Summer 2004

The BRIDGE

LINKING ENGINEERING AND SOCIETY

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

The BRIDGE

NATIONAL ACADEMY OF ENGINEERING

The Bridge (USPS 551-240) is published quarterly by the National Academy of Engineering, 2101 Constitution Avenue, N.W., Washington, DC 20418. Periodicals postage paid at Washington, D.C.

Vol. 34, No. 2 Summer 2004

Postmaster: Send address changes to *The Bridge*, 2101 Constitution Avenue, N.W., Washington, DC 20418.

Papers are presented in *The Bridge* on the basis of general interest and timeliness. They reflect the views of the authors and not necessarily the position of the National Academy of Engineering.

The Bridge is printed on recycled paper. ♻

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.

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Volume 34, Number 2 • Summer 2004
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THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

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

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

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

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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.

Engineering, Foreign Policy, and Global Challenges

Historically, many engineering advances have precipitated major changes in interactions between nations and have influenced the conduct and direction of foreign policy. The opening of the Suez and Panama canals had significant geopolitical impacts. The Berlin-to-Baghdad railroad influenced the strategies of the Allies in World War I, and the Trans-Siberian railroad enhanced the presence and power of Russia in Asia. Technologies for extracting and using oil have affected political balances throughout the world, starting with the decision of the British Admiralty before World War I to switch from coal to oil, which radically changed relations with the Middle East.

Information technology and the Internet have weakened the ability of central governments to maintain control of the flow of information across borders. Telecommunications have changed diplomacy, making it possible for governments at home to direct the actions of diplomats in distant countries in real time, who, until then, by necessity, had acted much more autonomously. With instant communications, governments no longer have time to deal with crises before the media arouse public awareness. Sputnik and subsequent developments in space challenged the concept of national sovereignty in space. Advances in military technology constantly challenge existing political balances. In addition, many engineering organizations—private companies, as well as societies, such as the American Society of Civil Engineering and the World Federation of Engineering Organizations—are working internationally.

The synergy of engineering and science, business, finance, and politics has changed the world. Even though engineering is an indispensable element of that synergy, it is rarely considered an instrument of foreign policy and international relations. In this context, it is sobering to review some of the challenges facing engineering and NAE, beginning with the necessity of keeping track of technological engineering developments throughout the world, as no nation has a monopoly on creativity, inventiveness, and technological skills.

The establishment of a dialogue with engineers and scientists from countries that are critical to the stability of the world, regardless of the vagaries of the political climate—what might be called scientific and engineering diplomacy—presents an even bigger challenge. Examples include the Pugwash conferences that maintained contacts between American and Russian engineers and scientists during the Cold War, recent meetings between American and Iranian engineers and scientists, under the auspices of the National Academies, the visit in January of this year by NAE member **Sig Hecker** to North Korea, and a growing number of interactions between NAE and other countries, including China, Germany, Japan, and Mexico.

An urgent challenge is reducing a global, "corrosive set of imbalances" (a term coined in a different context by Alan Greenspan, chairman of the Federal Reserve Board) between the affluent and the poor. Desperate deficiencies in food, housing, health, jobs, and infrastructure that keep almost one-third of humankind in abject poverty call for massive engineering involvement. Engineers Without Borders and the Gates Foundation, which funds capacity-building for health care in Africa, are examples of efforts to reduce these imbalances and fight poverty. But far more must be done.

Far more also remains to be done to address the related challenges to world sustainability, such as global warming, increases in carbon dioxide emissions, the predicted rise in sea levels, over-fishing, overconsumption, and the disappearance of species. Sustainability will require not only working defensively, but also creating imaginative new projects, like environmentally benign infrastructural systems in homes and cars and water-efficient desert agriculture. Sustainability and combating poverty are the foundations of a stable civil society, and they require the crossing of boundaries and the pooling of crucial human resources—particularly engineers.

A difficult international issue of immediate concern to nearly all of the U.S. engineering community is the migration of engineering jobs abroad. How can the

United States continue to pursue the advantages of global economic efficiency—the more than zero-sum game—without the loss of key engineering skills and technological capabilities, particularly in the manufacturing sector?

Although engineering is only one instrument for addressing global challenges and international relations, it is a crucial one. The engineering community must participate actively in policy discussions and planning, and may even sometimes provide a technological fix that cuts through the Gordian knot of seemingly unresolvable social or political impasses. Engineers must not be afraid to go where angels fear to tread, when necessary.

Scientists have acted boldly in pursuing genetics, molecular biology, and the green revolution. Economists and political scientists have done so with the market economy and the globalization of trade. Engineers have done so, too, in creating the indispensable bases for civilized living, from clean water to telecommunications and transportation systems. All of these developments at one time challenged dogmas and undermined the status quo.

The global challenges facing our nation and the world today will require even greater commitment and courage from engineers, new visions of the possible, and the championing of new global agendas. The papers in this issue address the issues of engineering and American diplomacy (Neureiter), Japanese-American collaborative efforts to counter terrorism (**Branscomb**), the nuclear crisis in North Korea (**Hecker**), and engineering for the developing world (Amadei).

George Bugliarello

We need engineering-literate people in the policy-making arena.

Engineering and American Diplomacy

Norman P. Neureiter is Distinguished Presidential Fellow for International Affairs of the National Academies.

Norman P. Neureiter

During my recently completed three-year tenure as the first science and technology adviser to the secretary of state, I got my comeuppance one day as I addressed a group at the National Academy of Engineering (NAE). As part of the U.S. Department of State's outreach to the U.S. science and technology (S&T) community, I frequently address technical audiences, trying to arouse their interest in S&T as an essential element in the formation of U.S. foreign policy (NRC, 1999a). When I finished my talk and asked for questions, a voice in the audience called out, "You talk about science and technology—well, what about engineering?" Slightly nonplussed, I mumbled something about the word "technology" being synonymous with engineering for me. But later I began to think that I may have been shortchanging engineering as a profession. I realized that to engage the engineering profession, I had to talk not just about technology but also about the role of engineers and engineering societies (Neureiter, 2004). That is why I am pleased to amplify George Bugliarello's eloquent editorial appeal in this issue for more engagement by engineers in addressing global challenges—in both policy and practice.

This is the first time I have written for an engineering publication, and I must begin with a confession. As an organic chemist in college, I admit I looked down on engineers. They were a slightly strange lot of guys (no girls in those days) with pocket protectors and dangling slide rules. Their building at Rochester was across campus, out in the boonies. There was no room in their schedules for English, history, foreign languages, or philosophy. We chemists may have had acid holes in our clothes, but we wore them as badges of honor because we were doing "pure science" in pursuit of "fundamental knowledge." Engineers always seemed to have a kind of academic grease under their fingernails.

My epiphany began when I joined the Humble Oil Company (now part of Exxon) where I found that chemists were outsiders whose ideas were usually dismissed by managers who had grown up in the oil patch. Engineers ran the place, turning sulfurous black crude into the gasoline and petrochemical feedstocks that fuel the national economy. Later, I joined Texas Instruments (TI), where the entire corporate cuture was defined by engineers; even the chief financial officer was an engineer. In 2001, when a revered friend, Jack St. Clair Kilby, a modest former electrical engineer at TI with no Ph.D., was awarded the Nobel Prize in physics for his 1958 invention of the integrated circuit, my false chemist's pride was dashed forever.

Most of the goals of U.S. foreign policy involve science, technology, or health.

Engineers make things, things that work, and engineers keep them working. After a visit a couple of years ago to a deepwater drilling and production platform in the Gulf of Mexico, it seemed to me that engineers could do just about anything they put their minds to. It was an unforgettable experience to see, and even more to feel, that huge, $1.5-billion floating structure tethered to the bottom, producing and partially processing some 50,000 barrels of oil and millions of cubic feet of natural gas per day from 14 different wells and feeding the output directly into pipelines for transit to the East Coast.

But what does engineering have to do with diplomacy and the Department of State? The role of the State Department, with its approximately 250 embassies and consulates abroad, is to formulate and implement the foreign policy of the United States and to manage our relationships with the some 190 countries and many international governmental organizations, such as the United Nations, the World Health Organization (WHO), the Food and Agricultural Organization, NATO, UNESCO, and many others.

Since September 11, 2001, U.S. foreign policy and domestic policy have been dominated by the global war on terrorism and ensuring homeland security. But beyond the horrors of today's headlines, a steadfast goal of U.S. foreign policy continues to be building a world of peace and prosperity for all people in the world. Beyond stopping terrorists and controlling weapons of mass destruction, U.S. foreign policy addresses climate change and global warming, environmental degradation, natural disasters, new sources of energy, food safety, HIV/AIDS and other infectious diseases, transportation, communications, the livability of cities, and economic viability for a world population that may reach nine billion by 2050.

To meet these formidable challenges in a complex, interdependent world, we must find a path to sustainable development—a way to reconcile development goals with the long-term environmental limits of our planet. The vocabulary of diplomats includes not only politics and conflict, but also other topics, such as new energy technologies, clean water, pandemic diseases, genetically modified foods, the preservation of tropical forests, computer security, education, intellectual property, marine resources, and the role of science and engineering in economic development, to name but a few. In the NRC report I mentioned earlier, the study committee noted that 13 of the 16 stated goals of U.S. foreign policy involve considerations of science, technology, or health. The committee called on the Department of State to strengthen its capacity to deal with these kinds of issues and to appoint a science and technology adviser to the secretary of state to drive the process.

The State Department is a very complex institution, with some 25 bureaus that participate in the policy formation process on a wide range of issues. The traditional heart of the department are the six regional or geographic bureaus that house the "country desks" that oversee U.S. relations with every country in the world. The other bureaus are functional bureaus—centers of expertise in specialized areas that may apply to any or all countries or regions. These specialized areas include economic and business affairs; arms control and nonproliferation; consular matters; oceans, environment, and science; democracy and human rights; and refugees and migration. Bureaus with different perspectives may have different opinions on issues, making the development of a coordinated policy position very challenging.

It would be nice if S&T inputs to policy could be made by whispering in the secretary's ear, but nothing could be further from the truth. Policies move up through the bureaus, and by the time they reach the secretary, they reflect the multiple views of the offices concerned. Because S&T inputs are essential elements of many policies, but rarely the ultimate subject of the policy, they must be made early in the policy process to have an impact. I concluded very soon that the department needed more in-house technical capacity—more scientists and engineers distributed throughout the bureaus—to make those technical inputs. We could no longer wait until policies had moved up through the bureaucracy and reached the secretary's level.

One longer term approach to increasing the in-house S&T capacity of the State Department is to recruit more scientists and engineers into the Foreign Service—to encourage them to change careers and become professional Foreign Service officers. We did make some efforts in that direction.

In the past, Foreign Service officers typically had backgrounds in political science, international relations, or history, but today the State Department is looking for more diversity in the disciplines and previous work experience of Foreign Service candidates. Scientists and engineers with firsthand experience of the scientific, technical, and health issues that are fast becoming the main items on the diplomatic agenda will become the diplomats of the twenty-first century. Technology has become a kind of new international currency, and intellectual property rights and technological competitiveness are items on the global trade agenda and the subject of international negotiations. Engineers can make unique contributions to discussions in all of these areas.

But the focus of our work was on fellowship programs to bring professional scientists and engineers into the State Department for one or two years to work alongside diplomats to ensure that the technical dimensions of policies were fully comprehended in the policy-making process. Our efforts in this direction succeeded beyond all expectations. In fact, I feel that my greatest legacy is the growth of these fellowship programs. By September 2003, 40 scientists and engineers had committed to work as fellows in 12 different bureaus on dozens of issues—everything from climate change and agricultural trade to nonproliferation of weapons of mass destruction and human rights.

The fellowship programs could not have succeeded without tremendous support from the scientific and engineering communities. We started with an expansion of the AAAS Fellows Program, which had been operating at a modest level for many years. Then the American Institute of Physics (AIP) stepped forward; AIP now provides one fellow each year. A similar program with the American Chemical Society is now beginning, and a fellowship agreement has been signed with the Industrial Research Institute. The IEEE made engineering history two years ago when it became the first professional engineering society to create a fellowship program, selecting one engineer each year. Collectively, these are now called the Professional Science and Engineering Society Fellows Program. My successor as science adviser has developed the Jefferson Fellows Program, in partnership with some 50 research universities, that will bring in active professors for one year and retain them as professional consultants for an additional five years. A three-year pilot program at a level of five fellows per year is being funded by the MacArthur and Sloan Foundations.

Technology has become a new international currency.

Of course, engineer-fellows cannot expect to design or build new gadgets, but to provide advice, counsel, and personal involvement in the daily business of American diplomacy. One engineer-fellow is working in the International Communications and Information Policy Office of the Economics and Business Affairs Bureau, which draws on his expertise in electrical engineering and information technology in formulating international telecommunications policies, frequency allocation negotiations, and so on. He loves his work, but he also told me that his engineer friends cannot understand why he is "wasting his time" working on policy, on international blah-blah, when he could be doing real work and making something. Convincing young engineers of the importance of formulating policies that organize and regulate a technologically driven world is a challenge for the engineering community. People who understand the consequences of those policies should play a major role in their formation. I would like to see at least 50 S&T fellows a year in the Department of State, a good share of them engineers.

An excellent way to sample the diplomatic life is to spend one or two years as a fellow under one of the Department of State's fellowship programs. Undergraduates and graduate students can also work in the State Department as interns—mostly during the summer, but programs are available throughout the year. Interns can work at U.S. embassies overseas as well as in Washington.

Scientists and engineers throughout the world have a common language.

Professional scientists and engineers are also welcome in many embassies overseas. Many ambassadors have become aware of the tremendous admiration of host countries for U.S. science and engineering. Professional scientists and engineers have immediate access to technical circles abroad at a level of acceptance rarely accorded regular diplomatic personnel. We succeeded in establishing one position for an embassy S&T adviser in Australia, an earth scientist on long-term detail from NASA, who has been tremendously successful in building closer ties between the embassy and the university and research communities and has initiated some cooperative projects. The new Jefferson Fellows Program provides for fellows to spend a portion of their time working with embassies abroad.

Under the Embassy Fellows Program, scientists and engineers from U.S government technical agencies are detailed for one to three months to U.S. embassies abroad to work on specific issues. The demand from embassies still exceeds the current supply, but with six or seven agencies now participating, the program is running at about 45 visits per year. Scientists and engineers readily find a common language throughout the world, regardless of the strains that may exist in political relations.

I recently read a fascinating history of the first 25 years of NAE and its ultimately successful struggle to become a respected source of advice to government on the vast range of technological issues that affect the lives of all Americans. The point is that foreign policies also need the advice and counsel of the engineering community. This advice can be formally commissioned from an outside body, such as the NAE/NRC, or obtained informally in roundtable discussions. But even these simple events will not take place unless there are more engineering-literate people inside the system, either as fellows or regular employees, who appreciate the value of technical advice and know how and where to get it.

Thirty-five years ago at Cape Kennedy in Florida, I marveled at the sight and sound of Apollo 11 blasting off for man's first step on the moon. NASA Administrator James Webb had described the challenges of managing an engineering enterprise of that magnitude—hundreds of thousands of separate parts, all supplied by the lowest bidder, that all had to work, and work together, for the program to succeed. The trick, he said, was to have at least 15 percent of the engineering capabilities in house, to ensure that NASA had enough "smarts" to manage and monitor what the contractors were doing. The State Department, too, needs a certain complement of S&T skills in house to ensure that S&T considerations are fully integrated into the policy process. The department needs scientists and engineers—as interns, as fellows, and as Foreign Service officers.

It is interesting to note that a majority of the senior political leaders of China were trained as engineers. They are driving both China's rapid rate of economic development and its huge national commitment to progress in S&T. The outsourcing of manufacturing jobs to China, the enormous U.S. trade deficit with China, and concerns about the lack of enforcement of intellectual property laws are the subjects of intense diplomatic dialogue, as well as internal U.S. political debate.

In Atlanta recently for an IEEE meeting, I met a recent Ph.D. engineering graduate from Georgia Tech, who had stayed on after graduation as an instructor. He and his research professor had formed a company to market a patented invention based on his thesis research. When he heard about my work, he provided me with the text of a lecture by John Sununu (2002) given at Georgia Tech some two years before.

John Sununu, a mechanical engineer with a Ph.D. from MIT, has had a remarkable career. He has been a professor and associate dean of engineering at Tufts, president of his own engineering company, a member of NAE, governor of New Hampshire, and then chief of staff in the White House to the first President Bush—an incredible leap from education and practical engineering to the arena of public policy and foreign policy at the very highest level. His speech in Atlanta contained some powerful and prescient words:

> *Good public policy needs engineers to be good public policy makers. There isn't much new or better that happens in the world today that isn't made possible by some innovation in engineering. But all the changes that make life better also make life a bit more complicated. To deal with these complications, we develop public policies, laws, and regulations to provide the framework for the operation of an orderly beneficial society.*
>
> *While engineers continue to drive real progress and improvements to the quality of life, they generally have been reluctant to get involved in the process of developing public policy. Unfortunately, they have long considered that arena as being more appropriately the domain for other professions such as lawyers. In fact, however, society needs a more active involvement in policy development by those who understand both the potential and the limitations of technology. Engineers need to think more seriously about accepting the responsibility of public office. If the problem solvers of the world don't participate in making public policy, then policies will be developed by those who don't know how to solve problems.*

Now that does not mean that engineers or chemists have greater insight on public policy issues than lawyers. But many foreign policy issues today involve technical considerations, and it is essential that we have people in the decision-making process who understand those considerations. Their advice may be the salient factor in whether or not a policy succeeds.

A primary challenge for the developed world is to deal not just with acts of terrorism, but also with the causes of terrorism. Many people believe that economic development in the Third World is an essential step toward this end. Certainly, development of Third World countries is an enormously complex process, but in simple terms it means enabling countries to participate effectively in the global economy—an economy driven by technology. To me this means countries must have an indigenous capacity for dealing with technology, and there must be a local decision-making process, which, at best, fully embraces science and engineering advice or, at least, does not ignore the technical realities in making national decisions.

In late 2002, the World Summit on Sustainable Development (WSSD) brought tens of thousands of political leaders, delegates, and observers to Johannesburg, South Africa, in an attempt to move toward a global consensus on how to advance the cause of sustainable development. In addition to stressing the importance of good governance, the United States made a strong effort to emphasize the role of science and engineering in an effective development program. Prior to the conference, NAE and the engineering community issued a "Declaration on Sustainability," which stressed the importance of involving engineers at every stage of the process. The meeting also emphasized the importance of public/private partnerships, bringing governments, corporations, universities, private foundations, international lending institutions, and nongovernmental organizations (NGOs) together to achieve specific goals.

WSSD should not be considered a one-shot event but the beginning of a long and enduring process. The State Department website (*www.state.gov*) lists examples of emerging partnerships. The present focus lasting two years is on clean water; energy will be the next two-year priority. In addition, the National Academies is beginning a series of initiatives on sustainable development that will build on their excellent earlier study on sustainability (NRC, 1999b).

The National Academies plans a series of initiatives on sustainable development.

