is entirely appropriate that we rethink our "balance point" with respect to each of these issues. The nature of our adversary *has* changed. The Soviet Union was both a "rational actor" and exquisitely "research capable"; terrorist cells are neither. We wanted the Soviets to know enough about our capabilities so they wouldn't miscalculate our capabilities. In addition, there was no sense in hiding what they were perfectly capable of reproducing. Although the same disclosures today might be counterproductive, the actions described below have not improved our security.

New Visa Policies

Much has been written about the impact of new visa policies on students. Although the situation has improved somewhat in the last several months (as of this writing, the average time for processing visas for students is less than two weeks), I am still concerned because the distribution has a "long tail." Some students must still wait a year or more for visas, and some senior scholars, including a Nobel laureate, are still being subjected to lengthy, demeaning treatment. These cases, not the shorter processing time, are being reported in the international press, and as a result, instead of the United States being seen as a welcoming "land of opportunity," it is now seen as exactly the opposite. When coupled with new, demeaning procedures for photographing and fingerprinting visitors, we are not just discouraging students, international conferences in the United States, and collaboration with our international colleagues. We are dramatically altering the image of our country in the eyes of the rest of the world.

Do these measures materially increase our security? I don't know what I don't know, of course, and classified information might indicate that they do. But with an estimated 10 million people who have entered the country illegally and an immense traffic in drugs and other illegal imports, it strains the imagination to think that a dedicated terrorist and his/her weapons will be stopped by these policies.

Export Controls

Export controls were first instituted in the United States in 1949 to keep weapons technology out of the hands of potential adversaries. But they have also been used as an economic tool against our competitors. The export of controlled technology requires an "export license" from either the U.S. Department of Commerce or State. In addition, since 1994 the disclosure of information about a controlled technology to certain foreign nationals (even in the United States) has been "deemed" to be the export of the technology itself. Thus, disclosure also requires an export license.

We are dramatically altering the image of our country in the eyes of the rest of the world.

Reports of the inspectors general (IGs) of the U.S. Departments of Commerce, Defense, and State have suggested that the implementation of the rules governing deemed exports be tightened further. For example, they have suggested that the exemption for basic research be altered, and possibly eliminated, and that the definition of "access" to controlled technology be broadened.

The university community is rightly concerned that a literal interpretation of the IGs' suggestions would essentially preclude foreign graduate students from participating in research and would require an impossibly complex system to enforce. Given that 55 percent of the Ph.D. students in engineering in the United States are foreign born, the effect could be catastrophic.

Again, one might ask if these policy changes would improve our security. And, again, with the same caveat, I would point out that the United States is not the only research-capable country; 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 barriers to the exchange of information about basic research, we wall ourselves off and slow our own progress. At the same time, the information we are "protecting" is often readily available from other sources.

The current idea that foreign students in our universities represent a danger to our security must be balanced with the advantages of having them here:

- Einstein, Teller, Fermi, and many other immigrants enabled the United States to have the bomb before Germany.
- Many students from abroad stay in this country and contribute greatly to our economy.
- Foreign students who return to their home countries are often our best ambassadors.
- The United States benefits economically from open trade, and our security is reinforced by a better quality of life in developing countries.
- The quality of life in the United States has improved from sharing scientific results, enabling us to "move faster" in the development and adaptation of new technologies.
- We benefit from funding basic research on the principles of nature and from a generally educated citizenry.

Sensitive but Unclassified Information

The proliferation of information designated "sensitive but unclassified" (SBU) is a less publicized problem than visas or deemed exports, but it has become a complicating factor in academic research and a bane to the National Academies. On the one hand, we agree that the issue needed to be revisited after 9/11. Some things not covered by traditional classifications—some biotechnology, for example—clearly would be better kept from a less research-capable adversary.

On the other hand, classifying SBU information is not backed by the precise laws, limited and specified authority to classify, mandatory declassification after a period of time, and a philosophy of "building high fences around small places" that are associated with the traditional classification of information. There are no laws, no common definitions, and no limits on who can declare information SBU. In some cases, the SBU classification appears to be used to suppress criticism. In other cases, it is being used to try to restrict the publication of legitimate research results.

There is no question that we need a serious discussion about new kinds of information that should be classified. But we are not having that discussion. The wholesale application of the SBU classification is more damaging to us than seems to be understood by those who use it.

Cluster 2: Disinvestment in the Future

A second cluster of pieces of my mosaic has to do with disinvestment in the future. Continued prosperity and security have always required that we forego some current consumption to ensure a better quality of life in the future. Aside from our notoriously poor individual savings rate, I think we are also failing to invest (save) collectively.

Demise of Corporate Research and Development

The U.S. research structure evolved after World War II as a self-reinforcing triangle of industry, academia, and government. Today, one side of that triangle—industry—is missing, and the remaining structure is much less stable. Some of the most important fundamental research in the last century was done in corporate laboratories—Bell Labs, GE Research, IBM Research, and others. Today, only vestiges of these laboratories still exist, and they have a much shorter time horizon and are heavily focused on product development.

Some would say that the demise of corporate research is the result of the short time horizon of the stock market and/or the demise of the regulated monopoly in telecommunications. Undoubtedly, both of these are important factors. But I think it also represents a failure to consider research an investment rather than an expense—in effect, saying research per se has no lasting value. As a result, instead of developing public policies that encourage corporate research, we are doing just the opposite.

Funding for Research in Physical Science and Engineering

Although support for research in the life sciences has increased enormously, funding for research in most physical sciences and engineering has declined or remained flat for several decades. This seems ironic because many of the medical devices and procedures we enjoy—endoscopic surgery, smart pacemakers, dialysis machines, imaging technologies (e.g., MRI, CAT scans, and PET scans), just to mention a few—are the results of research and development in the physical sciences and engineering.

Funding for research in physical sciences and engineering has declined or remained flat for several decades.

Coupled with, and perhaps caused by, the stagnation of funding levels, federal funding agencies have become increasingly risk averse and have focused increasingly on short-term results. The most obvious example is the Defense Research Projects Agency (DARPA), which used to be a shining example of investment in long-term, visionary research. DARPA now has a limit of three-year contracts with reviews every 12 months.

