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. 1, Spring 1999

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

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VOLUME 29, NUMBER 1
SPRING 1999

# The BRIDGE

# Editorial

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## Sustainability Engineering

In the last 30 years, the thinking about environmental concerns has evolved considerably, from simply diluting pollution in air, water, or the ground, to controlling it at the end of the pipe to, most recently, managing ecoefficiently (maximizing both economic gain and environment performance). As we enter the 21st century, the notion of sustainability has taken hold. Sustainability challenges businesses and society to measure and value economic development in new ways. As I hope to show, it challenges engineers perhaps most of all.

Measuring progress toward a sustainable future is a daunting task. The difficulty increases as the boundary conditions expand. It is relatively easy to measure and manage inputs to and outputs from a single facility. The boundary is small and the time scales of concern are short.

On the other hand, extended product responsibility, which is based on the principle that suppliers, manufacturers, and consumers share responsibility for managing the environmental impacts of products throughout their life cycles, adds many new wrinkles. These include making environmental considerations part of the design process and encouraging companies to take back (e.g., for remanufacture) products at the end of their lifetimes.

Within the emerging mix of measures of environmental performance, there appear to be at least two tensions. The first is between the desire for comparability and standardization of metrics and the need for metrics to be applied usefully in specific situations. The second is between the desire for clarity and simplicity and the desire for metrics that capture complexities associated with a particular cause. As we further extend the boundary conditions to include the interaction of humans with environmental, infrastructure, and political systems, these tensions become more pronounced. To help resolve them, a systems approach is needed. Industrial ecology, a field the NAE has helped pioneer, is one such approach.

Industrial ecology involves the analysis of the flows of materials, energy, capital, labor, and information within production and consumption systems. It considers the impacts of these flows on the environment, as moderated by the influences of technological, economic, political, regulatory, and social factors. The objectives of industrial ecology are to better integrate environmental and social concerns in the design and management of industrial activities, and inform public policy decision making. While metrics and systems approaches such as industrial ecology are needed, we neither need perfect metrics, nor should we be paralyzed by analysis.

In thinking about sustainability, we must carefully balance our human desire to live as we please with an increasing set of political, economic, social, and environmental constraints. We do not want to destroy, or even to damage severely or irrecoverably, valuable natural resources (e.g., animal and plant diversity, forests, lakes). We depend on these for the materials (e.g., food, medicines, building supplies) and basic “services” (e.g., the regeneration of clean air and water) that make life on Earth possible and comfortable.

We know that we are changing or damaging key components of the biosphere, such as forests, waterways, fisheries, and the ozone layer. We do not always clearly know how to reverse or repair the damage. Population increases will place even more pressure on these resources. And no one can be satisfied at our failure to universally provide even a minimum standard of living for all people. Decent living standards are not only a humanitarian and ethical issue, they are also an economic one: Those who are financially secure and living in stable communities represent potential new markets for business.

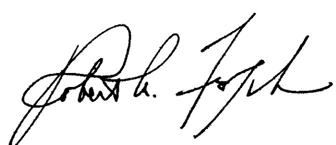
The problems of the environment and of social and economic equity are interrelated, and their solutions are technological in nature. I believe that engineers and the National Academy of Engineering have a special role to play in this regard.

A particularly relevant example of the likely scale of the coming challenge is urban population growth. Current population trends suggest that by 2050, 6 billion people will be living in cities, three times more than today. Most of this growth will take place outside of the major industrial countries. This increase of 4 billion people works out to an average increase of 80 million people per year, the equivalent of 8 new megacities of 10 million people every year for the next 50 years!

This calculation does not take into account the infrastructure problems of our existing urban areas. Many have water, sewage, and street systems that were designed—and largely built—in an earlier era of smaller cities and older technology. Much of this infrastructure already suffers from massive shortfalls in maintenance and replacement.

How can we refurbish our older cities without undo disruption? How can we design and build or somehow assemble the equivalent of 8 10-million-person cities a year for the next 5 decades? How can we site such cities, or have them grow, without damaging the environmental systems they will need to provide their sustenance? These are engineering challenges of gigantic magnitude. Addressing them will require massive invention and innovation, and different and cheaper techniques, if we have any hope of paying for what we design.

Yet, megacities are only one of a dozen or so major technological or engineering challenges facing society. This implies considerable opportunity—and responsibility—for engineers. The human footprint is expanding as population increases and living standards improve. The trick will be to keep the footprint from stamping out the environmental values and services we need and want. We have our work cut out for us.



Robert A. Frosch

# Getting the Most Out of Environmental Metrics

**Robert J. Eaton**

Environmental performance metrics must support innovation and growth, if industry is fully to benefit from their potential to improve product design and boost the bottom line.

*Robert J. Eaton is chairman of DaimlerChrysler and chair of the Council of the National Academy of Engineering.*

Environmental metrics were not much of an issue when I started as a young engineer at General Motors 36 years ago. The metrics we used were the number of cars we produced and how good their quality was. What few environmental metrics we had were mainly driven by regulatory-agency audits. It is not that we were not responsible. I think we were. We were just as concerned then about clean air and clean water as we are today. But we did not have the metrics necessary to optimize our environmental performance or to understand the implications of our decisions on either our business or the environment. The critical measurement was the profit we made. Either we met our program volumes and profits, or we did not. Environmental performance was not a key factor in whether or not we met our business objectives.

Over the last 3 decades, I have learned—like everybody else—that environmental issues have a direct impact on the bottom line and therefore affect how we design our products. Once we decided that we had to do more measuring, we faced two simple but thorny questions: What do we measure and how do we measure it?

First, we felt we had to measure things that added value to our decisions. Measuring for the sake of measuring was seen to be a waste of time.

Second, we had to measure the same way others around the world were measuring, because the global nature of business requires that metrics be harmonized. This latter concern is particularly important at my company right now. As Daimler Benz and Chrysler merge, the metrics of both companies must also merge, and new and innovative metrics must be created to address our global needs.

For DaimlerChrysler to grow as a corporation, a competitor, and a technology leader, we must achieve a level of performance that was beyond our wildest expectations just a few years ago. Success depends on having the correct set of metrics in place to gauge our progress in meeting our business objectives, and we include our environmental responsibilities as part of those objectives.

### Key Metrics Characteristics

I contend that these metrics must have the following key characteristics:

- They must address the needs of all stakeholders—community, government, and business.
- They must facilitate innovation and growth; continuous improvement must be the cornerstone.
- They must be harmonized at the local, state, national, and international levels.
- They must be fully compatible with existing business systems. If they do not add value, they will not support continuous improvement and will not be used.
- They must measure the right things—what is measured is what gets managed.

We are not starting from scratch in this effort. We have some proven techniques already in place. First, there is benchmarking, one of the oldest learning tools known. Figure out who is doing it best and learn from that. In the case of metrics, you must understand what they are doing and why. Once you know that, you may even figure out how to do it better. Second is continuous improvement. The status quo won't do in today's competitive world. When you think it can't be done better, you must redouble your efforts and find new and better ways of improving value and efficiency. Third, you must reduce cost while adding value. Fourth, you must measure. If you don't measure, you can't manage and you can't improve.

Finally, you *must* measure the effectiveness of your metrics.

Many of today's environmental metrics evolved from the end-of-pipe command-and-control regulatory approach that has been implemented in a piecemeal fashion over the past 30 years. Federal environmental regulations now span a mind-boggling 10,000 pages. Industry is required to measure its performance against these and other prescribed standards and then report to federal, state, and local regulatory agencies that have little understanding of how business works.

**What is measured is what gets managed.**

Simply put, these metrics don't work! They inhibit, rather than encourage, innovation and growth. They clearly are not harmonized—different agencies and countries require different measures of the same variable. And they don't add significant value to the business process—much of today's measurement is for measurement's sake alone. One thing is clear: We should not expect regulatory agencies to come up with environmental metrics that will create a win-win situation between environmental and business interests.