NAE recently published a splendid volume to celebrate the 20 greatest engineering achievements of the twentieth century, the engineering developments of the past 100 years that have had the greatest effect on peoples' lives (Constable and Somerville, 2003). In essence, those achievements and their broad availability in developed countries define the difference between the developed and developing worlds. A major goal of U.S. foreign policy is to narrow this gap significantly over the next 20 years. To do this, we must have the full support of the U.S. engineering community—in terms of both policy and implementation. Addressing the needs for water, energy, food, health, education, and jobs offers great and rewarding opportunities for bringing together American diplomacy and engineering—with immense portent for this perilous world.

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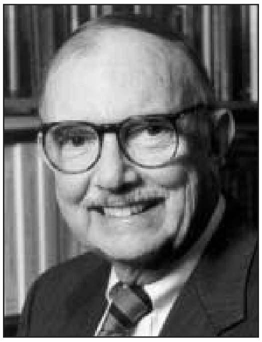
The author makes a case for bilateral counterterrorism projects.

Japanese-American Collaborative Efforts to Counter Terrorism



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Lewis M. Branscomb

Terrorism is a very old threat to established societies, most frequently from groups with political agendas (such as the IRA) or individuals with idiosyncratic motives for violence against the societies in which they live (such as Timothy McVeigh). No nation is immune. Even stable, homogeneous societies, such as Japan, are vulnerable. The religious sect Aum Shinrikyo made small quantities of a number of biological agents and carried out a successful attack on people in the Tokyo subway. The group also carried out marginally successful attacks on the Diet and the Crown Prince's wedding with botulin toxin and attempted an anthrax attack on the streets of Tokyo (Olson, 1999). With a reputed $1.5 billion in assets, the sect was rumored to have attempted to purchase nuclear weapons materials.

Two recent events have heightened Japan's awareness that it might be targeted by Al Qaeda. First was the threat, thought to come from Al Qaeda, of terror attacks if Japan sent troops to Iraq (as she has now done). The threat became manifest with the taking of three hostages (since released) by insurgents. Second, the attack on the trains in Madrid, attributed to Al Qaeda, reinforced the reality of terrorist threats against U.S. allies.

Motives for Cooperation

Japan and the United States face similar threats, and a strong case can be made that they have a mutual interest in collaborating to reduce their vulnerabilities:

- Both nations have sophisticated technical capabilities that might be used to reduce their vulnerabilities.
- The economies of Japan and the United States, as well as their research and innovation systems, are closely linked.
- The terrorist targets in the two countries are similar:
  - symbols of nationhood
  - large aggregations of people in confined spaces
  - even larger numbers of people widely distributed
  - control systems for critical infrastructure
  - the capability of responding effectively to attacks
- The highly efficient industrial and service economies of both nations continue to create new vulnerabilities.

In general, a strong argument can be made for multilateral efforts among the major democratic states to use technology to counter terrorism. The new brand of terrorism arises from transnational networks of linked terrorist groups that can launch cyberattacks on any nation from remote locations, can contaminate food in international trade, and can ship weapons (including nuclear weapons and nuclear material) into target states via international commerce. Ships, aircraft, trains, and trucks are themselves transnational targets. Thus, on the consequence side of the ledger, the economies of target societies are strongly linked. At the very least, for both fairness and efficiency, border control procedures, such as biometrics, require the collaborative development of standards to ensure that passports and other documents are effective in all cooperating nations.

Major democratic states can use technology to counter terrorism.

Advantages of the Terrorists

Despite their small numbers, terrorists have some important advantages. First, their actions are largely unpredictable because their objectives, at least in the case of ideological terrorists such as Al Qaeda and Aum Shinrikyo, are largely idiosyncratic and obscure.[1] Second, we must assume that some of their number reside covertly in the societies they plan to attack.[2] Third, terrorists appear to be very patient. They decide when they will strike. As a result, defenders against terrorism must be alert at all times, despite the apparent absence of terrorist activity.

Finally, terrorists may have international bases of operations and may even enjoy the sponsorship and assistance of a sympathetic or rogue state. The combination of stateless terrorists who can infiltrate target societies supported by the resources of an irresponsible but technically competent foreign government is particularly dangerous. The U.S. government identified the Taliban government of Afghanistan as such a state, and the Bush administration was concerned that the Baathist government of Iraq might also be such a state (although no credible evidence has emerged that Saddam Hussein had anything to do with the September 11 attack).[3]

Advantages of Industrial Societies

Modern industrial societies have some offsetting advantages, provided that they adopt a multilateral counterterrorism strategy. Global intelligence services and military presence, especially when societies cooperate with one another, may keep terror networks off balance and may be able to damage some of them and interfere with their communications and money flows. Military action, or the threat of it, may discourage rogue states from supporting them.

Both Japan and the United States have preeminent capabilities in science and technology, both military (in the United States) and commercial high-tech (in both countries). Through the application of available or new technologies, internal targets can be made less vulnerable, and thus less attractive. New technologies can also limit the damage from an attack, increase the speed of recovery, and provide forensic tools to identify the perpetrators. However, terrorist networks such as Al Qaeda are led by well educated and well financed people who may also have advanced technical skills. If they were supported by a government whose military establishment has developed weapons of mass destruction, these skills could be greatly amplified. Any technical strategy for responding to the threat of catastrophic terrorism must be configured to address this possibility.

Thus, there is an obvious incentive for collaboration in science and technology for countering terrorism. A dialogue between the United States and Japan is under way to explore how collaboration might be improved.

On February 12 and 13, 2004, a bilateral conference was held in Tokyo to explore possible collaborative activities by agencies of the two governments to use science and technology to counter terrorism. The U.S. contingent was led by Dr. George Atkinson, science advisor to the secretary of state; a delegation from the U.S. Department of Homeland Security (DHS) Science and Technology Directorate, headed by Dr. Penrose (Parney) Albright, also participated. The Japanese contingent was led by officials of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), representatives of the police, and Professor Kyoshi Kurokawa, chair of the Japan Science Council (Branscomb, 2004). A memorandum summarizing the working arrangements agreed to in that session is now being negotiated.

U.S. and Japanese Views of Safety and Security

The most striking contrast between the U.S. and Japanese positions was the difference in emphasis on preparations for and responses to unintentional (i.e., natural or accidental) disasters and failures from poor system design of critical infrastructure systems versus intentional (or terrorist) disasters. The U.S. view is based on the political image of "war on terrorism" and the sense that the American public expects counterterrorism to be the first priority on the administration's agenda. The Japanese, however, derive their agenda, which they call "safety and security," from two critical features of Japanese experience: (1) the frequency of devastating earthquakes, typhoons, and tsunamis; and (2) a constitutional commitment not to prepare for or engage in warfare. Thus, the Japanese consider preparations for high-consequence terrorism an extension of their "normal" civil duty of preparing for natural and accidental disasters. From the American point of view, preparations for the normal duties of providing safety and security are by-products of DHS's counterterrorism role.[4]

These contrasting views can be brought together. First, from the Japanese perspective, the threat of terrorism has, as discussed above, become real and apparent to the public. Thus, the major science and technology agency, MEXT, has a new, high-priority mission to research and develop systems for reducing vulnerabilities to terrorism and improving responses to terrorist acts.

Second, the technologies for counterterrorism have some attributes in common with military systems (e.g., high-technology, complex systems environment, markets created by public policy, et al.). Because the safety and security of the civil population (threatened by terrorists) is a civil, not a military, responsibility, this may be an area in which Japanese and U.S. contractors and agencies can do business without running afoul of constraints against Japanese military sales to the United States. Finally, by pursuing the counterterrorism science and technology program through a civil agency (MEXT), which has more benign, civil missions, the program may have more sustainability.

The Japanese approach to safety and security may be right for America, too.

From the U.S. perspective, an argument can be made that the Japanese approach is right for America, too. Because terrorist threats are expected to persist for decades, there are serious questions about the sustainability of U.S. investments in counterterrorism science and technology (Branscomb, 2004). A case can be made that, as long as both countries have conspicuous vulnerabilities that can be attacked by terrorists with very serious consequences, there will be individuals and groups eager to exploit those vulnerabilities. Even when Al Qaeda fades from the scene, other groups may be eager to exploit the extreme asymmetry inherent in the terrorist threat to economically advanced societies.

Americans may tire of incessant color-coded warnings in the absence of serious attacks on the homeland; they may resist the huge budgets of the counterterrorism effort. The captains of critical infrastructure industry may continue to resist the massive capital expenditures required to reduce their exposure to attack to a tolerable level. And, if it appears that Al Qaeda and affiliated groups have disbanded or become quiescent, the public may not believe the threat is still credible. Thus, presenting the U.S. strategy as a quest for safety and security may help to make the long-term effort sustainable. Hurricanes, earthquakes, and massive forest fires will not go away. Failures in our increasingly complex infrastructure will probably become more frequent with more serious consequences.

Thus, I believe the United States can learn a lot from the Japanese approach to characterizing the job ahead. If the goal of the search is for a dual-benefit[5] strategy that reduces the cost to the economy and reduces the failure rate of our infrastructure, the incremental added cost of reducing the vulnerabilities specific to terrorism can be greatly reduced.

The United States and Japan both need a counterterrorism industrial policy.

Ecological Economics[6]

Vulnerabilities Created by Efficiency

The vulnerabilities of modern industrial societies result not only from the possible escape of weapons of mass destruction (WMDs) from government control, but also from the possible uses of commercial and industrial products as weapons. A source of even greater vulnerability, however, is the very efficiency of competitive economic systems. The competitive drive for commercial efficiency creates linkages and vulnerabilities in critical infrastructure industries—energy, transportation, communications, food production and distribution, public health, and financial transactions. Industrial efficiency may compromise an industry's resilience to catastrophic terrorism in several ways:

- Single point failures in industries in which costs of equipment (e.g., ultrahigh-voltage transformers in electric power distribution systems) are high and the risks from small, more frequent events are low. This equipment is operated without redundant backup.
- Excessive concentration to increase economies of scale. For example, chicken processing and distribution are concentrated in a handful of large firms. Fuel and passengers are concentrated in large commercial air transports.
- Coupling of critical infrastructure systems to leverage economies of scope. For example, transportation safety depends on the availability of electric power and secure computer networks.

Thus, a competitive economy creates vulnerabilities that can only be reduced through government policy and industry cooperation (Branscomb, 1997). The President's Council of Advisers on Science and Technology (PCAST) estimates that 85 percent of U.S. infrastructure systems are owned and run by private firms, not government. To pay for reducing these vulnerabilities, industry would have to make public-goods investments with no reliable means of evaluating risk and thus justifying the expense.

Dual-Benefit Strategy

In a limited number of cases, firms may be able to devise protective strategies that also reduce costs or improve products or services so that the total cost is minimized, or even negative. The way many firms responded to the Y2K threat offers some hope for this option. A dual-benefit strategy would have several advantages:

- It would increase the likelihood that industry would invest in hardening critical infrastructure.
- It would encourage a more sustainable public commitment to and tolerance for the costs and inconveniences of national efforts to counter terrorist threats.
- It would integrate homeland security research and development and engineering to ensure a high-quality, national effort.

Because most terrorist targets and many of the weapons are embedded in the civil economy, security issues cannot be neatly separated from other issues. A strategy for gradually restructuring physical facilities, production processes, means of distributing food, and the like will have to reflect a balance of public-good investments, for which government will have to take the initiative, and commercial investments aimed at competitive success. The political economies of the United States and Japan are not designed to make this marriage of conflicting interests and responsibilities easy; European nations are more accustomed to balancing the public good and competitiveness in their economies. However ideologically distasteful the phrase, at least to Americans, both the United States and Japan will need a counterterrorism industrial policy.

There are many examples of civilian benefits in the United States that might result from a dual-benefits strategy:

- revitalization of the Public Health Service to meet the normal health needs of communities
- technical capability of responding even faster and more effectively to natural biological threats, such as SARS, the West Nile virus, and the monkey pox virus

- decrease in the number of illnesses caused by infection from the food supply
- more reliable electric power and other services, especially in the event of hurricanes, floods, and earthquakes
- improvements in the safety standards of the chemical industry
- fewer cyberattacks by hackers and financial systems that are more secure against theft and malicious damage
- more efficient and timely tracking of goods in transit and billing for their content
- a lower risk to fire, police, and emergency health professionals

A similar list could be constructed for Japan.

U.S.-Japan Cooperative Strategies

Bilateral cooperation includes exchanging information, experience, strategies, and tactics and identifying opportunities and gaps in each nation's strategy. Observing each other's system tests and evaluations might benefit both countries.

A comparison of preparations for high-consequence disasters in very large cities, such as New York and Los Angeles, with preparations in Tokyo and Osaka could be instructive. U.S. thinking does not traditionally include a city as critical infrastructure, yet the complexity and interdependence of critical services in a city creates an environment in which predicting consequences and providing emergency management are especially difficult. Other useful comparisons would be of first responder operations, communications, special equipment, and tactics.

Areas for cooperative research include the application of complex systems-engineering methods to determine both vulnerabilities and alternative tactics for response and recovery. Research could also focus on industry technologies and standards for products in international trade that could be used to deliver weapons (e.g., food products and pharmaceuticals). Another fruitful area for collaborative research is common strategies for protecting engineering and science systems, especially computer communications networks that are international by nature.

Exchanges of information and student and postdoctoral exchanges in areas of basic science and basic engineering could make the task of counterterrorism easier. Examples range from using very large sensor networks to produce actionable information, to inventing biomaterial detectors for explosives, to mimicking the olfactory capability of dogs. The joint development of standards for all technologies, such as biosensors for border control, require agreed-upon, compatible hardware and software interfaces.

Role of Engineering

Systems engineering skills are crucial for collaboration. The limitations of human performance are even more severe in homeland security than in military operations. The variety of circumstances under which attacks might occur, uncertainties about how sensor systems will respond to new circumstances, and above all, the need for data interpretation that results in credible information for emergency decisions will all stress systems designs and analysis. A cyberattack coupled with more conventional attacks would make getting "actionable" intelligence much more difficult. American expertise in systems engineering and human-factors design could be coupled with Japanese skills in rapid prototyping and fast learning and redesign to address these problems.

Observing each other's tests and evaluations might benefit both countries.

The engineering challenges posed by technical complexities are even more difficult because of the sensitivity of systems design to cost, which is a more sensitive issue in homeland security than in military technology for three reasons: (1) the need to prepare for a huge variety of potential targets and weapons; (2) the expectation that private firms in cities and critical infrastructure will pay to reduce vulnerabilities and improve response; and (3) the dependence on a civil department (DHS in the United States and MEXT in Japan) to cover much of the development costs. Unlike American defense industries, Japanese defense industries are firms with primary businesses in civil markets; thus, they have experience in dual-benefit design and manufacturing that could be very helpful.

Finally, engineering inventions are badly needed in many areas to convert some promising scientific principles into workable devices and systems. In the past, there has been no market in homeland security, and commercial markets are likely to be weak in the future. Thus, although national expenditures in science will surely lead to ideas applicable to homeland security, there will be a great need for engineering invention, prototyping, development, and innovation.

Next Steps

At the discussions in Tokyo, the participants agreed that the U.S.-Japan Science and Technology Cooperation Agreement is an appropriate framework for a variety of collaborative projects. This agreement expires in the summer of 2004 and must be renegotiated, but there seems little doubt that both sides wish to see it extended. Within that framework, a variety of joint project agreements between government agencies with like missions can be defined. In addition, discussions have begun on a framework for encouraging and coordinating an academic and basic research component of the program. The Science Council of Japan and the U.S. National Academies have been suggested as possible partners in that effort.

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Notes

[1] Politically motivated terrorists, such as the Irish Republican Army, may have a specific goal that, if achieved, might bring an end to attacks. One can imagine an attempt to negotiate an end to their terrorism. This is not the case for Al Qaeda, which carried out the September 11, 2001, attacks on New York and Washington.

[2] There may, of course, also be domestic terrorists, citizens of the target society motivated by ideologies that are local in nature, such as the attack on the Murrah Building in Oklahoma City, which was related to the government handling of the Branch Dividian sect in Waco, Texas.

[3] Gerald Holton anticipated just such a combination, individual terrorists supported by a rogue government, in a paper presented at a terrorism conference at the Hoover Institution in 1976 and published at that time in *Terrorism, an International Journal*. He called this threat Type III terrorism (Holton, 2002).

[4] The roughly 50 agencies that comprise DHS continue to be responsible for their "normal," pre-September 11 duties. Thus, DHS is truly a "dual-benefit" agency, as are MEXT and other emergency support agencies in Japan.

[5] The phrase "dual-benefit strategy" was suggested by Ruth A. David, CEO of ANSER Corporation.

[6] This section is taken from Branscomb, 2004.

A U.S. delegation was shown North Korea's nuclear facilities.

The Nuclear Crisis in North Korea

Siegfried S. Hecker is senior fellow at Los Alamos National Laboratory.

Siegfried S. Hecker

I was somewhat startled when my North Korean host asked me, "Do you want to see our product?" I responded, "You mean the plutonium?" When he nodded, I said "sure." Scientists and engineers often find themselves in the middle of major diplomatic issues. In the past 12 years, I have worked closely with Russian scientists and engineers (more than 30 visits) to help them deal with their nuclear complex after the breakup of the Soviet Union. However, my visit to North Korea was unexpected.

This adventure began with a phone call in late 2003 from my colleague, Professor John W. Lewis of Stanford University, who has been engaged in unofficial Track II discussions with North Korea since 1987. He was there in August 2003 (his ninth visit) trying to help resolve the current nuclear crisis on the Korean Peninsula, and his interactions with the North Korean government had gained him sufficient trust to be invited to visit the nuclear facilities at Yongbyon. He asked me to come along so there would be a nuclear specialist present.

This nuclear crisis, the second one in 10 years, was precipitated when North Korea expelled international nuclear inspectors in December 2002, withdrew from the Nuclear Nonproliferation Treaty, and claimed to be building more nuclear weapons with plutonium extracted from spent-fuel rods heretofore stored under international inspection. These actions were triggered by a disagreement over U.S. assertions that North Korea had violated the Agreed Framework (which had frozen the plutonium path to nuclear weapons to end the first crisis in 1994) by clandestinely developing uranium-enrichment capabilities as an alternative path to nuclear weapons.

Diplomatic efforts to resolve the nuclear crisis made little progress in 2003. The United States insisted on talking with the North Korean government only in a six-party format that included North Korea's four neighbors, South Korea, China, Russia, and Japan. The inaugural meeting in Beijing in August 2003 made little apparent progress. Our "unofficial" U.S. delegation was the first to visit the nuclear facilities at Yongbyon (about a two-hour drive north of the capital, Pyongyang) since the crisis erupted. Joining our delegation at Prof. Lewis's invitation was Charles L. (Jack) Pritchard, Visiting Scholar at the Brookings Institute and formerly the U.S. special envoy for negotiations with the Democratic People's Republic of Korea. In addition, we were joined by two Senate Foreign Relations Committee experts on Asian affairs, W. Keith Luse and Frank S. Januzzi, who had separately planned a trip to North Korea.