I believe that even the National Science Foundation is becoming increasingly risk averse, although this is difficult to quantify. A more concrete example is at the National Institutes of Health where a recent National Academies study revealed that the average age at which a principal investigator receives his or her *first* grant is 42—partly because of requirements for evidence of an extensive "track record" (to reduce the risk). Ironically, reducing the risk for individual research projects *increases* the risk that breakthrough, "disruptive technologies" will not be found—the kind of breakthroughs that could yield huge returns.

Higher Education as a Private Good

Historically, the United States has considered higher education a public good. That is, we agreed as a society that educated citizens benefited the country as a whole—not just the individuals who received the education. That is why we supported universal K–12 schooling; that is why we created the land grant colleges in the 1860s; that is why a system of superior state universities was created and generously supported and why scholarships were given to needy students; and that is why we passed the GI Bill after World War II and the National Defense Education Act in the 1950s.

Today, however, state support for state universities is disappearing, tuitions are soaring to replace that support, and we offer students loans rather than scholarships. These are all indications that we, as a society, now view higher education as a private good, that is, of value only to the individual student.

A particularly disturbing aspect of this change is the impact on economically disadvantaged students. College (and specifically engineering) has been a traditional path for upward economic mobility (the author is but one example). The shift to treating higher education as a private good, and the resultant shift in cost burden, have made it much more difficult for students from disadvantaged backgrounds to follow that path. In the long run, the nation will suffer from the lack of new talent that was made possible through affordable, accessible, public higher education.

Loss of Human Capital

An educated, innovative workforce—human capital—is the most precious resource of any country and is crucial in this new, flat world. Yet the number of engineering undergraduates in the United States peaked in the mid-1980s and declined by 25 percent during the 1990s. The number has rebounded recently—but not to the 1985 level. In fact, China and India both have about five times as many engineering undergraduates, and the United States now graduates only about 7 percent of engineers worldwide. Even more troubling, the percentage of undergraduates studying engineering in the United States is the second lowest among developed countries—4 to 5 percent in the United States compared to 12 percent in most European countries and more than 40 percent in China.

Conclusion

I have mentioned just some of the “tiles” in the mosaic, but many other problems could be added to the list—such as the failure to address the energy issue and the accumulation of greenhouse gas emissions—to complete this depressing picture. But these seven tiles reveal a common characteristic—they all give the *appearance* of providing short-term gains and conceal real long-term losses.

In closing, let me circle back to the issue of our flat world and the outsourcing/offshoring of U.S. jobs, especially jobs in science and engineering, which are the backbone of U.S. innovative capacity. I don’t believe that outsourcing/offshoring is a piece of the mosaic, but a protectionist reaction to it is. Of course, we must help those who lose their jobs, by providing financial assistance and retraining, for example, and it may even be appropriate to protect some jobs as a short-term tactic. But in the end, the country will be strengthened only by learning to compete in this new, flat world. Among other things, that means that we engineers must deliver value that justifies our cost, but the U.S. engineering community has yet to figure out how to do that.

Addressing just one part of the problem, however, is not enough. Unless we address the broad issue of short-term thinking, our children will live in a much less privileged country, and perhaps one substantially less comfortable on an absolute scale.

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NAE News and Notes

NAE Newsmakers

Charles Elachi, vice president of Caltech, director of the Jet Propulsion Laboratory (JPL), and professor of electrical engineering and planetary science, has been chosen to receive the **Bob Hope Distinguished Citizen Award** for 2005 "in recognition of outstanding dedication and service to the national security of the United States." The award will be presented by the National Defense Industrial Association at a black-tie dinner on February 25. During his 30-year career at JPL, Elachi has "played the lead role in developing the field of spaceborne imaging radar from a small research area to a major field of scientific research and application."

Robert W. Galvin, retired president and CEO of Motorola Inc., received the **Vannevar Bush Award** for his lifetime contributions to the nation in science and technology. The award, given by the National Science Board, was presented at a dinner ceremony on May 25, 2005.

Eta Kappa Nu (HKN), the honor society for electrical and computer engineers, has recognized **Bernard M. Gordon** as an **Eminent Member**, the society's highest honor. Dr. Gordon was recognized for his role in the development of pioneering technologies that have contributed to major advances in industrial instrumentation, medical imaging, computer systems, aerospace telemetry, and communications.

The Dan David Prize, awarded by the Dan David Foundation at Tel Aviv University, recognizes laureates who have contributed significantly to past, present, and potential (future) human development. Each year an international panel of renowned scholars and professionals chooses laureates for each category. **Robert Langer**, Institute Professor, Massachusetts Institute of Technology, and George Whitesides, Woodford L. and Ann A. Flowers University Professor, Department of Chemistry and Chemical Biology, Harvard University, received the **Future Time Dimension Award** for 2005.

Donald R. Paul, Ernest Cockrell Sr. Chair in Engineering and director, Texas Materials Institute, University of Texas at Austin, was awarded the 2005 **Herman F. Mark Polymer Chemistry Award** for "his research and leadership in major areas of polymer science and engineering." The biennial award will be presented to Dr. Paul at the fall meeting of the American Chemical Society Polymer Chemistry Division.

The Consul General of Italy recently presented the prestigious Italian recognition of **Cavaliere**, an honorary knighthood, to **Celestino R. Pennoni**, chairman of the board of Pennoni Associates Inc. This civic honor is bestowed by the president of the Italian Republic.

Tau Beta Pi, the engineering honor society, has selected **H. Vincent Poor**, George Van Ness Lothrop Professor in Engineering, Princeton University, as its **Distinguished Alumnus** for 2005. Dr. Poor will receive a commemorative plaque, and a $2,000 scholarship will be given to a deserving student member in his name. Dr. Poor was selected for "outstanding achievements in teaching and advancements of professional engineering."

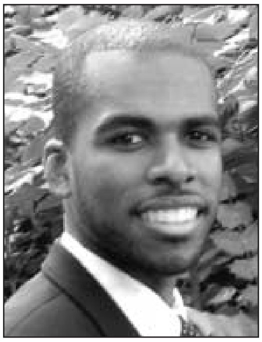
Robert A. Pucel, retired consulting scientist, Raytheon Company, and his colleague and collaborator, Dr. Hermann Statz, received the **Microwave Pioneer Award** from the Microwave Theory and Techniques Society (MTT-S) of the Institute of Electrical and Electronic Engineers. The Pioneer Award is given in recognition of a major, lasting contribution published in an archival journal at least 20 years prior to the year of the award. Drs. Pucel and Statz were honored for "development of the first comprehensive physics-based model of the short-gate Field Effect Transistor (FET) and a design tool which has played a significant role in the emerging field of Monolithic Microwave Integrated Circuits (MMICs)."