Let me give an example from our industry that clearly demonstrates how regulatory bureaucracy inhibits progress in this area. Auto manufacturing is a capital-intensive industry that has frequent new-model launches requiring investments of $1 billion or more. Timing is crucial and time is money. Lots of money. Cut months from the process and you cut hundreds of millions of dollars.

The industry has been very successful in reducing the time it takes to bring a new product to market. The product cycle has decreased from over 5 years to less than 3 years. That saves money and it makes us more competitive. However, a new problem has surfaced: the uncertainty associated with acquiring air emissions permits.

It takes over 9 months, on average, to negotiate an air emissions permit required for a major paint-shop change. Before we can even apply for a permit, we must complete the design of our process equipment, select the materials that will be used, and model the environmental impacts. We then begin negotiations with local, state, and federal regulators, and those negotiations are protracted. Easily half of the 3-year product-introduction cycle can be consumed by permit acquisition. And, *no facility construction or modification can occur* until a permit is issued.

If we have to change the planned process, materials, or production rate, we must modify the permit application and renegotiate the permit conditions. The process of acquiring air emissions permits has become a limiting factor in our new-product cycle. So far, the longest permitting period the industry has endured is 14 months, and that did not include the time it took to develop the process information necessary to apply for the permit. The largest industrial merger in the world took less time to complete!

**We need a new approach that uses continuous improvement to enhance environmental performance.**

The paint shop is the most environmentally sensitive of our production processes, so it's not surprising that the government wants to measure it. But how much is enough? How much can we learn from it? U.S. regulators like to measure everything: line speed; daily, monthly, and annual volume; pounds of pollutants per hour, per day, per month, and per year; composition of materials; point sources; fugitive sources; emissions by process; chemical inventories; and on and on. In addition, the regulations establish "limits" that tend to be moving targets.

Faced with the risk of huge investments and unplanned downtime, the business reaction is obvious: Try to avoid facility changes that trigger new permits. Unfortunately, this also means that many environmental improvements and cost savings are not realized as soon as they could be.

To solve this problem, we need a new approach that uses continuous improvement to enhance environmental performance and reduce time and cost. A new, single air-emissions metric such as pounds of toxics released per vehicle built, subject to an annual cap, could be the new tool. Toxics from all painting, sealing, coating, and cleaning operations would be added together to get a single plantwide emissions number.

With this type of metric, the plant would have a strong incentive to make material, process, and technology changes that improve overall environmental performance and lower cost. To stimulate further environmental improvements, some type of incentive needs to be offered. This could be in the form of tax credits or public recognition of a company's progress in this area. One critical improvement would be to allow timely modifications or construction to occur without preapproval from the regulators. As a trade-off, the plant operator would risk financial penalties if the modified operations exceeded a preestablished limit.

### The LCM "Tool"

Another important tool for improving environmental performance is life cycle management, or LCM. It is clear that we can no longer take a snapshot of the environmental implications of our products. Rather, we must assess their life-cycle impacts early in the design stage to optimize both environmental and business value. Innovative companies like DaimlerChrysler are using LCM to factor environmental, occupational health and safety, and recycling considerations into business decisions long before a product is ever manufactured. LCM is a cost-based approach that allows competing alternatives to be analyzed. Years ago, we didn't understand the environmental component of cost and, therefore, did not consider it fully. We didn't think it was significant. We've learned that's not true. The costs are high. You pay now or you pay later, and if you pay later, it usually costs a lot more.

LCM has convinced us that "pollution prevention pays." Not only does it pay, it can be a competitive advantage. Chrysler has completed 22 case studies that have demonstrated we can better protect the environment and reduce costs *at the same time.* This is a win-win situation—a win for the environment and a business win for us and our suppliers. Let's look at several examples.

Most auto companies use an electrocoat primer to rustproof automobile bodies. Historically, we used a material that contained lead. When we considered using a leadfree electrocoat, we found that it cost 10 percent more than the lead-containing material. After completing an LCM analysis, however, we found we could reduce our operating expenses by $150,000 to $300,000 per plant per year, because the life-cycle cost of the leadfree material turned out to be lower. Not only did we save money, we also improved quality, reduced maintenance downtime, and better protected the environment.

Another example is the use of mercury switches in underhood convenience lighting applications. The mercury switch had the lowest initial purchase price and, therefore, was the preferred choice. But when an LCM analysis was completed, we found that the total life-cycle cost for the mercury switch exceeded the cost of a mercuryfree alternative. We eliminated the mercury switch and, subsequently, other mercury-containing components using LCM metrics to guide us.

Chrysler has applied the LCM approach to splash guards made from used tires, water-based paints for buildings and equipment, and the use of recycled materials in applications such as low volume roof rails and protective plastic seat covers. Clearly, the right metrics can yield concurrent value to business and the environment.

But those metrics must be based on sound science, flexible, and able to operate in the global business economy. They must support innovation and growth. And they must be harmonized, so that we understand and measure performance the same way no matter where in the world our operations are located.

Accomplishing this task will require close cooperation between government, industry, and academia. Industry input is critical to ensure that the metrics are meaningful and workable in the business world. Government involvement assumes that the public's concerns are properly understood and balanced, and that incentives are present to encourage the active support of business. Academia must assure that the metrics are based on sound science and then teach students how to use them.

Unfortunately, metrics alone will not solve the problem. Our regulatory system must be revamped to embrace a more cooperative, collaborative approach, rather than the contentious command-and-control system that has prevailed for nearly 3 decades. This is a challenge that the National Academy of Engineering should address.

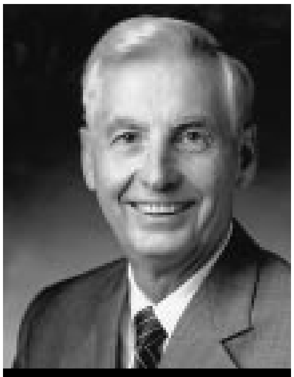
I began by noting how metrics have changed during my career. Globalization and environmentalism weren't the driving forces then that they are now. I'm sure there are emerging concepts, like sustainability, that will drive future changes. And as the world changes, so must our metrics.

Metrics can do one of two things: They can tell you what you should do, or they can tell you what you should have done. If you use them to tell you what to do, you'll be using them to measure your successes. But if you use them to tell you what you should have done, you'll be using them to measure your failures. Clearly, it is the former approach, not the latter, on which we should focus our efforts.

# Creating Corporate Environmental Change

**Edgar S. Woolard**

DuPont's drive toward sustainable practices follows on a decade of corporate leadership that challenged the company and its employees to think and act in new ways.



*Edgar S. Woolard is former chairman and CEO of DuPont. This paper is adapted from remarks he made 3 November 1998 at the NAE International Conference on Industrial Environmental Performance Metrics.*

I would like to share my experiences in working to bring about a change in environmental attitude, policies, and performance at DuPont. At present, DuPont has a single standard against which all environmental performance is measured. That standard can be summed up in a phrase heard all the time at the company: "The goal is zero."

Contrary to what some may think, we did not set out consciously to create a zero standard, and certainly I did not have that in mind when I became chairman and CEO in 1989. However, I did begin my tenure in office with a determination to change the way we thought about environmental performance. The first major public speech I delivered as chief executive was in England, and given the public policy climate at the time, many at DuPont urged me to use that platform to say something about the environment. I agreed, with the proviso that what I said had to be substantive. I also wanted it to be proactive, not so much for the external audience, but rather for the internal audience that I knew would be listening very carefully to what the new CEO was going to say.

In the late 1980s, the prevailing attitude toward environmental performance in the chemical industry in general, as well as at DuPont, was still largely reactive. The industry's environmental practice consisted chiefly of following regulations and avoiding fines. Our public posture with regard to environmental policy making was grounded in science. Unless we could be persuaded scientifically that a product, operation, or waste posed a genuine threat, we saw no need to change.

