The
BRIDGE

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. 29, No. 2, Summer 1999

Editor: Karla J. Weeks

Production Assistants: Penelope Gibbs, Kimberly M. West

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

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.

Papers are presented in *The Bridge* on the basis of general interest and timeliness in connection with issues associated with engineering. They reflect the views of the authors and do not necessarily represent 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 online at **http://www.nae.edu/TheBridge** in PDF format. Some of the articles in this issue are also available as HTML documents and may contain additional commentary, links related to sources of information, multimedia files, and other content.

VOLUME 29, NUMBER 2
SUMMER 1999

The BRIDGE

Editorial 2

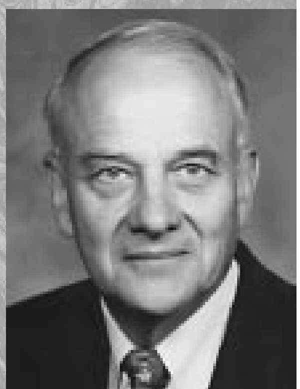
Features 4

NAE News and Notes 25

National Research Council Update 34

Publications of Interest 36

Editorial



Wm. A. Wulf is president of the National Academy of Engineering.

E. Gail de Planque, a member of the NAE, is a consultant and former commissioner of the Nuclear Regulatory Commission. She chaired the steering committee that organized the NAE Summit on Women in Engineering, held 17–18 May 1999.

Women in Engineering

The United States is one of the world's leaders in technology and innovation, a position it owes largely to the strength of its engineering and technical workforce. However, that workforce faces increasing challenges, both internal and external in nature, that threaten our nation's preeminent position. The external challenges are well known, and they face every company: the shift from a manufacturing to a service economy, the rapid pace of change, and the global distribution of markets. The internal challenges relate to the very makeup of our engineering workforce and in many ways are more difficult to address.

The U.S. engineering workforce is predominantly white male and is aging rapidly. Over the last 15 years, the total number of individuals choosing engineering studies and careers has been decreasing. Of those students who initially choose engineering coursework, even fewer actually graduate with engineering degrees. This decline in the number of students in the engineering pipeline, coupled with increasing rates of retirement among engineers trained in the early 1960s, points to a potential resource crisis. Projected market demands and current enrollment trends suggest that the United States may experience a serious shortfall in the number of engineers needed to fill jobs within the next decade. This need not be as it is!

At first glance, our nation seems to have an untapped resource ready to respond to this need—more than half our population is female, and more girls than boys graduate from high school and enter college. Unfortunately, fewer than 20 percent of the college students who choose to study engineering are female. And beyond college the numbers are worse. There are proportionately fewer women in engineering than in all other scientific or technical fields, and women constitute less than nine percent of the engineering workforce. This is unacceptable.

For the United States to remain competitive in a global, technological society, the country as a whole must take serious steps to create a diverse, well-trained, and multicultural workforce. Of specific concern is our ability to "engineer well" without a workforce that reflects the face of America as well as that of global markets. The ability to attract young women is a significant challenge faced by the engineering community, specifically by those corporations with a stake in the nation's technological future.

In order to address this issue, the NAE initiated the Celebration of Women in Engineering (CWE) project. Key individuals from academia, industry, engineering-related societies, and educational support organizations—noted for their active roles in encouraging women to pursue math, science, and engineering fields—were solicited to participate on the steering committee for this project. Once assembled, the committee noted that many initiatives related to women in engineering have been implemented in both the public and private sectors, and yet significant change in the workforce has remained elusive. The committee felt that new national initiatives—with strong corporate involvement—would be required before any effective change could occur. To guide its efforts, the steering committee defined three goals:

- Elevate the visibility of outstanding women engineers, drawing attention to their careers and their respective fields of engineering.
- Encourage young women at the secondary school and undergraduate levels to consider engineering as a course of study.

- Increase active participation in addressing this problem by helping corporate executives and other national leaders understand the issues related to the low numbers of women in engineering.

To support these goals, the steering committee pursued two major initiatives. The first was to establish a website with information pertaining to the pursuit of an engineering career. The CWE website provides information about educational resources, mentoring programs, careers, and funding, as well as a discussion room and an event calendar. The centerpiece of the site is a gallery of women engineers that profiles women from various professions and industry sectors, demonstrating the wide variety of options open to women interested in engineering. The CWE website can be found at http://www.nae.edu/cwe.

The second initiative was the Summit on Women in Engineering, convened by the NAE 17–18 May 1999. The summit brought together 175 top decision makers from industry, academia, professional societies, government, education and outreach organizations, and the media to examine existing and potential solutions for attracting more women to the engineering workforce. The purpose of the summit was to create a national action plan, based upon new partnerships among the various stakeholder groups, to pursue these solutions.

The summit plenary sessions were devoted to the different points at which girls and women are "lost" from the engineering pipeline (e.g., dissuaded from science interest in middle school, discouraged from studying science and math in high school, discouraged from pursuing an engineering degree as an undergraduate, deterred from advancement in the workforce). The summit participants heard from several women who achieved exciting and successful engineering careers, despite obstacles along the way. But the obstacles they described were all too familiar: the poor image of engineering as a career for women, the chilly climate faced by women in college and in the workplace, and a professional life that limits the career potential of women.

On the second day of the summit, participants took part in a series of action forums that concentrated on specific issues and strategies, such as changing the public perception of who can become an engineer, promoting opportunities in engineering for women, and highlighting the best programs for attracting women to engineering. These sessions explored ways to improve existing programs and to create a national approach to address the problem more effectively.

We are pleased to report that the response to the summit was strong—as evidenced by the high energy levels in the action forums, the language used to craft the forum reports, and the initial commitments from the participants. The outcomes of the summit are still in development, and in the next issue of *The Bridge* we plan to report on some of the new partnerships and collaborative efforts that have been formed. In the meantime, we'd like to thank the steering committee, the NAE program staff, and the summit participants for their hard work.

A few of the keynote addresses from the summit are included in this issue of *The Bridge,* and we encourage you to read them and join us in our excitement. The Summit on Women in Engineering marked the beginning of a process that we hope will help to foster a diverse and strong workforce ready to support this nation in the next century. But it was only a beginning—it will take commitment from all of us before we can claim success in creating this new movement toward recruiting, retaining, and advancing women in engineering.

Wm. A. Wulf

Wm. A. Wulf

E. Gail de Planque

E. Gail de Planque

Creating Opportunities for Participation

Rodney E. Slater

As we begin a new century and a new millennium, attracting women to the U.S. engineering enterprise is part of the larger global concern with diversity and opportunity.

Rodney E. Slater is the U.S. Secretary of Transportation. This is an edited version of the speech he gave 18 May 1999 at the NAE Summit on Women in Engineering.

On behalf of President Clinton and the Department of Transportation, I am delighted to have this opportunity to address the Summit on Women in Engineering. There is no question in my mind that the action plans you have developed are of strategic importance to the future of this nation. What we need are not merely new choices for women, but new choices for engineering.

The livable communities of the twenty-first century that the president and vice president have championed will be designed and built by talented engineers—men as well as women. As we begin a new century and a new millennium, attracting women to the U.S. engineering enterprise is part of the larger global concern with diversity and opportunity. There are still places on this planet where women are not allowed to learn to read or write.

As an African-American, I am acutely sensitive to the connection between education and freedom. As the Greek poet and philosopher Epictetus wisely said more than 21 centuries ago, "Only the educated are free."

Who should we cut off from full participation in the future? There are some six billion people living on Earth with ideas and talent to share: they speak more than 4,000 languages; they are members of more than 255 nationalities, each with different perspectives and goals; they practice more than 20 major religions. And half of them are women. Each one of these unique human beings has something to offer.

As the president has said, we must ensure that the twenty-first century is "a world in which people are working together and cherishing both their diversity and their interdependence."

Transportation System Needs More Engineers

I can think of no more appropriate time to hold this summit than during National Transportation Week, which the president has designated as a time to give "due recognition to the individuals and organizations that build, operate, and maintain this country's transportation system." A substantial number of these individuals need an engineering education in order to do their job.

Transportation is easily the most engineering-intensive sector of America's economy, and it accounts for 11 percent of our gross domestic product. About one out of five dollars spent by the average American household goes for transportation, and one in every nine jobs is a transportation job.

As Secretary of Transportation, I can tell you that the declining number of students in the engineering pipeline over the past 15 years has already started to create shortages of trained engineers in many parts of the country. This is a source of serious concern. As the current generation of seasoned transportation engineers, trained in the 1960s, continues to retire, these shortages threaten to impede our continued economic success.

Between now and 2015, we will need to create the equivalent of 10 new airports the size of Chicago's O'Hare to meet the projected capacity demand. To accomplish this we need engineers.

Right now, 59 percent of the nation's major roads are in poor, mediocre, or fair condition. Thirty-one percent of America's bridges are structurally deficient or obsolete. Thirty percent of America's urban freeways are congested. Twenty-one percent of all rail tracks in the United States need to be improved, and of our 10 largest ports, only 5 are deep enough to accommodate the new supertankers. To repair our transportation infrastructure, to improve our rail and harbor systems, we need engineers.

We also need engineers to design, deploy, and operate the information and sensor technology we need to ensure that America's twenty-first century transportation system can fully support our twenty-first century economy. We need engineers to help us improve the logistics and management of freight transportation, to automate terminal operations, and to develop and deploy intelligent vehicle technology—a technology that could potentially reduce the number of accidents by one-sixth, or about 1.2 million incidents each year.

We need engineers to design and use smart materials in the repair and retrofit of bridges, docks, highways, and other structures. As engineers take advantage of the potential of high-performance concrete, fiber-reinforced polymers, and other new materials, the nation will benefit from reductions in traffic delays, downtime, and other costs associated with infrastructure repair.

We need more young women to enter the engineering profession.

In other words, the transportation industry needs engineers—engineers of all kinds, in huge numbers. And, as we are hearing at this summit, to produce engineers in the numbers we need, we need more young women to enter the engineering profession.

As we see it at the Department of Transportation, this will require us to do three things: first, focus on intervening early in the education process to encourage young women to take more math and science; second, take direct action to support engineering programs that focus on minorities and women; and third, introduce young women to successful women engineers in action. We are attempting to do all three.

First, through the Garrett A. Morgan Transportation and Technology Futures Program, we are reaching out to both young women and young men, starting with kindergarten programs and extending through high school, to encourage them to take as much math and science as possible.

Our department is also encouraging other federal agencies, state transportation departments, the education community, and private-sector companies to work with us to ensure that students at all levels are literate in math, science, and technology.

Since establishing this program at the request of President Clinton during the 1997 Summit on America's Future, the Department of Transportation alone has reached more than 650,000 young people.

Second, the Department of Transportation operates two institutions of higher education that award undergraduate degrees in engineering—the U.S. Coast Guard Academy, one-third of whose graduates are women, and the Maritime Academy.

Third, through programs like "Groundhog Job Shadow Day," where students "shadow" an employee throughout the course of a normal workday, this department, along with other federal departments and private-sector organizations, provides half a million school-age students with a direct experience of how important math and science, as well as other skills, are to performing well on the job.