Scientists and engineers can play a crucial role in the diplomatic process.

I told our North Korean hosts that my objective was to reduce the ambiguities associated with their nuclear program. I realized that some ambiguities might be deliberate. However, ambiguities often lead to miscalculations, and in the case of nuclear weapons-related matters, miscalculations can be disastrous. I also stated that I believe scientists and engineers can play three important roles in the diplomatic process. First, they can clarify the issues and thus facilitate a diplomatic solution to the nuclear crisis. Second, if a diplomatic solution is found, scientists can help implement the solution, such as a freeze or the eventual elimination of the nuclear program. Third, scientists can play a crucial role in verifying a solution.

Our principal host, Vice Minister of Foreign Affairs Kim Gye Gwan, responded positively and explained the motivation for inviting us to Yongbyon. He indicated that North Korea wanted to resume the six-party talks to negotiate a freeze and eventual elimination of its nuclear program. A freeze, he explained, means "no manufacturing, no testing, and no transferring of nuclear weapons." He continued, "We view the delegation's visit to Yongbyon as a way to help contribute to breaking the stalemate and opening up a bright future. We will not play games with you. We have invited you to go to Yongbyon. The primary reason for this is to ensure transparency. This will reduce the assumptions and errors. . . . This visit can have great symbolic significance."

"We want you to take an objective look, and we will leave the conclusions to your side," he said. "This is why the inclusion of Dr. Hecker is so significant. Hecker's presence will allow us to tell you everything. This is an extraordinary approval by us. . . . We, too, emphasize that you are not making an inspection. But, because we are allowing this visit, we will provide you enough access to have good knowledge."

Vice Minister Kim explained that U.S. actions in November 2002 had convinced the North Koreans that adhering to the Agreed Framework was no longer in their interest, so they terminated the International Atomic Energy Agency (IAEA) inspections and withdrew from the Nonproliferation Treaty. "We decided to operate the 5 megawatt electric (MWe) reactor and resume reprocessing plutonium for peaceful nuclear activities. However, the hostile U.S. policy had been intensified. So, we changed our purpose and informed the U.S. that the plutonium that was to have been used for peaceful purposes would now be used for weapons."

Vice Minister Kim added that North Korea wants a peaceful resolution of the nuclear crisis and denuclearization of the Korean Peninsula. He emphasized that North Korea had been very flexible and very patient, adding, "I should note that the time that has been lost [in dealing with us] has not been beneficial to the U.S. side. With an additional lapse in time, our nuclear arsenal could grow in quality and quantity. The outcome has not been a success for the U.S."

These comments provide the context for our invitation to Yongbyon. In public statements, the North Korean government said fuel rods have been reprocessed to extract plutonium and strengthen the country's "deterrent." Concerned that the United States (and perhaps others) did not believe these statements, they may have invited us to provide independent confirmation of their claims. However, Vice Minister Kim also expressed a concern about the decision to invite us to Yongbyon. "If you go back to the United States and say that the North already has nuclear weapons, this may cause the U.S. to act against us."

In spite of these reservations, the North Korea government arranged our visit to Yongbyon to verify that it had taken significant steps forward in its nuclear program since December 2002 and to impress us with its nuclear capabilities. The leadership and specialists at Yongbyon were very cooperative within the boundaries of what they were authorized to show us.

The offer to show us their plutonium "product" followed visits to North Korea's 5 MWe reactor, the spent-fuel pool building, and, on January 8, 2004, the Radiochemical Laboratory at Yongbyon. The key questions in my mind were: (1) the operating status of the 5 MWe reactor and its two larger companions, a 50 MWe reactor at the Yongbyon site and a 200 MWe reactor about 20 km away, that were under construction at the time of the freeze in 1994; (2) the status of the 8,000 spent-fuel rods that were removed from the 5 MWe reactor in 1994 and stored in a pool under international safeguards; (3) the extent of the nuclear weapons program; and (4) the existence of a uranium-enrichment program.

On the drive from Pyongyang to Yongbyon in two Toyota Land Cruisers, our drivers wound their way past young policewomen directing more traffic than I had expected at Pyongyang intersections, then along a well built, all but deserted, four-lane highway to the north (Figure 1). After about an hour, we turned off onto a dirt road toward the city of Yongbyon with its historic South Gate and Great Wall. As we drove along the Nine Dragon (Kuryong) River, we passed many peasants on foot and on bicycles. The nuclear center is located in its own "closed" city, reminiscent of Russia's closed nuclear cities, with Soviet-style apartment complexes and monuments to the Great Leader and Dear Leader and memorials to the Korean war. The streets and playgrounds were clean and bustling with people.

We met our technical host, director Ri Hong Sop at the Guest House for introductions before visiting the technical facilities. The tours were conducted by knowledgeable chief engineers at each site. I will address the four questions I listed above by first summarizing what we were told by our North Korean hosts (in italics) and then describing my observations.

Status of the Reactors

The 5 MWe reactor was restarted in February 2003 and is now operating smoothly at 100 percent of its rated thermal power. Since shipments of heavy fuel oil from the United States were cut off, it is producing electricity and heat for the town.

FIGURE 1 Map showing North Korean nuclear facilities. Source: Center for Nonproliferation Studies.

FIGURE 2 American delegation in the control room of the 5 MWe reactor.

We confirmed that the 5 MWe reactor is operating smoothly. We were shown the control room and the reactor hall, and, based on our discussions and the displays in the control room, all indications were that the reactor is now operating smoothly (Figure 2). The steam plume emanating from the cooling tower confirmed operation. We also note that, in addition to producing electricity and heat, the reactor is accumulating approximately 6 kilograms (kg) of plutonium annually in natural-uranium fuel rods.

Construction of the 50 MWe reactor had been stopped in 1994, when it was within one year of completion. No work has been done on the reactor since. The government is currently evaluating its options and deciding what to do with the reactor.

We drove past the 50 MWe reactor site twice. This reactor is similar in design to the 5 MWe reactor, but with an annual plutonium production capacity roughly 10 times greater. We confirmed that no construction is going on at this site. The reactor building appeared to be in a terrible state of repair. The concrete building structure showed cracks. The steel exhaust tower and other steel equipment on the site were heavily corroded. The building was not closed up and resembled a deserted structure. Director Ri expressed his great dismay about the deterioration of the facility during the eight-year freeze on construction. This reactor is much more than one year from completion now. It is not clear how much of the structure can be salvaged.

Our hosts stated that construction of the 200 MWe reactor at Tacheon, 20 km from Yongbyon, also stopped in 1994 and that the government is currently evaluating what to do with the reactor.

Because we did not visit the site, we were not able to assess the current situation. However, it was clear from our discussions that neither of the two reactors under construction in 1994 could be completed any time soon. Therefore, it will not be possible for North Korea to increase its plutonium output beyond the 6 kg/year being produced in the 5 MWe reactor.

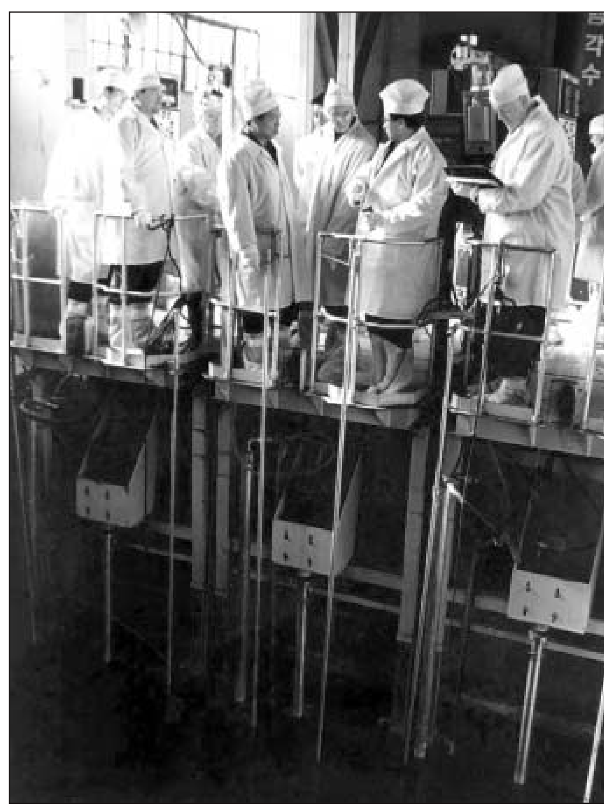

FIGURE 3 American delegation at the storage pool for spent-fuel rods.

Status of Spent Fuel Rods

At the spent-fuel storage building, we were told that all 8,000 fuel rods had been removed from the storage pool and reprocessed (to extract the plutonium) in the Radiochemical Laboratory.

The spent-fuel rods had been removed from the 5 MWe reactor after operation ceased in 1994 as part of the Agreed Framework. The fuel rods were "re-canned" by a U.S. Department of State and Department of Energy team (supported by the Pacific Northwest National Laboratory and the Nuclear Assurance Corporation) to ensure safe, secure storage before eventual shipment of the plutonium-containing fuel rods out of North Korea. It was imperative that the spent-fuel rods be re-canned in an inert atmosphere because their initial exposure to water in the pool would be detrimental to the magnesium alloy cladding. In addition, the fuel rods had to be stored under the watchful eyes of IAEA inspectors to ensure that no fuel rods were removed clandestinely. However, the inspectors were expelled in December 2002.

Our initial look into the spent-fuel pool showed that the safeguarding equipment previously used by the inspectors was gone (video cameras were still present but were disconnected) (Figure 3). We confirmed that not all of the fuel rods were in the pool because many of the canisters were missing and many were open. When I expressed concern that some of the canisters were still closed, our hosts took the extraordinary step of allowing me to pick one at random and have it opened (all done underwater in the pool) to demonstrate that no fuel rods remained, even in the closed canisters. The empty randomly selected canister and other observations convinced me that the spent-fuel pool is empty; the fuel rods are gone. It is possible that the 8,000 fuel rods had been moved to a different storage location, but such storage would represent a serious health and safety hazard.

At the Radiochemical Laboratory, we were told that all 8,000 spent-fuel rods had been reprocessed to plutonium metal in the Radiochemical Laboratory during one continuous campaign from mid-January 2003 to the end of June 2003. We were told that the campaign had been completed and that the facility is not operating now. (It is estimated that the spent-fuel rods contained 25 to 30 kg of plutonium.)

In this six-story, industrial-scale reprocessing facility, we were conducted through the corridor next to the hot cells where reprocessing is done remotely with manipulators (Figure 4). We noted that the North Koreans had the requisite facilities, equipment, and technical expertise for large-scale plutonium reprocessing. They use the standard PUREX (plutonium uranium extraction) process for separating plutonium from the fission products and uranium fuel. All of our technical questions about reprocessing chemistry were answered very competently. Based on our tour, we concluded that the facility had been operated, but we could not confirm that all of the fuel rods had been reprocessed.

FIGURE 4 American delegation in the Radiochemical Laboratory (reprocessing facility).

Although we were not permitted to see the plutonium glovebox operations, our hosts took the extraordinary step of showing us the "product" of what they claimed was the most recent reprocessing campaign. In a conference room following the tour, a metal case was brought in for us to inspect.

The box contained a wooden box with two glass jars, one said to contain 150 grams of plutonium oxalate powder and the other 200 grams of plutonium metal.

The glass jars were fitted with screw-on metal lids and were tightly taped with transparent tape. (The plutonium's alpha-radiation is easily stopped by the glass jar.) The green color of the plutonium oxalate powder was consistent with the color of plutonium oxalate that has been stored in air for some time. The plutonium metal was a thin-walled funnel that was described as scrap from a casting from this reprocessing campaign. When we asked about its density, we were told that it was "between 15 and 16 g/cm^3 and that it was alloyed" (a common metallurgical practice to retain the Δ-phase of plutonium to make it easier to cast and shape). When I asked what alloying element had been used, I was told that that they could not answer that question, but that I know what the United States uses and that theirs is the same. The surface and color of the metal were consistent with moderately oxidized plutonium metal from a casting. I tried to get a feel for the density and heat content of the metal by holding the glass jar in my gloved hand. The very thick glass jar was reasonably heavy and slightly warm (importantly, it was definitely not cold as was everything else in this building). With the rather primitive tools at hand, I was not able to identify definitively the metal or the powder as plutonium. The metal was radioactive, however, because a Geiger counter turned on near the wooden box containing the glass jars registered a count. With a few relatively simple tests, we could have made a positive identification of the product as plutonium metal, but that was not possible during this visit.

The concept of nuclear deterrence may have little meaning for the U.S.–North Korean situation.

Nuclear Weapons

During follow-up discussions with Vice Minister Kim and Ambassador Li Gun in Pyongyang, we were told that North Korea had strengthened its nuclear "deterrent"—in both quality and quantity—because of recent hostile actions by the United States. Ambassador Li inquired if what I had seen at Yongbyon had convinced me that they possessed this deterrent. I explained that nothing we had seen enabled me to assess whether or not they possessed a nuclear deterrent, if that meant a nuclear device or nuclear weapon. The North Koreans tend to use the term "deterrence" rather ambiguously.

I explained that I consider a "deterrent" to have at least three components: (1) the ability to make plutonium metal; (2) the ability to design and build a nuclear device; and (3) the ability to integrate the nuclear device into a delivery system. Our visit to Yongbyon had shown us that the North Koreans apparently have the capability to make plutonium metal. However, I saw nothing and talked to no one that gave me a basis for assessing their ability to design a nuclear device. And, of course, we were not able to assess the integration of such a device into a delivery vehicle.

During additional discussions, I cautioned that "deterrence" might have worked between the United States and the Soviet Union, two equally armed nuclear superpowers under rather predictable circumstances. The concept of nuclear deterrence may have little meaning, however, for the U.S.-North Korean situation. I asked Ambassador Li in the late morning of the last day of our visit if I could meet individuals who could talk to me in some detail about their "deterrent" in the spirit that I had just described. He said he would try, but that evening he told me that there was not enough time to make such arrangements.

Based on the overall technical capabilities we observed, and given that they apparently have sufficient plutonium metal, we must assume that the North Koreans are able to construct at least a primitive nuclear device. On April 13, 2004, David Sanger reported in the *New York Times* that Pakistani scientist A.Q. Khan had told authorities that he was shown three nuclear weapons during one of his visits to North Korea in 1999. However, given Khan's record of deceit and his sketchy description of the weapons, one must treat his statement with great skepticism.

The Highly Enriched Uranium Issue

We discussed the contentious issue of North Korea's admission on October 4, 2002, that it had a clandestine highly enriched uranium (HEU) program in violation of the 1994 Agreed Framework. There is still a good deal of controversy over whether or not the North Koreans had admitted having such a program at a meeting with U.S. officials. Mr. Pritchard, who was present at the October meeting, told our hosts that regardless of what may have been said, the HEU issue is very serious and that it is now mandatory that we come to a complete, verifiable resolution of this issue. In response, Vice Minister Kim Gye Gwan stated categorically that the North Koreans had no HEU program.

Upon further questioning, Vice Minister Kim stated that they had chosen the plutonium path to a deterrent and that North Korea had no facilities, equipment, or scientists dedicated to an HEU program. These statements now ring hollow because a few weeks after our visit reports surfaced of A.Q. Khan having clandestinely transferred uranium-enrichment technology to North Korea, Iran, and Libya. Vice Minister Kim concluded our discussions with: "However, we can be very serious when we talk about this. We are fully open to technical talks."

Conclusion

I found the remarkable access afforded us to North Korean nuclear facilities and specialists very encouraging. Based on this visit, we were able to answer some key questions of interest to our government. Upon my return home, I presented my findings to several U.S. government agencies and to the Senate Committee on Foreign Relations. However, before I left Pyongyang, I gave my hosts a summary of my findings at the closing banquet so they would be the first to hear them and would not be surprised by reports from the United States. Vice Minister Kim had hoped that I would draw more definitive conclusions, but he recognized that from a scientific perspective this would be difficult. He said: "I understand. I would like you to make this report to your government. Don't add anything and don't subtract anything."

Our report provided input to the second round of six-party talks held on February 25–28 in Beijing. However, the contentious and unresolved HEU issue limited progress. Professor Lewis and I hope to return to North Korea in the coming months and contribute to a diplomatic solution of the nuclear crisis. In the meantime, a great deal could be done to prepare for the eventual complete, verifiable, irreversible dismantlement of the nuclear program. North Korea's ability to shut down safely and securely and eliminate its nuclear program will depend on what is done technically in the nuclear complex in the short term.

Finally, our delegation met with other government officials regarding economic, military, and human rights issues. On behalf of the U.S. National Academies, we also met with officials of the North Korean Academy of Sciences to explore the potential for future cooperative activities in the areas of energy and agriculture. If the nuclear crisis can be resolved diplomatically, it will be essential that the technical communities help to resolve the chronic energy and food problems faced by the people of North Korea.

Engineers have a collective responsibility to improve the lives of people around the world.

Engineering for the Developing World

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Bernard Amadei

The world is becoming a place in which the human population (which now numbers more than six billion) is becoming more crowded, more consuming, more polluting, more connected, and in many ways less diverse than at any time in history. There is a growing recognition that humans are altering the Earth's natural systems at all scales, from local to global, at an unprecedented rate, changes that can only be compared to events that marked the great transitions in the geobiological eras of Earth's history (Berry, 1988). The question now arises whether it is possible to satisfy the needs of a population that is growing exponentially while preserving the carrying capacity of our ecosystems and biological and cultural diversity. A related question is what should be done now and in the near future to ensure that the basic needs for water, sanitation, nutrition, health, safety, and meaningful work are fulfilled for *all* humans. These commitments were defined as the "Millennium Development Goals" by the United Nations General Assembly on September 18, 2000 (United Nations Development Programme, 2003).

In the next two decades, almost two billion additional people are expected to populate the Earth, 95 percent of them in developing or underdeveloped countries (Bartlett, 1998). This growth will create unprecedented demands for energy, food, land, water, transportation, materials, waste disposal, earth moving, health care, environmental cleanup, telecommunication, and infrastructure. The role of engineers will be critical in fulfilling those demands at various scales, ranging from remote small communities to large urban areas (megacities), mostly in the developing world (United Nations, 1998). If engineers are not ready to fulfill such demands, who will? As George Bugliarello (1999) has stated, the emergence of large urban areas is likely to affect the future prosperity and stability of the entire world. Today, it is estimated that between 835 million and 2 billion people live in some type of city slum and that the urban share of the world's extreme poverty is about 25 percent (United Nations, 2001).

Considering the problems facing our planet today and the problems expected to arise in the first half of the twenty-first century, the engineering profession must revisit its mindset and adopt a new mission statement—to contribute to the building of a more sustainable, stable, and equitable world. As Maurice Strong, Secretary General of the 1992 United Nations Conference on Environment and Development, said, "Sustainable development will be impossible without the full input by the engineering profession." For that to occur, engineers must adopt a completely different attitude toward natural and cultural systems and reconsider interactions between engineering disciplines and nontechnical fields.