In this climate, environmentalists were generally viewed as adversaries. They were promoting change—sometimes very radical change—based on what many in the industry perceived to be philosophical or ideological grounds at best and pure emotionalism at worst.

In the late 1970s, I watched as this strategy of inertia began to unravel on the chlorofluorocarbon (CFC) issue. For the first time, the global community was coming together and building a consensus on what was perceived to be a major environmental threat to the global commons. DuPont was then the largest manufacturer of CFCs. For years, we had rebutted environmentalists' arguments with science. Then the scientific tide began to turn. To our credit, once we examined the new data, we did an about-face and led the industry conversion away from CFCs to the substitutes we use today.

### A More Proactive Approach

But that experience demonstrated—to me, at least—that a much more proactive approach was appropriate. I believed and still believe that good science is an indispensable element in environmental policy. But it is not the only element. And the environmental activist community had done society a service by correctly pointing to an industrial and consumer economy that could not be sustained over the long term without dire consequences. In the face of this challenge, industrial corporations were complacent and antagonistic. So, in my speech in London in May 1989, I said that we had to become environmentalists ourselves. As far as I was concerned, CEO stood for chief environmental officer as well as chief executive officer.

We introduced the concept of "corporate environmentalism," which, in addition to reliance on science and compliance with regulations, required a company to satisfy public expectations. Public expectations are something of a moving target, because the public view of how much and what should be traded off for a clean environment varies depending on economic circumstances. That meant that we in industry had to spend a lot more time listening and evaluating.

We could have stopped there. And in retrospect, I'm sure that many people in DuPont at the time would have loved for me to do just that. But we went on. If corporate environmentalism was to be more than empty rhetoric, we had to put the company's performance on the line. So, I proposed a series of numerical goals by which we could measure our performance and for which the public could hold us accountable. These goals included reducing levels of hazardous waste at the source; eliminating heavy metal pigments used in the manufacture of some plastics; achieving major reductions in airborne emissions, especially carcinogens; and setting aside land for wildlife habitat. Looking back on those early goals from the perspective of what we have accomplished nearly 10 years later, they almost seem quaint. But I assure you, a pledge to reduce hazardous waste production by 35 percent and air emissions by 90 percent was a wake-up call. Six months later, in a speech in Washington, I upped the ante. I said we were going to try to eliminate discharges to deep wells and had to begin to think about the possibility of moving toward zero emissions.

> **Many people at DuPont were stunned, wondering whether this guy was for real.**

That was the approach I continued on for another year and a half. I gave a speech on an environmental topic about every quarter and made sure that everyone within the company knew I was very serious about making this change happen. This initial phase I call "leadership and challenge." I must admit, most of the leadership and most of the challenge came from me—but I knew that was not going to be sufficient.

Phase two, "leadership and persuasion," began shortly after my first speech in London. I think many people back at DuPont were stunned, wondering whether this guy was for real. Some, I know, convinced themselves that what I was saying was an exercise in smoke and mirrors. Others knew I was very serious and would insist on step-change. Many were just plain skeptical—not so much about whether I was serious, but about whether we could change. During this period, we continually had to remind everyone that the drive behind this change was not to make this or that numerical goal or to accomplish any particular performance objective, although the goals were concrete and had to be taken seriously. Our ultimate goal was to make the value of environmental protection comparable in importance to that which we had assigned to safety for nearly 2 centuries. We believe that our concern for safety has made us one of the safest—if not the safest—companies in the world. In the same way, we wanted a high level of environmental performance to become second nature. Our company would become an industry leader in this important area of corporate social responsibility.

I had learned very quickly that in an engineering culture such as exists at DuPont, philosophical statements will not carry the day. However, put a number on something—commit to a target that is measurable—and the focus is immediate and intense. Even so, employee reaction was not all favorable and supportive. Everyone had an opinion as to why the company could not achieve the goals we had set. There was the cost argument: It would be prohibitively expensive. There were the legal arguments: If we voluntarily went beyond the letter of the law, we would invite even more onerous legislation or increase our liabilities. Or, the government would mandate a different standard or remedy, and our investment would be lost. And then there was the technical argument: It simply couldn't be done from an engineering standpoint.

**Everyone had an opinion as to why the company could not achieve the goals we had set.**

That last argument was one of my favorites. The watershed case concerned our plant in Beaumont, Texas, where we manufacture acrylonitrile. Ammonium sulfate waste from that process was being disposed of in underground injection wells. I told the plant managers that they had to figure out a way to dramatically reduce that waste and stop putting it in deep wells. They said I was not sufficiently technically trained to understand why this could not be done! I responded that while I might not have all of the necessary technical expertise, I was technical enough to insist they improve or shut down. So, they went back and examined their models, which they had not done for some time. I am happy to say that they successfully modified the process to produce better yields and cut their emissions by two-thirds. The plant also realized net savings of $1 million per year, demonstrating that a financial benefit to improved environmental performance was often, though not always, possible.

During this phase of leadership and persuasion, the most encouraging development was the emergence of leadership from other parts of the company. Several senior executives understood precisely what we were trying to accomplish and led the way in their respective businesses units. Most heartening of all, employees around the company responded with affirmation, encouragement, and ideas. In fact, in my 40 years at DuPont, no other corporate initiative had so galvanized the company's employees.

### Awards Program Established

One of the best ideas came from a plant operator in Tennessee, who recommended that we begin a corporate awards program for environmental excellence. Beginning in 1990, we did just that. We used a panel of judges that included outside environmentalists to pick the winners. It is easy to be cynical about awards programs, but this program accomplished several very important things: It rewarded innovation; it reminded the entire company that this effort was here to stay; and it served as an excellent means of intelligence gathering and information sharing. As nominations poured in, we learned very efficiently and directly what was happening, where the best practices were being developed, and who the leaders were. It became a self-generating inventory of our best ideas and accomplishments on an annual basis.

The success of the awards program, which continues to this day, indicated that we had entered into a third phase, "leadership and response." In this phase, we saw leadership occurring everywhere at all levels in the company. It was at this point that support really began to build for moving beyond numerical targets and establishing a zero goal for all wastes, emissions, and environmental incidents. Collectively, employees had made the link between environmental performance and performance in safety, where DuPont has a nearly 200-year history of a zero goal for accidents, injuries, and illnesses.

This shift was made possible not only because we sensitized everyone in the company to the value of environmental excellence, but also because we took the necessary steps to make certain that environmental performance was a fundamental factor in all our engineering protocols. By 1992, we had our engineering department create what we called our Corporate Environmental Plan, which encompassed 3,000 projects and programs at more than 150 sites.

The plan enabled us to do three important things. First, it connected environmental goals to the actual day-to-day work of our manufacturing sites, so that employees could see that what they were doing was vital and necessary to reaching our goals. Second, the plan put in place performance measures by which we could gauge progress toward our goals as well as others of interest to society and government agencies. Third, the plan provided for competitive execution and proper prioritization. It gave us the big picture and enabled us to focus our technical resources, identify opportunities for synergy, and determine best practices. As a result, even though a very large company, DuPont was able to climb the learning curve one time, sharing what was learned along the way, rather than go up the curve a dozen times in different businesses.

### A $15 Billion Environmental Budget

This efficiency in corporate learning was vital, because at the beginning of the 1990s, we expected to spend about $15 billion on environmental work during the decade, and we wanted that expense to be as productive as possible. It worked. In the early part of the decade, our environmental costs were increasing at a rate of 8–10 percent per year. By 1995, that growth rate plateaued, and by 1996, it began to decline. During the same period, emissions of chemicals tracked by the Environmental Protection Agency Toxic Release Inventory dropped close to 70 percent and total emissions went down even more.

As much progress as we have made, we are now just entering a fourth phase of environmental progress at DuPont, "leadership and sustainability." I believe that we have in place everything we need for our company to attain a level of environmental performance that meets the expectation society had for an industrial company during the 1990s. What we have to work toward now is meeting the expectations that will exist in the next 10 years and beyond.