We need to create possibilities for every American to participate in the high-tech, twenty-first-century economy

Women have always played a key role in transportation in America—women such as Rebecca Lukens, whose company produced iron for ships, locomotives, and rails in the mid-nineteenth century; Mary Riggins, inventor of the first railway crossing gate; and Mary Anderson, who invented the windshield wiper to improve safety while driving in bad weather. By 1923, more than 175 transportation-related patents were granted to women inventors.

In the area of aviation, Bessie Coleman, an African-American, refused to let racism or sexism stand in her way. She went to Europe to earn her pilot's license and came back to the United States to thrill crowds with her daring stunt-flying maneuvers. Women like Sally Ride (the first female astronaut), Mae Jemison (the first African-American female astronaut), and Shannon Lucid (the U.S. record-holder for continuous time in space) have changed the face of flights in space.

I would like to conclude my remarks by saying that my interest in this issue is not just institutional or even political—it is personal. Last fall I went down to Cape Canaveral to watch John Glenn take off in the space shuttle. My five-year-old daughter, Bridgette, was with me at the launch.

We stood there together, feeling the ground shake. The shuttle was as big as the Statue of Liberty, with payload doors as large as a school bus. As the spacecraft lifted off and moved farther and farther away, it seemed to get smaller and smaller. Bridgette could hold her tiny hand out in front of her, blocking the shuttle from view, or shift her hand slightly, and watch it reach for the stars.

That tiny hand symbolizes my commitment, and your commitment, to the cause of women in engineering. Sometimes that which is big can appear very small. And just as the oak tree lives in the small acorn, there are big dreams yet to be fulfilled. If those dreams are to be fulfilled by this nation, then its people, all of its people, must be allowed to realize those dreams.

We need to create new possibilities for every American to participate in the exciting opportunities of the high-tech, twenty-first-century economy, with no one left out. You have done some great work here over the past two days. Congratulations, and on behalf of Bridgette and all the other future aerospace engineers, my heartfelt thanks for a job well done.

Women in Engineering: Focus on Success

Donna Shirley

Numerous opportunities exist for creative solutions to the problem of insufficient numbers of women engineers in the workforce.

Donna Shirley is president of Managing Creativity, Inc., and former manager of the Mars Exploration Program at NASA's Jet Propulsion Laboratory. This article is an edited version of a speech she gave 17 May 1999 during the NAE Summit on Women in Engineering.

I would like to offer some suggestions, based on recent research and my personal experience, for increasing the number of women engineers in the workforce, the satisfaction and productivity of those women, and the productivity of the workforce as a whole. The premise of my argument rests on the notions that creativity and diversity are linked and that both are necessary to fully exploit the potential of women to contribute to the science and technology enterprise.

There are considerable challenges to creating a more diverse workforce, as well as considerable rewards. While diverse teams may be more creative than homogenous ones (Peters, 1994), they are often harder to manage (Shirley, 1997). If you're a member of a diverse team, some people on the team are probably going to make you uncomfortable just by not acting the way your culture expects them to. For instance, I'm the classic "pushy broad." After more than 35 years in a male-dominated business, I've become vocal, assertive to the point of aggressiveness, and, to some people, obnoxious. On the other hand, I have a lot of experience being overlooked or ignored if I'm not assertive. I've had to learn to walk the fine line between being ignored because people overlook me, and being suppressed because people are angry with me. And however I am, it creates cognitive dissonance in a male culture where women acting like women are out of place and women acting like men are just plain weird.

The advantage of diverse teams is that the viewpoints of one group are very likely new to the others.

The advantage of diverse teams is that the viewpoints of one group are very likely new to others. This newness is what fuels creativity. Hammer and Champy (1993) emphasize the need for reengineering teams to include women. They maintain that a team with women will be much more creative than an all-male team. Coates and Jarratt (1994) note that even in Japan women are slowly entering the creative workforce: "Japanese companies . . . are breaking open conventions of Japanese society and culture to bring creativity up to the surface. . . . Toshiba's break with tradition was to recruit women scientists and engineers, now 10 percent of its R&D workforce." Other research and my personal experience have confirmed the increased creativity of diverse teams over homogenous teams.

There are many books addressing gender-related culture in the workplace (see, for example, Reardon, 1995; Tannen, 1990). But it's perfectly possible for men and women to be on the same creative team. In fact, it's highly desirable, particularly if both men and women will be using your product. What's required to make it work is an environment of mutual respect.

To get gender diversity in the engineering workforce there have to be reasons for women to want to enter the field. My personal reason was a passion for flight.

I know many people who have no idea what they want to be when they grow up, but one recent study (Carr, 1996) shows that it's important for people's mental well-being to have and reach career goals. For those who are lucky enough to have a life passion, it's easy to decide on those goals. For instance, ever since I was a little girl, I loved airplanes. My room was full of airplane pictures, books, and models.

When I was 10, my family went to my uncle's graduation from medical school. In the program was an intriguing list of people who were becoming aeronautical engineers. "What's that?," I asked my mother. "Those are people who build airplanes," she replied. "That's what I want to be when I grow up!," I cried.

For my fifteenth birthday my father bought me flying lessons. I learned to fly Aeronca Champs—65 horsepower "tail draggers." We had no radios and only needle-ball and airspeed indicators for instruments. I was the only female pilot at the Pauls Valley, Oklahoma, airport, tolerated as a "kid sister" by the male pilots.

At barely seventeen, having graduated first in my high school class of 49 students, I set out confidently for the University of Oklahoma. I walked into my advisor's office. He glared at me. "What are you doing here?" he growled. "I'm signing up for aeronautical engineering."

"Girls can't be engineers!"

"Yes, I can!"

The Only Girl in Class

It was a struggle, but eventually I got a degree in aeronautical engineering, which by then had been updated to the more modern name of aerospace mechanical engineering. I also had a commercial and flight instructor's rating, and for a while gave flying lessons. All this time, I was the only girl in my engineering classes.

Between the time my uncle graduated and when I went to college, I had discovered science fiction and become awed by the idea of space travel. In my first job, at the McDonnell Aircraft Company in St. Louis, I wrote specifications for the Gemini spacecraft that carried two astronauts into orbit. Later, I became involved at McDonnell in a proposal to land a spacecraft on Mars. I had become a space nut, and I looked beyond flying in earthly skies to landing on alien planets, even if only in robotic spacecraft.

In 1966, I successfully applied for a job at the Jet Propulsion Laboratory (JPL) as an aerodynamicist, a person who calculates how airplanes and spacecraft interact with atmosphere. Out of about 2,000 engineers at JPL when I arrived in 1966, I was the only degreed female. There was a woman scientist who had come to

JPL in 1959, but I seldom got a chance to interact with her. There were a number of women doing semitechnical work, running the mechanical Frieden calculators that were used to determine planetary spacecraft trajectories. These women were called “computers.”

By the middle 1970s, there were about five female engineers at JPL. Today, some 15 percent of the JPL technical workforce is women. But women are just beginning to penetrate the ranks of technical management. For my whole 32-year career at JPL, I was always the only woman at my management level. Today, JPL has one woman on the executive council, the director of human resources. The highest-ranking technical woman since I retired last year is the deputy manager of a line organization, about four rungs down from the top of JPL.

Role Models Needed

Women interested in engineering in the 1950s and 1960s had to be willing to do without role models, mentors, special training, or any of the other things that surveys indicate are necessary to increase the participation of women in the engineering workforce. Passion was what drove most women to the profession. How can we strike up a passion in more women today?

One way would be for more engineers, especially women engineers, to tell their stories. I’ve moderated panels at the American Film Institute that discussed the portrayal of scientists and engineers in movies and television. The stereotypes of mad scientists and nerd engineers are ubiquitous. Few stories of real engineers in action are portrayed, partly because few engineers write about their experiences in a publicly appealing way. A recent exception is Homer Hickam, a NASA engineer who wrote *Rocket Boys* (Delacorte Press, 1998), a story based on his experiences as a teenager in West Virginia, building home-made rockets. The book was made into a fairly successful movie called *October Sky*.

Astronauts are very visible role models, and movies like *Apollo 13* have made them even more visible. I give many talks to school children, most of whom express a wish to be astronauts. Very few say they want to be one of the engineers who help propel the astronauts into space.

Astronauts have written books, for example *Moon Shot* (Turner Publishing, 1994) by Deke Slayton and Alan Shepard. Authors like Tom Clancy and Michael Crichton write high-tech adventures. Even scientists like Richard Feynman, Steven Hawkings, and Carl Sagan have written for the masses. But where are the women engineers and scientists writing popular literature? My autobiography, *Managing Martians* (Broadway Books, 1998), is a lonely example.

Even without a lot of role models, today we know more about what it takes to broaden the participation of women in engineering. A recent study (Tidball et al., 1999) of how education contributes to success for women outlines a number of key institutional characteristics of colleges:

- Visionary leadership committed to the education of women
- Critical mass of women in all constituencies (students, faculty, boards of trustees, etc.)
- Belief in women’s capacities and high expectations
- Places and spaces for women’s voices to be heard
- Opportunities for women’s leadership in all aspects of institutional life
- Celebration of traditions and institutional history
- High degree of trust and responsibility
- Active and empowering alumnae association

Few engineers write about their experiences in a publicly appealing way.

This research found that women’s colleges were much better than other postsecondary institutions in terms of producing successful career women in virtually all fields, including the physical sciences. Since there are very few women’s colleges that offer engineering degrees, most women engineers have been educated under difficult conditions, in colleges that do not have the success-linked criteria listed above.

Even in schools where women comprise 20 or 30 percent of engineering classes, they are unlikely to have many female faculty or administration role models. They will be lucky to have one or two female teachers during their college years. The leadership at engineering colleges is not as concerned with the commitment to women's education as it is to the technical quality of the program, especially of the research. And it's hard for male engineers to be visionary about the education of women. For the most part, alumnae associations and professional associations for engineers are focused on jobs, continuing engineering education, and technical communications—not on empowering women.

So how can we break the pattern? How can we provide an engineering education in an environment that will have a high probability of attracting young women, retaining them through college, and sustaining them in the world of work? There are some positive trends.

For instance, Smith College, a liberal arts college for women in Massachusetts, plans to offer an engineering degree beginning in September 1999 (Smith College, 1999). This is facilitated by Smith being in a consortium of nearby colleges, including the University of Massachusetts at Amherst, which has an established engineering program. Smith also has a joint engineering program with Dartmouth College.

Women are beginning to attain positions of leadership in engineering schools.

Scripps College for Women in Claremont, California (from which my daughter graduated in May 1999), is across the street from Harvey Mudd, an engineering and science college. Some women at Scripps take engineering courses at Harvey Mudd, since the five Claremont colleges allow cross-enrollment. Scripps offers a "3/2" program where women can get a Scripps liberal arts education for two years and then get an engineering degree at an affiliated engineering school in three years. Scripps is also graduating increasing numbers of science majors and is adding women scientists to its faculty. This model could be applied to other women's colleges that are in close proximity to schools offering engineering degrees, such as Spelman College for Women in Atlanta, which is close to all-male Morehouse University.

Women are beginning to attain positions of leadership in engineering schools. For instance, Shirley Ann Jackson was just selected as president of Rensselaer Polytechnic Institute in Troy, New York. Some engineering schools are making sincere efforts to attract women as faculty and as members of their advisory committees. I am on the advisory council of the Georgia Tech Aerospace Engineering School and the University of Oklahoma Aerospace/Mechanical Engineering School, and I serve on the Board of Visitors of the University of Oklahoma College of Engineering. There are two other women on the board, both Oklahoma engineering alumnae.