Richard A. Tapia, Noah Harding Professor of Computational and Applied Mathematics, Rice University, was recently recognized as one of the **50 Most Important Hispanics in Technology and Business** for 2005 by *Hispanic Engineer* and *Information Technology* magazine. Honorees are chosen based on their work in a field of technology and their institutional leadership.

Wm. A. Wulf, president, National Academy of Engineering, was selected by the Washington Academy of Sciences (WAS) to receive the 2005 **Distinguished Career in Science**

and Engineering Award. Founded in 1898, WAS has been honoring distinguished Washington-area scientists since 1940. Dr. Wulf was also elected a **Foreign Fellow** of the Australian Academy of Technological Sciences and Engineering. Fellows are elected on the basis of their personal achievements in the technological sciences or engineering. The Certificate of Fellowship was presented to Dr. Wulf on July 12 at the 2005 International Council of Academies of Engineering and Technological Sciences (CAETS) Convocation in Cairns, Australia.

Christine Mirzayan Science and Technology Policy Graduate Fellows Join Program Office



Bruk T. Berhane

Kristen Bethke

Ashrujit Mohanty

Devin Stewart

Bruk T. Berhane (NAE/CDEW) is pursuing an M.S. at George Washington University in engineering management, with a focus on energy and environmental management. He expects to graduate in May 2006. Bruk received his B.S. in electrical engineering from the University of Maryland in May 2003.

During the 2002 to 2003 academic year, Bruk was president of the University of Maryland chapter of Eta Kappa Nu, the national honor society for electrical and computer engineering. He was also selected for membership in the Ronald E. McNair Post-Baccalaureate Achievement Program and was awarded a Meyerhoff Scholarship from the University of Maryland, Baltimore County.

Bruk worked at the Johns Hopkins University Applied Physics Laboratory in the Research Technology Development Center from 2003–2005. He is also actively involved with the Maryland Business Roundtable for Education (MBRT).

This summer, Bruk worked in the Diversity in the Engineering Workforce Program. His primary task was to upgrade/update the *EngineerGirl!* website. In addition, he held four focus groups with middle school girls to assess their receptivity to *EngineerGirl!*. Bruk and several other policy fellows at the National Academies planned and presented an educational seminar on the costs and benefits of implementing a national identification card system.

Bruk's career goals are to serve as an advisor or educator on scientific and technological issues, either as an elected official or through an outreach office affiliated with an educational institution or a nonprofit organization. This fall, Bruk will be teaching 10th-grade algebra and geometry at Baltimore Polytechnic Institute.

Kristen Bethke received an M.S. in aeronautics and astronautics from the Massachusetts Institute of Technology in June 2005, and she will return in the fall as a Ph.D. candidate. She earned her B.S. in mechanical and aerospace engineering from Princeton University in 2003. At MIT, Kristen conducted her master's research on advanced spacesuit design. Although she is still passionate about space exploration, she is now using her engineering background to explore new opportunities, such as applying engineering concepts to primary education. As a result of weekly volunteer sessions helping out in K–12 science classrooms, Kristen has become deeply concerned about the shortcomings of science education and the lack of technological literacy in our schools. In her future studies, her goal is to demonstrate the educational effect of challenging young students to use math and science to solve real problems in real communities.

As a Christine Mirzayan Fellow at NAE, Kristen worked in the Center for the Advancement of Scholarship on Engineering Education (CASEE), specifically on the *CASEE Chronicles*, a publication that features the work of groups and scholars affiliated with CASEE. Kristen surveyed the latest educational research results and successful programs of the 28 CASEE-affiliated groups and compiled the information into a publication intended to disseminate the information to educators and influence policy makers to provide more support for reform in engineering education.

Ashrujit Mohanty, who is pursuing his D.Sc. in computer engineering at George Washington University, received his bachelor's degree in computer science and engineering from the National Institute of Science and Technology at Berhampur University, India, in October 2002. He worked as an assistant system engineer at Tata Consulting Services in Mumbai, India, for a year before going back to school for graduate studies.

Ashrujit is a research assistant at George Washington University in the High Performance Computing (HPC) Laboratory working on parallel distributed computing, parallel languages, and benchmarking of HPC systems. He is also a youth coordinator and volunteer at the National Council of Asian Indian Associations (NCAIA) (*http://www.merabharatmahan.org*) where he helps organize sociocultural events for the Asian-Indian community in the Washington, D.C., area.

As a Christine Mirzayan Graduate Policy Fellow at the National Academies, Ashrujit worked in CASEE on several projects. For a project being conducted in collaboration with Sigma Xi, the scientific research society, Ashrujit summarized the availability, outcomes, and effectiveness of programs designed to attract new students to engineering education and retain students who have already expressed an interest in engineering. The program focuses on precollege and early undergraduate students.

As part of a project being conducted by CASEE Boeing Engineering Education Senior Fellow Dr. Christine Grant, Ashrujit identified prominent African-American and Hispanic-American engineers in industry and government to provide material for leadership seminars bringing together minority students to learn about their predecessors and encourage the development of peer mentoring networks. Ashrujit also participated in a project that complements an activity of the World Bank to find ways to leverage the educational infrastructures of institutions that serve minority groups to launch a continent-wide initiative for scientific and engineering education in sub-Saharan Africa. Finally, Ashrujit participated in benchmarking activities to provide support for Engineering Education Leadership Institutes; this project is supported by the Intel Foundation and the National Science Foundation.

Devin Stewart is currently finishing his M.S. in aerospace engineering from Virginia Polytechnic Institute and State University. His graduate research is focused on an experimental wind tunnel study of rough-wall turbulent boundary layers using laser doppler velocimetry. He also teaches upper-level aerospace laboratory courses. Devin earned his B.S. and B.A. in aerospace engineering and Spanish language and literature, respectively, from the University of Maryland, College Park. In the fall of 2001, Devin worked as an English language teacher in Madrid, Spain, helping business people increase their proficiency skills.