These expectations will almost certainly deal with minimizing the environmental footprint of a company from its use of resources to the ultimate disposition of its products. For many industrial companies, especially chemical companies, the creation of value is still linked to throughput of materials and increased pounds of production made possible by the expenditure of tremendous amounts of energy in the form of fossil fuels. To become sustainable, we have to develop ways of creating value while minimizing the burden we place on the environment and meeting the basic human needs that our companies and products have historically satisfied.

**We are now entering a fourth phase of environmental progress: leadership and sustainability.**

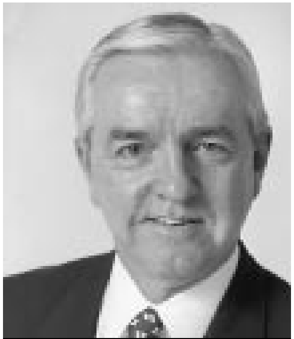
We believe that step-change will have to come from advances in biotechnology, microengineering, information science, and other fields. Regarding biotechnology, I believe progress will come in three waves. Presently, developments in this field are contributing to advances in agricultural products and improved nutrition. Just around the corner will be advances in human health. Five to 10 years out, we expect biotechnology will begin making a major contribution to sustainability. It will do this by allowing us to replace fossil-derived hydrocarbons with biologically derived intermediates. Biotechnology will also enable the manufacture of consumer products in facilities that are simpler, more cost efficient, and that create far fewer environmental impacts than the facilities we have today.

It will be to these newer fields that we will look for ways to augment the advances we have made through classical chemistry and chemical engineering. As far as we have come in the last decade, it may well be that the most important work lies ahead. Getting a grip on our impact on the environment through metrics and engineering will turn out to be only the prelude to truly sustainable practices in the century ahead.

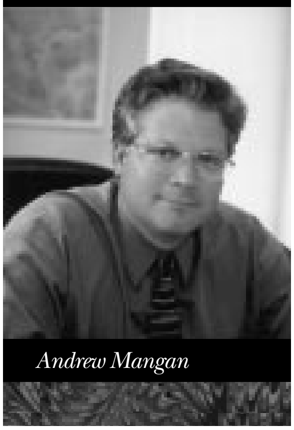
# By-Product Synergy


## Gordon Forward and Andrew Mangan


By taking "wastes" from one company and using them as raw materials for another, industry can turn a negative into a positive — for the environment and shareholders.



Gordon Forward



Andrew Mangan

At first glance, it's hard to imagine how anyone could get excited about slag, a by-product of the steel-making process. But when managers of Chaparral Steel got together with their counterparts at a Texas Industries Inc. (TXI) cement plant, they came up with a surprising discovery: Steel slag could be converted into a valuable raw material for cement production.

Together, they developed a patented process, now being marketed worldwide, that uses steel slag in a cement kiln to create high-quality Portland cement. The partnership has increased profits for both companies, cut energy usage, and reduced greenhouse-gas emissions.

The collaborative venture is a successful example of "by-product synergy," a growing practice that is changing the way business looks at so-called wastes. By taking the by-products of one company and using them as valuable raw materials for another, businesses can turn a negative into a positive. Like fallen leaves that break

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down in the soil and nourish the plants around them, these by-products can be recycled and reused.

The Chaparral-TXI partnership also spurred the creation of a new company, Applied Sustainability LLC, which is helping businesses around the world identify ways that their wastes can become someone else's treasures. The company recruits clusters of businesses in regions around the world and helps them establish synergy projects. This partnership provides a model of how industry leaders can overcome initial corporate skepticism and make by-product synergy work.

What makes the Chaparral-TXI case unusual is that the companies were willing to consider how they could improve their operations by collaborating with another industry. In this case, the collaboration came naturally, since Chaparral is a subsidiary of TXI, the company that runs the cement plant in Midlothian, Tex. Chaparral was also already an experienced recycler. Much of the scrap steel that the company recycles into steel products comes from its adjacent automobile shredding facility, which transforms more than 750,000 old cars annually into raw material for steel production.

### Steel, Cement Reps Get Together

However, the first time representatives of the steel and cement companies got together to consider possible synergies, the gathering was awkward. They weren't accustomed to thinking about—much less working with—managers from another industry. But as the talks continued, the awkwardness ceased and a palpable excitement filled the air. The participants, who ranged from executives, supervisors, and academics to government regulators, began to consider several interesting questions:

- Is by-product synergy a true business opportunity, not just cost-reduction strategy?
- Can industrial thinking shift from producing zero waste to producing 100 percent product?
- Can every gram of raw material become product?
- What if wastes are not really wastes at all but raw materials for other industries?

Looked at this way, the glass that was half empty suddenly seemed half full. The challenge became finding a way to fill it to the top. With this goal in mind, TXI and Chaparral launched the Systems and Technology for Advanced Recycling (STAR) program. Its main feature was a new patented process, dubbed "CemStar," that uses steel slag to create Portland cement. The goal of the STAR program is to eliminate waste by developing links between the cement, steel, and automobile recycling operations. Eventually, everything the steel mill produces will, in synergy with adjacent enterprises, be a useful product.

That same philosophy prompted Chaparral to develop the technology to separate another by-product stream—residue from its automobile shredding operation—into essentially pure components that can be reused (e.g., as a clean fuel source). The business potential is enormous. The average cost of landfilling waste has tripled over the last decade, from $10 per ton in 1986 to $31 per ton in 1996, according to the U.S. Environmental Protection Agency. At the same time, the public is dead set against building more landfills. A company that finds ways to shrink or even eliminate landfills has hit upon a potential gold mine.

**The glass that was half empty suddenly seemed half full.**

In these and other projects, a key consideration is profit. Companies cannot be expected to pursue by-product synergy for altruistic reasons. Unless the strategy positively affects the bottom line, it is likely to go the way of other feel-good efforts that fizzle when they end up costing the company money.

That is not the case with the STAR project, where the bottom-line results have been impressive. By adding slag to the cement manufacturing processing, cement production has jumped 10 percent and energy consumption has dropped more than 10 percent. All of this has been accompanied by a comparable reduction in greenhouse-gas emissions.

CemStar allows cement manufacturers to skip two energy-intensive steps. The CemStar process uses steel slag that has already been subjected to the high temperatures of the steel furnace, which supplied the heat of formation of its principal compound, dicalcium silicate, the building block for Portland cement. This saves energy in the cement process, since the step doesn't have to be repeated. In addition, by using lime that has already been calcined, cement manufacturers are able to skip a step that would have expended considerable energy and generated $CO_2$. The use of CemStar may also eliminate the need for certain raw materials such as clay and shale, which are major sources of hydrocarbon and sulfur emissions.

The implications of this partnership are far reaching. If applied to the entire U.S. cement industry, CemStar could potentially reduce the nation's $CO_2$ emissions by 8.8 million tons per year, thus offering an economically beneficial way for the industry to help the nation reduce greenhouse-gas emissions. In addition, companies may one day receive carbon-trading credits for their by-product synergy efforts.

The benefits of the synergy approach go far beyond the steelmaking industry, as TX1 leaders learned when they teamed up with the Business Council for Sustainable Development for the Gulf of Mexico (BCSD-GM) to promote the idea worldwide. Rather than waiting for companies to discover each other, the Gulf council decided to step in and play matchmaker. One of its most successful "marriages" involves 21 major companies in the Mexican seaport of Tampico.

**The benefits of synergy go far beyond the steelmaking industry.**

The participants, who include numerous chemical and petrochemical companies as well as the local Coca-Cola bottling company and an electricity producer, met several times over the course of a year. They collected data on each company's materials and energy flows and identified 68 potential synergies, of which 29 had immediate commercial possibilities. They decided initially to pursue 13 demonstration projects. One of the most promising of these involves an industrial-gas company that wants to manufacture carbon dioxide using waste $CO_2$ generated by several nearby businesses. The carbon dioxide could then be marketed in areas as diverse as carbonated beverages and agricultural and medical applications.