The Role of Organizations

Another positive sign is the proliferation of women's technical and business organizations, most of which have some sort of connection with college-level education. Especially noteworthy is the Society of Women Engineers (SWE), which has chapters on most engineering campuses. Another important organization is Women in Technology International (WITI), which has conferences around the country and which lowers its fees for college students. Women are slowly penetrating the ranks of professional engineering societies. For example, I am an associate fellow of the American Institute of Aeronautics and Astronautics and was extremely honored to receive the Holley Medal from the American Society of Mechanical Engineers (ASME) in 1998. Even the National Academy of Engineering (NAE) has 44 women among its 2000 members, and admits it could do better.

A little-known organization called the American Academy of Achievement sponsors an annual event where a couple hundred select high school students can meet high-achieving adult role models. A number of the members of this academy are engineers and scientists, a few of these are women, and the academy's organizers are working hard to include more technically trained women.

Sponsorship of the Summit of Women in Engineering by the NAE is an excellent step. The summit is squarely addressing the issue of how to get girls into engineering and produce successful women engineers. The next summit (I trust there will be one) should include experts in the education of women, and the NAE should aggressively disseminate the results of the summits to America's engineering colleges.

The main responsibility for educating women engineers lies, of course, with colleges of engineering. And some engineering schools are beginning to rethink their educational processes. Distance-learning schools are springing up, competing with established colleges for students and resources. In response, some engineering schools, such as those at the University of Oklahoma and Georgia Tech, are considering adding distance learning to their classical curricula. Engineering pedagogy is being examined, too. The old model of a professor standing at a blackboard scribbling equations that the students frantically copy is being questioned. While different methods of teaching engineering are being developed for other reasons, universities might very well consider what methods work best for educating women.

Engineering is being increasingly practiced in a team environment. If engineering education focused not only on developing the minds of the smartest individuals but also on developing people who can be effective working in teams, that would be a very good environment for attracting women. (My personal belief is that more women like working in teams than working alone.) Extending that thought, engineering is increasingly a creative endeavor. And as I've already noted, creative teams require diversity. If universities can learn to train people to work in creative teams, this will go a long way to providing a woman-friendly environment.

Furthermore, the training of creative teams need not be restricted to "technical subjects." Harnessing collective creativity to produce useful, saleable, and innovative products can be made a lot more effective by using a process that specifically addresses all the phases of a product life cycle, and all the techniques available to create and bring the product to reality.

Elements of the Creative Process

Such a creative process can be visualized as a system of interrelated elements:

- Build teams
- Generate concepts
- Achieve alignment
- Design/plan
- Manage risk
- Produce
- Deploy
- Evaluate
- Communicate

These elements are described briefly below.

Build teams. Building a team means not only assembling the right set of people with the diverse skills to do the job, but the process by which the team grows in capability and alignment throughout the process of collective creativity.

Generate concepts. This is where people tend to think that creativity occurs, and, indeed, a creative enterprise needs to start with a creative concept. However, an enterprise needs creativity at all stages, and the concept evolves throughout the process.

Achieve alignment. Alignment is required within the creative team, between the team and its customers and suppliers, between the team and other teams in an organization, and between the team and its management. Alignment means agreement between the parties not only as to the vision for the enterprise, but also alignment between the vision and the resources required to achieve it. A failure to align properly is responsible for many cost overruns and product delivery problems.

Engineering is increasingly a creative endeavor.

Design/plan. The design and planning process forms the basis for the implementation of the creative enterprise, as well as for the "contracts" which are the basis of a formal alignment.

Manage risk. Creative enterprises are inherently risky. Management of risk throughout the creative process is key to success and allows creativity to be channeled. Risk management must begin at the earliest stages of the process and be an integral part of alignment, planning, production, and deployment.

Produce. Production may be carried out by anything from a laboratory experiment to a production line. The ability to produce must be considered at all stages of the process.

Deploy. Deployment can involve putting a product into the marketplace and providing maintenance support for it, or it can be merely handing a product off from the laboratory bench to the prototyping process.

Evaluate. Proactive, efficient, and constant evaluation is key to managing any creative enterprise. Evaluation includes selecting the right metrics, performing those measurements, and having the appropriate skills to assess how the enterprise is doing. Evaluation is an inherent part of the risk management process.

Communicate. The glue of the creative system is communication, which must be constant, effective, information-rich, and well managed. Communication technology is burgeoning, and the extraction of information from data is becoming ever more difficult. But if dealt with effectively, these factors can be used to move an enterprise forward with great speed.

The glue of the creative system is communication.

If colleges were training engineers to create collectively in addition to developing engineering competency, the following abilities (and associated coursework) would fit into such a curriculum:

- Build teams (psychology, anthropology, organizational development)
- Generate concepts (creativity, fine arts)
- Achieve alignment (negotiation, business/management, psychology, political science)
- Design/plan (business/management)
- Manage risk (cost estimation, business/management)
- Produce (manufacturing processes, industrial engineering, business/management)
- Deploy (marketing)
- Evaluate (management, marketing)
- Communicate (speech/broadcasting, information systems, visual arts)

While there are few women on engineering faculties, there are many in the arts, humanities, and business. Integration of these kinds of classes into engineering curricula would not only help prepare engineers to work in creative enterprises, but also would allow female role models to penetrate the engineering classrooms. Collaborative teaching involving male engineers and, say, female artists would provide a paradigm for gender teaming in the workplace.

I want to mention a new experiment in multidisciplinary education at the K–12 level that might have implications for woman-friendly engineering education. The Mars Millennium Project, a project of the White House Millennium Council, provides an opportunity for children to design a Martian community for 100 humans. The project will take place during the 1999–2000 school year and is sponsored by the Department of Education, the National Endowment for the Arts, the National Aeronautics and Space Administration (NASA), and the J. Paul Getty Trust. The children must consider not only the technical design of the community, but also issues of art, entertainment, governance, and architecture. Information is available on the project's website, http://www.mars2030.net.

A Multidisciplinary Project

The project aims to have children who are interested in the arts and humanities participating in teams with children whose focus is more technical. Autobiographies of famous artists and scientists will be provided on the website as inspiration, and engineers, scientists, and practitioners of arts and humanities will be available for web chats and as role models. A videotape is being produced that will feature discussions between artists and scientists about what it would be like to do art on Mars. They are considering questions like, Is there sufficient silicon in the soil to make glass for glass blowing? Is there clay for pottery? What are the colors of Mars and the lighting conditions? What are dance and architecture like when the gravity is only three-eighths that on Earth? Would low-pressure air in the habitats affect the sound of music? I am the project spokesperson and will be moderating the videotape.

In the first week after the project was announced, 15,000 classrooms and groups had signed up to participate. We anticipate that hundreds of thousands to millions of school children will have the experience of a multidisciplinary Mars adventure. It would be fascinating for someone to do a study of how such multidisciplinary exercises work, and perhaps to extrapolate the experience to the college level.

Let's assume that some of these ideas work, and we get more women engineers into the workplace. How do we keep them there? Women are increasingly dropping out of corporate life and starting their own companies. I have read that 80 percent of new businesses are started by women and that women-owned businesses employ more people than the Fortune 500. However, most engineers are still employed by large companies. Why are women entrepreneurial rather than corporate, and what would it take for engineering companies to retain women?

I believe that many of the same factors that are linked to the success of women's colleges can apply to women in corporate life. Paraphrasing *Taking Women Seriously* (Tidball et al., 1999), these include

- visionary leadership committed to the acquisition and retention of women,
- a critical mass of women in all constituencies (technicians, engineers, scientists, managers),
- belief in women's capacities and high expectations,
- places and spaces for women's voices to be heard,
- opportunities for women's leadership in all aspects of corporate life,
- celebration of traditions and institutional history,
- a high degree of trust and responsibility, and
- active and empowering women's associations in the company (e.g., Hewlett Packard's Women's Networks and JPL's Advisory Council for Women).

Instilling these qualities will not be easy for most engineering organizations, many of which are mature, led by middle-aged or elderly white males, and steeped in Cold War engineering culture. It will be particularly difficult for aerospace and energy companies (i.e., oil companies and power utilities) and somewhat easier for companies in newer industries such as computers and information systems. It is no accident that the stronghold of WITI is Silicon Valley.

Future Efforts

We should focus our efforts on influencing companies in evolving industries like biotechnology to hire women, and on encouraging women to go into emerging engineering fields like bioengineering. Universities could team up with the new industries to provide information to prospective students about career opportunities. Organizations like the NAE and SWE could provide workshops and seminars for high school or even middle school girls about opportunities in these fields.

Organizations like ASME and the NAE could make special efforts to include a number of women, not just one or two, on their governing bodies, so that there would be a critical mass of women in important constituencies who could provide leadership in getting those organizations to focus on creating and retaining women engineers.

Government organizations such as the Department of Education, NASA, and the National Science Foundation could provide incentives (e.g., grants) to universities to promote women on their faculties and in their administrations and to develop woman-friendly engineering curricula. Companies can encourage the creation of women's organizations that can provide "places and spaces" for women's voices to be heard. The JPL Advisory Council for Women, established in 1980, has provided not only a voice for women but for all employees, resulting, for example, in the establishment of a child care center.

What would it take for engineering companies to retain women?

Some companies, like Texas Instruments (TI), are making real strides in promoting women to management positions. TI currently has six women vice presidents. On the other hand, many companies and organizations (like JPL and the other NASA centers) have virtually no women in management positions. The administration and Congress could pay more attention to getting women into technical management positions in the organizations that they control. Even among congressional staffers, women in responsible positions are rare. Women engineers and scientists on the Hill are as scarce as a roc's eggs.

As I hope I've shown, numerous opportunities exist for creative solutions to the problem of insufficient numbers of women engineers in the workforce. They include taking a hard look at how engineering is done in the modern world and adapting educational strategies to the new situations, paying attention to what works to educate women and applying those principles to engineering schools, and inducing or persuading private and public organizations and universities to become more woman-friendly.

References

Carr, D. 1996. The Fulfillment of Career Dreams at Midlife: Does It Matter for Women's Mental Health? Paper presented to American Sociological Association Conference, New York.

Coates, J. F., and J. Jarratt. 1994. Workplace creativity. Employment Relations Today 21(1):11-22.

Hammer, M., and J. Champy. 1993. Reengineering the Corporation: A Manifesto for Business Revolution. New York: HarperCollins Publishers.

Peters, T. 1994. The Pursuit of WOW! Every Person's Guide To Topsy-Turvy Times. New York: Vintage Books.

Reardon, K. K. 1995. They Don't Get It, Do They? Boston: Little Brown and Company.

Shirley, D. 1997. Managing Creativity: A Practical Guide to Inventing, Developing, and Producing Innovative Products. Available online at http://www.managingcreativity.com [24 May 1999].

Smith College. 1999. Trustees vote to expand curriculum to include study of engineering. Press release. Available online at http://www.smith.edu/collegerelations/Release/engineer.html [25 May 1999].

Tannen, D. 1990. You Just Don't Understand: Men and Women in Conversation. New York: William Morrow and Company.