Devin's work at CASEE was focused on issues related to improving engineering education and student retention. The Christine Mirzayan Fellowship, he said, gave him an opportunity to study "how government can create an environment conducive to the improvement of science and engineering education."

Devin researched current federal funding levels for engineering education research and gathered information on strategies to improve the funding environment. Based on conversations with congressional staff members and education advocates, he attempted to map the political landscape and the prospects for funding of education research. Despite tight budgets, he found that several senators and representatives are focusing on science and engineering education as a critical component of America's competitiveness in a global economy and a key element in national defense. Devin put together ideas for raising the profile of engineering education.

Recommendations for Enhancing the U.S. Visa System to Advance America's Scientific and Economic Competitiveness and National Security Interests

Statement dated May 18, 2005

Following the terrorist attacks of September 11, 2001, the U.S. government put in place new safeguards in the nation's visa system that made it extremely challenging for bona fide international students, scholars, scientists, and engineers to enter this country. While intended to correct weaknesses exposed by the attacks, the changes proved to be significant barriers for legitimate travelers and created a misperception that these visitors were no longer welcome here.

Other countries have used this opportunity to attract these individuals to their own educational, scientific, and technical institutions. In addition, key sending countries have enhanced their higher education systems in an effort to keep their best students at home.

Despite significant recent improvements to the U.S. visa system, considerable barriers remain that continue to fuel the misperception that our country does not welcome these international visitors, who contribute immensely to our nation's economy, national security, and higher education and scientific enterprises. These misperceptions must be dispelled soon, or we risk irreparable damage to our competitive advantage in attracting international students, scholars, scientists, and engineers, and ultimately to our nation's global leadership.

One year ago, most of the undersigned organizations of higher education, science, and engineering, in an effort to enhance national security and international exchange made a joint commitment to work with the federal government to make sensible changes to the visa system. We recommended several improvements, some of which have been adopted in the past year. Today we come together again to express gratitude and support for the changes that have been made, to continue to urge approval of those that have not, and to recommend additional improvements, so that America can continue to compete for and welcome the world's best minds and talents. We offer the following recommendations in the spirit of cooperation that has already resulted in improvements to the visa system:

- **Extend the validity of Visas Mantis security clearances for international scholars and scientists from the current two-year limit to the duration of their academic appointment.** While we appreciate that the limit has already been extended from one year to two years, this further extension would be comparable to that already provided for international students and would prevent redundant security checks that can waste resources and cause unnecessary delays and hardships.

- **Allow international students, scholars, scientists, and engineers to renew their visas in the United States.** Allowing individuals to complete, or at least initiate, the visa revalidation process before leaving the country to attend academic conferences or to visit family would reduce, and in many cases eliminate, visa delays, thus permitting them to continue their studies and research uninterrupted.

- **Renegotiate visa reciprocity agreements between the United States and key sending countries, such as China, to extend the duration of visas each country grants citizens of the other and to permit multiple entries on a single visa.** We applaud the State Department's initial efforts to achieve this and encourage continued efforts. Improved reciprocity would allow the federal government to focus its visa screening resources by reducing the number of visa renewals that must be processed.

- **Amend inflexible requirements that lead to frequent student visa denials.** The Immigration and Nationality Act of 1952 should place greater emphasis on student visa applicants' academic intent and financial means to complete a course of study in the United States, instead of their ability to demonstrate evidence of a residence and employment in their home country and their intent to return home. Up to 40 percent of student visa applicants from key sending countries are rejected because they are unable to demonstrate to the satisfaction of consular officials their intent and ability to return home after completing their studies. The United States is losing too many top students to this policy, and the Act should be revised.

- **Develop a national strategy to promote academic and scientific exchange and to encourage international students, scholars, scientists, and engineers to pursue higher education and research opportunities in the United States.** In addition to visa reforms, this strategy should include a plan to counter prevailing negative perceptions of studying and conducting research in the United States and should promote study abroad by American students.

The following recommendation, while not related to visa issuance, addresses a potential barrier to international scientists and engineers seeking to study and conduct research in the United States.

- **The federal government should not require that export licenses be obtained for international scientists and engineers to use equipment required to conduct unclassified, fundamental research in the United States.** The Department of Commerce is considering expanding existing regulations to require that licenses be obtained before certain foreign nationals are permitted access to specialized scientific equipment required for unclassified, fundamental research. Requiring such licenses would further discourage top international scientists and engineers from making the United States their destination, prompting them to seek research opportunities overseas.

Lastly, it is essential that adequate resources continue to be provided by Congress and the Administration to administer an effective visa system and to implement the above recommendations.

We reiterate our commitment to work with the federal government to improve the visa system. That system should maintain our nation's security by preventing entry by those who pose a threat to the United States and encouraging the entry of the brightest and most qualified international students, scholars, scientists, and engineers to participate fully in U.S. higher education and research enterprises. Such a system will foster American scientific and economic competitiveness. We commend the Administration for the improvements made to the visa system to date, and we look forward to continuing to work together for these further needed changes.

[signed]

Nils Hasselmo, President, Association of American Universities

Alan I. Leshner, President, American Association for the Advancement of Science

Bruce Alberts, President, National Academy of Sciences

David Ward, President, American Council on Education

C. Peter Magrath, President, National Association of State Universities and Land Grant Colleges

Wm. A. Wulf, President, National Academy of Engineering

Harvey V. Fineberg, President, Institute of Medicine

Deborah L. Wince-Smith, President, Council on Competitiveness

Marlene M. Johnson, Executive Director and CEO, NAFSA: Association of International Educators

Marvin L. Cohen, President, American Physical Society

Debra W. Stewart, President, Council of Graduate Schools

Allan E. Goodman, President and CEO, Institute of International Education

Constantine W. Curris, President, American Association of State Colleges and Universities

James M. Tiedje, Ph.D., President, American Society for Microbiology

Jerry P. Draayer, President and CEO, Southeastern Universities Research Association

Paul W. Kincade, Ph.D., President, Federation of American Societies for Experimental Biology

Gerard A. Alphonse, 2005 President, Institute of Electrical and Electronics Engineers-United States of America