For the past 150 years, engineering practice has been based on a paradigm of controlling nature rather than cooperating with nature. In the control-of-nature paradigm, humans and the natural world are divided, and humans adopt an oppositional, manipulative stance toward nature. Despite this reductionistic view of natural systems, this approach led to remarkable engineering achievements during the nineteenth and especially twentieth centuries. For instance, civil and environmental engineers have played a critical role in improving the condition of humankind on Earth by improving sanitation, developing water resources, and developing transportation systems. Ironically, these successes have unintentionally contributed to current problems by enabling population growth (Roberts, 1997). Most engineering achievements of the past were developed without consideration for their social, economic, and environmental impacts on natural systems. Not much attention was paid to minimizing the risk and scale of unplanned or undesirable perturbations in natural systems associated with engineering systems.

As we enter the twenty-first century, we must embark on a worldwide transition to a more holistic approach to engineering. This will require: (1) a major paradigm shift from control of nature to participation with nature; (2) an awareness of ecosystems, ecosystems services, and the preservation and restoration of natural capital; and (3) a new mindset of the mutual enhancement of nature and humans that embraces the principles of sustainable development, renewable resources management, appropriate technology, natural capitalism (Hawken et al., 1999), biomimicry (Benyus, 1997), biosoma (Bugliarello, 2000), and systems thinking (Meadows, 1997).

Engineers must adopt a new attitude toward natural and cultural systems.

In addition, engineering educators must take a closer look at how engineering students are being prepared to enter the "real world." Current graduates will be called upon to make decisions in a socio-geo-political environment quite different from that of today. In their lifetimes, engineering students now attending college can expect to see an increase in world population from 6 to 9 or 10 billion people, major global warming phenomena, and major losses in biological and cultural diversity on Earth. Whether colleges and universities are doing enough proactively to teach students what they need to know to operate in a future environment is an open question (Orr, 1998). Clearly, engineers must complement their technical and analytical capabilities with a broad understanding of so-called "soft" issues that are nontechnical. Experience has shown that social, environmental, economic, cultural, and ethical aspects of a project are often more important than the technical aspects.

An issue of equal importance is the education of engineers interested in addressing problems specific to developing communities. These include water provisioning and purification, sanitation, power production, shelter, site planning, infrastructure, food production and distribution, and communication, among many others. Such problems are not usually addressed in engineering curricula in the United States, however. Thus, our engineers are not educated to address the needs of the most destitute people on our planet, many of them living in industrialized countries. This is unfortunate, because an estimated 20 percent of the world's population lacks clean water, 40 percent lacks adequate sanitation, and 20 percent lacks adequate housing.

Furthermore, engineers will be critical to addressing the complex problems associated with refugees, displaced populations, and the large-scale movement of populations worldwide resulting from political conflicts, famine, shortages of land, and natural hazards. Some of these problems have been brought back to our awareness since the tragedy of September 11, 2001. The engineer's role is critical to the relief work provided by host governments and humanitarian organizations. According to the World Health Organization (WHO), 1.8 billion people (30 percent of the world's population) currently live in conflict zones, in transition, or in situations of permanent instability.

It is clear that engineering education needs to be changed (or even reinvented) to address the challenges associated with these global problems. There is still a large disconnect between what is expected of young engineers in engineering firms, the magnitude of the problems in our global economy, ABET 2000 engineering criteria (Criteria 3 and 4 for instance), and the limited skills and tools traditionally taught in engineering programs in U.S. universities.

Engineering education must address the challenges associated with global problems.

Engineers of the future must be trained to make intelligent decisions that protect and enhance the quality of life on Earth rather than endangering it. They must also make decisions in a professional environment in which they will have to interact with people from both technical and nontechnical disciplines. Preparing engineers to become facilitators of sustainable development, appropriate technology, and social and economic changes is one of the greatest challenges faced by the engineering profession today. Meeting that challenge may provide a unique opportunity for renewing leadership of the U.S. engineering profession as we enter the twenty-first century.

Earth Systems Engineering

In the past five years, a new, promising concept called earth systems engineering (ESE) has emerged as an alternative to the usual way engineering has looked at the world. ESE acknowledges the complexity of world problems and encourages the use of more holistic and systemic tools to address interactions between the anthrosphere (i.e., the part of the environment made and modified by humans and used for their activities) and natural and cultural systems.

In 1998, Allenby (1998) introduced the concept of ESE with reference to industrial ecology. The latter is defined as "the multidisciplinary study of industrial systems and economic activities, and their links to fundamental natural systems" (Allenby, 1999). First proposed in Japan in 1970, industrial ecology was brought to the attention of people in the United States in the late 1980s and 1990s through several studies by the National Academy of Engineering (NAE) on the relationship between engineering and ecological systems. Industrial ecology was also the subject of two Gordon Conferences in 1998 and 2000 at Colby-Sawyer College in New London, New Hampshire.

The success of industrial ecology, along with the recommendations in *Our Common Journey*, a report prepared by the National Research Council Board on Sustainable Development (NRC, 1999), motivated NAE to organize a one-day meeting on ESE on October 24, 2000 (NAE, 2002). In that meeting, and in the exploratory workshop that preceded it, the following working definition of ESE was adopted:

> *ESE is a multidisciplinary (engineering, science, social science, and governance) process of solution development that takes a holistic view of natural and human system interactions. The goal of ESE is to better understand complex, nonlinear systems of global importance and to develop the tools necessary to implement that understanding.*

ESE acknowledges that, so far, humans have demonstrated a limited understanding of the dynamic interactions between natural and human (non-natural) systems. This is partly attributable to the complexity of the problems at stake. On one hand, natural systems are traditionally nonlinear, chaotic, and open dissipative systems characterized by interconnectedness and self-organization. Small changes in parts of natural systems can have a big impact on their response to disturbances. On the other hand, human (anthropogenic) systems are based on a more predictable Cartesian mindset.

Understanding the relationship between natural and non-natural systems remains a challenge. We do not yet have the tools and metrics to comprehend and quantify complex systems and their interactions. According to Dietrich Dörner (1996), this is one of the many reasons technology often fails. Other reasons cited by Dörner include the slowness of human thinking in absorbing new material and human self-protection through control. According to Dörner: "We have been turned loose in the industrial age equipped with the brain of prehistoric times."

In 2001, I co-organized a three-day workshop at the University of Colorado at Boulder on ESE sponsored by the National Science Foundation. The workshop brought together about 90 industry, government, and university participants from engineering, physical sciences, biological sciences, and social sciences. The overall goals of the workshop were: (1) to provide an intellectual framework for interdisciplinary exchange; (2) to make recommendations for changes to engineering education, research, and practice that would further the understanding of the interactions between natural and non-natural systems at multiple scales, from local to regional and global; and (3) to create a plan of action to implement the recommendations. More specifically, the workshop addressed the interactions of natural systems with the built environment. The workshop participants unanimously adopted the following definition of the "engineer of the future":

> *The engineer of the future applies scientific analysis and holistic synthesis to develop sustainable solutions that integrate social, environmental, cultural, and economic systems.*

The workshop participants also recommended the adoption of a transformative model of engineering education and practice for the twenty-first century that (University of Colorado, 2001):

- unleashes the human mind and spirit for creativity and compassion
- expands engineers' professional and personal commitments to include both technical and nontechnical disciplines
- inspires engineers to embrace the principles of sustainable development, renewable resources management, appropriate technology, and systems thinking
- prepares engineers for social, economic, and environmental stewardships

Since 2001, ESE has been endorsed as a major initiative in the College of Engineering at the University of Colorado at Boulder. An example of the application of ESE to engineering for the developing world is presented below.

We do not have the tools or metrics to quantify complex systems and their interactions.

Engineering for Developing Communities

Engineering schools in the United States do not usually address the needs of the most destitute people on our planet, many of them living in industrialized countries (including the United States). This is unfortunate because the needs of the developing world for engineering solutions are likely to increase as population grows. How can engineers in the industrialized world contribute to the relief of the hunger, exploitation, injustice, and pain of people trying to survive day by day? How can they contribute to meeting the United Nations "Millennium Development Goals" (United Nations Development Programme, 2003; World Bank, 2003; World Federation of Engineering Organizations, 2002)? Clearly, we need to train a new generation of engineers to meet the challenges and needs of the developing world.

The College of Engineering at the University of Colorado at Boulder has started a new program called the Engineering for Developing Communities (EDC) Program (*www.edc-cu.org*). The overall mission of the program is to educate globally responsible students who can offer sustainable, appropriate technology solutions to the endemic problems of developing communities worldwide (including the United States).

The proposed interdisciplinary program, which involves both engineering and nonengineering disciplines, is offered to engineering students interested in community service and international development. The program is being developed in partnership with a wide range of academic and nonacademic groups in the United States and developing countries to address a wide range of issues, such as water provisioning and purification, sanitation, health, power production, shelter, site planning, infrastructure, food production and distribution, communication, and jobs and capital for developing communities, including villages, and refugee settlements. Finally, the three components of the program are: outreach and service; research and development; and education.

Outreach and Service

The outreach and service component of the EDC Program was launched in fall 2001 with a national initiative, Engineers Without Borders. This new activity was created as a follow-up to fieldwork in May 2001, when I took 10 undergraduate students from the Department of Civil, Environmental, and Architectural Engineering to help with the construction of a water distribution system for a small Mayan village in southern Belize (Figure 1).

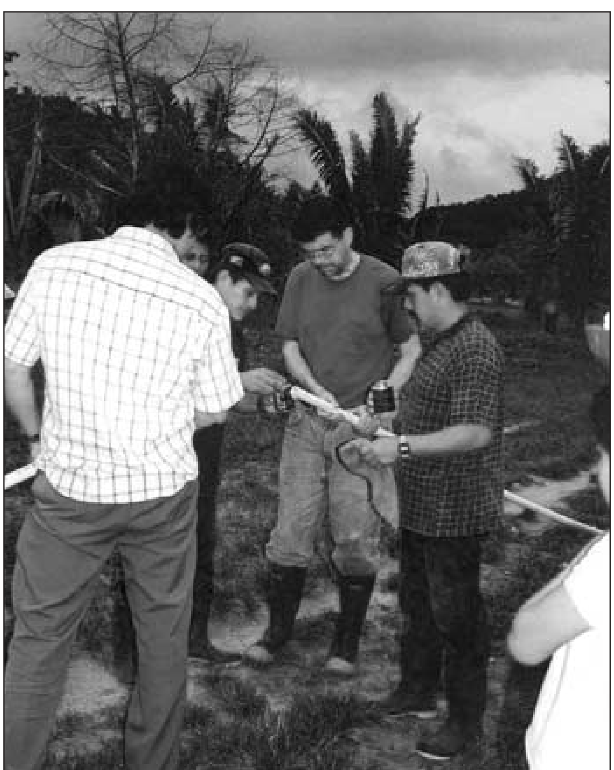

FIGURE 1 Professor Amadei (center) with students and local participants in a water-distribution project in Belize.

The work in Belize led to the creation of a nonprofit 501(c)(3) tax-exempt corporation, called Engineers Without Borders™-USA (*www.ewb-usa.org*). The first chapter was formed at the University of Colorado at Boulder in late fall 2001. Three years later, EWB-USA has 74 student and professional chapters across the United States and involves 950 engineering students, faculty, and professional engineers.

In general, the purposes of EWB-USA are (1) to help disadvantaged communities improve their quality of life through implementation of environmentally and economically sustainable engineering projects, and (2) to develop internationally responsible engineering students. Projects are initiated by, and completed with, contributions from the host communities, which are then trained to operate the systems without external assistance. The projects are carried out by groups of engineering students under the supervision of professional engineers and faculty. The students select a project and go through all phases of conceptual design, analysis, and construction during the school year; implementation is done during academic breaks and summer months.

EWB-USA has about 50 projects in 22 different countries. In 2003 alone, more than 50 students from U.S. schools were involved in projects in Mali, Mauritania, Senegal, Thailand, Haiti, Belize, Nicaragua, Afghanistan, and Peru (Figure 2). The EWB-USA model of education goes beyond traditional service-learning concepts and models in engineering (Tsang, 2000). By involving students in all steps of the projects and through experiential learning, students become more aware of the social, economic, environmental, political, ethical, and cultural impacts of engineering projects.

EWB-USA is a member of Engineers Without Borders-International (*www.ewb-international.org*), a network of like-minded humanitarian organizations that transcends national borders. As of April 2004, the EWB-International network includes 24 groups around the world.

Research and Development

The field work conducted by EWB-USA has revealed an urgent need for appropriate technologies specific to the developing world. An "appropriate technology" is usually characterized as small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community. It must be simple enough to be maintained by the people who use it. In short, it must match the user and the need in complexity and scale and must be designed to foster self-reliance, cooperation, and responsibility (Hazeltine and Bull, 1999; Schumacher, 1989).

Because appropriate technology is often perceived as "low tech" and unimportant, it is not usually addressed in engineering education or university research. Studies by the World Bank and the United Nations have shown, however, that appropriate technology is critical to bringing more than three billion people out of poverty.

FIGURE 2 Professor Amadei with village children in Mali.

To respond to the need for research and development in appropriate technology, a Center for Appropriate and Sustainable Technology (CU-CAST) is under development in the College of Engineering at the University of Colorado at Boulder. The center has three goals: (1) to provide a university research environment where teams of undergraduate and graduate students can work under the supervision of faculty and professional engineers; (2) to foster the innovation, development, and testing of technologies that can be used to address water, sanitation, energy, shelter, and health issues in the developing world; and (3) to provide services in database development and maintenance; the testing and improvement of existing technologies; technology transfer; and education and training. Examples of ongoing studies by students and faculty include: prototype rope pumps for water wells and ram pumps; pesticide removal during basic treatment of drinking water; attenuation of pathogens from latrines to nearby water sources; phytoremediation affects on wastewater treatment; thin-shell acrylic concrete roofing; solar pasteurization, cooling, heating, cooking, and pumping; production of biofuel and biomass; and earthenware cooling techniques for storage of food and vaccines.

Education

The EDC Program brings together courses in engineering, sustainability, appropriate technology, renewable energy, international education and development, business, and various fields of humanities and provides an opportunity for undergraduate students in engineering to enroll in a regular program of study in the College of Engineering and, at the same time, take some of their socio-humanities electives, technical electives, and independent study classes in courses emphasizing engineering for developing communities.

The success of EWB convinced me that we need new engineering courses to provide students with better tools and skills for work in the developing world. In spring 2002, I introduced Sustainability and the Built Environment, a three-credit course for undergraduate and graduate students that presents the fundamental concepts of sustainability and sustainable development, with the emphasis on understanding natural systems, interactions between the built environment and natural systems, and the technical and nontechnical issues that influence engineering decisions. (Information about this course can be found at *http://ceae.colorado.edu/~amadei/CVEN4838*.)

In fall 2002, I introduced a design course for undergraduates (engineering freshmen) that emphasizes appropriate technology. Since 2002, the course has been offered twice through the Integrated Teaching and Learning Laboratory (*http://itll.colorado.edu*). The course gives students a thorough understanding of some of the most common and important technologies being introduced in small-scale community developments. Students are asked to create, design, and construct appropriate technological systems, processes, and devices for a variety of settings associated with the developing world. Examples include: production of biodiesel; production of biomass from bananas; generation of electricity using water turbines; heating of water for refugee camps; water filtration systems; solar-powered refrigeration; and solar-powered water pumping. (Information about these projects can be found at *www.edc-cu.org/geen1400.htm.*)

The educational component of the EDC Program also includes continuing education and training for U.S. engineers and foreign personnel in international development and capacity building. The EDC Program sponsors and organizes workshops and conferences, bringing world experts and leaders to the University of Colorado at Boulder for discussions and sharing of research and applications in areas dealing with the developing world. For instance, last year, the EDC Program co-organized Sustainable Resources 2003: Solutions to World Poverty, which was attended by about 800 participants from 44 different countries. (Information about that conference and the forthcoming Sustainable Resources 2004 conference can be found at *www.sustainableresources.org.*)

Conclusions

Creating a sustainable world that provides a safe, secure, healthy, productive, and sustainable life for all peoples should be a priority for the engineering profession. Engineers have an obligation to meet the basic needs of all humans for water, sanitation, food, health, and energy, as well as to protect cultural and natural diversity. Improving the lives of the five billion people whose main concern is staying alive each day is no longer an option; it is an obligation. Educating engineers to become facilitators of sustainable development, appropriate technology, and social and economic changes represents one of the greatest challenges faced by the engineering profession today. Meeting that challenge may provide a unique opportunity for renewing the leadership of the U.S. engineering profession as we enter the twenty-first century.

The EDC Program described in this paper provides a unique opportunity to promote engineering, a discipline that has traditionally been taken for granted by government agencies and political groups. It also provides higher visibility to a profession that will certainly play a critical role in creating structures and technologies to sustain a decent quality of life for current and future generations, especially in the developing world.

The new program offers many opportunities for practicing engineers to become involved in engineering education through projects in developing communities around the world (including the United States). Finally, it provides an innovative way to educate young engineers interested in addressing the problems of developing countries and communities. It is clear that engineers of the twenty-first century are called upon to make critical contributions to peace and security in our increasingly challenged world.

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NAE News and Notes

NAE Newsmakers

R. Byron Bird was awarded Knighthood by Queen Beatrix of the Netherlands in recognition of 50 years of work "on behalf of the Dutch culture." Sir Robert Byron Bird was appointed by her order of 25 September No. 03.003913 as **Knight in the Order of Oranja Nassau**.

Two NAE members were elected fellows of the American Association for the Advancement of Science (AAAS). **Russell D. Dupuis** and **William J. Koros** were among 384 scientists and engineers elected to the AAAS.

Farouk El-Baz received the Desert Research Institute's top annual research award on March 9, 2004. The silver **Nevada Medal** and $20,000 were presented to Dr. El-Baz for his research and pioneering use of satellite images to characterize arid landforms worldwide.

Yuan-Cheng Fung received the **Lifetime Achievement Award** at the 2004 Chinese Institute of Engineers Asian American Engineer of the Year Award Banquet in Santa Clara, California. Dr. Fung was honored for initiating a new direction in bioengineering; he also coined the term "tissue engineering."

Alan Kay has been named the winner of the **2003 Turing Award**, considered the "Nobel prize of computing," for leading the team that invented Smalltalk, an influential programming language that used object-oriented concepts, and for fundamental contributions to personal computing. The Turing Award carries a $100,000 prize, with funding provided by Intel Corporation. The prize is presented by the Association for Computing Machinery (ACM.)

Leonard J. Koch is one of three recipients of the **2004 Global Energy International Prize**. Russian Federation President Vladimir Putin will present the $900,000 prize to be shared by the three scientists in June 2004. Mr. Koch is being recognized for fundamental research of thermophysical properties of substances at extremely high temperatures.

Gerald Nadler, president of the Center for Breakthrough Thinking Incorporated, an international firm of consulting affiliates, and IBM Chair Emeritus in Engineering Management at the University of Southern California, is coauthor (with William J. Chandon) of *Smart Questions: Learn to Ask the Right Questions for Powerful Results* (Jossey-Bass). The authors present a radical new framework for problem solving based on holistic thinking. The book includes separate chapters on each phase of creating solutions, as well as case studies and guidelines.