Tidball, E., Smith, D., Tidball, C., and L. Wolf-Wendel. 1999. Taking Women Seriously: Lessons and Legacies for Educating the Majority. American Council on Education. Phoenix, Ariz.: Oryx Press.

Increasing Diversity in the Engineering Workforce

Neal Lane

Scientists and engineers with diverse backgrounds, interests, and cultures can produce better scientific and technological results, as well as ensure the best uses of those results.

Neal Lane is assistant to the president for science and technology and director of the White House Office of Science and Technology Policy. This article is a revised version of the talk he gave 18 May 1999 during the NAE Summit on Women in Engineering.

Earlier this month, the National Science Foundation (NSF) reported some positive news in its 1998 report on *Women, Minorities, and Persons with Disabilities in Science and Engineering* (1999):

- The number of women and minorities enrolled and earning undergraduate science and engineering degrees continues to increase.
- Between 1982 and 1994, the percentage of black, Hispanic, and American Indian students taking basic and advanced math courses doubled.
- The gender gap in K–12 mathematics achievement has, for the most part, disappeared.

However, not all of the news NSF reported was good. Despite the gains, women, minorities, and persons with disabilities remain underrepresented in science and engineering fields. You have come together this week because much work remains to be done if we hope to eliminate this deficiency in the twenty-first century.

I think we all are pretty clear about why underrepresentation in science and engineering is a serious problem for our nation, but let me give you three reasons:

Underrepresentation in science and engineering is a serious problem.

- Careers in science and engineering are immensely rewarding, and all Americans should have the opportunity to participate—it's what America is all about.
- Scientists and engineers with diverse backgrounds, interests, and cultures can produce better scientific and technological results, as well as ensure the best uses of those results.
- We simply need people with the best minds and skills, and many of those people are women, many are persons with disabilities, and many are persons of diverse ethnic groups and nationalities.

Through this summit you have addressed one of the greatest challenges facing this nation. I hope you will share with me and others in the administration what you have learned in this conference, and what you will learn as you carry out the action plans you have proposed today. We will be most successful if we work together to increase the participation of women, minorities, and persons with disabilities in the science, engineering, and technology workforce.

President Clinton and Vice President Gore want every American to have the chance to reach his or her dreams. Education and training are the pillars of that commitment. They have asked me to advise them on what actions the federal government should take to build a workforce for the global economy that reflects our great diversity. Such a workforce must include the finest scientists and engineers in the world.

Today I would like to discuss some of the actions the administration has taken—through the National Science and Technology Council and through individual agencies—to help create the science, engineering, and technology workforce of the future.

First, I want to describe some innovative programs in K–12 education. Then I will spend some time previewing the likely recommendations of an interagency working group formed last fall at President Clinton's direction. He asked for advice on how to achieve greater diversity throughout the U.S. scientific and technical workforce, and I want to try out some of our preliminary thinking on you today.

Our first and greatest challenge is to make science accessible to all Americans, especially our children. Our world is increasingly technological. Science, mathematics, engineering, and technology surround us in the classroom, the home, and the workplace. Prosperity in the twenty-first century will hinge on how we handle this knowledge and technology, and on what we do now to develop scientific and technical talent in our youth.

We have a long way to go. Science and technology may be always with us, but in many ways our era still resembles the situation in the 1950s, which compelled Rachel Carson to write: "We assume that knowledge of science is the prerogative of only a small number of human beings, isolated and priest like in their laboratories. This is not true. The materials of science are the materials of life itself. Science is part of the reality of living; it is the what, the how, and the why of everything in our experience."

Two New Education Programs

All kids start out wanting to know "the what, the how, and the why" about their world. It is up to us—as parents, teachers, and citizens—to sustain that curiosity, and the joy of science and math, throughout their school years. I am sure you are already familiar with the major programs in the Department of Education (DOE) and NSF, where the focus typically has been on broad-based reform. Today I want to review two relatively new efforts: the first is a remarkable new partnership between NSF, DOE, and the National Institute of Child Health and Human Development (NICHD) to conduct large-scale education research; the second is an initiative by a relative newcomer to the K–12 education effort—the Department of Commerce.

The NSF/DOE/NICHD partnership started with the recognition that advances in education and student learning depend in no small part on rigorous and sustained research. Indeed, state and local policymakers, as well as school-level administrators, are clamoring for information about what works to guide their decisions.

Historically, investments in educational research have been insubstantial. President Clinton's Committee of Advisors on Science and Technology (PCAST) pointed out in 1997 that we spend more than $300 billion on K–12 public education each year, but we spend less than 0.1 percent of that amount on the examination and improvement of educational practice. That's far less than what it ought to be by comparison with almost any sector of industry. PCAST has recommended significant increases to fund a large-scale research program on education in general, and on educational technology in particular.

In response, the federal government launched the Interagency Education Research Initiative (IERI). This year the IERI will emphasize three key research areas: school readiness; learning core subjects, including math and science, in the early grades; and teacher training. We expect the IERI to tell us what works in K–12 education and how to make it work in diverse settings.

Teacher training has long been a priority for NSF and DOE, and their ongoing and new programs are vitally important. Today, however, I want to highlight an effort by a relatively new player in this area of growing interest—the Commerce Department's National Institute for Standards and Technology (NIST). NIST and the Office of Science and Technology Policy (OSTP) have joined forces to address the imminent math and science teacher shortage.

Partnerships Between Schools and Businesses

We have started a pilot program that partners school boards with local businesses to recruit and hire math, science, and technology teachers and provide them with full-year salaries (as opposed to typical nine-month teacher salaries) for at least four years. Business leaders will guarantee summer employment for the teachers and support the development of teaching methods that incorporate real-world experience.

The partnership builds a network for transferring knowledge from the classroom to the workplace and back again. We anticipate several benefits from this initiative:

- Kids will get better math and science teachers.
- Graduates will have a better chance of securing jobs in their communities.
- Companies will have a better chance of getting workers with the skills they need.
- Teachers will get better salaries.

Including NIST in our efforts to improve K–12 education has brought new ideas and perspectives to this issue—the very result we hope for by increasing diversity throughout science, engineering, and technology.

The federal government's interest in science and math education does not end when children graduate from high school. We take an interest in the science, engineering, and technology pipeline from beginning to end. Many federal agencies have made major commitments to encouraging students, including women and minorities, to choose careers in science, engineering, and technology. But it hasn't been enough. Margaret Mead said in 1949 that "we need every human gift and cannot afford to neglect any gift because of artificial barriers of sex or race or class or national origin." The nation—not just the federal government, but all sectors of the economy—must take that statement to heart before we are through.

Advances in education depend on rigorous and sustained research.

So where are the other sectors of the economy on this issue? In 1998, my office held a dialogue for President Clinton's Initiative on Race. We convened representatives from government, industry, and academia to discuss how to address America's science and technology challenges in the twenty-first century. Some very thoughtful observations and models for action emerged from that discussion. I took particular note of the comments of Cathleen Barton, director of Partnering for Workforce Development Programs at SEMATECH/Intel Corporation. She said, very succinctly, that education is a business, economic, and workforce development imperative (Barton, 1998). She described SEMATECH's decision to sponsor a program that would address the projected shortage of skilled operators and technicians, focusing on the community and technical colleges as primary suppliers. From June 1996 to September 1997, the SEMATECH program increased the number of colleges offering semiconductor manufacturing programs by 50 percent, and increased enrollment in semiconductor manufacturing programs by 110 percent.

We need more success stories like that. I believe the administration should engage in a national dialogue with private industry, academia, and local government and community leaders to identify the barriers that inhibit the full participation of women, minorities, and persons with disabilities in the nation's science, engineering, and technology workforce. We can work with the private sector to overcome those barriers by ensuring that the companies who depend on this workforce know about best practices that lead to increased participation of the affected groups. The interagency working group convened last fall at the president's direction is hard at work on building this national dialogue.

I want to encourage agencies to think about diversity as a part of everything they do.

I expect the working group to make a number of recommendations for the president's action. It is likely we can do more, for instance, to facilitate key transition points in education. We have some excellent models of success to build on. A great example is the Bridges Program at the National Institutes of Health (NIH), which helps minority students at two-year community colleges make the transition to four-year colleges, and students in master's degree programs to make the transition to doctoral programs. Two successful NSF initiatives—the Advanced Technological Education Program and Alliances for Minority Participation—may also be transferable to other agencies.

We may also try to enhance support for undergraduate and graduate education. Ideally, this support would include general financial aid as well as outreach and recruitment, mentoring programs, counseling and academic support, internships, and other practical training experiences. NSF and NIH, as well as NASA, the Department of Agriculture, the Department of the Interior, the Environmental Protection Agency, and other research and development agencies, have well-grounded programs ripe for expansion.

I particularly want to encourage agencies to think about diversity as a part of everything they do, not just special programs. The Department of Energy has done this with its contracting process for the national laboratories, with great success at Los Alamos. And NSF recently adopted new merit review criteria, which are used to identify and fund the best research proposals. One of the new criteria addresses societal impacts, including human resource development and contributions to increased diversity. We have a long way to go before all agencies think this way all the time.

We hope that our national dialogue with industry will encourage businesses to support undergraduate and graduate education, perhaps through privately administered funds devoted to awarding science and engineering scholarships to women, minorities, and persons with disabilities. Companies and federal agencies should also be encouraged to form partnerships with community colleges near their operations sites to provide students with relevant skills. The Los Alamos partnership with community colleges in New Mexico is a model for action in this area.

Additional Research Needed

Last, but never least, we should conduct additional research. The federal government should take the lead in fully understanding the dimensions of the human resources challenge in the science, engineering, and technology workforce. Research areas should include the demographics of this workforce, the value of diversity in science and engineering research and application, and barriers to participation.

To conclude my remarks, I want to cite President Clinton, who said: "First, science and its benefits must be delivered toward making life better for all Americans—never just a privileged few. . . . Science must not create a new line of separation between the haves and the have-nots, those with and those without the tools and understanding to learn and use technology. . . . Science can serve the values and interests of all Americans, but only if all Americans are given a chance to participate in science."

I agree with the president, and we are taking seriously his admonition to open science, engineering, and technology careers to all Americans. But at the same time, we must remain an open society—a society that welcomes immigrants and visitors from foreign lands—if we are to succeed at anything, especially science. I want to quote one more brilliant woman, Pearl Buck, who said, “Exclusion is always dangerous. Inclusion is the only safety if we are to have a peaceful world.”

No matter how successful we are in recruiting Americans into the science, engineering, and technology workforce, there has always been and must always be a place for foreign workers if we are to remain the world’s leader in this enterprise. I believe this view is widely shared, and I hope that cooler heads will ultimately prevail on Capitol Hill, and that we will go no further down the path of exclusion.

I want to close by repeating what I said at the outset about why underrepresentation of women, minorities, and persons with disabilities in science and engineering is so important to our nation’s future.

- Everyone deserves a chance to become a scientist or an engineer; these are, without question, among the most exciting and fulfilling careers available.
- Science and engineering are vitally important to this nation’s future, and we need all the best minds concentrated on advancing our knowledge and skills in those areas.
- Homogeneity makes us stale—we need diverse backgrounds and perspectives to keep our lead in this age of innovation.