David L. Warren, President, National Association of Independent Colleges and Universities

Eugene Arthurs, Executive Director, SPIE—International Society for Optical Engineering

Stephen Dunnett, President, Association of International Education Administrators

Rev. Charles L. Currie, S.J., President, Association of Jesuit Colleges and Universities

Sally T. Hillsman, Ph.D., Executive Officer, American Sociological Association

Judith Bond, President, American Society for Biochemistry and Molecular Biology

Katharina Phillips, President, Council on Governmental Relations

George R. Boggs, President and CEO, American Association of Community Colleges

Marc H. Brodsky, Executive Director and CEO, American Institute of Physics

Felice J. Levine, Executive Director, American Educational Research Association

James E. Morley, Jr., President and CEO, National Association of College and University Business Officers

Roger Bowen, General Secretary, American Association of University Professors

Norman B. Anderson, Ph.D., Chief Executive Officer, American Psychological Association

Richard S. Dunn, Co-Executive Officer, American Philosophical Society

Mary Maples Dunn, Co-Executive Officer, American Philosophical Society

Richard L. Ferguson, CEO and Chairman of the Board, ACT

John A. Orcutt, President, American Geophysical Union (AGU)

Jerome H. Sullivan, Executive Director, American Association of Collegiate Registrars and Admissions Officers

Steven Block, President, Biophysical Society

Elizabeth A. Rogan, CEO, Optical Society of America

Richard W. Peterson, President, American Association of Physics Teachers

Alyson Reed, Executive Director, National Postdoctoral Association

Robert P. Kirshner, President, American Astronomical Society

Stephen J. Otzenberger, Executive Director. CUPA-HR

Report of the Foreign Secretary

George Bugliarello

Among the many international activities of the NAE this summer, I shall highlight three: the visit of President Xu Kuangdi of the Chinese Academy of Engineering (CAE); the latest meeting of the International Council of Academies of Engineering and Technological Sciences (CAETS); and a discussion at the NAE Council of the goals and structure of our international programs.

President Xu Kuangdi arrived at NAE on June 6, together with Ambassador Zhou Wenzhong of the People's Republic of China. After visiting our main building at 2101 Constitution Avenue, President Xu and the ambassador engaged in a discussion on ways to increase collaboration between CAE and NAE through projects of mutual interest. The first project will be a joint study on air pollution in Chinese and American cities, which will include visits later this year by American engineers, scientists, and economists to Chinese cities followed by reciprocal visits by Chinese colleagues to American cities. The staff coordinator of the study from the U.S. side is Jack Fritz, Senior Program Officer, Engineering and the Environment. President Wulf and I will travel to Beijing in mid-September to continue planning for this and other collaborative projects.

The CAETS meeting was held in Cairns, Queensland (Australia), the second week of July, under the chairmanship of Dr. John Zillman, president of the Australian Academy of Technological Sciences and Engineering and current president of CAETS. President Wulf, **Lance Davis**, and I represented NAE.

CAETS membership now encompasses 23 academies of engineering worldwide; the secretariat (held by William Salmon, former NAE Executive Officer) is in Washington, D.C. CAETS meetings are held once a year in the home country of the president for that year. Last year, the meeting was held in Norway and was accompanied by a symposium on energy. The next meeting will be held in Brussels in June 2006; it will be accompanied by a symposium on hydrogen technology.

The symposium associated with the meeting this year was Oceans and the World's Future. Sessions focused on oceans as food resources; oceans and non-living resources; oceans and climate; consequences for humans of the impacts of climate change on the oceans; oceans and coastal regions; oceans and transport; ocean observation, prediction, and protection; and science, technology, and engineering for sustainable use of the oceans. At the end of the symposium, CAETS issued a statement emphasizing the urgency of governments and the global community addressing these issues. A workshop on tsunamis preceded the symposium, with presentations on scientific, technological, and engineering aspects of the phenomenon and on disaster warnings and responses.

Given the increasing importance of NAE's international activities, considerable time at the August meeting of the NAE Council in Woods Hole, Massachusetts, was devoted to a discussion of the purpose, goals, and structure of NAE's international activities and the development of a realistic, actionable plan and organizational structure, including funding and staffing. Recommendations will be presented at the Annual Meeting in October.

George Bugliarello

George Bugliarello
Foreign Secretary

Extraordinary Women Engineers Project

The Extraordinary Women Engineers Project (EWEP) is a national initiative to encourage girls to consider pursuing degrees and subsequent careers in engineering. The project is led by a coalition of engineering associations, the American Association of Engineering Societies (AAES), American Society of Civil Engineers (ASCE), and WGBH Educational Foundation. NAE is represented on the coalition by Mary Mattis, staff officer for the NAE Diversity in the Engineering Workforce Program.

Formed in spring 2004, the coalition began by addressing the reasons academically prepared girls decide not to enroll in engineering degree programs. Studies have shown that girls take high school science and math courses at approximately the same rate as boys, so the reason must lie elsewhere. Perhaps, girls and the people who influence them—teachers, school counselors, parents, peers, and the media—have a false perception of engineering.

To test this assumption, WGBH, on behalf of the coalition and funded by the National Science Foundation, conducted qualitative consumer research with high school girls, science and math teachers, and school counselors; male and female college-level engineering students; and practicing engineers. From June 2004 to January 2005, WGBH hosted in-person and online focus groups: (1) to gauge the level of interest among high school girls in careers in engineering; (2) to assess general career motivators and barriers toward engineering; (3) to evaluate the messages being put forward to the target audience; (4) and to explore ways to improve messages that could increase enrollment.

Strategic Recommendations

Based on the findings of this research, EWEP recommends fundamental changes in the way engineering is portrayed. First, rather than focusing on the processes and challenges of becoming an engineer, messages should focus on the benefits and rewards of being an engineer as they relate to the career motivators identified by girls. The EWEP coalition also recommended: (1) that the engineering community engage in a public dialogue to redefine engineering as a desirable career option, not just for males but also for academically prepared high school girls (and other underrepresented groups); (2) that messages illustrating engineering as a career that complements and supports community interests, family interests, and self-interests be developed and tested; (3) that the selected messages be conveyed through creative materials that promote engineering to high school girls; (4) that training opportunities and resources be provided to help engineers promote engineering education and careers to girls, their parents, and educators; and (5) that training opportunities and resources be provided to school counselors and teachers to promote engineering education and careers to girls and their parents.