Robert M. Nerem received the **Pierre Galletti Award** from the American Institute of Medical and Biological Engineering. Dr. Nerem was recognized for his efforts to raise public awareness of medical and biological engineering and technical education.

On April 8, 2004, a symposium was held at Drexel University, Philadelphia, Pennsylvania, in recognition of **Robert E. Newnham**. Professor Newnham was also awarded the **2004 Benjamin Franklin Medal in Electrical Engineering** for his pioneering work on the properties of composite piezoelectric materials for use as transducers, sensors, and actuators.

James S. Thorp, Charles N. Mellowes Professor in Engineering at Cornell University, will become the head of Virginia Tech's Bradley Department of Electrical and Computer Engineering effective July 1, 2004. He plans to continue the department's leadership in existing areas and focus on selected emerging areas, such as nanoscience, complex systems, and energy and environment. Dr. Thorp was the director of the School of Electrical Engineering at Cornell University from 1994 to 2001.

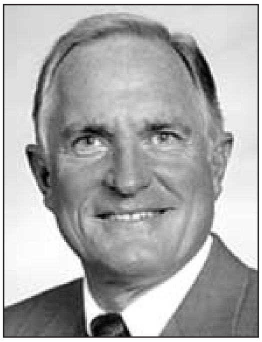
Richard N. Wright, retired director, Building and Fire Research Laboratory, National Institute of Standards and Technology, received the **International Award** from the Japan Society of Civil Engineers in Tokyo on May 28, 2004. Dr. Wright, U.S. chairman of the U.S.-Japan Panel on Wind and Seismic Effects from 1983 to 1999, was honored for his contributions to technological exchange between Japan and the United States and to the advancement of wind and seismic design technologies in both countries. The award is given annually.

On Wednesday, May 12, 2004, the American Society of Civil Engineers presented the **Outstanding Projects and Leaders (OPAL) Award** to NAE members **George J. Tamaro**, partner, Mueser Rutledge Consulting

Engineers (for design); **G. Wayne Clough**, president, Georgia Institute of Technology (for education); and **Harl P. Aldrich Jr.**, chairman emeritus (retired), Haley & Aldrich, Inc. (for management). OPALs recognize lifetime achievements in civil engineering that have contributed to the health, safety, and economy of the nation and the world.

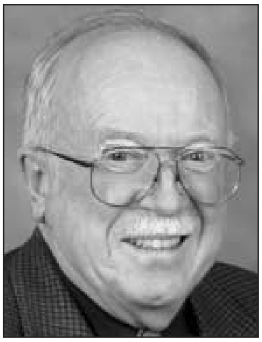
The following NAE members were elected to membership in the National Academy of Sciences on April 20, 2004: **Stephen H. Davis, Jacob N. Israelachvili, Ronald L. Rivest,** and **Alan M. Title**. NAE Foreign Associate **Jacob Ziv** was elected a Foreign Associate of the National Academy of Sciences.

NAE Elects Officers and Councillors


Craig R. Barrett


George M.C. Fisher


William F. Ballhaus Jr.


Robert R. Beebe


M. Elisabeth Paté-Cornell


Robert M. Nerem


Lawrence T. Papay

In the spring 2004 Officers and Councillors Election by the active members of NAE, a new chair was elected, and the home secretary and three members were re-elected to the NAE Council. An additional councillor was subsequently chosen by vote of the Council, in accordance with the NAE bylaws. All terms begin July 1, 2004.

Elected for a two-year term, **Craig R. Barrett**, chief executive officer (CEO), Intel Corporation, Chandler, Arizona, will be the eighth NAE chair. The chair works with the NAE president to promote NAE policies to the engineering community and the public. Barrett joined Intel in 1974 as a technology development manager. He was named a vice president of the corporation in 1984 and was promoted to senior vice president in 1987 and executive vice president in 1990. Barrett was elected to the Intel Board of Directors in 1992 and was named chief operating officer in 1993. He became Intel's fourth president in May 1997 and CEO in 1998. Barrett, who was elected to NAE in 1994, succeeds **George M.C. Fisher**, retired chair and CEO, Eastman Kodak Company. Dr. Fisher has been NAE chair since 2000; his term will end on June 30.

W. Dale Compton, Lillian M. Gilbreth Distinguished Professor of Industrial Engineering, Purdue University, West Lafayette, Indiana, will serve a second four-year term as NAE's home secretary. Before joining the Purdue faculty, Compton spent two years at NAE as the first senior fellow (1986–1988). Prior to that he was vice president of research at Ford Motor Company. As home secretary, Dr. Compton oversees membership activities.

Councillors **William F. Ballhaus Jr.**, president, Aerospace Corporation, Los Angeles; **Robert R. Beebe**, retired senior vice president, Homestake Mining Company, Tucson, Arizona; and **M. Elisabeth Paté-Cornell**, professor and chair, Department of Management Science and Engineering, Stanford University, were re-elected to second three-year terms.

In accordance with NAE bylaws, a fourth councillor was chosen by vote of the NAE Council at its May meeting to ensure that the distribution of engineering disciplines on the council is representative of the NAE membership. The fourth councillor is **Lawrence T. Papay**, sector vice president, Science Applications International Corporation, San Diego, California.

On June 30, 2004, **Robert M. Nerem**, Parker H. Petit Professor and director, Institute for Bioengineering and Bioscience, Georgia Institute of Technology, will complete six years of service as councillor, the maximum allowed under the bylaws. Drs. Nerem and Fisher were recognized for their distinguished service and contributions at a luncheon attended by other council members and NAE staff on May 14.

Draper and Gordon Prize Recipients Honored

(L to R) George M.C. Fisher, chair, NAE; Vince Vitto, president and CEO, Charles Stark Draper Laboratory; Kurt Taylor (accepting the prize on his father's behalf); Charles P. Thacker; Alan C. Kay; Butler W. Lampson; Aaron Cohen, chair, 2004 Draper Prize Committee; and Wm. A. Wulf, president, NAE.

NAE President **Wm. A. Wulf** hosted the NAE Awards Dinner and Presentation Ceremony on February 20 to honor the 2004 recipients of the **Charles Stark Draper Prize** and the **Bernard M. Gordon Prize**. The formal dinner was held at historic Union Station in Washington, D.C.

Alan C. Kay, Butler W. Lampson, Robert W. Taylor, and **Charles P. Thacker** received the **Charles Stark Draper Prize** "for the vision, conception, and development of the principles for, and their effective integration in, the world's first practical networked personal computers."

These pioneers, along with many other contributors, designed and built the first prototypes of the Alto personal computer (PC), which combined groundbreaking features, such as a built-in bit-mapped display, the mouse, and the Ethernet network interface. Today these features are standard, but they had never before been combined in a desktop-sized machine linked to other personal machines through a fast network.

Alan C. Kay, an NAE member since 1997, one of the earliest members of Xerox PARC (Palo Alto Research Center), was the inventor of Smalltalk—the first dynamic, object-oriented language, development, and operating system—which originated the overlapping window and icons graphical user interface. Dr. Kay earned a B.A. in mathematics and molecular biology from the University of Colorado and an M.S. and Ph.D. in computer sciences from the University of Utah. He is

(L to R) Alan C. Kay, Kurt Taylor (accepting the prize on his father's behalf), Charles P. Thacker, and Butler W. Lampson.

a member of many organizations, including the American Academy of Arts and Sciences (AAAS) and the Royal Society of the Arts, and is currently a Senior Fellow at the Hewlett-Packard Company, an adjunct professor at the University of California-Los Angeles, and a visiting professor at Kyoto University, Japan.

Butler W. Lampson, an NAE member since 1984, was the Alto system architect at Xerox PARC. He designed the operating system for the machine and was later instrumental in adding further capabilities, most notably the laser printer. His innovations at Xerox PARC included the development of techniques for the first successful "what-you-see-is-what-you-get" (WYSIWYG) text editor. In addition, he was one of the designers of the SDS 940 time-sharing system, the Xerox 9700 laser printer, two-phase commit protocols, the Autonet LAN, the simple distributed security infrastructure (SDSI) system for network security, Microsoft Tablet PC software, and several programming languages. Dr. Lampson received a B.A. from Harvard University and a Ph.D. in electrical engineering and computer sciences from the University of California at Berkeley. He is a member of the AAAS and the Association of Computing Machinery (ACM) and is currently a Distinguished Engineer at Microsoft Research working on security, fault tolerance, and user interfaces.

Robert W. Taylor, an NAE member since 1991, the founder and manager of the Computer Science Laboratory at Xerox PARC, recruited fellow Draper Prize recipients Alan Kay, Butler Lampson, and Charles Thacker, in addition to the other talented computer researchers who came after them at Xerox PARC. An acknowledged leader at assembling teams of outstanding researchers, suggesting avenues of exploration, and motivating his colleagues to push the technological envelope, Mr. Taylor was instrumental in PARC's exceptional record of innovation and accomplishment. Before Xerox PARC, Mr. Taylor was director of the Information Processing Techniques Office of ARPA, U.S. Department of Defense, where he supported key research underlying much of the fundamental technology in today's computer industry. During his tenure at ARPA, he initiated a project to build the first packet network, the ARPAnet, the direct ancestor of today's Internet. Mr. Taylor earned his B.A. and M.S. from the University of Texas. He was awarded the National Medal of Technology in 1999.

Charles P. Thacker, an NAE member since 1994, was responsible

(L to R) Wm. A. Wulf, president, NAE; Frank S. Barnes, Gordon Prize recipient; Alice Agogino, chair, 2004 Gordon Prize Committee; and George M.C. Fisher, chair, NAE.

(L to R) George M.C. Fisher, chair, NAE; Frank S. Barnes, Gordon Prize recipient; Bernard M. Gordon, chair, Analogic Corporation; and Wm. A. Wulf, president, NAE.

for engineering the hardware for Alto; he wrote much of its microcode and can be credited, together with Butler Lampson, for the superb economy of the Alto design. Mr. Thacker constructed the first batch of Altos himself and oversaw the production of the rest. In addition, he devised its packaging. Over the years, Mr. Thacker has led teams that designed a number of innovative networks and computer systems, including the first multiprocessor personal workstation, the first system to use the DEC Alpha chip, the Autonet and AN2 local area networks, and the Microsoft Tablet PC. He has a B.A. from the University of California at Berkeley and is a Distinguished Alumnus of the Computer Science Department at the University of California. He is also a member of many organizations, including the Institute of Electrical and Electronics Engineers (IEEE) and ACM.

The Bernard M. Gordon Prize was awarded to **Dr. Frank S. Barnes** of the University of Colorado at Boulder "for pioneering an Interdisciplinary Telecommunications Program (ITP) that produces leaders who bridge engineering, social sciences, and public policy." ITP is an innovative educational vision that brings together students from all backgrounds in all locations and teaches them the complete engineering, business, and policy disciplines that collectively drive the telecommunications industry.

An NAE member since 2001, Dr. Barnes was a cofounder of ITP, which was developed a decade before the divestiture of the Bell System, in anticipation of the need for broad education in the telecommunications industry as it shifted from a monopoly to a competitive industry. Since the inception of ITP, Dr. Barnes has continued to expand and modify it. The program began using distance education techniques in 1983 and now offers master's degrees to students around the world. In addition, the curriculum has been expanded to include a complex array of networking and communications technologies driven by market-based financing and regulation. Dr. Barnes has also taught optical electronics, bioelectromagnetics, and optical communications.

Dr. Barnes received his B.S. in electrical engineering from Princeton University and his M.S., engineer, and Ph.D. from Stanford University. He is a member of the American Society of Engineering Education (ASEE) and IEEE and is still working on bringing ITP to its full potential at the University of Colorado at Boulder.

The Power of the Context

Remarks by Alan C. Kay, NAE member and Senior Fellow, Hewlett Packard Laboratories, upon being awarded—with Robert Taylor, Butler Lampson, and Charles Thacker—the Charles Stark Draper Prize of the National Academy of Engineering, February 24, 2004.

When Bill Wulf called to say that the four of us had been awarded this year's Draper Prize, I was floored, because the possibility had not entered my mind. Given the amazing feats of engineering in the twentieth century, the stature of previous laureates, and the fact that this is just the tenth time the prize has been awarded, it seems unbelievable that we have been chosen. Of course, as every engineer, mathematician, and scientist—every artist—knows, the greatest privilege is being able to do the work, and the greatest joy is turning yearnings into reality. So we were rewarded abundantly many years ago when we created a new genre of practical personal computing. Three people were indispensable to Xerox PARC's success—Bob Taylor, Butler Lampson, and Chuck Thacker—and receiving this award with them is truly an incredible honor. Their special abilities, good will, and tolerance made my contributions possible.

Because this award is about a whole genre of computing, it is important that we acknowledge and thank the larger group of several dozen PARC researchers who helped conceive the dreams, build them, and make them work. This was especially true in our Learning Research Group. I particularly want to thank Dan Ingalls and Adele Goldberg, my closest colleagues at PARC, for helping realize our dreams.

I owe more intellectual debts than most because I have long been an enthusiastic appreciator of great ideas in many genres—ranging from graphic, musical, and theatrical arts to mathematics, science, and engineering. I got a lot of early encouragement from my artistic and musical mother and my scientist father. In fact, my best insights have come from odd takes on ideas around me—more like rotations of point of view than incremental progressions. For example, many of the strongest aspects of my object-oriented ideas are based on philosophy, mathematics, biology, and computing in the early 1960s.

I got my start in personal computing with my colleague and friend, the wonderful and generous Ed Cheadle, who got me deeply involved in building "a little desk-top machine"—the FLEX machine—that we called a "personal computer." Many later ideas were adapted from the lively ARPA interactive-computing community and the cosmic visions of Licklider, Taylor, Engelbart, Clark, Evans, Shaw, Ellis, and many others, about "man-computer symbiosis and intergalactic networks."

My interest in children's education came from a visit to Seymour Papert's early classroom experiments with LOGO. Adding in Marshall McLuhan led me to make an analogy to the history of printed books—hence the idea of a notebook-sized, wireless-networked "personal computer for children of all ages." The special quality of computers is their ability to simulate arbitrary descriptions rapidly, and the real computer revolution will not take place until children learn to read, write, argue, and think in this powerful new way. The romance of that idea has driven all of my subsequent research.

All of this was catalyzed when I was immersed in the ARPA dream at the University of Utah—what I call "the power of the context." One of the greatest works of art during that fruitful period of ARPA/PARC research in the 1960s and 1970s was the almost invisible context and community that catalyzed the energies of many researchers, making them better dreamers and thinkers. That it was a great work of art is confirmed by the world-changing results that followed so swiftly. That it was almost invisible, in spite of its tremendous success, is revealed by the disheartening fact that, as far as I'm aware, no government or company is doing edge-of-the-art research based on these principles. Of course, I would like to be shown that I'm wrong on this last point.

When I think of ARPA/PARC, I think first of good will, even before brilliant people. Dave Evans, my advisor, mentor, and friend, had the amazing ability to act as though his graduate students were incredible thinkers. Only fools ever let him find out otherwise! I really do owe my career to Dave, and I learned from him most of what I think is important. Therefore, my part of this prize is dedicated to him. (Is it just coincidence that Dave was also Butler Lampson's advisor when they were both at Berkeley?)

Good will and the assumption that graduate students were "world-class researchers who didn't have Ph.D.s yet" was the general rule throughout the ARPA community. If one made a pilgrimage to Doug Engelbart's diggings in Menlo Park, Bill English, the co-inventor of the mouse, would drop what he was doing to show visiting junior researchers everything. Later at PARC, Bill went completely out of his way to help me set up my research group. On our first visit to the Lincoln Labs ARPA project, we students were greeted by the principal investigator Bert Sutherland, who couldn't have been happier to see us or more interested in showing us around. Not too many years later Bert was my lab manager at Xerox PARC. A visit to Carnegie Mellon University in those days led to Bill Wulf, a terrific systems designer who loved not only his own students but also students from elsewhere. (What ever happened to that guy?)

A few simple principles administered with considerable purity made all of this work. It is no exaggeration to say that ARPA/PARC had visions rather than goals and funded people rather than projects. The vision was of interactive computing as a complementary intellectual partner for people pervasively networked worldwide. Because we did not try to derive specific goals, ARPA/PARC was able to fund different, sometimes opposing, points of view. For example, Engelbart and McCarthy had extremely different ways of thinking about the ARPA dream, but ideas from both of their research projects are important in today's interactive computing and networked world.

The second cornerstone of ARPA/PARC's success was funding people, not projects. ARPA/PARC had two high thresholds—self-motivation and ability. People who had to do something, whether they were paid or not, and whose doings were likely to be highly interesting and important were cultivated. Thus conventional oversight was not only unnecessary, it was really impossible. Peer review could not be easily done, even with actual peers.

The situation was out of control, yet extremely productive, and not at all anarchic. It was out of control because artists have to do what they have to do. It was extremely productive because a great vision acts like a magnetic field from the future that aligns all of the little iron-particle artists to point north without seeing it. They then make their own paths to the future.

An important principle at PARC was Bob Taylor's and Butler Lampson's idea of the *Living Lab:* that we actually had to scale up and use our inventions as our daily tools. Roadblocks were avoided by first making sure everything necessary was created within a research group and then encouraging sharing. Thus, virtually all of the PARC hardware—including two big time-sharing mainframes, the Alto, the Ethernet, the laser printer, file servers, etc.—and software—including operating systems, programming languages, and development systems, productivity tools, etc.—were built completely in house by the same few dozen researchers. Living Lab, avoiding roadblocks, respect for complexity, lack of knowledge, the small number of researchers, and modest budgets at PARC all led to a *finessing* style of design. Instead of trying to build complex artifacts from scratch—like trying to build living things cell by cell—for the most important projects, we built a kernel that could *grow* the artifact as new knowledge was gained. In other words, we got one cell's DNA in good shape and then let it help grow the whole system.

For example, Chuck Thacker's and Butler Lampson's beautiful and parsimonious architecture for the Alto allowed most functions that were normally frozen in hardware to be re-microcoded at will as new ideas came forth, without requiring that the low-level hardware be redesigned and rebuilt. The Smalltalk system used an important meta-idea that allowed its DNA to be completely described on one sheet of paper, implemented in a month, and then *grown* in the presence of experience and new ideas into the powerful system it became. The bit-map display acted as "silicon paper" that could show any image, so the graphics that could be displayed did not have to be perfect. This led directly to bit-map painting, animation, and typography. The overlapping window interface was a finesse that gave children of all ages a simple, universal way to communicate with all objects on the computer.

All of these principles came together a little more than 30 years ago to create a new genre of personal computing. Eventually 1,500 Altos appeared that were Ethernetworked to each other, laser printers, file servers, and the ARPAnet and were distributed to many kinds of end-users to be used in real situations. The commercial availability of this genre of computing was anticipated by 10 to 15 years. As I once tried to explain, the best way to predict the future is to invent it!

The history of ARPA/PARC shows that a combination of vision and modest funding in a felicitous context can almost magically give rise to new technologies and sciences that both enhance civilization and produce enormous wealth for society. In spite of this, today—astoundingly—many excuses are given—variously ignorant, vacuous, and fearful—as to why the ARPA/PARC style of funding is not being done, especially by government institutions that are supposed to provide such funding.