Please work with me—with all of us in the White House and federal agencies—to put the face of America on science and engineering. It will make for a better America, and for a better world.

References

Barton, Cathleen. 1998. Partnering for workforce development: A model for increasing the supply of skilled workers. Paper presented at Meeting America’s Needs for the Scientific and Technology Challenges of the Twenty-First Century: A White House Roundtable Dialogue for President Clinton’s Initiative on Race, Washington, D.C., February 13.

National Science Foundation (NSF). 1999. Women, Minorities, and Persons with Disabilities in Science and Engineering: 1998 (NSF 99–338). Arlington, Va.: NSF.

The Future of Women in Engineering

Nancy Ramsey

New, sustainable, and comprehensive initiatives for bringing women into engineering are possible but will require changes in the status quo.

Nancy Ramsey, former legislative director to Senator John Kerry, is a futurist, entrepreneur, and author. This is an edited version of her speech given 17 May 1999 at the NAE Summit on Women in Engineering.

Several months ago I began my research for these comments by asking what there was to celebrate about women in engineering. Over the months, in interviews and readings, I've found that there is indeed a great deal to celebrate.

First, there are great pioneers like Grace Hopper, who contributed groundbreaking work in computing. And there are outstanding contemporary women, many of whom are here today as participants, who make daily contributions to engineering through the excellence of their work and their support of other women, professional organizations, and schools.

There are also men to celebrate—the mentors, relatives, colleagues, and leaders who have encouraged and welcomed women engineers. Students should also be celebrated. From grammar school to graduate school, tomorrow's engineers are preparing for exciting, challenging, and rewarding careers. And, finally, there are the institutions and organizations that provide support, networking, encouragement, and funding to women in engineering.

But the celebration goes beyond the individuals. As a futurist I search for trends, and the most encouraging trend for women in engineering is best portrayed in contrasting pictures. Nearly 30 years ago this nation's engineers led one of the greatest accomplishments of all time when America landed the first humans on the moon and returned them safely to Earth. Four subsequent crews followed in successive triumphs. Can you recall a picture of those engineers? They were all white men in white shirts, most with plastic pocket protectors to hold tidy rows of pens and pencils.

A Glimpse of the Future

On July 4, 1997, American engineers achieved another triumph in space, landing a craft on Mars and rolling out the diminutive but elegant Sojourner to explore the surface. That historic moment was shared with a rapt television and Internet audience of hundreds of millions worldwide. But the picture of Sojourner wasn't the only memorable picture that day—another was of women engineers working as equals in a program that obviously couldn't have been executed without them.

That July 4 picture provided a glimpse into the future of engineering. It is a future rich in women and men of diverse cultures and races working to solve problems in a connected, technological world. It is what expanding companies tell us they need, and it is what the challenges of a new global economy dictate.

But that picture of a diverse team is a rare one. Engineering for the most part remains a predominantly white male profession. As Smith College found in its recent study of the engineering education system, roughly 5 out of 6 engineering students are male, as are 9 out of 10 engineering professors (Connolly, 1999). Women still make up less than 10 percent of working engineers in America today. A woman in engineering today is often a woman alone.

Is it changing? Yes. Are more women engineers joining the workforce every year? Yes. But despite these reasons for celebration, we should not pop all the champagne corks yet. Some should be saved for celebrating the milestones of progress in engineering accomplishments ahead. Some should be saved for those accomplishments that bring in and retain a broader, deeper pool of capable individuals doing the work they love—engineering.

While each person's decision to pursue her or his career is ultimately a personal one, an increasing body of research provides some insight into why there are so few women in science and engineering (see, for example, Blaisdell, 1995; Georgia Institute of Technology, 1998; MIT Faculty Newsletter, 1999). There are no secrets or mysteries in understanding the missing girls and women, and there are no magic bullets to solve the problems that contribute to their absence. What we know is this: "environmental" factors—such as isolation, exclusion from networks, and lack of role models—are a major source of discouragement for girls and women in science and engineering.

Much of the literature about women in science and engineering contains familiar stories. In interview after interview, women tell of workplaces where small, daily, demeaning, and condescending acts wear away at them. Some tell of assignments passed over and promotions denied. Others tell of being promoted too soon with little support in a new and difficult position, or of feeling set up for failure. Often these women choose to leave. If they sue they might win, but they might also risk never working again.

Although many women engineers persevere through such difficulties to achieve success, there are others who are less able to endure or fight for themselves. If progress is to be made, it is imperative that the subtle gender preference awarded to men in education and industry be understood, acted upon, and changed.

Science, technology, and engineering all need the talent of women's minds.

Executives, managers, line engineers, and educators sometimes state that it is not engineering's job to deal with the attitudinal and behavioral factors that discourage girls and women from entering the field. Is it not fair, then, to ask whose job is it? Science, technology, and engineering all need the talent of women's minds and the richness of their different perspectives. It must be all of our jobs to challenge and change those factors that discourage women.

Engineering is on a demographic collision course with the future. The generation of engineers who joined the workforce in the 1960s is well on its way to retirement, and the baby boomers will be leaving right behind them. Currently, 20 percent of our population is over 65, and by 2011 that number will double. A baby boomer turns 50 every 6.7 seconds—more than 10,000 each day—and we do not have a replacement generation.

Nearly half the graduates of America's engineering schools today are foreign nationals—welcome participants in our society, but people who don't necessarily stay. Every year high-tech companies are forced to plead for more work visas for foreign engineers to fill positions for which there are not qualified American candidates.

Our task is to draw a new map for recruiting, retaining, and advancing women in engineering.

This dependence on skills and talents beyond our borders is considered by some to be a national crisis. If so, we must address it by mining the intelligence, energy, and resourcefulness of our female population. We need to raise our daughters to be engineers.

If we can put women into business, law, and medicine at levels nearly equal to men, why can't we do it in engineering? If engineers can put people on the moon and robots on Mars, surely they can figure out how to put women in engineering.

Our task over these two days is to engage our collective creativity and intelligence to draw a new map for the recruitment, retention, and advancement of women in engineering. We are here to identify and expand actions that have proved successful in the past, and to explore and adopt new ones. We are here to engage ourselves and others in this task, to go beyond lofty rhetoric, and to commit to ending this gender gap.

This is an exciting time to take up the challenge. We are midstream in rapid, deep, discontinuous changes in our economic, political, and social systems. While these changes are unsettling, they also offer an opportunity to review past practices and hold them up to the light of new realities. Let me paraphrase Alan Greenspan in his testimony before the Senate Budget Committee this year (Greenspan, 1999). When discussing the difficulties in making economic forecasts, he noted that we are facing completely new situations, with no models to follow and no successes to duplicate. To keep pace with change, we must make up new responses every day.

More of the Same Will Not be Enough

A Silicon Valley electrical engineering executive voiced it this way in explaining the demands in the technology world of the future: "What got us here won't get us there." That simple sentence also fits the challenge of recruiting more women to engineering. More of the same will not be enough.

It is helpful to review the breadth of changes we experience each day:

- Breakthroughs in technology are redrawing the parameters of communication and learning at levels of magnitude as great as those generated by the printing press in the sixteenth century. From distance learning to real-time news, the world is growing more connected.
- Advances in biotechnology, medicine, and pharmaceuticals are extending the human life span. Many of us here today are likely to live to be 100.
- New models for open, horizontal, transparent organizational systems are replacing the top-down hierarchies of aging command and control systems. From business to the military, open systems are challenging old structures.
- Global economic integration is creating interdependence beyond what we could have imagined even a decade ago. International standards, agreements, and institutions are establishing new models in trade and commerce. Currencies and work efforts pulse around the globe 24 hours a day in never-ending cycles of intellectual and commodity production.
- Environmental awareness has grown worldwide. International agreements are framing an approach to deal realistically with global climate change, and citizen groups prod and monitor corporate compliance and progress.
- In the arts, designers and architects are using new materials and creativity to redesign the interface

between light and space in public places in a manner unmatched since the great cathedrals of Europe. Dance is resplendent with new explorations of the human body's grace and movement, and music is exploding with new sounds, new rhythms, and new ways of delivering classic and folk melodies.

And what about women? In the midst of this diverse, historic change, nothing has affected the twentieth century social order more than the change in the status of women. Every family, workplace, man, and woman feels it. Can we look at the magnitude of change around us and honestly believe that the kinds of programs we have used in the past will succeed now to encourage the sustainable recruitment and retention of women in engineering? If engineering is to recruit and retain women above current levels, can it do so without being more responsive to their expectations and needs?

Welcoming Women into Engineering

Perhaps we can answer those questions best by looking more closely at what researchers, pollsters, marketers, and women themselves tell us about their priorities and lives. First and foremost, women are clear that being equal with men does not mean being the same as men. Today more than ever, women see the characteristics and qualities of gender difference without any attached judgement of better or worse. Instead, they appreciate and celebrate those differences.

Women have confirmed through their experiences a confidence that there is often more than one way to accomplish a task, do an assignment, meet a deadline, or land a client. They articulate that the male norm is no longer acceptable as the default for what is standard or "right." Particularly in younger generations, women are determined to try new models for living and working, without the limiting stereotypes that so many of us have known. Their understanding can give us a new perspective of how to open the field of engineering to women.

Women go where they are welcomed. As they have been welcomed into law and medicine, they can be welcomed into engineering.

In their years of work on social and political issues, women have developed networks of contacts and informal communication channels. Today every community, business, political, and professional organization has a women's network. Tapping into those networks gives women information they won't find in newsletters or web pages. It tells them, for example, what other women are experiencing at work, from promotion fairness to family leave and wage equity.

Women today are working outside the home more than ever before. Fully 90 percent of America's women will work outside the home during their lifetimes. How many work as engineers will be partly our responsibility. Young women know their options and are looking for workplaces and professions that treat them fairly and promote them equally.

Women continue to carry the majority of family responsibilities for both children and elder family members. While data show that increasing numbers of men share these responsibilities, particularly in younger generations, women still bear most of the burden, juggling work and family in a daily dance of improvisation. To meet their needs, women search out work situations that allow flexibility, and they reward those employers with increased loyalty. When intransigent work structures and attitudes make balancing work and family impossible, they increasingly leave, taking with them their education, training, experience, and clients.

As women have been welcomed into law and medicine, they can be welcomed into engineering.

Women are increasingly visible in corporate management—nearly 40 percent of middle managers are women. But in the executive jobs and corporate board positions, their numbers remain at approximately 10 percent, only slightly higher than they were nearly 30 years ago.

Women are now the majority of graduates in high school and college, and their numbers are increasing in almost all graduate schools. They know that an education is the most demonstrable credential toward equality in the workplace, and they are willing to work hard and stay in school.

There are unique opportunities to build new, sustainable and comprehensive initiatives for bringing women into engineering today. To accomplish this, engineering must be ready for some changes. A key question for engineering is how much can it, like other professions, adapt to survive?

Engineering adapts well to technological change, but in terms of human resources it has a long way to go. To some minds, engineering's survival as a profession may be at stake. If the predicted demand for engineers is left unmet, it could lead the marketplace to redefine the profession and establish new criteria to meet its own economic needs. The market will not wait forever to fill vacant engineering slots.