The EWEP coalition has developed a proposal for a second phase of this project that will include designing and disseminating the messages and materials described above and a plan for creating new materials targeting high school girls for the NAE *EngineerGirl*! website.

New Reports from the National Academy of Engineering

Building a Better Delivery System: A New Engineering/Health Care Partnership, a joint study by the NAE and Institute of Medicine (IOM), includes findings and recommendations for building a strong partnership between engineers and health care professionals to address the crises facing health care delivery in the United States. The report focuses on two major applications of systems-engineering tools: (1) systems-design, -analysis, and -control tools to promote a better understanding of health care processes and system interactions and improve/optimize system performance within the severe constraints of a system in crisis; and (2) information and communications technologies to facilitate information flow, connectivity at all levels (patients, care teams, health care organizations, and the larger regulatory and financial environment), and coordinated, patient-centered health care.

In addition to the committee's consensus report, the published volume includes 38 individually authored papers based on presentations given at three fact-finding workshops. The papers address not only the operational challenges confronting the U.S. health care delivery system, but also opportunities for improvement in the areas of information technology, including biosensors and wireless communications, remote monitoring, and systems engineering (e.g., human factors engineering, financial engineering, supply-chain management, and modeling and simulation).

NAE members involved in the study were: **W. Dale Compton**, cochair, Lillian M. Gilbreth Distinguished Professor of Industrial Engineering Emeritus, Purdue University; and **Kensall D. Wise**, William Gould Dow Distinguished University Professor of Electrical Engineering and Computer Science, University of Michigan.

Copies of the report are available for purchase from the National Academies Press (*www.nap.edu*). PDFs of the executive summary can be downloaded free of charge.

Educating the Engineer of 2020: Adapting Engineering Education to the New Century. This report, the second phase of the Engineer of 2020 Project, recommends guidelines for faculty, industry, and government leaders working toward the transformation of engineering education. The first report, *The Engineer of 2020: Visions of Engineering in the New Century*, described the skills and attributes future engineers will need to succeed. The second report highlights issues that must be addressed to ensure that those skills and attributes are passed on to engineering students. The report also calls for a careful consideration of the minimum "body of knowledge" practicing engineers must have and urges industry and government to consider ways to make postgraduate study for engineers more attractive.

In addition to recommendations for (1) increasing student awareness of engineering careers in industry and research; (2) introducing the engineering "design, build, test" process early in the curriculum; and (3) encouraging domestic students to pursue postgraduate degrees, the report urges institutions to tackle issues related to (1) accreditation; (2) the faculty reward system; and (3) the responsibility/relationship of traditional institutions of higher education and community colleges and the K–12 education system.

NAE member **G. Wayne Clough**, president, Georgia Institute of Technology, chaired the study committee. Other NAE members on the committee were **Alice M. Agogino**, Roscoe and Elizabeth Hughes Professor of Mechanical Engineering, University of California, Berkeley; **Mark E. Dean**, IBM fellow and vice president, IBM Corporation; **Simon Ostrach**, Wilbert J. Austin Distinguished Professor of Engineering, Case Western Reserve University; **Ernest T. Smerdon**, Dean of Engineering, Emeritus, University of Arizona; and **David C. Wisler**, manager, University Programs and Aero Technology Labs, GE Aircraft Engines. NAE member **Stephen W. Director**, senior vice president and provost, Drexel University, was project liaison to the committee.

Copies of the report are available for purchase from the National Academies Press (*www.nap.edu*). A PDF summary can be downloaded free of charge.

Enhancing the Community College Pathway to Engineering Careers. This report, undertaken jointly by NAE and the Board on Higher Education and Workforce of the National Research Council, describes notable programs designed to improve the transfer of engineering students from community colleges to four-year institutions. The transfer mission is one important way by which community colleges start diverse students down the road to careers in engineering. However, students face challenges in making successful transitions to four-year programs. The report identifies five areas for improvement: ineffective articulation agreements; poor recruitment and retention programs; lack of coordination of curricular content and quality between partner institutions; lack of diversity; and inadequate data on transfers. Fortunately, some two- and four-year institutions are working together, within and across state systems, to ensure successful transfers; several of these programs are described in the report. Intended to be a road map, this report charts progress to date and lays out an agenda for future research and actions.

Engineering Research and America's Future: Meeting the Challenges of a Global Economy. With funding from the National Science Foundation, NAE convened a committee of engineering leaders during the summer of 2004 to conduct (1) an assessment of the past and potential impact of the U.S. engineering research enterprise on the nation's economy, quality of life, security, and global leadership; and (2) to determine whether the level of public and private investment is sufficient to sustain U.S. preeminence in basic engineering research. The committee documented and evaluated recent contributions of U.S.-based engineering research to critical national interests; assessed the potential contributions of engineering research to emerging national challenges and opportunities; and outlined a national strategy for ensuring that the engineering research foundations of American global economic, military, scientific, and technological preeminence remain solid in the face of rapid, often disruptive, societal and global change. Findings and recommendations are intended to inform public-sector and private-sector decision making regarding the scale and allocation of investments in engineering research, engineering research infrastructure, and engineering education. Implementation of the committee's recommendations should strengthen the U.S. engineering research enterprise and ensure that engineering research continues to contribute to U.S. economic prosperity, national security, and global technological leadership. The report is being widely disseminated to leading stakeholders in the U.S. engineering enterprise from industry, academia, and government.

This report will be available for purchase this fall and can be read in open-book format on the National Academies Press website (*www.nap.edu*). A PDF summary can be downloaded free of charge.

Technological Options for User-Authorized Handguns: A Technology-Readiness Assessment. It could take as long as 10 years and cost as much as $30 million to bring a user-authorized handgun to the commercial marketplace. This is a major conclusion of the 11-member Committee on User-Authorized Handguns, which conducted an engineering-focused feasibility analysis.

User-authorized handguns (firearms that can only be operated by designated individuals) must have sensor technology integrated with locking and firing mechanisms. The committee found that limited research has been done on a variety of biometric and nonbiometric technologies, but no development efforts to date have moved beyond the bread-board stage. In addition, most research has come to a halt for lack of funding and, in some cases, lack of interest.