Isn't it time we recapture these higher visions for the sake of good reason, even if there is no cold war? For example, how about helping the children of the world grow up learning to be better thinkers than most adults are today? How about inventing technologies for the entire world that do not have disastrous side effects? How about dealing with our planet as a whole system that we all have to live on? These quests are as romantic as any quests in the past. Reengaging our young engineers, mathematicians, scientists, and physicians with the romance of their arts would truly create "power of the context" for the twenty-first century.

Thank you all again for this wonderful honor.

The Ongoing Computer Revolution

Butler W. Lampson is a member of NAE and Distinguished Engineer, Microsoft Corporation.

I remember reading about the Draper Prize a few years ago and thinking, "Wow, they give that to people for inventing the jet engine or communications satellites or the integrated circuit." It's a great honor to join that august company tonight.

I studied physics in college, and I went to graduate school at Berkeley to study more physics. But I started programming in high school on an IBM 650, and it was always a big distraction from physics. At Berkeley I was lucky enough to stumble across an ARPA project hidden behind an unmarked door that was building one of the first time-sharing systems; that system later became a commercial product, the SDS 940. I was immediately seduced, and I abandoned physics and never looked back (which was fortunate considering the job market for new physics Ph.D.s five years later).

Since then, after brief stints on the Berkeley faculty and at a failed start-up company, I've worked for three major computing research laboratories: Xerox PARC's Computer Science Laboratory; Digital's Systems Research Center; and Microsoft Research. I worked for Bob Taylor, directly or indirectly, for 30 years, from my time at Berkeley until I joined Microsoft, and I have unbounded admiration for his two outstanding qualities. First, he has the ability to attract outstanding people and coax them into working as a whole that is greater than the sum of its parts. Second, he has great judgment about which research problems are both truly important and ripe for solution. The late Roger Needham [managing director, Microsoft Research Laboratory] said that the secret of success in computer systems research is to attack problems you know are easy but that everyone else thinks are hard. That's what we always did in Bob's research programs.

At PARC we stood on the shoulders of giants, the people who invented time-sharing, the ARPA and Aloha networks, programming languages, operating systems, Doug Engelbart's on-line system and his mouse, Sketchpad. Nearly all of us came from the community of researchers fostered by ARPA.

Xerox asked us to invent the electronic office, even though no one knew what that meant. We did it, though, and everyone uses it today. That makes it hard to remember what the world was like in 1972. Most people back then thought it was crazy to devote a whole computer to the needs of one person—after all, machines are fast and people are slow. But that's true only if the person has to play on the machine's terms. If the machine makes things comfortable for the person, it's the other way around. No machine, even today, can keep up with a person's speech and vision.

The most important property of what we built was its universality (within its domain, of course). Everyone knew that a computer could compute anything, but in the Alto system, the screen can also display any image (well, on the Alto it has to be black and white), the printer can print any image, the network can communicate anything, and the software lets you construct anything—perhaps not quite anything, but you can typeset text, do drawings, pictures, music, animation, and voice. Of the things you can do today with computers, we missed numbers, because we didn't have much personal use for spreadsheets, and databases, and mathematics were too hard.

The system is enabled by the hardware conceived, designed, and built by Chuck Thacker. In spite of that, the software is everything, even though it's nothing tangible. With software, you can make the system do anything. This is even more true today.

There's a story about some people who were writing the software for an early avionics computer.

One day they were visited by the weight control officer, who was responsible for the total weight of the plane.

"You're building software?"

"Yes."

"How much does it weigh?"

"It doesn't weigh anything."

"Come on, you can't fool me. They all say that."

"No, it **really** *doesn't weigh anything."*

After half an hour of back and forth, he gave up. But two days later he came back and said, "I've got you guys pinned to the wall. I came in last night, and the janitor showed me where you keep your software." He opened a closet door, and there were boxes and boxes of punch cards. "You can't tell me those don't weigh anything!"

After a short pause, they explained to him, very gently, that the software was in the holes.

People often ask whether we foresaw a PC on every desk. Certainly we did, since we knew Moore's law. I wrote a paper in 1972 that predicted exactly that. We even predicted today's Tablet PC; there's a picture of it, from the late sixties, in the text of Alan's talk on the Academy's web site. And we were pretty cocky. We thought people would want the bit-map displays, laser printers, networking, what-you-see-is-what-you-get editors, drawing programs, file servers, and point-and-click e-mail that we built. One thing we didn't foresee was that software would become such an important industry; perhaps this was because it doesn't weigh anything.

People often write that Xerox didn't benefit from our work. Actually Xerox benefited a lot, in high-end computer printing, where they've made billions of dollars. Xerox also brought a wonderful office system product to market in 1981, the Star. It was much better than anything we built in research; in fact, that was its problem—it was too expensive. It's ironic that the researchers tried, and failed, to get the product group to build something less wonderful, but much simpler and cheaper. Star was a failure of product planning and marketing, not a case of technology left on the shelf.

Today's PC is about 10,000 times as big and as fast as an Alto; in fact, the MSN Direct wristwatch I'm wearing is bigger and faster than an Alto. But the PC doesn't do 10,000 times as much, or do it 10,000 times as fast, or even 100 times as fast as either. Where did all the bytes and cycles go? They went into visual fidelity and elegance, integration, backward compatibility, bigger objects (whole books instead of memos), and most of all, time to market. Today's PC obeys Alan's dictum. It's like Kleenex; you use it once and throw it away. The Alto, much to his frustration, lasted for eight years.

What can we learn from the Alto about the future of computing? In Alan's words, "the best way to predict the future is to invent it." I'm constantly amazed at the number of people who think there's not much more to do with computers. Actually, the computer revolution has only just begun.

Looking at the history of computing from 50,000 feet, you can see that computers are good for three things: simulation, communication, and embodiment. We started with simulation, of nuclear weapons and payrolls. Twenty-five years later, communication blossomed, with e-mail, the Internet, and the web. Today, after another 25 years, we're in the earliest stages of embodiment—computers that interact with the physical world. The Mars rovers and the Roomba vacuum cleaner are just the beginning. For 20 years, I've been predicting that the next decade would be the decade of household robots. Well, now we have one, so I was only 20 years too early.

And we're also in the early stages of computers that can understand speech and pictures, drive cars, and repair themselves. I dictated this talk to my computer, which is quite a bit faster than typing it and much more comfortable. I've proposed a grand challenge research problem—to reduce highway traffic deaths to zero. This can only be done by making cars that can drive themselves, at least in emergencies. We have good enough cameras, microphones, brakes, and steering, so this is a pure computer science problem—vision, modeling the world and its uncertainties, planning, system reliability. And success would have valuable by-products. Existing roads could carry a lot more traffic, and drivers could spend their time doing something else. Perhaps someone here can explain why I haven't been able to sell this idea.

The four of us being honored tonight did only a fraction of the work of building the Alto system. About 50 remarkably talented people worked on it for about eight years, and many of them went on to found major companies. I wish I could say something about each one of them, but it would be overwhelming to list even the major contributors.

Lois, my wife of 35 years, works in biology, which will be an even more exciting field than computing in the next few years; she wrote her Ph.D. thesis on the Alto. My son Michael is also a biologist, a postdoc at Rockefeller University. He is here with his wife, Min-Young Kim, a violinist who plays in the Daedalus Quartet. My other son, David, a writer, is in Machu Picchu in Peru and couldn't be here. There's a bright future before all of them.

Thank you.

Following the Dream

Robert W. Taylor is an NAE member and Director Emeritus, Systems Research Center, Compaq Computer Corporation. His son, Kurt H. Taylor, delivered these remarks on his father's behalf.

Good evening, officers and members of the National Academies and guests. Before I read my dad's remarks, I'd like to say a few words on my own. Let me first explain Bob's absence. I am happy to report that he is alive and well and enjoying life in his modest mountainside home overlooking the Silicon Valley that he helped to shape. Bob retired in 1996 after four enormously productive careers with NASA, ARPA, Xerox, and DEC. For more than 35 years, those jobs required that he travel extensively, both in the United States and abroad. By the time he retired, he had determined that travel had become work—and very unpleasant work at that. So when he retired from work, he decided to retire from travel also, and he hasn't traveled since—not even to the White House to accept the National Medal of Technology in 1999. But the cause of his intransigence does not end there.

As I mentioned, Bob's home is modest by any standard, but it sits in a rural area on a marvelous site at 1,400 feet in the Santa Cruz Mountains amid huge, beautiful oaks and Douglas firs. The house overlooks Palo Alto, the south San Francisco Bay, and the mountains to the east, all of which we call the Silicon Valley. It is easy to imagine him on his deck surveying the population below and smiling inwardly at the impact of his work and the work of the groups he worked with.

He seems to think of his domicile as Shangri La. So there he is, happily ensconced with his two standard poodles, Max and Lara, his Beethoven, his books, his big dish satellite, his DSL-connected Internet, and the enjoyable climate of northern California, which I would add, enables him to grow his own heirloom tomatoes, which he shares with friends and family annually at his well attended "Tomato Fest."

He seldom comes down to the "flats," as he calls them, except for required trips to the grocery, the barber, and his dog groomers. But he is not a hermit. In fact, he welcomes visitors and receives them often. Many of his former colleagues live in the Bay area, and he enjoys keeping in touch with them. When asked why he prefers to stay at home, he is fond of saying that whenever he leaves his immediate neighborhood, his quality of life goes down. It's hard to argue with that.

Finally, I want to say what an honor and pleasure it is to be here with the other three Draper Prize recipients. I have known all of them since I was a teenager—I saw them often at Bob's office and at our home for dinners or parties. They, and many other folks working in the Xerox PARC computer science labs, were our family friends, as well as my dad's colleagues. I've played tennis with Alan Kay, and I've heard him play the harpsichord. My two younger brothers were babysitters for the Thackers, who lived just down the street from us. Whenever Butler [Lampson] was around, I (and everyone else) marveled at how fast he talked—a trait for which he has always been known as well as the speed of his thought and the power of his logic.

Of course, today, these three are world famous in the domain of computing. But I feel fortunate to have known all of them early in their careers, to have witnessed firsthand the work they are being honored for tonight as it was developed and talked about around our house. I'm proud that I knew them "when"—before networked systems, personal computers, bit-mapped displays, electronic mail, laser printing, or any of the technologies they pioneered became ubiquitous in our lives. I, and everyone in this room and countless people around the world, have benefited personally from the work of this year's Draper Prize recipients. And I would say, with apologies to Mr. Churchill, that never have so many "end users" owed so much to so few!

Now I would like to read a few words from my dad.

On the Occasion of Receiving the 2004 Draper Prize from the National Academy of Engineering

by Robert W. Taylor

Before I address matters directly related to the 2004 Draper Prize, I ask for your indulgence while I state a few personal facts and give you some sense of my career. I was adopted when I was 28 days old by a Methodist minister and his wife in Texas, where I grew up and went to college. College was temporarily interrupted by some unexciting time in the Navy during the Korean War. In the late 1950s, after being a professional student with numerous majors and minors, I did a graduate thesis in psychoacoustics and earned a master's degree. In the process, I learned enough about computers to be repelled by the idea of punching holes in cards, taking them to a priest behind a glass wall, and then waiting hours or days for results. A now famous paper published in March 1960 by J.C.R. Licklider convinced me that there was a better way called "interactive computing." This realization, given to me by Lick, set the theme for the rest of my career.

By the early 1960s, after some experience with a flight-simulator company, I was a program manager for the NASA Headquarters Office of Advanced Research and Technology. While there, perhaps my best decision was to award a NASA research contract to Doug Engelbart's group at SRI. The invention of the computer mouse was one result of their work. Did you think NASA gave us only Tang and Teflon?

J.C.R. Licklider joined ARPA in late 1962 and founded the now famous Information Processing Techniques Office. This office supported most of the U.S. computer research throughout the 1960s and provided the funding base for the creation of academic computer science. Licklider was succeeded by Ivan Sutherland, and they suggested I join ARPA in 1965 as Ivan's deputy. When Ivan left soon after, I became the director. In February 1966, with the support of my boss, ARPA Director Charles Herzfeld, I launched my most important ARPA project—the ARPAnet.

In 1970 I founded the Computer Science Lab of the then new Xerox Palo Alto Research Center, called PARC, where I worked for 13 years. This is the period relevant to the Draper Prize, and I will say more about it later.

In 1983, Digital Equipment Corporation asked me to build SRC, the Systems Research Center, in Palo Alto. More than a dozen PARC people joined me there (the glory days at PARC were over). SRC developed an excellent reputation in the computer research community and had a number of achievements, of which web search technology, Alta Vista, is probably the best known. I retired in 1996.

From this sketch, perhaps you can see how fortunate I was, beginning with my adoption by loving parents. The importance of being in the right place at the right time cannot be overestimated. I was very, very lucky; and as has often been said, the harder you work, the luckier you get.

Sometimes I am asked why I never started a company. I was never interested in starting a company because I didn't want to work with the nonresearch people necessary to the founding of a company. I loved the world of research. Looking back, one of my greatest joys was that I could pick and choose my colleagues—and such wonderful colleagues they were!

And now, about the 2004 Draper Prize. Once upon a time and for many centuries, beginning with the first computer, the abacus, the purpose of computers was to solve arithmetic problems. With electricity, they could solve them faster, and the advent of the integrated circuit made them even faster, more reliable, and a lot cheaper. But they were still only arithmetic engines. Then a remarkable transformation occurred.

Xerox opened its Palo Alto Research Center in 1970, and it grew over time to about 300 people. Today, PARC is known for its innovative computer science research of the 1970s, but computer science was only a small part of its research investment. Most of it went into physics, materials science, and optics. But a few dozen computerists at PARC redefined the nature and purpose of computing, and their research put PARC on the map. The 2004 Draper Prize honors this research.

The four individuals named in this year's prize formed the cadre of that extraordinary group, which today reads like a "Who's Who" in computer science. In the last half of the 1960s, they were graduate students at a handful of universities, where, with support from ARPA, they built the first experimental interactive computer systems. From these, they gained insights into interactive computing that were not available to others. In the 1970s, when they were recruited to PARC, they shared a dream—that computer systems could be completely redesigned and that this redesign could enable personal interactions with text, pictures, and networking for millions of individuals. The dream promised to encourage creative potential and new forms of communication. The value of connecting people and their interests could dwarf the value of computing only for arithmetic.

The dream was not widely shared outside the group. The great majority of computing experts and leading computer manufacturers in the 1970s rejected these ideas as absurd. Some said, "No one wants it; the world doesn't need so many computers. What could I possibly do with my own computer?" It was asserted that there weren't enough people to maintain so many machines. Some calculated that the costs would be prohibitive or that it would be a profligate waste of valuable computer time. A Xerox senior manager once said to me, "If this is such a good idea, why isn't IBM working on it?"

The established computer manufacturers had their own products to protect, and the dream did not fit their visions of their businesses. So they ignored the new technology and suffered somewhat as a result. They became victims of what were later referred to as "disruptive technologies," and their suffering gave a certain, perhaps perverse, pleasure to those of us who believe that the punishment should fit the crime. When a company encounters a technology that could disrupt its business, it ignores it at its peril. If possible, the company should embrace, understand, protect, and nurture a disruptive technology, or else the company may be bitten—sometimes fatally.

The list of technical innovations from PARC that were disruptive to the computer companies of the 1970s included: the first operational internet; the first local area network; the direct precursor to Microsoft Word; the first graphical user interface; the first laser printer; the first client-server architecture; the first networked personal computer; and desktop publishing. Of these, the least disruptive to Xerox was the laser printer. That and the Ethernet were the only technologies on the list that Xerox developed into successful products. However, the laser printer created a billion dollar business that paid for their research investment many times over.

In the next 20 years, a number of new companies developed successful products based on the technologies created at PARC, and the world was changed. A list of these companies includes Adobe, Apple, Cisco, Microsoft, Novell, 3Com, and Sun, among others. By the mid-1990s, the Internet, which was fundamentally dependent upon all these products, was in full swing and growing. The result is arguably one of the greatest and most beneficial engineering innovations of the twentieth century, as influential as the automobile, the airplane, and television and, perhaps, just ahead of duct tape and Post-It notes, which have also been very beneficial.

This story began with "once upon a time," and if we keep our perspective, we might just "live happily ever after." Thank you, National Academy of Engineering, for recognizing this work!

A Long Way to Go

Charles P. Thacker is a member of NAE and Distinguished Engineer, Microsoft Corporation.

As you can imagine, it's a great pleasure to be here with you tonight. I want to thank the academy, the nominators, and NAE President Wulf for including me as a recipient of this year's Draper Prize. It is an honor I never in my wildest dreams expected to receive.

Before I tell you about the work being recognized this year, let me tell you a bit about myself. Unlike many other people, I was extremely fortunate in knowing my career path from an early age. I knew what engineers did because my father was one, and engineering seemed to me the best way to make an impact on the world while solving interesting puzzles—and being paid to do so. I was the quintessential young nerd, complete with slide rule and pocket protector. I built radios, was a "ham" operator, and was a member of all my schools' science clubs.

As an undergraduate, I decided the best way to follow a path in science and engineering would be to study physics. I had worked for a while at Caltech's Synchrotron Lab, and the lure of these large machines, with their cutting-edge engineering challenges and their potential to improve our understanding of how the world works, was irresistible. I planned to become an accelerator designer, and therefore took both engineering and physics classes. Fortunately, things didn't work out. In retrospect, this would have been a very poor career choice, given today's substantial reduction in government support for high-energy physics.

I was self-supporting during most of my university years, and I decided to take a year off after graduation and work while I applied to graduate schools. This is usually a *very* bad idea, but it was one of the best decisions I ever made because I got a job at the Genie Project in the University of California's Electrical Engineering and Computer Science Department. There I fell in with very good companions indeed, most notably Butler [Lampson]. I had worked with, but not on, computers before but hadn't been very interested in them, because most of the machines were protected from their users by a priesthood of operators and programmers.

But the Genie Project, funded by Bob Taylor at ARPA, had something new—time-sharing. The project had built one of the first machines, the SDS 940, that allowed users to interact with it directly, rather than through acolytes. I was captivated by this idea. I switched fields, abandoned graduate school, and haven't looked back since. The Genie Project was planning a successor to the 940, but it seemed difficult to carry out such an ambitious project in academia, so a number of us left to form the ill-fated Berkeley Computer Corporation. Although we managed to get the system—the BCC 500—working, the company failed in 1970.

Bob Taylor had just joined Xerox to start the new PARC Computer Science Lab in Palo Alto, and a number of the BCC staff [including me] went to work for him. I spent an enormously productive and exciting 13 years at the computer science lab (CSL), where I did some of the work being recognized tonight. I'll talk more about this in a moment. In 1983, Bob and a few members of the CSL group left Xerox and started the Digital Equipment Corporation (DEC) Systems Research Center (SRC). I continued to work in the area of computer architecture and networks and remained at DEC until 1997, when I joined Microsoft, where I remain today.