The days are over when engineering, science, and technology firms could count on the deep pockets of federal government agencies to fund research and prototype development. In the global marketplace the profit margin is increasingly generated from the intellectual capital of people, and more often, that capital has a woman's face. Engineering, like the market, needs diversity to grow.

Changing Mental Maps

Changing long traditions and "mental maps" may be necessary, but it is not easy. Let me illustrate with a brief story. Early cartographers who drew North America for Spanish missionaries identified California as an island. It was a logical assumption based on observations of the Pacific Ocean and the Bay of Baja. So, the first missionaries to California took with them huge wooden boats. They hauled those boats across the state and over the mountains, only to find the great California desert—a mighty big beach. The missionaries sent word to the cartographers that the maps were wrong. "California is not an island," they reported, "change the maps." The cartographers sent back word from Spain. "The map is right. You are in the wrong place." For nearly 80 years the maps stayed unchanged until the King of Spain prevailed upon the cartographers to correct them.

It is hard to change any map, especially our mental map. But if we are following the wrong map, our journey is surely in jeopardy. Gender-diverse recruitment and retention are essential to engineering. To achieve them we must first acknowledge the male gender preference that exists today. And like academic excellence and mathematics proficiency, we must make gender equity a concrete goal and adjust our mental map of engineering to include it.

Gender equity is as profound a change as the transition from the industrial to the digital age. It is as profound as leaving this beautiful blue Earth for the far reaches of space. It is possible. Engineers have led the way to historic triumphs in our lifetime and they can lead the way here too.

Consider with me what legacy this profession can leave. Engineers can make social and cultural changes of such depth and breadth that future generations will look back at this time and call it an engineering feat as profound as Stonehenge, as great as the pyramids.

Engineers took us to the moon in only 10 years. Engineers have taken us to Mars. Engineers can take us to gender equity.

Ladies and gentlemen, start your engines. The race is on.

References

Blaisdell, S. 1995. Factors in the Underrepresentation of Women in Science and Engineering: A Review of the Literature. Women in Engineering Programs & Advocates Network (WEPAN) Working Paper 95-1. West Lafayette, Ind.: WEPAN.

Connolly, J. 1999. Speech delivered at All College Meeting, Smith College, Northampton, Mass., January 25.

Georgia Institute of Technology (GIT), 1998. InGEAR Report on the Status of Women at Georgia Tech. Atlanta, Ga.: GIT.

Greenspan, A. 1999. Statements before Committee on the Budget, U.S. Senate, Washington, D.C., January 28.

MIT Faculty Newsletter. 1999. A study on the status of women faculty in science at MIT. MIT Faculty Newsletter XI(4):1–16.

NAE News and Notes

NAE Newsmakers

Anil K. Chopra, the Johnson Professor of Civil Engineering at the University of California at Berkeley, received the 1999 **Distinguished Teaching Award,** the highest teaching award given by the university.

Charles Concordia, private consulting engineer, received the 1999 **Medal of Honor,** awarded by the Institute of Electrical and Electronics Engineers (IEEE). Dr. Concordia was cited for outstanding contributions in the area of power system dynamics which resulted in substantial improvements in planning, operating, and security of extended power systems.

The American Academy of Environmental Engineers (AAEE) presented the **Stanley E. Kappe Award** to **Richard A. Conway,** environmental consultant, Charleston, West Virginia. The award was presented in recognition of his extraordinary and outstanding service that contributed to significant advancement of public awareness to the betterment of the environment.

Albert A. Dorman, founding chairman, AECOM, received an honorary doctor of science degree from the New Jersey Institute of Technology in January 1999.

Harvey F. Ludwig, chief environmental engineer, Seatec International Consulting Engineers, was made an **Honorary Diplomate** of the AAEE. Only five other individuals have been given this award of distinction.

Carver Mead, Gordon and Betty Moore Professor, California Institute of Technology, won the 1999 **Lemelson-MIT Prize.** Dr. Mead was awarded the $500,000 grant for his many contributions to the field of microelectronics, which have led to a new business model for the industry and enabled a new wave of innovation in information technology.

David G. Messerschmitt, Roger A. Strauch Professor, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, was awarded the 1999 IEEE **Alexander Graham Bell Medal** for fundamental contributions to communications theory and practice, including VLSI for signal processing, and simulation and modeling software.

Foreign Associate **John R. Philip,** fellow emeritus, Land and Water Commonwealth Scientific and Industrial Research Organization, was awarded the 1998 **Jaeger Medal** of the Australian Academy of Science. The medal is given for outstanding research in the earth sciences.

John M. Prausnitz, professor of chemical engineering, University of California, Berkeley, is the recipient of the **William Corcoran Award** of the American Society for Engineering Education.

John W. Townsend, Jr., retired director, NASA Goddard Space Flight Center, was awarded the 1999 **Edward A. Flinn III Award** from the American Geophysical Union.

James E. Turner, Jr., president and chief operating officer, General Dynamics Corporation, is the recipient of the **Distinguished Alumnus Award** from Virginia Tech's College of Engineering.

Andries van Dam, Thomas J. Watson, Jr., University Professor of Technology and Education and professor of computer science, Brown University, is the recipient of the 1999 IEEE **James H. Mulligan, Jr., Education Medal.** Dr. van Dam was honored for his field-defining textbooks, the introduction of innovative educational technology, and inspired undergraduate teaching.

• • •

The following NAE members were elected to the National Academy of Sciences (NAS) on 24 April 1999: **Elwyn R. Berlekamp,** professor of mathematics, University of California, Berkeley; **Paul A. Fleury,** dean and professor, School of Engineering, University of New Mexico, Albuquerque; **Thomas J. Hanratty,** James W. Westwater Professor of Chemical Engineering, emeritus, University of Illinois, Urbana-Champaign; and **Ronald F. Probstein,** Ford Professor of Engineering, Massachusetts Institute of Technology.

NAE Members Elect Councillors

As a result of the spring 1999 Officers and Councillors Election by the members of the NAE, the foreign secretary and three other members of the Academy's governing Council were re-elected. A fourth councillor was also chosen in May, by vote of the Council, in accordance with the Academy's bylaws. All terms begin 1 July 1999.

Harold K. Forsen, retired senior vice president at Bechtel Corporation, was re-elected to a second four-year term as the NAE's foreign secretary and a member of the governing Council. Dr. Forsen will continue to oversee the international activities of the Academy and coordinate its contact with engineering academies in other countries. Forsen was elected to the NAE in 1989 and is a member of the Electric Power/Energy Systems section. He earned a Ph.D. in electrical engineering from the University of California at Berkeley.

Re-elected as councillors for three-year terms were **Thomas E. Everhart, Julia R. Weertman,** and **Eugene Wong. Robert A. Pritzker** was elected by the Council at its May meeting. This position is filled subsequent to the members' election of councillors to ensure that the distribution of engineering disciplines on the Council is representative of the Academy membership. Councillors have paramount authority with respect to the funds, activities, policies, and purposes of the Academy.

Thomas E. Everhart, president emeritus, California Institute of Technology, was elected to the NAE in 1978 and is a member of the Electronics Engineering section. Everhart earned a Ph.D. in engineering from Clare College, Cambridge University, Cambridge, England.

Julia R. Weertman is the Walter P. Murphy Professor of Materials Science and Engineering at Northwestern University, Evanston, Illinois. She was elected to the NAE in 1988 and is a member of the Materials Engineering section. Dr. Weertman earned a D.Sc. from Carnegie Institute of Technology (now Carnegie Mellon University) in Pittsburgh, Pennsylvania. Her husband, **Johannes Weertman,** is also an NAE member.

Eugene Wong is assistant director for engineering with the National Science Foundation in Arlington, Virginia. He was elected to the NAE in 1987 and is a member of the Electronics Engineering section. Dr. Wong received his Ph.D. in electrical engineering from Princeton University.

Robert A. Pritzker

Robert A. Pritzker is president and chief executive officer of the Marmon Group, Inc. in Chicago. He was elected to the NAE in 1991 and is a member of the Industrial, Manufacturing and Operational Systems Engineering section. Pritzker received a B.S. degree in industrial engineering from the Illinois Institute of Technology.

Davis Joins NAE as Executive Officer

Lance A. Davis

The NAE is very pleased to announce that **Lance A. Davis** assumed the position of executive officer on 1 May 1999. In that position he will oversee the daily operations of the NAE and play a significant role in the Academy's fundraising activities. He was elected to membership in the NAE in 1992 "for personal contributions to and leadership of the development of novel amorphous and microcrystalline materials via rapid solidification technology."

Dr. Davis comes to this position with an impressive background. As deputy director for defense research and engineering and director of the Office of Technology Transition for the Department of Defense (DOD), Davis was charged with facilitating DOD's defense reinvestment and conversion activities to enhance national security and the industrial base. In a dual role as the director for laboratory management, Dr. Davis also had oversight responsibility for restructuring and revitalizing the DOD's $10 billion laboratory system.

Prior to his tenure with DOD, Dr. Davis had a long and distinguished career with AlliedSignal in Morristown, New Jersey. He began as a research staff applied scientist, during which time he conducted independent research on the mechanics of thermoplastics and Metglas alloys. He served as vice president for research and development for nine years prior to joining DOD.

Dr. Davis received his Ph.D. in engineering and applied science from Yale University and was elected to Phi Beta Kappa and Tau Beta Pi while an undergraduate at Lafayette College. He has authored or coauthored 53 technical papers related to the synthesis, microstructure, and properties of materials. Davis is the coholder of six U.S. patents related to Metglas alloys.

Davis succeeds William C. Salmon, who stepped down as executive officer after serving in that capacity since 1986.

NAE Staff Awards

At the NAE Council luncheon held 14 May 1999 in Washington, awards were presented to several NAE staff members. Victoria Friedensen, program officer, was presented the award for her leadership, dedication, and contributions in working with the steering committee for the Celebration of Women in Engineering (CWE) project and for coordinating the NAE Summit on Women in Engineering. Long Nguyen, program assistant, received the award for his initiative in developing a project/meetings logistics management database, his leadership in coordinating FACA-compliance issues, and for his assistance wherever needed.

Thomas Roberts, web manager, was given the award for outstanding performance and for helping create the website for the CWE project. Presented awards for dedication and length of service were Vivienne Chin, senior administrative assistant, and Maribeth Keitz, senior information assistant, each with 10 years; and Mary Kutruff, administrative assistant, with 5 years.

It was also announced that Penelope Gibbs, senior administrative assistant, would receive a 1999 NRC Individual Staff Award. Penelope was nominated by her colleagues for exemplary performance in terms of productivity, quality, professionalism, team effort, and congeniality. She is the first NAE staff member to receive such an award.

Councillor **Walter L. Robb** was also recognized at the luncheon for six years of service on the NAE Council. His term ends 30 June 1999.

"The National Academies" Adopted as Identifier

On 21 May 1999, "The National Academies" was implemented as the new collective identifier for the four institutions formerly known as the "Academy Complex." The new name was adopted to raise the public image of the Academies and to encourage a unified identity. In the past, it has been difficult to explain clearly that the NAE, NAS, Institute of Medicine (IOM), and NRC, although four separate entities, have a unique working relationship. It is anticipated that this new identifier will clear up any confusion among our audiences.