The committee considered handguns for two broad categories of users: law enforcement personnel and individuals who store and use firearms at home. The law enforcement application has more stringent technical requirements because weapons are often used under adverse conditions, such as rain, mud, blood, and extreme temperatures; in addition, operators may be wearing gloves. The committee concluded that no current biometric technology is completely suitable for use in firearms. The technology that comes closest to satisfying all of the requirements is radio frequency identification (RFID) tags, which is not a truly biometric technology.

The committee was chaired by NAE Executive Officer **Lance Davis**. NAE members **T. Dixon Dudderar**, Lucent Technologies (retired), and **Laurence C. Siefert**, AT&T Wireless (retired), also served on the committee. The project was funded in part by the David and Lucile Packard Foundation.

Copies of the report are available for purchase from the National Academies Press (*www.nap.edu*). PDFs of the executive summary can be downloaded free of charge.

Calendar of Meetings and Events

2005

October 7	NAE Finance and Budget Committee Meeting
October 7	NAE Council Meeting/Dinner
October 8	NAE Council Meeting
	NAE Peer Committee Meeting
October 9–10	NAE Annual Meeting
October 11	NAE Nominating Committee Meeting
	NRC Executive Committee Meeting
October 21	NAE Congressional Lunch
October 25	Draper Prize Committee Meeting
November 3–5	Fifth Japan-America Frontiers of Engineering San Jose, California
November 15	NRC Executive Committee Meeting
December 3	NAE Committee on Membership Meeting
December 13	NRC Executive Committee Meeting

2006

February 7	NAS/NAE Council Dinner Irvine, California
February 8–9	NAE Council Meeting Irvine, California
February 9	NAE National Meeting Irvine, California
February 15	NRC Executive Committee Meeting
February 21	Awards Forum/Awards Dinner

All meetings are held in the National Academies buildings, Washington, D.C., unless otherwise noted.

In Memoriam

JAMES G. BAKER, 90, associate, Harvard College Observatory, Harvard University, died on June 29, 2005. Dr. Baker was elected to the academy in 1979 for the design of optical devices to meet diverse, unusual, and exacting requirements.

BRUCE A. BOLT, 75, Professor of Seismology, Emeritus, University of California, Berkeley, died on July 21, 2005. Dr. Bolt was elected to the academy in 1978 for applications of the principles of seismology and applied mathematics to engineering decisions and public policy.

GARY L. BORMAN, 72, Emeritus Professor, Mechanical Engineering Department, University of Wisconsin, died on January 17, 2005. Dr. Borman was elected to the academy in 1990 for pioneering the analytical simulation of internal combustion engines and verification with advanced experimental techniques.

A. PHILIP BRAY, 71, retired vice president and general manager, Nuclear Power Division, General Electric Company, died on July 31, 2005. Mr. Bray was elected to the academy in 1979 for his contributions to the development and application of thermal hydraulic and performance analyses to the safety and performance of boiling-water reactors.

MORRIS COHEN, 93, Institute Professor Emeritus, Department of Materials Science and Engineering, Massachusetts Institute of Technology, died on May 27, 2005. Dr. Cohen was elected to the academy in 1972 for elucidating the strengthening mechanisms of steel and for unifying engineering disciplines with materials science.

GEORGE B. DANTZIG, 90, professor of operations research and computer science, Department of Engineering Economic Systems and Operations Research, Stanford University, died on May 13, 2005. Dr. Dantzig was elected to the academy in 1985 for his pioneering contributions to the science and practice of operations research.

BERNARD GOLD, 81, retired senior staff, Lincoln Laboratory, died on January 15, 2005. Dr. Gold was elected to the academy in 1982 for the development of digital signal processing theory and processors and their applications to speech compression and pattern recognition.

CHARLES C. JOHNSON JR., 83, Rear Admiral (retired), U.S. Public Health Service, died on December 14, 2004. Mr. Johnson was elected to the academy in 1990 for his leadership in the development of public health engineering and environmental hygiene programs.

JACK K. KILBY, 81, consultant, died on June 20, 2005. Mr. Kilby was elected to the academy in 1967 for inventions basic to integrated circuits.

ARTHUR S. LODGE, 82, Emeritus Professor, University of Wisconsin-Madison, died on June 24, 2005. Dr. Lodge was elected to the academy in 1992 for outstanding monographs and major developments in continuum mechanics, molecular theories of polymer flow, and high-precision measurement of rheological properties.

JOHN P. LONGWELL, 86, Professor Emeritus, Massachusetts Institute of Technology, died on October 6, 2004. Dr. Longwell was elected to the academy in 1976 for contributions to the basic knowledge of combustion, particularly the design basis for gas turbines, rockets, and ramjets.

BENJAMIN LUSTMAN, 90, retired manager, Fuel Systems Development, Westinghouse Electric Corporation, died on December 21, 2004. Dr. Lustman was elected to the academy in 1968 for his work on metallurgical developments in nuclear fuels and reactor materials.

GORDON K. TEAL, 95, retired vice president and chief scientist, Texas Instruments Incorporated, died on January 7, 2005. Dr. Teal was elected to the academy in 1969 in recognition of his pioneering research on single crystals of germanium and silicon and his co-invention and reduction to practice of the single-crystal-grown junction transistor.

Publications of Interest

The following reports have been published recently by the National Academy of Engineering or the National Research Council. Unless otherwise noted, all publications are for sale (prepaid) from the National Academies Press (NAP), 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055. For more information or to place an order, contact NAP online at <*http://www.nap.edu*> or by phone at (888) 624-8373. *(Note: Prices quoted are subject to change without notice. Online orders receive a 20 percent discount. Please add $4.50 for shipping and handling for the first book and $0.95 for each additional book. Add applicable sales tax or GST if you live in CA, DC, FL, MD, MO, TX, or Canada.)*

Are Chemical Journals Too Expensive and Inaccessible?: A Workshop Summary to the Chemical Sciences Roundtable. On October 25–26, 2004, the Chemical Sciences Roundtable held a workshop to explore issues involving the readers of and contributors to the chemical literature, as well as the publishers and disseminators of chemical journals. As a follow-up to the workshop, a summary was written to capture highlights of the workshop presentations and discussions. The purpose of the workshop was to provide a forum for discussing chemistry journals in the larger context of scientific, technical, and medical journal publishing. Topics at the workshop addressed whether chemists and chemical engineers need journals with unique characteristics and, if so, whether their needs are being met in the current publishing environment. Workshop participants also discussed how open-access publishing might be applied to the chemical literature, for example, by giving authors more freedom to distribute their articles after publication and allowing free access to the archives of chemical literature.