During the CSL and SRC years, Bob, Butler, and I worked together closely on many projects. I am enormously fortunate to have had them as mentors, colleagues, and friends for 30 years. I still work today with a number of valued colleagues from those days, some of whom are here tonight. After PARC, Alan [Kay] followed a different path, working to achieve his dream of improving our ability to educate children. This has recently become the focus of my own work at Microsoft, so Alan and I may see much more of each other in the future.

I'm frequently asked which of the many innovations that came out of PARC have fundamental and lasting importance. Certainly not the computers we built, which seem quaint today. In fact, personal computing didn't become pervasive and economical until another decade of progress had been made in microelectronics, an area in which we did only a little work. Certainly not the mouse, which was invented in Doug Engelbart's group at SRI. We seized on Doug's idea and refined it, but we didn't innovate.

I think only four PARC innovations in the area of hardware have stood the test of time. First is the bit-mapped display. For the first time, we were able to provide a display device with properties that approximated those of paper. Earlier displays could do nothing but draw lines or text in a limited number of fonts. With the bit-mapped display, the computer could display *anything*, subject only to the limits of the programmer's imagination.

The second is the laser printer, a marriage of xerographic and computing technology that enabled the infinite variety of images we could display on our screens to be faithfully reproduced on paper. Today's laser printers are much less expensive than earlier devices, but they aren't much faster or higher in resolution, and their basic form hasn't changed in 30 years. Curiously enough, one of the themes of PARC was the quest for the "paperless office." The laser printer stopped this quest dead in its tracks, and the consumption of paper has increased enormously because of its widespread adoption.

The third is the Ethernet. The idea that a computer should be a communications device in addition to being a fancy calculator was long advocated by Bob Taylor and his mentor J.C.R. Licklider. The Ethernet made this possible. Although today's Ethernets are thousands of times faster than our original version, they employ most of the original ideas. Ethernet has become the dominant local area networking technology.

Fourth, and perhaps most profound, is the idea that we could *combine* these technologies to produce what we'd call today a *distributed system* with total utility that exceeds the sum of its parts. This is a software engineering challenge that depends on the availability of a variety of commodity hardware devices, and for this reason, has taken longer than some other innovations to become widespread. Nevertheless, most large systems today, from search engines to databases, are built in this way; and a substantial amount of research is now being done to understand how to scale them up to attack ever larger computing problems.

But the most important PARC innovations were in software, without which a computer is no more useful than a hot rock. Butler and Alan have spoken with much more authority than I about this, so I'll be brief. CSL and the other computing labs at PARC worked in three broad areas: (1) theoretical computer science, which is mostly mathematics; (2) systems research, including operating systems, programming languages, and tools; and (3) applications programs that allow users to interact with the system and get their work done. I believe PARC's largest impact on the way we use computers today was in this third area. The windowed user interface, in which the user interacts with the machine by pointing and clicking with a mouse in addition to typing, had been explored earlier in Engelbart's NLS (oN Line System).

But Doug's hardware could only display text, which left a lot of unexplored territory. Several approaches were tried, and the results of those explorations are with us today in systems from Apple and Microsoft.

CSL also pioneered the "what you see is what you get" text editor. The "Bravo" text editor developed by Butler and Charles Simonyi is the direct ancestor of Microsoft Word, although we've added a quite a few features over the years.

As frequently happens with awards like the Draper Prize, the work being recognized is not solely the contribution of the individuals being recognized. This is definitely the case tonight. Butler, Alan, Bob, and I are only representatives of a much larger group of extremely talented people who came together on different projects during the PARC years. This honor belongs as much to them as to us.

Finally, there is one special person I'd like to thank, my wife, Karen. We have been married for 40 years, and she has been an unfailing source of companionship, support, and love. She and my daughter, Christine, who with her husband, Daniel, is also here tonight, put up with a lot during the early days of PARC, including seeing me at home primarily during the 2 a.m. feeding. This doesn't seem to have done any permanent damage, however, and she and Daniel are happily pursuing careers in marine biology. I'm sorry our other daughter, Kathy, and her husband, Dean, who are expecting our second grandchild, were unable to attend tonight.

In conclusion, Butler has said that the computing revolution has just begun (actually he's said similar things about every five years for the last 30 years). But he's surely right. Although there are a few hundred million computers, there are six billion people. So a lot of opportunity is still out there, and we have a long way to go. Thank you again.

Bridging the Gap between Engineering and Business

Frank S. Barnes is a member of NAE and Distinguished Professor in the Department of Electrical and Computer Engineering at the University of Colorado, Boulder.

I am honored and excited to receive the Bernard Gordon Prize from the National Academy of Engineering for the Interdisciplinary Telecommunications Program (ITP). A great many people contributed to the success of this program, but time will permit me to mention only a few. First are the students who, year in and year out, have proven that our approach has value by making significant contributions to the growth and development of the telecommunications industry over the past 30 years. The contributions of our more than 2,000 graduates range from heading up major corporations to implementing a data communications system that reduced the error rate by more than a factor of five in the delivery of drugs to tuberculosis patients in the slums of Peru. Others have operated major military command and control systems and are helping to rebuild communications systems in Iraq.

In about 1970, after a conversation with Dr. John Richardson, I recognized the need for a program that would bridge the gap between engineering and political and business processes. Dr. Richardson introduced me to the man who became cofounder of the program, political science professor George Codding. We put together a program that included political science, sociology, business, and electrical engineering. As many of you may know, these academic units do not work together naturally, and it isn't easy to keep the demands of the home departments from pulling it apart. Unfortunately, George passed away a few years ago, but I am sure he would be thrilled at this recognition for his many years of effort.

Leonard Lewin, Floyd Becker, Sam Maley, Petr Beckmann, and Esther Sparn made major contributions to the success of the program in its early years. Dr. Joe Pelton had the vision to expand the program in many ways, including adding a distance-education component that now represents about half of the program. It took unconventional faculty, such as Gary Bardsley, Gerald Mitchell, Harvey Gates, and Dale Hatfield, to bring practical experience into the classroom. As with every new program, no schools were graduating fresh Ph.D.s in the field, and experience counts. The commitments of the current faculty and staff, including Tim Brown, Jon Sauer, Jim Alleman, Tom Lookabaugh, Doug Sicker, Scott Savage, Ray Nettleton, Phil Wiser, and Eydi Mitchell, are the major reason for the program's continuing survival and success.

Let me take a moment to describe some of the things that make ITP an innovative program and a model, at least in part, for expanding the scope of engineering education to reach new groups of students and make our engineering graduates more effective. One major innovation in ITP was a recognition of the need for graduates with a grasp not only of the technical fundamentals of telecommunications but also of government regulations, politics, and the economics of the industry. In the early 1970s, some of the politicians who made policy decisions had little knowledge of the technical and economic aspects of the industry, and engineers had little or no knowledge of the politics that defined the industry. There was a great need for people with knowledge in both areas to help manage the growth of cable TV and, as it later turned out, the whole telecommunications industry as it evolved after the breakup of AT&T.

Second, because neither George nor I wanted to teach service courses forever, we had to design a program that accepted both electrical engineering and political science graduates. This meant the program had to have limited science, math, and other prerequisites. The result is a program that enables students with limited technical backgrounds to enter the telecommunications industry with a working knowledge of the technology that prepares them to assume important management positions.

Finally, because the program was fundamentally limited by what could be accomplished in a little more than a year, we included a thesis requirement as a way of ensuring that each student had mastered at least one subject in depth. We were forced to replace this requirement with a capstone course when the program grew to more than 400 students. A faculty of about 10 simply could not supervise more than 150 theses a year and do a quality job.

Several things can be learned from this program that are important to the future of engineering education. First, a large number of potential students who do not start their undergraduate work in engineering or science are looking for a way to acquire significant technical information. Given a chance, they can fill important roles in the management of technical industries as they bring with them skills that many of our engineering students do not have. I can remember being surprised, pleased, and shocked to hear a religion major in our program explaining a Cisco router to an industrial visitor. She has since moved on to a satisfying high tech job as a technical writer. The need to provide technical skills to a wide range of students goes beyond the telecommunications industry and includes civil engineering, especially water and sewer systems, chemical engineering, especially the environment and biotechnology, and electrical engineering, especially power systems.

Even more important, we must learn how to teach our students to learn new material more efficiently. We must draw on neural science, psychology, education, and computer science to get a better understanding of how students learn and to develop ways to help them learn more quickly. We must recognize that in a fixed period of time we can teach only a small fraction of the information our students need to know. Therefore, selecting material that provides a foundation for further learning is extremely important. We must teach students how to learn on their own in a way that helps them use new material in solving important problems.

Third, we should incorporate telecommunications into programs both to reach out to the community of students on a worldwide basis and to import courses to improve the quality of education on our campuses. This will mean bringing on the best professors we can find, no matter where they are located, and finding a way to use telecommunications to make them available to our students. It will also mean using telecommunications to enable students to work in teams with other students located around the world to prepare them to work in the global economy and compete on the world stage.

In closing, I want to thank my family for their support and for putting up with many hours of work in the evenings, travel on weekends, and being a very slow learner when it comes to saying “no.” I also want to thank the many supporters of ITP who have backed the program through good times and bad. When doubters said students did not know this or that or that the program did not fit into standard academic structures or value systems, they stayed the course. I would like to ask the faculty and former students in ITP who are here tonight to stand and be recognized. They are all important contributors to the success of this program.

Finally, I want to thank Mr. and Mrs. Gordon, members of the academy, and Bill Wulf for recognizing the importance of innovation in engineering education and for providing the kind of recognition and support that will make possible other changes that will improve the quality of the education we provide our students. Thank you.

Seventh German-American Frontiers of Engineering Symposium

On April 29 and 30 and May 1, NAE hosted the seventh German-American Frontiers of Engineering (GAFOE) Symposium at the National Academies Building in Washington, D.C. Modeled on the U.S. Frontiers of Engineering Symposium, this bilateral meeting brought together 65 engineers (ages 30 to 45) from German and U.S. companies, universities, and governments. NAE works with the Alexander von Humboldt Foundation to organize this activity.

Like U.S. Frontiers symposia, the goal of GAFOE is to provide a forum for emerging engineering leaders to get together and learn about leading-edge developments in a broad range of engineering fields, thereby facilitating interdisciplinary transfers of knowledge and methodologies. GAFOE also helps build cooperative networks of younger engineers that cross national boundaries.

NAE member **Elsa Reichmanis**, director of the Materials Research Department at Bell Laboratories/Lucent Technologies, and Theodor Doll, professor of microstructural physics at the University of Mainz and research director at the Institut für Mikrotechnik Mainz GmbH, co-chaired the organizing committee and the symposium.

The four topics covered at the meeting were: engineering and art; the Internet; quality management tools and methods in production design, innovation, and logistics; and bioengineering and the food industry. Two Germans and two Americans presented talks in each of the four areas. The topics included engineering artistic environments, the state of the art in searching the web, the demands on quality management methods created by intelligent logistical processes, and nanostructures and nanoengineering in foods. Presentations were limited to 25 minutes to allow plenty of time for questions and discussions, which carried over into the breaks, receptions, and dinners. On Friday afternoon, April 30, the group toured the National Air and Space Museum's recently opened Steven F. Udvar-Hazy Center in Chantilly, Virginia, and then had dinner at Top of the Town in Arlington, Virginia, which features an impressive view of Washington, D.C. The talk by the dinner speaker, NAE member **Hans Mark**, professor and John J. McKetta Centennial Chair in Engineering at the University of Texas, Austin, was on "The Problem of Energy."

Funding for the GAFOE meeting was provided by the National Science Foundation, Bell Laboratories/Lucent Technologies, Cargill Inc., the NAE Fund, and the Alexander von Humboldt Foundation. Plans are under way for an eighth GAFOE meeting to be held in Germany in 2005.

For more information about this activity, contact Janet Hunziker in the NAE Program Office at 202/334-1571 or by e-mail at *jhunziker@nae.edu*.

GAFOE attendees

A Serious Game in Las Vegas

On April 20, about 300 news directors from television and radio stations around the country converged on a softly lit ballroom at the Las Vegas Hilton to consider the hard choices they will face in the event of a terrorist attack. In a 75-minute session at the Radio-Television News Directors Association annual meeting, organized by the Radio-Television News Directors Foundation and NAE, the news directors participated in an exercise that gave them an opportunity to respond to an imaginary "dirty" bomb explosion and to think about how they would convey vital information to the public.

NAE members **Ruth David**, president and CEO, ANSER, and **Siegfried Hecker**, senior fellow and former director, Los Alamos National Laboratory, who provided expertise on attacks using radiological devices, were joined by two news directors (Daniel Rosenheim, KPIX-TV, San Francisco, and Kathy Walker, KOA-AM, Denver) and two government leaders (Tim McAndrew, Las Vegas Office of Emergency Management, and Robert Stephan, special assistant to the secretary, Department of Homeland Security [DHS]) in a tabletop scenario exercise.

ABC News national security correspondent John McWethy facilitated the discussion and related new information as events unfolded in "real" time. During the exercise, the news directors "contacted" David and Hecker for information about different types of radiation, health effects, and protective measures for people in the vicinity of an explosion. The NAE experts also explained the differences between dirty bombs and nuclear bombs.

In general, the NAE experts provided news directors with impartial, knowledgeable explanations of risks and scientific and technical context for their reports. They also cautioned about drawing conclusions based on incomplete information.

When the exercise ended, workshop participants were anxious to ask questions of scenario participants and organizers about everything from the effectiveness of emergency alert systems to when more sessions like these might be held. In fact, NAE will head an 18-month project (sponsored by DHS and the Gannett Foundation) to hold 10 similar day-long workshops in cities around the country. The project was announced by DHS Secretary Tom Ridge in a speech on April 19. NAE will work closely with other units in the National Academies, DHS, and the Radio-Television News Directors Foundation to plan and conduct the workshops.

EngineerGirl! Contest Winners

The EngineerGirl! website (*www.engineergirl.org*) recently sponsored an essay contest on the subject of "Engineering Is a Dream Career." Kids in grades 4 through 12 were asked to imagine how an engineering development would change their lives in 2020. Engineering achievements might change how we communicate, how we treat the environment, how we protect our health, how we protect ourselves, our country, our property, and belongings, or how we travel. Three winners were chosen in each of two categories (grades 4 through 8 and 9 through 12). First prize winners were awarded $250 each. Sudhandra Sundaram of Richland, Washington, winner in grades 4 through 8 category, wrote about a biocard, a device the size of a credit card that reads and stores all of a person's biomedical information merely by being placed in the palm of the hand. The winner in the grades 9 through 12 category was Dewi Harjanto of Irvine, California, whose essay was about Operation Vac, an engine for boats that also cleans and filters water. All winning essays can be found on *www.engineergirl.org*.

NAE Development Notes

The Grainger Foundation recently awarded $500,000 to NAE for the establishment and administration of the National Academy of Engineering Grainger Challenge Prize. The purpose of the prize is to encourage the creation of technologies that consume fewer resources, generate less waste of all kinds, and are affordable by people throughout the world. The prize will be awarded to the winner of a "best-entry contest" to be administered by a committee of 13 NAE members. An announcement of the target achievement for the initial prize and the criteria for selection will be made later this year.

The **Boeing Corporation** has provided $100,000 in funding to the NAE Center for the Advancement of Scholarship on Engineering Education (CASEE), which works collaboratively with diverse elements of the engineering community to expand the research base on teaching and learning in engineering disciplines and translate research results into practice in classrooms, internship sites, and workplaces.

NAE member **Alan M. Voorhees** has given $100,000 to support planning for the development of international programs on urban infrastructure for sustainable cities in the developing world. To begin this initiative, NAE will open a dialogue with the Chinese Academy of Engineering and Chinese Academy of Sciences on a joint project that would serve two objectives: (1) to make a contribution in an area that the Chinese government regards as significant at the national, provincial, and local levels; and (2) to help NAE learn how to develop and implement partnerships of this type as a basis for projects with other partners throughout the world.

A grant from NAE member **Harry E. Bovay Jr.** will make it possible for NAE to provide a permanent home for the On-Line Ethics Center for Engineering and Science (OECS), the foremost engineering and science ethics website in the world. The center was launched in 1995 by Professor Caroline Whitbeck of Case Western Reserve University with seed funding from NAE member, **Raymond S. Stata**, and underwriting from the National Science Foundation (NSF). With more than 2,200 pages and 3,000 files, OECS provides a wealth of ethics-related materials, including case studies, essays, training resources, and links to corporate, research, government, and academic websites.

Mr. Bovay's grant of $25,000 will enable NAE to relocate the website over a period of two years and provide for the services of web specialists and ongoing technical support. By mid-2006, when Professor Whitbeck plans to retire, the transition will be complete. With NAE's wide reach in the engineering community and access to the full resources of the National Academies, it is ideally situated to build upon the solid OECS base, extend its reach, and increase its impact on the practices and professions of engineering and science. NAE's ultimate goal is to establish a clearinghouse/resource website that connects researchers, educators, practitioners in engineering, science, and ethics disciplines, and leaders in industry, the business community, and students. The website also has the potential to support active learning via hyperlinks that provide alternative pathways through the content of the site.

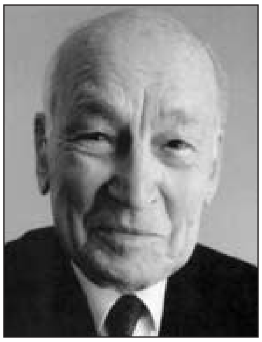
Susan Sink Joins NAE as Senior Director of Development

Susan Sink

In March 2004, Susan Sink joined the National Academies as the top development officer for NAE. "The NAE plays a pivotal role for America," Susan said. "It is an honor to work with the best engineers in the country who are eager to help confront and solve pressing technical issues while advancing the engineering profession."

Susan joins the Academies from the Prospect Information Network, where she was associate vice president of sales for the Mid-Atlantic states. She also has 20 years of experience in administration and development in higher education. She was assistant vice president of development for colleges and constituent units at Virginia Polytechnic Institute and State University, and during the recent "Making a World of Difference" campaign, she was director of development for the university's flagship school, the College of Engineering. Susan was awarded the Virginia Tech President's Award for Excellence in 2000. Susan was also a member of the faculty of Pamplin College of Business at Virginia Tech and an admissions administrator at Radford University, where she earned her B.A. and M.B.A.

Arnold Beckman, Inventor, Chemist, and Philanthropist



Arnold O. Beckman

Arnold O. Beckman, Ph.D., retired founder and chairman of Beckman Instruments, Inc., died after a long illness at the age of 104. Dr. Beckman was elected to NAE in 1967 for the invention and development of precision instruments. He received a distinguished service award from NAE in 1986 and the Founders Award in 1987. In 1999, he was awarded the NAS Public Welfare Medal for his leadership in the development of analytical instrumentation and for his deep and abiding concern for the vitality of the nation's scientific enterprise.

Dr. Beckman received many other awards during his career, including the 1988 National Medal of Technology for his outstanding technological contributions to the United States and the 1989 Presidential Citizens Medal for his exemplary deeds.