The new identifier extends to the Academies website, which now employs this URL: http://www.nationalacademies.org. Staff e-mail addresses will not be affected by this change. The bridge logo will continue to represent the NAE and will be included, along with the new identifier, on NAE printed materials.

Construction of New Academies Building Begins

The NAE, NAS, IOM, and NRC will bring more than 900 employees together in a new state-of-the-art office building to be built at Fifth and E Streets, N.W., in Washington, D.C. The National Academies purchased the site in January; groundbreaking for the new building occurred June 17, and the building will open in late 2001. The total cost for the project is estimated at $130 million.

The site for the 11-story, 350,000-square-foot building is adjacent to the MCI Center, a downtown sports and entertainment facility. Currently, the National Academies staff is located in office buildings in upper and lower Georgetown, and in the headquarters building at 2101 Constitution Avenue. About 200 people will remain at the headquarters building, where the executive offices are located.

1999 Annual Meeting Preview

The 1999 NAE Annual Meeting will be held 3–5 October at the National Academies building in Washington, D.C. The format will be similar to last year with an expanded schedule of activities for members, foreign associates, and their guests.

New members will gather on Saturday, 2 October, for the Class of 1999 orientation. The afternoon will begin with a luncheon and will be capped off by an invitation-only black tie dinner and reception in the Great Hall that evening, both hosted by the NAE Council.

The program for all members and foreign associates begins Sunday afternoon, 3 October. NAE Chair **Robert J. Eaton** and NAE President **Wm. A. Wulf** will address the gathering prior to the induction of the Class of 1999. The awards ceremony follows with the presentation of the 1999 NAE Founders Award to **Stephen D. Bechtel, Jr.,** chairman emeritus and director, Bechtel Group. Bechtel served as the first chairman of the NAE from 1982–1986 and was cited "for decades of exceptional accomplishments in civil engineering, corporate management, and civic, educational and professional development, all of which have been of great benefit to people in the United States and around the world." The 1999 Arthur M. Bueche Award will be presented to **H. Guyford Stever,** former president of Carnegie Mellon University and former director of the National Science Foundation. Stever, who served as foreign secretary of the NAE from 1984–1988, was cited "for a lifetime of exceptional service to engineering and society as a researcher, university president, and government official, and for the style of leadership that has made him a preeminent U.S. statesman in science and technology."

Monday, 4 October, will start with the annual business session. Members, foreign associates, and their guests will then have the opportunity to choose from among a number of briefings on a variety of topics. The afternoon will be devoted to section meetings, allowing each section to set their own agenda and participate in a focused discussion on topics of special interest. That evening the traditional NAE dinner dance will be held at the J. W. Marriott Hotel.

The final day of the meeting, Tuesday, 5 October, will be devoted to a technical symposium on the engineering challenges of expanding urbanization. The symposium will address the social and engineering challenges posed by the crumbling infrastructure of our cities and the implications of urbanization on cities and surrounding areas.

Second German-American Frontiers of Engineering

The second German-American Frontiers of Engineering Symposium was held at the Beckman Center in Irvine, California, 8–10 April. Modeled on the U.S. Frontiers of Engineering Symposium, this bilateral Frontiers meeting brought together 60 engineers, ages 30–45, from German and U.S. companies, universities, and government. Observers from the United Kingdom, the Netherlands, France, Australia, and Japan also attended the meeting.

The goal of the Frontiers meetings is to bring together emerging engineering leaders in a forum where they can learn about leading-edge developments in a range of engineering fields, thereby facilitating an interdisciplinary transfer of knowledge and methodology. In the case of the bilateral Frontiers, there is the added dimension of helping build cooperative networks of younger engineers that cross national boundaries.

NAE member **Robert A. Brown,** provost and Warren K. Lewis Professor of Chemical Engineering at the Massachusetts Institute of Technology, and Wolfram Boeck, chair in electrical power and systems technology at the Technical University, Munich, cochaired the organizing committee and the symposium. NAE member **Matthew V. Tirrell,** University of Minnesota, also served on the organizing committee.

The four topics covered at the meeting were biological engineering, information technology, precision engineering, and microelectromechanical systems (MEMS). Specific presentations, given by two Germans and two Americans in each of the four areas, covered such topics as artificial biosensing interfaces, content protection of digital media, magnetically levitated precision positioning stages, and microsystems in medicine. As with the U.S. meeting, there was ample opportunity for discussion among the participants, both during the formal sessions and during breaks, receptions, and dinners. A highlight of the meeting was a tour of the Jet Propulsion Lab in Pasadena followed by a dinner at The Athenaeum at the California Institute of Technology, hosted by NAE member **Thomas E. Everhart.**

Funding for the German-American Frontiers of Engineering was provided by the German-American Academic Council Foundation (GAAC). The GAAC was founded in an agreement between German Chancellor Kohl and President Clinton in 1993 and has as its objective the strengthening of German-American cooperation in all fields of the sciences, engineering, and the humanities, particularly by fostering interaction among younger scientists, engineers, and scholars and by supporting policy studies on topics of mutual interest to both countries.

A booklet containing the abstracts of the symposium presentations will be published in English this fall. A third German-American Frontiers of Engineering symposium, cochaired by Matthew Tirrell and Eduard Reithmeier, University of Hannover, will be held 13–15 April 2000 in Bremen, Germany. At that meeting, participants from other European countries will be invited in a continuing effort to transition this activity into a European-American Frontiers of Engineering Symposium.

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

Workshop Held on Prizing Innovation

On 30 April 1999, at the request of the White House National Economic Council (NEC), the NAE convened a workshop to assess the potential of using federally sponsored "inducement" prizes to advance science and technology in the public interest. The workshop was funded by the National Science Foundation (NSF) and organized by a five-member steering committee comprised of **Erich Bloch** (chair), president, Washington Advisory Group; **Paul G. Kaminski,** chairman and CEO, Technovation, Inc.; **Daniel M. Tellep,** retired chairman, Lockheed Martin; David Mowery, Milton W. Terrill Professor of Business, University of California, Berkeley; and former Congressman Robert S. Walker.

In the past, inducement science and technology prizes—competitions designed to encourage progress toward or achievement of a specific objective—have been sponsored almost exclusively by private entities. This one-day workshop brought together 35 representatives of federal research agencies, private firms, universities, foundations, and other organizations to consider whether such prizes should be added to the U.S. government's science and technology policy portfolio. Specific questions considered by workshop participants included: What are the advantages and disadvantages of inducement prizes vis-à-vis other policy instruments? What would be appropriate objectives for such contests and prizes? How should such contests and prizes be designed and administered?

Former House Speaker Newt Gingrich and Claude Barfield, senior fellow at the American Enterprise Institute, set the context for the day's discussions by providing an advocate's and a skeptic's perspective, respectively, on the potential of federal inducement prizes. The ensuing discussion, moderated by Erich Bloch, was followed by a panel of prize administrators and prize winners. Chaired by David Mowery, the panel included presentation of a background paper on technology prizes prepared by Patrick Windham, consultant, and remarks by Ronald Kerber, executive vice president and chief technology officer of Whirlpool Corp., whose company won the utility-sponsored Superefficient Refrigerator Program (SERP) Prize in 1992; Peter Diamandis, president of the X-Prize Foundation, which seeks to advance human space flight by offering a prize to the first group able to put three people into suborbital space twice within a three-week period; Neen Hunt, executive director of The Albert and Mary Lasker Foundation; and Harry Hertz, program director of the Malcolm Baldrige Quality Awards.

A second panel during the afternoon combined industry, agency, and legislative perspectives on the potential contributions of prizes to the missions of specific agencies as well as on broader policy challenges of inducement prizes. Chaired by former Congressman and House Science Committee Chair Robert S. Walker, the panel included Rita Colwell, director of the NSF; Richard Dunn, general counsel at the Defense Advanced Research Projects Agency; Robert Galvin, chairman of the executive committee, Motorola, Inc.; Lori Garver, associate administrator for policy and plans, NASA; and Harold Varmus, director of the National Institutes of Health.

There was general agreement among workshop participants that the utility of prizes as policy instruments is unproven. However, most participants agreed that inducement prizes might prove to be a small yet potentially potent complement to the prevailing means by which government supports research and innovation—namely, research grants and technology procurement.

Possible goals for federal inducement prizes include identifying and engaging nontraditional participants and unorthodox ideas in pursuit of specific technical or societal objectives; addressing important yet neglected or seemingly intractable societal problems such as adult illiteracy, air pollution, and buried mines; fostering new applications and diffusion of existing technology (as is the case of the SERP Prize); and educating the public about the excitement and usefulness of research and development.

The steering committee is currently preparing a brief report on the workshop with recommendations for action that it expects to submit to the NEC, the NSF, other relevant agencies, and members of Congress later this summer.

Technological Literacy Project Launched

The first meeting of the Committee on Technological Literacy was held 12 May at the National Academies building in Washington. The committee, chaired by NAE member **A. Thomas Young,** Lockheed Martin (retired), is overseeing Making the Case for Technological Literacy, a joint project of the NAE and the NRC Center for Science, Mathematics, and Engineering Education. The project is funded by the National Science Foundation and Battelle.

Making the Case is the keystone effort in a larger program of activities devoted to the issue of technological literacy. NAE President Wm. A. Wulf has made improving technological literacy in the United States—particularly among K–12 students—a central theme of his administration. NAE member **William A. Anders,** General Dynamics Corp. (retired), also serves on the study panel. (See box for the full committee roster.)

At the 12 May meeting, the committee discussed the nature of the technological literacy "problem," the audiences the project should reach, and the types of products that would most effectively carry the committee's message. The next meeting of the committee is scheduled for 10–11 September.

Other NAE work under the technological literacy banner includes providing input to a set of K–12 technology education standards being developed by the International Technology Education Association and working to engage the engineering education community in regional precollege science education reform efforts.

For more information about the project, contact Greg Pearson, program officer, at (202) 334-2282 or via e-mail at gpearson@nae.edu.

Committee on Technological Literacy
National Academy of Engineering / Center for Science, Mathematics, and Engineering Education

A. Thomas Young (Chair)
Retired Executive Vice President
Lockheed Martin Corporation

Paul Allan
Colony High School
Palmer, Alaska

William A. Anders
Retired Chairman
General Dynamics Corporation

Jonathan R. Cole
Provost and Dean of Faculties
Columbia University

Rodney L. Custer
Chair, Department of Industrial Technology
Illinois State University

Paul De Vore
President
PWD Associates

Goery Delacote
Executive Director
The Exploratorium

Denice Denton
Dean of Engineering
University of Washington

Peter Eio
President
LEGO Systems, Inc.

Karen Falkenberg
Manager
Elementary Science Education Partners Program
Emory University

Shelagh A. Gallagher
Associate Professor
Department of Counselling, Special Education, and Child Development
University of North Carolina at Charlotte

Joyce Gardella
Principal
Gardella & Associates

David T. Harrison
Sinclair Community College

Paul Hoffman
Senior Vice President and Publisher
Encyclopedia Brittanica

Jondel Hoye
President
Keep the Change, Inc.

Mae C. Jemison
Professor
The Jemison Institute for Advancing Technology in Developing Countries
Dartmouth College

F. James Rutherford
Education Advisor to the Executive Officer
American Association for the Advancement of Science

Kathryn C. Thornton
Professor
Division of Technology, Culture & Communication
University of Virginia

Robert F. Tinker
President
The Concord Consortium, Inc.