NAE member **Jeffrey J. Siirola**, technology fellow at Eastman Chemical Company, is a member of the Chemical Sciences Roundtable. Paper, $18.00.

Assessment of Options for Extending the Life of the Hubble Space Telescope: Final Report. The Hubble Space Telescope has operated continuously since 1990. During that time, four space shuttle-based service missions were launched, three of which added major observational capabilities to the telescope. A fifth mission (SM-4) was planned to replace key telescope systems and install two new instruments. After the loss of the space shuttle Columbia, however, the National Aeronautics and Space Administration (NASA) decided not to pursue the SM-4 mission, which would probably mean the end of Hubble's useful life in 2007–2008. In response to an unprecedented outcry from scientists and the public, NASA began to explore and develop a robotic servicing mission, and Congress directed NASA to request a study from the National Research Council to assess the robotic and shuttle servicing options for extending the life of Hubble. This report provides an assessment of the contributions made by Hubble, a projection of likely contributions as the result of a servicing mission, and a comparative analysis of the potential risks of the two options for servicing Hubble. The study concludes that the shuttle option would most effectively prolong Hubble's productive life.

NAE member **Louis J. Lanzerotti**, Distinguished Research Professor, New Jersey Institute of Technology, chaired the study committee. Other NAE members on the committee were **Rodney A. Brooks**, Fujitsu Professor of Computer Science and director, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology; **B. John Garrick**, independent consultant, Laguna Beach, California; and **Richard H. Truly**, director, National Renewable Energy Laboratory. Paper, $32.50.

Assessment of the Benefits of Extending the Tropical Rainfall Measuring Mission: A Perspective from the Research and Operations Communities. Interim Report. Launched jointly in 1997 by the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency, the Tropical Rainfall Measuring Mission (TRMM) is a satellite mission that placed a suite of instruments, including the first precipitation radar, in space. These instruments are used to monitor and predict tropical cyclone tracks and intensity, estimate rainfall, and monitor climate variability (precipitation and sea surface temperature). The data collected by TRMM for the past seven years is used by the

Joint Typhoon Warning Center, National Center for Environmental Prediction, National Hurricane Center, and other organizations worldwide. In July 2004, NASA announced that it would terminate TRMM in August 2004, but, at the request of the National Oceanic and Atmospheric Administration (NOAA), the White House, and the science community, NASA agreed to continue TRMM operations through the end of that year. Meanwhile, NASA asked the National Research Council to assess the benefits of keeping TRMM in operation beyond 2004. After holding a workshop with a number of experts in the field, the study committee concluded that TRMM would make significant contributions to operations and science and strongly recommended that the program be continued, with the caveat that cost and risk be re-examined before a final decision is made.

NAE member **Eugene M. Rasmusson**, Research Professor Emeritus, University of Maryland, chaired the study committee, and NAE member **Kristina B. Katsaros**, retired director, Oceanographic and Meteorological Laboratory, NOAA, was a committee member. Available online only at: *http://www.nap.edu.*

Building an Electronic Records Archive at the National Archives and Records Administration: Recommendations for a Long-Term Strategy. The federal government generates and saves a large and growing fraction of its records in electronic form. In 1998, the National Archives and Record Administration (NARA) launched its Electronic Archives (ERA) Program to create a system to preserve and provide access to federal electronic records. To assist in this project, NARA asked the National Research Council to conduct a two-phase study to provide advice during the development of the ERA program. The first two reports (phase one) provided recommendations on the design, engineering, and related issues facing the program. The current report (phase two) focuses on longer term, more strategic issues, including technological trends that will shape the ERA system, archival processes, and future evolution of the system. The report also provides an assessment of technical and design issues associated with maintaining the integrity and authenticity of electronic records.

NAE member **Robert F. Sproull**, vice president and Sun Fellow, Sun Microsystems Inc., chaired the study committee, and NAE member **Jerome H. Saltzer**, Professor of Computer Science, Emeritus, Massachusetts Institute of Technology, was a committee member. Paper, $26.50.

Creating a Disaster Resilient America: Grand Challenges in Science and Technology: Summary of a Workshop. The 12th Disasters Roundtable Workshop, held in October 2004, focused on grand challenges in science and technology related to vulnerabilities to disasters. Agencies and stakeholders from the disaster research and policy community gathered to discuss research and program priorities and identify problems in science and technology that might be resolved by coordinated, sustained investments in research, education, communication, and the application of knowledge and technology. Discussions focused on how investments might lead to significant reductions in the loss of life and property from natural, technological, and human-induced disasters.

NAE member **Ross B. Corotis**, Denver Business Challenge Professor, University of Colorado at Boulder, is a member of the Disasters Roundtable, and NAE member **Lloyd S. Cluff**, manager of the Geosciences Department, Pacific Gas and Electric Company, is an *ex officio* member. The report is only available online at *http://www.nap.edu/catalog/11274.html.*

Impact of Revised Airborne Exposure Limits on Non-Stockpile Chemical Materiel Program Activities. The U.S. Army's Non-Stockpile Chemical Materiel Program is responsible for dismantling former chemical agent production facilities and destroying recovered chemical materiel. In 2003, in response to congressional requirements, the Centers for Disease Control and Prevention recommended that new airborne exposure limits (AELs) be established to protect workers and the public during operations to destroy this materiel. To assist the Army in meeting the recommended limits, the National Research Council was asked to review the Army's implementation plans for the destruction of production facilities at the Newport Chemical Depot and the operation of two types of mobile destruction systems. This report includes recommendations on analytical methods, airborne containment monitoring, operational procedures, the applicability of the Resource Conservation and Recovery Act, and the involvement of workers and the public in implementing the new AELs.

NAE member **Benjamin Y.H. Liu**, CEO and president, MSP Corporation, was a member of the study committee. Paper, $25.75.

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