Dr. Beckman founded the National Technical Laboratories in 1935. Later renamed Beckman Instruments Company, the firm is now known as Beckman Coulter, Inc. As a professor at Caltech, Dr. Beckman invented a method of measuring acidity, and the pH meter was the first product of the new company. In 1987, he was inducted into the National Inventors Hall of Fame.

In 1986, the Beckman Foundation provided $20 million for the establishment of the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering in Irvine, California.

Harold Liebowitz, Former NAE President

Harold Liebowitz, 79, president of NAE in 1995 and dean of the George Washington University School of Engineering and Applied Science from 1968 to 1991, died on April 7, 2004, at his home in Tucson, Arizona, from complications of Parkinson's disease. Dr. Liebowitz was elected to NAE in 1975 for his management of research programs in structural mechanics and his contributions to the engineering literature in this field. An aeronautic and astronautic engineer, he worked at the Office of Naval Research for 20 years. Dr. Liebowitz is survived by his former spouse, Marilyn Liebowitz, and three children, Dr. Jay Liebowitz, Jill Liebowitz, and Alisa Liebowitz.

In Memoriam

WILLIS A. ADCOCK, 81, Cockrell Family Regents Chair Emeritus in Engineering, University of Texas at Austin, died on December 16, 2003. Dr. Adcock was elected to NAE in 1974 for his contributions to the advancement of silicon material and device technology.

ALFRED E. BROWN, 87, retired director, scientific affairs, Celanese Corporation, died on March 12, 2004. Dr. Brown was elected to NAE in 1975 for his leadership and motivation of technical organizations working in textile, chemical, and materials engineering research.

KENNETH G. DENBIGH, 92, professor emeritus, University of London, died on January 23, 2004. Professor Denbigh was elected to NAE in 1981 for formulating the concept of "chemical reactor engineering" and for the application of chemical thermodynamics to industrial processes.

JOHN K. GALT, 82, AT&T Bell Laboratories, retired, died on June 11, 2003. Dr. Galt was elected to NAE in 1986 for discoveries related to magnetic and composite materials and for his leadership in the development of new optical-device technology.

THOMAS J. HAYES III, 89, U.S. Army, retired, and retired chairman and CEO, International Engineering Company Inc., died on March 16, 2004. Maj. Gen. Hayes was elected to NAE in 1975 for his work on unique and complex engineering and construction programs in support of national space and missile programs.

JOHN D. HOFFMAN, 81, research professor, Department of Materials Science and Engineering, Johns Hopkins University, died on February 21, 2004. Dr. Hoffman was elected to NAE in 1980 for his contributions to the field of high polymers and his leadership in materials research.

JOHN K. HULM, 80, Chief Scientist Emeritus, Westinghouse Science and Technology Center, died on January 16, 2004. Dr. Hulm was elected to NAE in 1980 for his contributions to the theory, development, and application of superconductors.

FREDERICK G. JAICKS, 80, retired chairman, Inland Steel Company, died on December 10, 1998. Mr. Jaicks was elected to NAE in 1979 for his promotion of technological advancements in the steel industry.

GEORGE H. KIMMONS, 85, retired manager, Office of Engineering Design and Construction, Tennessee Valley Authority, died on March 23, 2004. Mr. Kimmons was elected to NAE in 1980 for contributions to the Tennessee Valley's total resource development through technical management of complex engineering design and construction programs.

G. ALEXANDER MILLS, 90, retired senior scientist, Catalysis Center, University of Delaware, died on April 28, 2004. Dr. Mills was elected to NAE in 1977 for his contributions to the science and technology of petroleum catalysis and coal conversion.

EUGENE J. PELTIER, 93, U.S. Navy, retired, died on February 13, 2004. Rear Admiral Peltier was elected to NAE in 1979 for his pioneering work on the development of engineering and management activities.

WILLIAM H. PICKERING, 93, chairman, Lignetics Inc., and a founding member of NAE, died on March 15, 2004. Dr. Pickering was director of the Jet Propulsion Laboratory in Pasadena, California, from 1954 to 1976; during that time he oversaw the first robotic missions to the moon, Venus, and Mars.

PHILIP N. ROSS, 87, retired manager, Power Systems Planning, Westinghouse Electric Corporation, died on July 24, 2003. Mr. Ross was elected to NAE in 1968 for his contributions to nuclear propulsion systems and power plants.

REUBEN SAMUELS, 78, principal professional associate, Parsons Brinkerhoff Inc., died on February 18, 2004. Mr. Samuels was elected to NAE in 1994 for his leadership in the practice of heavy and underground construction and for improving contracting practices.

JOHN M. WEST, 84, consultant, died on February 24, 2004. Mr. West was elected to NAE in 1979 for his contributions to the development and application of nuclear reactors and to the commercial success of light-water nuclear power plants.

Dane and Louise Miller Symposium

The Center for the Advancement of Scholarship on Engineering Education (CASEE) will host the Dane and Louise Miller Symposium and its annual meeting on October 20, 2004, at the Savannah Riverfront Marriott in Savannah, Georgia. The symposium is a working meeting that promotes innovations in engineering education based upon rigorous research in the cognitive and social sciences. Keynote speakers include Robert A. Eisenstein, president of the Santa Fe Institute, **Wm. A. Wulf**, president of NAE, and Steve Kirsch, founder of Infoseek and CEO and founder of Propel.com. Registration information is available at <*www.nae.edu/CASEE*>.

Preview of the 2004 NAE Annual Meeting

The 2004 NAE Annual Meeting is scheduled for Sunday and Monday, October 3 and 4, 2004. Orientation and a black-tie dinner for new members will be held on October 2, the Saturday prior to the meeting. Also on October 2, meetings of peer committees will be held to initiate the selection of candidates for the 2005 election. A guest program is being planned for Monday, October 4.

Pre-meeting Activities

Saturday, October 2
NAE Council meeting
Peer committee meetings
Special events for the Class of 2004:
- lunch with the NAE Council
- introduction to the National Academies and NAE
- NAE Council reception and dinner honoring the Class of 2004 (black tie)

Annual Meeting

Sunday, October 3
Brunch
Estate planning seminar
Induction ceremony
Awards ceremony—Founders and Bueche Awards
Talk by recipient of 2004 Gordon Prize
Gilbreth Lectures
Reception

Monday, October 4
Continental breakfast
Home Secretary and Foreign Secretary breakfasts
NAE business meeting
Symposium celebrating developments in manufacturing technology
Lunch
Section meetings
Dinner and dance at the Mellon Auditorium with entertainment by Gross National Product

Calendar of Meetings and Events

June 1	NAE Finance and Budget Conference Call
June 3	NAE Regional Meeting Ithaca, New York
June 10	NRC Governing Board/ Executive Committee Meeting
June 17	NAE Audit Committee Meeting
July 9	Russ Prize Committee Meeting
July 13	NRC Governing Board/ Executive Committee Meeting
August 3–4	NAE Council Meeting
August 6–7	NRC Governing Board Meeting
September 8–11	10th U.S. Frontiers of Engineering Symposium Irvine, California
September 15	NRC Governing Board Meeting
October 1	NAE Finance and Budget Committee Meeting
October 1–2	NAE Council Meeting
October 2	NAE Peer Committee Meetings
October 3–5	NAE Annual Meeting
October 6	NRC Executive Committee Meeting
October 12	Russ Prize Committee Meeting
November 9–10	NRC Governing Board/ Executive Committee Meeting

All meetings are held in the Academies Building, Washington, D.C., unless otherwise noted. For information about regional meetings, please contact Sonja Atkinson at *satkinso@nae.edu* or (202) 334-3677.

The National Academies Update

Grant from the Gates Foundation Supports African Science Academies

The National Academies has received a $20 million grant from the Bill and Melinda Gates Foundation to help African academies of science—and the continent's scientific, engineering, and medical communities as a whole—improve their ability to provide evidence-based advice to inform government policy and public discourse. The initiative, which will be carried out over the next 10 years, will focus on efforts to improve human health. Three science academies in Africa will be chosen as partners for the initiative.

Africa faces many serious problems that require scientific and medical expertise, including the HIV/AIDS epidemic, chronic malnutrition, and life-threatening diseases, such as malaria and diarrheal illnesses. The goal of the new initiative is to enable scientists and health care professionals to contribute to policy decisions to tackle these issues. Some of the funds will be used to train staff members of African academies in planning and conducting scientific studies and major conferences; raising and managing money from outside sources; using information technology; and cultivating relationships with government officials and other stakeholders in their countries.

"Every country needs an organized way to call upon its own scientific and medical communities for guidance," said Bruce Alberts, president of the National Academy of Sciences. "The ultimate goal of this initiative is to help each participating academy achieve, by the end of the 10-year period, a well developed and enduring capacity to provide credible policy advice for its nation."

Several academies of science in Africa are already working toward these goals, but most of them have limited experience in providing policy guidance and marshaling the talents of the scientific and medical communities. Through a recently formed organization, New Partnership for Africa's Development, African nations have collectively expressed a desire to pursue and finance scientific research to meet pressing needs.

"To eliminate global inequities in health between rich and poor, the world must ensure that the fruits of science, technology, and medicine are available to all countries," said Richard Klausner, executive director of the Gates Foundation Global Health Program. "We hope that this important initiative will help achieve the goal of better health for all by engaging the African scientific community in critical African policy decisions."

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 (800) 624-6242. *(Note: Prices quoted by NAP 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.)*

Frontiers of Engineering: Reports on Leading-Edge Engineering from the 2003 NAE Symposium on Frontiers of Engineering. This volume includes 13 papers from the National Academy of Engineering 9th U.S. Frontiers of Engineering Symposium held in September 2003. This annual symposium brings together 100 outstanding engineers (ages 30 to 45) to exchange ideas and discuss leading-edge technologies in a range of fields. The 2003 symposium covered four general areas: environmental engineering; nanotechnology; counterterrorism technologies and infrastructure protection; and biomolecular computing. A talk on the most important lessons not learned in engineering schools by William F. Ballhaus Jr., president and CEO of Aerospace Corporation, is also included. Appendixes include the symposium program and a list of meeting participants. This is the ninth book in the U.S. Frontiers of Engineering series. Paper, $40.00.

2003 Assessment of the Office of Naval Research's Marine Corps Science and Technology Program. The Office of Naval Research (ONR) funds research in a broad range of scientific and engineering disciplines in support of the Navy and Marine Corps. To ensure that its investments are serving those ends and are of high quality, ONR requires that each of its departments undergo an annual review. Since 1999, the Naval Expeditionary Warfare Department has requested that the National Research Council conduct these reviews. This report presents the results of the second review of the Marine Corps Science and Technology (S&T) program. The first review was conducted in 2000. The 2003 assessment examines the overall Marine Corps S&T program, the future littoral-combat naval capability, the core thrusts of the program, and basic research activities. Paper, $29.75.

Burning Plasma: Bringing a Star to Earth. With significant advances in fusion science, the United States has reached a decision point about initiating a burning plasma experiment. Burning plasma—in which at least 50 percent of the energy to drive a fusion reaction is generated internally—is an essential step in fusion power generation. The National Research Council Burning Plasma Assessment Committee was formed to provide advice on this decision. The committee concluded that the United States is ready to proceed and that the international thermonuclear experimental reactor (ITER), with the United States as a significant partner, would be the best choice for the experiment and should be a high priority of the U.S. fusion research program. Funding should both capture the benefits of joining ITER and retain a strong focus on the long-range scientific goals of the program. This dual focus will require that the content, scope, and level of activities be defined by the Office of Fusion Energy Science, which should set priorities for the program. Paper, $47.00.

Effects of Degraded Agent and Munitions Anomalies on Chemical Stockpile Disposal Operations. Concerns about the condition of munitions containing sarin, VX, and mustard stored at eight U.S. military sites prompted the U.S. Army to request that the National Research Council review its current monitoring activities. Concerns over stored munitions include: the possibility that leaks may increase with temperature variants, which may also affect the rate at which agents degrade and may damage container materials; the lack of knowledge about the risk of leakage from degradation; the possibility of an explosion of pressurized hydrogen gas formed when mustard agents degrade; and the unpredictability of leaks and other anomalous conditions. The report recommends that the Army monitor the condition of stored munitions more aggressively. Improved tracking could result in a better assessment of the risks posed by chemical agents during storage and facilitate disposal operations for aging stockpiles. Paper, $18.00.

Fairness and Effectiveness in Policing: The Evidence. As the nation paid its respects to the police officers who lost their lives in the September 11 terrorist attacks, it became clear that "cops on the beat" would never be seen in the same way again. This report explores police work in the new century, replacing myths with research findings and providing recommendations for updating policies and practices. This book answers the most basic questions about what police do—how police work is organized, how police responsibilities have expanded, increasing diversity among police, and complex interactions between officers and citizens. The report also addresses community policing, the use of force, racial profiling, and more. *Fairness and Effectiveness in Policing* evaluates the success of common practices, such as focusing on "hot spots," and the issue of legitimacy—how the public gets information about police work, how different groups view police, and how police can gain community trust. This report will be helpful to policy makers, administrators, educators, police supervisors and officers, journalists, and interested citizens. Hardcover, $49.95.

Forensic Analysis: Weighing Bullet Lead Evidence. Since the 1960s, FBI testimony in thousands of criminal cases has been based on evidence from compositional analysis of bullet lead (CABL), a forensic technique that compares the elemental composition of bullets found at a crime scene to the elemental composition of bullets found in a suspect's possession. Unlike ballistics techniques that compare striations on the barrel of a gun to those on a recovered bullet, CABL is used when no gun is recovered or when bullets are too small or mangled to be examined for striations. After assessing the scientific validity of CABL, the study committee concluded that the FBI should use a different statistical analysis for CABL, and that, considering the variations in manufacturing processes, expert witnesses should make clear the very limited conclusions that CABL results can support. The committee also recommends that the FBI improve documentation, publish details, and improve training and oversight to ensure the validity of CABL results. Paper, $47.00.

Future Challenges for the U.S. Geological Survey's Mineral Resources Program. In 1996, the National Research Council provided the U.S. Geological Survey (USGS) Mineral Resources Program with a comprehensive review and recommendations for improvement. In this report, the study committee assesses the program's responses to the 1996 recommendations, evaluates the minerals information team, and suggests how the program's mission and vision might evolve over the next decade to meet the nation's changing needs. Paper, $34.00.

Future Needs in Deep Submergence Science: Occupied and Unoccupied Vehicles in Basic Ocean Research. Deep-diving manned submersibles, such as Alvin, which attracted worldwide attention when researchers used it to reach the wreck of the *Titanic*, have helped advance deep-ocean science. But many scholars in this field have noted that the number and capabilities of underwater vehicles no longer meet current scientific demands. At the same time, the relative value of manned and unmanned vehicles is still in dispute. The report finds that new, more capable submersibles—both manned and unmanned—would greatly advance ocean research. Paper, $30.00.

Giving Full Measure to Countermeasures: Addressing Problems in the DoD Program to Develop Medical Countermeasures against Biological Warfare Agents. In recent years, substantial efforts have been made to develop new drugs, vaccines, and other medical interventions against biological agents that might be used in bioterrorist attacks against civilian populations. According to this new, congressionally mandated report from the Institute of Medicine and National Research Council, Congress should authorize the creation of a new agency within the Office of the Secretary of the U.S. Department of Defense to ensure the successful development of these drugs, vaccines, and other medical interventions against biowarfare agents. The committee recommends that Congress increase liability protection for the developers and manufacturers of these products to encourage investment in new research and development for biowarfare protection. The report also identifies some barriers to be overcome—such as the need for appropriate animal models and the need for laboratories equipped with high-level biosafety protections. Paper, $32.00.

Groundwater Fluxes across Interfaces. Estimates of groundwater recharge and discharge rates at many different scales are used for evaluating the risks of landslides; managing groundwater resources; locating nuclear waste repositories; and estimating global budgets of water and greenhouse gases. This report focuses on scientific challenges: (1) spatial and temporal variability of recharge and discharge; (2) how information at one scale can be used at another scale; and (3) interactions between groundwater and climate. Paper, $35.00.

Health and Medicine: Challenges for the Chemical Sciences in the 21st Century. This summary of a workshop held in December 2002 is the last in the "Challenges for the Chemical Sciences in the 21st Century" series. Topics discussed at the workshop were: new tools for, and approaches to, drug discovery, diagnostics, and the prevention of disease; new methods of synthesizing and developing pharmaceuticals; and new directions in the manufacture and delivery of medicines. Despite the tremendous accomplishments of chemists and chemical engineers in the area of health and medicine in recent years, the increasing amount of information poses significant future challenges. With myriad complex biological processes yet to be understood, the situation is likely to become more complicated as more pieces of the puzzle are revealed. Paper, $18.00.

Materials Count: The Case for Material Flows Analysis. The increasing population and industrial growth are increasing strains on a variety of material and energy resources. Making the most efficient use of materials, economically and environmentally, will require understanding the flow of materials from the time they are extracted, through processing, manufacturing, use, and disposal as waste or reusable resources. This report examines the usefulness of material flows accounts as a basis for public policy, evaluates the technical basis for material flows analysis, assesses the current state of material flows information, and suggests who should have institutional responsibility for collecting, maintaining and providing access to data. Paper, $25.00.

Ocean Noise and Marine Mammals. Sound is the primary means of learning about the environment, of communicating, navigating, and foraging for the 119 species of marine mammals and some other aquatic animals. Concerns have arisen that human-generated noise might harm marine mammals or significantly interfere with their normal activities. Since the passage of the Marine Mammal Protection Act of 1972, noise levels have been regulated. Public awareness of the issue escalated in the 1990s when researchers began using high-intensity sound to measure changes in ocean climate. The recent stranding of beaked whales in proximity to areas where the Navy has used sonar returned the issue to the spotlight. This report reviews sources of noise in the ocean environment, the responses of marine mammals to acoustic disturbances. Recommendations address data gathering, studies of marine mammal behavior and physiology, and modeling to determine the long-term and short-term effects of ocean noise on marine mammals. Paper, $47.00.

Review of NASA's Aerospace Technology Enterprise: An Assessment of NASA's Pioneering Revolutionary Technology Program. The Aeronautics and Space Engineering Board of the National Research Council is in the midst of a series of studies to review the National Aeronautics and Space Administration (NASA) Aerospace Technology Enterprise for NASA and the Office of Management and Budget. In this report, the second in the series, the study committee addresses questions posed by NASA about the structure and quality of its three aeronautics technology programs: vehicle systems; airspace systems; and aviation safety. The report provides recommendations to guide Congress, the administration, and NASA in setting priorities, as well as findings and recommendations for improvements at the program and project levels. Paper, $32.00.

Technology for Adaptive Aging. Emerging and currently available technologies have shown great promise for helping older adults, even if they have no serious disabilities, to live healthy, comfortable, and productive lives. This report is the product of a workshop that brought together experts in aging research and in technology to discuss applications of technology to communication, education and learning, employment, health, living environments, and transportation for older adults. It includes all of the workshop papers and a synthesis and evaluation by the organizing committee. Recommended priorities for federal support of translational research in technology for older adults are also provided. Paper, $49.00.

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