NAE Calendar of Meetings

1999

28 June	German-American Frontiers of Engineering Committee
29 June	Committee on the Impact of Academic Research on Industrial Performance
15 July	NAE Finance and Budget Committee (conference call)
16 July	NAE Congressional Luncheon
3–5 August	NAE Council Woods Hole, Mass.
6–7 August	NRC Governing Board Woods Hole, Mass.
8 August	NRC Governing Board Executive Committee Woods Hole, Mass.
26 August	Charles Stark Draper Prize Committee
2 September	Committee on Making the Case for Diversity in the Engineering Workforce
9 September	NRC Governing Board Executive Committee
10–11 September	NAE/CSMEE Committee on Technological Literacy Green Building
15 September	NAE Finance and Budget Committee
17 September	NAE Congressional Luncheon
1–2 October	NAE Council
2 October	NAE Peer Committees
3–5 October	NAE Annual Meeting
8 October	NRC Governing Board Executive Committee
14–16 October	Fifth Annual Frontiers of Engineering Symposium Irvine, Calif.
29 October	NAE Congressional Luncheon

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

In Memoriam

J. LELAND ATWOOD, 94, retired president and CEO, Boeing-North America, died on 5 March 1999. Mr. Atwood was elected to the NAE in 1974 for leadership in the design and development of numerous military aircraft, including the X-15.

JULIAN D. COLE, 74, Margaret Darrin Distinguished Professor, Rensselaer Polytechnic Institute, died on 17 April 1999. Dr. Cole was elected to the NAE in 1976 for contributions to education, the literature of engineering and applied science, and for his creative application of mathematics to fluid mechanics.

DONALD E. HUDSON, 83, professor of mechanical engineering and applied mechanics, emeritus, California Institute of Technology, died on 24 April 1999. Dr. Hudson was elected to the NAE in 1973 for development of widely used instruments to record destructive earthquake ground shaking.

ROLF W. LANDAUER, 72, IBM fellow, IBM Thomas J. Watson Research Center, died on 27 April 1999. Dr. Landauer was elected to the NAE in 1978 for leadership in the development of large-scale integration in electronics and contributions to the physics of computing devices.

HARVARD LOMAX, 77, senior research scientist, NASA Ames Research Center, died on 1 May 1999. Mr. Lomax was elected to the NAE in 1987 for leadership in establishing a major national center for computational fluid dynamics, and for outstanding contributions to supersonic aerodynamics.

FRANKLIN F. OFFNER, 87, professor emeritus of biomedical engineering and biophysics, Northwestern University, died on 1 May 1999. Dr. Offner was elected to the NAE in 1990 for fundamental contributions to electronic technology and its application to instrumentation and control, especially in biomedical engineering.

DONALD W. PRITCHARD, 76, professor emeritus, Marine Sciences Research Center, State University of New York at Stony Brook, died on 23 April 1999. Dr. Pritchard was elected to the NAE in 1993 for contributions to understanding the hydrodynamics of estuaries and coastal waters and innovative applications of benefit to the environment and society.

ARTHUR E. RAYMOND, 99, founding member of the NAE and former vice president, Douglas Aircraft Company, died on 22 March 1999. Dr. Raymond's aircraft designs, including his work on the DC-2, DC-3, and DC-8, ushered in an era of global air travel and helped move Douglas from the age of propellers to jet power.

WERNER STUMM, 74, retired professor, Swiss Federal Institute of Technology, died on 14 April 1999. Dr. Stumm was elected to the NAE in 1991 for outstanding contributions to the theory and practice of water quality control and to the education of environmental engineers.

LE GRAND VAN UITERT, 77, retired supervisor, Solid-State Materials Synthesis Group, AT&T Bell Laboratories, died on 3 June 1999. Dr. van Uitert was elected to the NAE in 1981 for contributions to the synthesis and crystal growth of new magnetic and optical materials and their use in devices.

THORNTON A. WILSON, 78, former chairman and CEO, The Boeing Company, died on 10 April 1999. Mr. Wilson was elected to the NAE in 1974 for leadership in the engineering and management of major complex aerospace systems for commercial and military use.

National Research Council Update

Emissions Standards Affect Automotive Research

A new report from the NRC Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles (PNGV) says that increasingly tougher environmental standards being proposed by state and federal governments could jeopardize efforts of the public-private program to develop a highly fuel-efficient and affordable car.

The PNGV is an alliance of government agencies and the United States Council for Automotive Research (USCAR), whose members are the country's three major automakers—DaimlerChrysler, Ford, and General Motors. PNGV was formed in 1994 to develop a mid-size vehicle by 2004 with a fuel economy of up to 80 miles per gallon, while meeting or exceeding government safety and emission requirements.

According to the report, the program has made considerable progress in developing new automotive technologies and is only one year away from introducing its first concept vehicles. The report calls on the Environmental Protection Agency (EPA) to be directly involved in assessing advanced engines and new fuels in conjunction with emissions based on the newly proposed standards.

More-stringent clean air standards for engine emissions in California, as well as those expected to be proposed by EPA for nitrogen oxides and particulate matter, have placed significant burdens on PNGV's work toward technological breakthroughs. Changing standards within such a short time frame disrupts ongoing research, the report says. The federal government should review how future emission requirements will affect automotive technologies, and develop a plan that responds to its findings.

The report is titled *Review of the Research Program of the Partnership for a New Generation of Vehicles: Fifth Report.* The following NAE members are current members of the committee: **Trevor O. Jones** (chair), Biomec Inc.; **Alexis T. Bell,** University of California, Berkeley; **Harry E. Cook,** University of Illinois, Urbana-Champaign; **Norman A. Gjostein,** University of Michigan, Dearborn; **John B. Heywood,** Massachusetts Institute of Technology; **John G. Kassakian,** Massachusetts Institute of Technology; **Craig Marks,** University of Michigan, Ann Arbor; **John S. Newman,** University of California, Berkeley; and **Jerome G. Rivard,** Global Technology and Business Development.

Framework for Information Technology Fluency

The explosive growth of information technology is having a profound impact on our lives. Whether accountants or assembly-line workers, people are using technology such as computers, the Internet, and electronic commerce in different ways and with varying levels of skill and understanding. Moreover, many people feel uneasy in sorting out which technologies to use, and uncertain about how they can be used effectively.

Because new technologies appear on the market regularly, people need the proper knowledge and intellectual resources to learn and adapt to the latest advancements. A new NRC report, *Being Fluent with Information Technology,* proposes a framework to help people become more fluent with information technology. This involves going beyond traditional computer literacy, which is usually defined as the ability to use a few computer applications like a spreadsheet program or a word processor.

Developing fluency is a life-long learning process, the report says. It requires that people continually build on their knowledge of information technology to apply it more effectively in their lives. Fluency also is characterized by different levels of sophistication in a person's understanding and use of technology.

Successfully teaching how to use information technology effectively will require serious rethinking of the entire college curriculum, the report says. Rather than having individual instructors review course content or approach, academic departments should examine how students will obtain the necessary capabilities by the time they graduate. Another key element of promoting fluency at the college level is to ensure universal access to various forms of information technology.

The report was written by a committee that included NAE members **Alfred V. Aho,** Bell Laboratories, Lucent Technologies, **Jeffrey D. Ullman,** Stanford University, and **Andries van Dam,** Brown University.

Oxygen Additives Do Little to Reduce Ozone

In a study undertaken to examine the differences between the additives ethanol and methyl tertiary-butyl ether (MTBE), an NRC committee found that reformulated gasoline made with ethanol is less effective, but that the overall impact of either oxygen additive on reducing ozone—a major component of smog—is very small.

The committee found that, compared with MTBE blends, ethanol blends result in more pollutants evaporating from vehicle gas tanks. Ethanol blends also increase the overall potential of emissions to form ozone. However, available data indicate that the potential for either additive to lower smog levels is small, and it will continue to decrease as other measures to reduce vehicle emissions take effect. Tougher air-quality regulations and improvements to vehicles over the last few decades have substantially reduced emissions that help create near-ground ozone.

The report is *Ozone-Forming Potential of Reformulated Gasoline*. The study committee included NAE members **Charles A. Amann,** KAB Engineering, and **John P. Longwell,** Massachusetts Institute of Technology.

Publications of Interest

The following publications result from the program activities of the National Academy of Engineering or the National Research Council. Except where noted, each publication is for sale (prepaid) from the National Academy Press (NAP), 2101 Constitution Avenue, N.W., Lockbox 285, Washington, DC 20055. For more information or to place an order, contact NAP online at http:// www.nap.edu. To place an order by phone, contact NAP at (202) 334-3313 (in the Washington metropolitan area) or (888) 624-8373 (outside the Washington metro area). *(Note: Prices quoted are subject to change without notice. Online orders receive a 20 percent discount. Please add $4.50 for shipping and handling for the first book ordered 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.)*

A Vision for the National Weather Service: Road Map for the Future. Reviews modernization efforts of the National Weather Service and recommends strategies to introduce new technologies for improved weather analysis and prediction. Paperbound, $18.00.

Being Fluent with Information Technology. Proposes a framework to help people become more fluent with information technology and able to adapt to changing information systems. Paperbound, $35.00.

Black and Smokeless Powders: Technologies for Finding Bombs and the Bomb Makers. Offers general conclusions and recommendations about the detection of devices containing smokeless and black powders and the feasibility of identifying makers of the devices from recovered powder or residue. Paperbound, $20.00.

Chemical and Biological Terrorism: Research and Development to Improve Civilian Medical Response. Identifies R&D efforts needed to implement recommendations for responses to domestic terrorist attack. Addresses the differences between biological and chemical attacks, the challenges to the military and civilian medical communities, and other broad issues. Hardbound, $44.95.

Managing Speed: Review of Current Practice for Setting and Enforcing Speed Limits. Reviews current practice and offers guidance for setting and enforcing speed limits on all types of roads. Copies available through the NRC's Transportation Research Board, (202) 334-3214.

Measures of Environmental Performance and Ecosystem Condition. Examines indices and measures that are used to assess the environmental performance of industrial operations and ecosystem conditions. Reviews properties of ideal indices, surveys and evaluates families of indices, and identifies needs for new or improved measures. Hardbound, $57.95.

Reducing Disaster Losses Through Better Information. Advises the federal government to continue laying plans for an integrated disaster information network, which could be a powerful tool in saving lives and minimizing losses. Paperbound, $18.00.

Review of the Research Program of the Partnership for a New Generation of Vehicles: Fifth Report. Assesses progress made towards development of high fuel economy vehicles. Examines engine technologies, batteries for energy storage, fuel cells, lightweight materials, emissions control systems, power electronics, and vehicle systems engineering. Paperbound, $32.00.

The Ozone-Forming Potential of Reformulated Gasoline. Examines a suggested method for assessing the air quality benefits of fuels for the EPA's reformulated gasoline program. Fuel blends using ethanol or MTBE (methyl-tertiary butyl ether) are considered. Paperbound, $35.00.

Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan. Discusses opportunities for enhancement of water supplies and avoidance of overexploitation of water resources in the Middle East. Emphasizes conservation, improved use of current technologies, and water management approaches that are compatible with environmental quality. Paperbound, $35.00.