In another project, one company's 51,000 tons of unusable butadiene (a hydrocarbon used in making synthetic rubber) became a source of cheaper combustion gas for another industry. Another company converted its polyvinylchloride residuals into shoe soles. Other synergies involve sets of companies that generate the same by-product. Individually, the companies can't afford to recover and resell the wastes; together, they can. For example, six companies that together produce 134 tons per year of polyethylene/polypropylene wastes will sell the waste to a seventh company that hopes to build plastic platforms for ship-loading operations.

A less tangible but equally important outcome of the demonstration projects is the ongoing communication and collaboration among the companies. Instead of operating in isolation, they are now working together toward common goals.

### Why Isn't Everybody Doing It?

Projects such as the one in Tampico have gotten the attention not only of the companies within the Gulf council, but also of those in the worldwide organization. The World Business Council for Sustainable Development, based in Geneva, consists of business leaders from 125 companies in 30 countries who are working to implement sustainable-development projects. Simply put, sustainable development is a way to meet present-day needs without compromising the ability of future generations to meet their own needs. The Gulf council is one of its 17 regional councils promoting this idea around the world.

Sustainable development makes good business sense because it can create competitive advantages and new opportunities. By-product synergy is a clear example of this concept. So why isn't everybody doing it? For one thing, most businesses are so narrowly focused that they rarely—if ever—consider cross-industry synergies. They're expending so much energy keeping up with the competition within their own industries that they don't have the time to devote to such efforts.

A second barrier is government regulations that dictate how businesses must dispose of waste. Such rules can discourage companies from seeking creative alternatives and inhibit technological breakthroughs.

By the middle of the next century, world population is expected to reach nearly 10 billion—4 times what it was in 1950 (United Nations Population Division, 1998). The challenge will be to meet the needs of this growing population without depleting the world's natural resources and worsening pollution.

In order to be successful in the next century, business leaders will have to find ways to balance the seemingly contradictory pulls of economic development and environmental protection. It is not a matter of choosing between growth and environmental protection; companies must pursue both simultaneously. No matter how compelling the societal benefits, companies will pursue by-product synergy primarily because it's in their self-interest. As an industry-driven initiative, it will succeed in a way that government regulations could never achieve.

Many environmental regulations are designed to catch the cheater and are predicated upon the assumption that business cannot be trusted. They offer little incentive for companies to come up with their own creative solutions. By-product synergy offers a cooperative, rather than confrontational, approach in which business can take the lead. In doing so, corporate leaders discover that environmental protection offers benefits beyond the cost savings associated with waste reduction. Companies can actually make money by coming up with innovative ways to convert their waste into useful products for others.

### Seeing Regulators As Partners

Many government regulators welcome such initiatives from business and can even be viewed as partners, rather than adversaries. The Texas Natural Resource Conservation Commission, for instance, offered to streamline the permitting process and to help TXI identify potential applications for its recycling efforts. The BCSD-GM also found a valuable partner in the Commission for Environmental Cooperation (CEC), an international organization led by the environment ministers of Canada, Mexico, and the United States. The CEC, which was created in conjunction with the North American Agreement for Environmental Cooperation, is helping remove regulatory barriers and promote by-product synergy projects in Calgary and Tampico, among other locations. Canadian companies actively pursuing by-product synergy include Suncor Energy, whose projects include efforts to generate electricity from waste flare gas.

Another example is a collaborative project called "MultiEnergi" on the coast of Norway. Participants, including Conoco and Norwegian oil producer Statoil, are using by-product heat from a large methanol plant to raise the temperature of the seawater a few degrees. That allows them to farm premium fish species like halibut, turbot, and sea bass, which they can sell both in Norway and internationally. Despite the site's proximity to the Arctic Circle, they are also planning to grow fruit, vegetables, and herbs with the help of by-product heat, $CO_2$, and solar power.

By-product synergy breaks down the traditional boundaries between industry sectors, individual companies, and countries. It also provides boundless opportunities for the future. The day is not far away when companies will mine landfills to extract metals, plastics, and other materials. As businesses join forces to reuse and recycle their wastes, those landfills will shrink and even disappear from our landscape.

Ecoindustrial parks will spring up around the world, making it easy for companies to pursue profitable synergies. Some of the best opportunities will be in developing countries, where industrial parks can be built with by-product synergy in mind from the beginning. Instead of erecting walls, companies will build bridges that encourage interaction and cooperation among industry, government agencies, and environmental groups.

In his 1993 book, *The Ecology of Commerce: A Declaration of Sustainability* (Harper Business), author Paul Hawken eloquently describes how nature depends on such synergies:

> Nature is by definition cyclical; there is virtually no waste in the natural world that does not provide food for other living systems. . . . The lodgepole pine, when it becomes aged and unproductive in its growth, puts out an audible noise, a call, one might even consider it a song. This signal can be heard by the mountain pine beetle, which then begins to eat and break down the tree, creating humus for the next generation of trees. (p. 38)

It is time for business to take an approach toward resource management that reflects the principles of nature. By-product synergy holds great promise as a way to ensure that, like the lodgepole pine and the mountain pine beetle, companies work together to ensure a sustainable future.

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# Harnessing Ingenuity for Sustainable Outcomes

**Deanna J. Richards**

Reconciling economic growth with the needs of the environment and society will require human creativity and technological innovation.

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Will technological innovations save us from an unsustainable future? Or will the major social and environmental challenges facing the planet—poverty and inequity, pollution, climate change, and resource depletion—overwhelm us? More to the point, will technological progress and economic growth lead to a better life for the majority of humankind? These are controversial questions.

Robert J. Eaton (this issue of *The Bridge*) observes that when he started his engineering career, the major design constraints were economic (i.e., material and labor costs, time to market, and manufacturability). Today, environmental considerations are routinely being internalized in management and design decisions. "Ecoefficiency" has emerged as a buzzword for maximizing economic returns while minimizing environmental impact.[1] It gives environmental considerations strategic importance rather than treating them simply as overhead. Sustainable development captures this idea but takes it farther: Economic and environmental goals must be met, along with social goals, creating a new triple bottom line.

The questions posed above present a good starting point for exploring technological futures in terms of economic vitality (which is well understood), ecological sustainability (which requires a better understanding of the ecological constraints on human endeavors), and social desirability (which is manifested in a mix of cultural and social values).

The history of technological adaptation to meet societal objectives (sustainable development being one of the more recent) suggests that we can reconcile economic growth with the needs of the environment and society. To do so will take human ingenuity and technological innovation. It will require the creation of new markets for redesigned products. And it will take a willingness to take calculated risks and develop engineered systems that are better integrated with natural and social systems. It will also mean navigating the unintended consequences of technological advance: Even our greatest accomplishments sow the seeds of future problems.

### Achieving Sustainability

The impact of human activity on the environment is a product of population, wealth or affluence (a surrogate for consumption), and technology and know-how (which create wealth). To achieve sustainability, environmental impacts will have to be reduced and the equilibrium between economic growth and the environment maintained. This can be done by stabilizing population, decreasing wealth, or applying technology and know-how.

Population stabilization is a daunting social challenge. Improving the education of women so that childbearing is delayed is often cited as an effective way to relieve the global population burden (World Bank, 1992). Such an approach may seem more acceptable than more aggressive strategies. Yet, even progressive social innovations such as this are stymied by differing political and cultural values. Typically, the rate of social change is very slow, making population stabilization a necessary but not sufficient approach for achieving sustainability.

Reducing wealth (or, rather, consumption) appeals to some as a way to encourage sustainability, but it is an unlikely outcome. It may even prove to be foolhardy: Decreasing wealth may make the situation more unsustainable. Birth rates fall when education levels and standards of living are raised. Indeed, education and economic growth will be necessary for stabilizing population.

### A "Lever" for Sustainable Outcomes

That leaves technology (including know-how) as the most promising lever for sustainable outcomes. Technology is broadly defined here as the application of science and the entire body of methods and materials used to achieve industrial or commercial objectives. The energy crisis of the 1970s demonstrated that Americans would not readily give up their automobiles, throw on extra sweaters, or lower their thermostats. Energy companies like AES[2] recognized and cashed in on these aspects of human behavior. Indeed, the challenge is to harness technological innovations that create, deliver, and manage superior goods and services—the vital engineered systems humanity depends on—for sustainable outcomes. While population and consumption are social issues, technology is an industry concern. It is the business and pursuit of engineering.

Over the last decade, the National Academy of Engineering, through its program on Technology and Sustainable Development (TSD), has tried to illuminate the relationship between technology, economic growth, and the environment. It has done so through a series of annual industrial ecology workshops, related studies, and resulting publications. (See box.) The work of the

### NAE Technology and Sustainable Development Publication Series

Green Tech•Knowledge•y: Information and Knowledge Systems for Improving Environmental Performance (Forthcoming)
Industrial Environmental Performance Metrics: Opportunities and Challenges (Forthcoming)
Measures of Environmental Performance and Ecosystem Condition (Forthcoming)
The Ecology of Industry: Sectors and Linkages (1998)
Industrial Green Game: Implications for Environmental Design and Management (1997)
Technological Trajectories and the Human Environment (1997)
Engineering Within Ecological Constraints (1996)
The Greening of Industrial Ecosystems (1994)
Keeping Pace with Science and Engineering (1993)
Energy: Production, Consumption, and Consequences (1990)
Technology and Environment (1989)

TSD program spans three broad areas: environmental design and management of systems of production and consumption; ecologically informed engineering; and technological futures and the environment. Several important ideas have emerged regarding prospects for an environmentally sustainable future.

We are a learning society. In this regard, the "greening" of industry that has occurred over the last 30 years is instructive (Allenby and Richards, 1994; Richards, 1997). It has changed forever how industry conducts business. Prior to the 1970s, environmental considerations were externalities not captured on the balance sheets of industrial operations. During the 1970s, highly visible environmental incidents such as Bhopal and Love Canal led to calls for regulations. These regulations, however imperfect (see Eaton), began the process of internalizing environmental costs.

**EPR extends upstream and downstream the boundaries of environmental consideration.**

Industry's attitude changed from denial to feeling threatened, and the approach adopted was one of compliance. In the 1980s, competitiveness and globalization led to new approaches such as total quality management and just-in-time manufacturing. These encouraged the identification and elimination of inefficient processes and practices, which led to waste reduction and pollution prevention. Environmental change was further affected by strong corporate leadership (as described by Woolard in this issue of *The Bridge*). Reports began to emerge of companies realizing cost savings while also improving environmental performance.

The 1980s also found industry struggling to find substitutes for ozone-depleting substances in a range of applications, including electronics where they were used as solvents to clean components. The electronics industry was the first to develop usable substitutes. Shortly thereafter, the industry introduced design for environment, which integrated environmental considerations during the design of products rather than after the fact. This focus on product design grew in importance in the 1990s, as European product take-back and other regulations introduced the notion of extended product responsibility (EPR) around the world. EPR is based on the principle that suppliers, manufacturers, and consumers share responsibility for managing the environmental impacts of products throughout their life cycles. EPR extends the boundaries of environmental consideration downstream to products (and delivery of services). This is important, since in the case of many consumer durables (e.g., cars, refrigerators, washing machines), environmental impacts during use far exceed those during manufacture. EPR also looks upstream to the management of complex supplier chains (Committee on Industrial Environmental Performance Metrics, forthcoming).

As a result of the evolution in corporate environmental stewardship that has occurred over the last 3 decades, there are new opportunities to improve ecoefficiency. Operational strategies for realizing these improvements include

- minimizing emissions, increasing yields, reducing the generation of nonproductive material streams, using energy more efficiently, and substituting more benign materials for ones that are hazardous; and
- considering wastes as "food" and creating symbiotic industrial linkages (Allenby and Richards, 1994; Richards, 1997) like those described by Gordon and Mangan (this issue of *The Bridge*).

### Improving Ecoefficiency

Strategies for improving product-related ecoefficiency include

- designing and selling more energy-efficient products that use fewer (or new and different) materials with equivalent or superior performance;
- designing and making products with manufacturability, remanufacturability, and recyclability in mind; and
- improving logistics and distribution associated with the delivery of supplies and product to markets and their take-back.

More ambitiously, ecoefficiency improvements from an EPR perspective suggest designing products and engineering systems to optimize "functionality" or "service" (Allenby and Richards, 1994; Richards, 1997). This means, for example, offering pest control instead of pesticides, refrigeration instead of refrigerators, document reproduction or printing instead of copiers or printers. For this approach to work, the design has to take into account upgradability and, for diverse product lines, interchangeability. In the latter case, managing the complex logistics of juggling different products, parts, and their recovery and remanufacture, as Xerox does (Committee on Industrial Environmental Performance Metrics, forthcoming), is key.

The hurdle for ecoefficient products and services is the customer. In many instances, the customer base for these products is small. However, it may be growing. Electrolux's new line of ecoefficient products now accounts for as much as 8 percent of its revenues. In addition, companies that are aggressive in pursuing ecoefficiency improvements in their industrial practices and products see potential markets looming simply from the demands placed on physical and natural resources by a growing population.

Most of the innovations discussed so far have resulted from incremental change. Incremental change is driven by pressures to reduce costs or meet quality, design, performance, manufacturability, or environmental goals. Change of this sort seldom results directly from any deliberate R&D, although it frequently is influenced indirectly by R&D conducted for other purposes.

### Three Types of Innovation

There are at least three other types of innovation that have to be harnessed for sustainability to be realizable: radical innovations, technology-system innovations, and techno-economic revolutions (Freeman, 1992). Radical innovations are discontinuous events that result from deliberate R&D. (For example, incremental improvements in canoes did not lead to steamships and the developments of glass and paper did not lead to the creation of plastics). The underlying science and engineering are often incremental, but the deployment of the technologies leads to radical departures from past production practices. These innovations are unevenly distributed over industry sectors and over time. However, when they occur, they can spawn new markets or significantly improve the use of inputs (by lowering cost and improving the quality of existing products), as occurred with the shift to the oxygen steelmaking process.

Technology-system innovations affect many branches of the economy through far-reaching technological change. New sectors of economic activity are created. The development of the semiconductor industry can be attributed to technology-systems innovation, as can synthetic materials and petrochemicals introduced during the 1930s, 1940s, and 1950s. Adjunct developments in machinery for injection molding and extrusion and later innovations in packaging, construction, electrical equipment, agriculture, textiles, clothing, toys, and other applications resulted in a range of interrelated innovations that were not contemplated when the materials and chemicals were first developed.

Even more far-reaching change results from new technology that has a ubiquitous effect on the economy, creating a techno-economic revolution. These innovations transform production and management throughout the economy, in essence changing the ecology of industry (Richards and Pearson, 1998). The introduction of electric power is an example of one such dramatic transition. The computer, microelectronics, and biotechnology are more recent cases in point.

**The hurdle for ecoefficient products and services is the customer.**

Computers and microelectronics have radically improved the monitoring and control of emissions, and of energy and materials use, and they have facilitated more effective quality and inventory control. They have changed the social and management fabric of commerce and communications (e.g., through the Internet and workplace practices such as telecommuting) and raised the importance of knowledge management for environmental and other purposes (Richards, forthcoming). Biotechnology tools are transforming chemical companies into biotechnology companies. Monsanto, for example, is focusing on health services and food production as part of its sustainable-development vision (Magretta, 1997).

Indeed, it is insufficient to think in terms of strictly green or sustainable technologies, if sustainability concerns are to be effectively addressed. Technology is dynamic. Change is inevitable. History and projections of technological advance show that we have been replacing resources that are limited (or found to be wanting in other ways) with substitutes of similar or superior performance. For example, there has been a decarbonization of energy systems over the centuries. Studies of technological trajectories of energy systems indicate a shift to a hydrogen economy (which will require solar and nuclear power) (Ausubel and Langford, 1997).

Data also show that the economy is dematerializing (not literally, but in the sense of using less material by weight and per unit product). For example, newer materials (plastics and composites) have led to the lightweighting of cars. Lightweighting and more sophisticated electronics for monitoring and controlling on-board systems have led to greater fuel efficiency.

Other areas have also benefited from efficiency improvements. Water conservation is relieving pressures on fresh-water supplies, and further improvements are possible through technology and policy change (e.g., eliminating subsidies for certain consumptive uses, such as agriculture in arid areas like California). Improvements in agricultural practices and yields, combined with the potential that biotechnology promises, offers brighter prospects for meeting the food needs of the planet.

**Today's environmental threats are cumulative and interactive.**

However, new technologies often create new problems. Newer materials such as plastics and composites that have environmental advantages are used dissipatedly. This makes their management (to prevent leaks and accumulations in the environment) an important design consideration. Similarly, improvements in agricultural yields may improve the availability of food but are not sustainable if they also damage ecosystems (e.g., as a result of pesticide use) or result in other unintended environmental impacts.

Unlike the environmental concerns of the 1970s, which were often local and recognized at their points of origin (e.g., smokestacks, effluent pipes, unregulated dumps), today's environmental threats are cumulative and interactive, often arising from multiple causes that are not sector specific. In addition, many more-recent environmental concerns, such as the potential of toxins to bioaccumulate or to disrupt basic human and animal endocrine systems, are subtle, often difficult to identify, and complex to manage.

The complexities associated with the interactions between human and natural systems make quantification and management in the sustainable-development context daunting. These tasks must be approached at many levels: national policy; interfirm decisions that change production and consumption patterns; process and product decisions made by firms; and choices made by consumers. In the short term, the move toward sustainable business practices presents an opportunity to disseminate "best practices" in environmental management as well as environmentally friendly products and services. The longer-term challenge is to manage the uncertainties inherent in resolving complex, coupled interactions between human and natural systems (Schulze, forthcoming; Schulze, 1996).

### Addressing Indirect, Delayed Effects

We also need to improve our ability to predict and deal with systems effects. While any action has direct effects, interconnection within a system produces indirect and delayed effects. Chlorofluorocarbons were invented in the 1930s as a safe alternative to ammonia and sulfur dioxide, then used in home refrigeration. The intent was to eliminate the toxicity, flammability, and corrosion concerns of the other chemicals used at the time. The indirect and delayed effect was stratospheric ozone depletion (Ausubel and Sladovich, 1989) due to CFCs leaking from refrigerators, air conditioners, and electronics-cleaning operations.

Policies intended to address social and environmental concerns similarly have often had indirect and delayed effects. For example, solid-waste management policies enacted a decade ago led local jurisdictions to develop waste management plans. These included the siting and financing of landfills and the encouragement of curbside recycling. The intent was to have municipalities take responsibility for the waste they generated. The indirect and delayed effect has been the creation of an overcapacity of heavily financed landfills in search of trash. In this case, system interactions were interactive, not additive. Local trash volumes were lower than anticipated because of the success of recycling. The trash example also shows that when there are more than two actors in a system, the relationship between any two is determined not by the actions of the two players, but by the interactions among all those in the system. Landfill owners, including municipalities, struck deals with cities like New York to take their trash. As these deals have become public, they are being questioned by communities and environmental groups, who are concerned about what is in the trash and if it will cause problems locally.

System effects such as these are everywhere. Hence, even the greatest steps toward sustainable development will bring future problems. Accepting this fact frees us from the futility of searching for magic bullets or having groundless faith in the perfectibility of human societies (which underlies much of the sustainable-development rhetoric). It allows us to embrace progress and take steps to improve the quality of life of humans and the environment.

As noted by Robert Frosch (this issue of *The Bridge*), over the next 50 years, assuming current trends continue, roughly 80 million people per year will be added to the world's urban population. That is equivalent to building an average of 8 cities of 10 million people each year for 50 years. How can the needs of those new urbanites be met without further affecting the sustainability of the planet?

### The Need for Social Innovation

Large parts of Russia, China, and Africa are already unlivable by any reasonable standard and face serious trade-offs in their national investment decisions. For example, China burns coal as its primary source of power. Cleaner coal-burning technologies exist but are more expensive than traditional coal-powered plants. China is also a cold country, and a significant share of its population still lacks electricity, heat, or adequate nutrition. So, given the choice between building several dirty power plants or fewer cleaner ones that would deprive many of power, the economic and social choice is simple: Build the cheaper, dirtier plants.

In many instances, technologies exist to dramatically improve the world's worst environmental and social problems. What is missing are social innovations that can transcend or alter current political and economic realities.

The situation of the Dinka tribe in southern Sudan illustrates one extreme of the need for sustainable development. The Dinkas are on the brink of starvation, after having been uprooted from their homeland. They live on international handouts. One in six people in the world live like the Dinka (Hertsgaard, 1999). That is a huge number. The more telling point is that for much of history, that proportion has been closer to 9 out of 10. That means we've made tremendous progress.

The challenge posed by sustainable development is one of spreading and speeding this progress through technological ingenuity and economic growth that successfully integrate ecological constraints and social needs. This requires harnessing technological innovations already in the pipeline and developing new systems of sustainable production and consumption—essentially reengineering industrial systems within emerging ecological constraints and social demands.

This challenge can be met by taking an integrated approach that taps the human capacity to learn and improve efficiency; harnesses the spirit of innovation; anticipates and acts on unintended consequences of systems of technology and public policies; and leverages new knowledge about ecological and social needs to improve the quality of human life and the environment.

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## Notes

1. The World Business Council for Sustainable Development (1996) has suggested that ecoefficiency is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life and the progressive reduction of ecological impacts and resource intensity throughout the life cycle to a level commensurate with the Earth's estimated carrying capacity.
2. AES (previously known as Applied Energy Services) was founded by Roger Sant and Dennis Bakke, who headed up the energy conservation programs at the old Federal Energy Administration. Their experience showed them that Americans were not about to give up the comforts of industrial civilization, nor were those in developing countries going to accept poverty. They started AES with the goal not of producing energy-conserving products, but of providing services—heat, light, and power—at the lowest possible cost.

# NAE News and Notes

## NAE Newsmakers

**Arnold O. Beckman,** founder and retired chairman, Beckman Instruments, is the recipient of the National Academy of Sciences' most prestigious award, the **Public Welfare Medal.** Beckman was chosen for his leadership in developing analytical instrumentation and for his deep and abiding concern for the vitality of the nation's scientific enterprise.

**Cyril M. Harris,** Charles Batchelor Professor Emeritus of Electrical Engineering and professor emeritus of architecture, Columbia University, is the recipient of the **Pupin Medal** from the university for "distinguished service to the nation in science and technology."

**Paul C. Jennings,** professor of civil engineering and applied mechanics, California Institute of Technology, has been inducted as the new chairman of the California Council on Science and Technology, a statewide group dedicated to improving science and technology policy and applications in California.

**Dean L. Kamen,** founder and president of DEKA Research and Development Corporation, is the recipient of the 1999 **Heinz Award** in technology, economy, and employment for his leadership in "awakening America to the excitement of technology." The $250,000 Heinz Awards are presented annually by the Heinz Family Foundation.

**Robert G. Loewy,** chair, School of Aerospace Engineering, Georgia Institute of Technology, was presented the **1999 Dryden Lectureship in Research** at the 37th American Institute of Aeronautics and Astronautics Aerospace (AIAA) Sciences Meeting and Exhibit on 28 January 1999 in Reno, Nevada. The title of his lecture was "Avionics: A 'New' Senior Partner in Aeronautics."

**Paul B. MacCready,** chairman, AeroVironment, gave the keynote address at the 1999 American Society for Nondestructive Testing Spring Conference and 8th Annual Research Symposium in Orlando, Florida, on 23 March 1999. The topic of his address was "Innovation by Destructive Testing."

**A. Alan B. Pritsker,** senior consultant, Symix-Pritsker, received an honorary doctor of engineering degree from Purdue University on 20 December 1998.

**Dennis M. Ritchie** and **Kenneth L. Thompson,** members of the technical staff, Bell Laboratories, Lucent Technologies, were awarded the **1998 National Medal of Technology** "for their invention of the UNIX operating system and the C programming language, which together have led to enormous advances in computer hardware, software, and networking systems and stimulated the growth of an entire industry, thereby enhancing American leadership in the Information Age."

**Lucien A. Schmit, Jr.,** Rockwell Professor of Aerospace Engineering, emeritus, University of California, Los Angeles, is the second recipient of the **Walter J. and Angeline H. Crichlow Trust Prize.** The prize is presented every 4 years by AIAA for excellence in aerospace materials, structural design, structural analysis, or structural dynamics.

**Alexander C. Scordelis,** The Byron L. and Elvira E. Nishkian Professor Emeritus of Structural Engineering, University of California, Berkeley, is the recipient of the first **Anton Tedesko Medal,** presented by the International Association for Bridge and Structural Engineering. Scordelis was cited for "his dedication to excellence in structural engineering and his role as a mentor for young engineers."

**Eugene Sevin,** consultant, received the inaugural **Melvin L. Baron Award** from the Department of Defense's Shock and Vibration Information Analysis Center on 13 October 1998. The award, in honor of NAE member Mel Baron, who died in 1997, is for "outstanding contributions and leadership in the field of computational structural dynamics and constitutive modeling."

**Joseph F. Traub,** Edwin Howard Armstrong Professor of Computer Science, Columbia University, was selected by the Accademia Nazionale dei Lincei to present a cycle of lectures called the Lezioni Lincee. Cambridge University Press has just published a greatly expanded version of the lectures as the book *Complexity and Information.*

**C. Grant Willson,** IBM Almaden Research Laboratory (retired), and professor and Rashid Engineering Regents Chair, University of Texas, Austin, was awarded the National Academy of Sciences **Award for Chemistry in Service to Society.** Willson was recognized "for his fundamental contributions to the chemistry of materials that produce micropatterns in semiconductors and for its widespread application in the microelectronics industry for the benefit of society."

## NAE Elects Class of 1999

Members of the National Academy of Engineering elected 88 engineers to membership in the Academy, including 8 foreign associates. This brings the Academy's total U.S. membership to 1,984 and the number of foreign associates to 154.

Election to the National Academy of Engineering is among the highest professional distinctions accorded an engineer. Academy membership honors those who have made "important contributions to engineering theory and practice, including significant contributions to the literature of engineering theory and practice," and those who have demonstrated "unusual accomplishment in the pioneering of new and developing fields of technology."

A list of the newly elected members and foreign associates follows, with their primary affiliations at the time of election and a brief statement of their principal engineering accomplishments.

### Members

**Alfred V. Aho,** associate research vice president, communications science research division, Bell Laboratories, Lucent Technologies, Holmdel, N.J. For contributions to the fields of algorithms and programming tools.

**Kyle T. Alfriend,** professor and head, department of aerospace engineering, Texas A&M University, College Station. For theoretical contributions, applied research, and leadership in satellite orbital mechanics and spacecraft altitude control.

**G. Ken Austin, Jr.,** co-owner and president, A-dec Inc., Newberg, Ore. For inventing, designing, manufacturing, and marketing innovative dental equipment systems and facilities.

**Benton F. Baugh,** owner, Radoil Inc., Houston. For implementation of concepts for subsea equipment used in offshore oil production.

**Mark G. Benz,** metallurgist, General Electric Corporate Research and Development, Niskayuna, N.Y. For contributions to nuclear fuel bonding, superalloys, and superconductors.

**Leon E. Borgman,** professor of geology and statistics, University of Wyoming, Laramie. For contributions to the theory and practice of ocean wave statistics, probabilistic hydrodynamic loading, and risk analysis of ocean structures.

**Robert W. Bower,** professor, department of electrical and computer engineering, University of California, Davis. For inventing the self-aligned, gate ion-implanted MOSFET and for establishing ion implantation to fabricate semiconductor integrated circuits.

**John F. Brady,** professor of chemical engineering and executive officer for chemical engineering, California Institute of Technology, Pasadena. For work in elucidating the basic mechanics of and developing methods for the simulation of multiphase flows.

**Corale L. Brierley,** principal, Brierley Consultancy LLC, Highlands Ranch, Colo. For innovations applying biotechnology to mine production and remediation.

**Melvin W. Carter,** international radiation protection consultant, Atlanta. For leadership and teaching in radiation protection, health physics, and public health standards and practices.

**John T. Christian,** consulting engineer, Waban, Mass. For leadership in geotechnical earthquake engineering, computer methods in geotechnical engineering, and engineering education standards.

**Wesley A. Clark,** principal, Clark, Rockoff, and Associates, Brooklyn, N.Y. For the design of early computers.

**David R. Clarke,** professor, department of materials engineering, University of California, Santa Barbara. For research on the role of grain boundary phases and their importance to the engineering of technical ceramics.

**Reg Davies,** DuPont Fellow, particle science and technology center (PARSAT), E. I. du Pont de Nemours & Co., Wilmington, Del. For the development of particle technology in the United States for business application and contributions to higher education.

**James W. Demmel,** professor, computer science division, University of California, Berkeley. For contributions to numerical linear algebra and scientific computing.

**Alan H. Epstein,** R. C. Maclaurin Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge. For time-resolved flow and heat transfer measurements in turbomechanics, and for conception and development of smart engines and microengines.

**Francis B. Francois,** retired executive director, American Association of State Highway and Transportation Officials, Washington, D.C. For engineering and policy leadership in surface transportation infrastructure and research.

**Richard J. Fruehan,** U.S. Steel Professor, department of materials science and engineering, Carnegie Mellon University, Pittsburgh. For research in iron and steel making.

**Haren S. Gandhi,** Ford Technical Fellow and manager, chemical engineering department, Ford Motor Co., Dearborn, Mich. For contributions to the research and development of automotive catalysts.

**Louis V. Gerstner, Jr.,** chairman and chief executive officer, IBM Corp., Armonk, N.Y. For technical leadership in enhancing the competitiveness of U.S. industry.

**Don P. Giddens,** The Lawrence L. Gellerstedt Jr. Chair in Bioengineering, Georgia Institute of Technology, Atlanta. For contributions to the understanding of the ultrasound and fluid mechanics of arteriosclerosis, and enhancing academic bioengineering education.

**Bruce Hajek,** professor, department of electrical and computer engineering, University of Illinois, Urbana-Champaign. For contributions to stochastic systems, communication networks, and control.

**Patrick M. Hanrahan,** professor of computer science and electrical engineering, Stanford University, Stanford, Calif. For contributions to computer graphics and to the practice of rendering complex scenes.

**David R. Heebner,** proprietor, Heebner Associates, McLean, Va. For aerospace systems engineering accomplishments that have substantially improved our national security.

**Andrew R. Hileman,** consultant, Monroeville, Pa. For contributions to the understanding of lightning and its effects on electric power system performance.

**Stanley Hiller, Jr.,** founder, Hiller Aviation Museum, San Carlos, Calif. For leadership in helicopter development with great value to human life, safety, and quality.

**Ronald A. Howard,** professor of engineering-economics systems, Stanford University, Stanford, Calif. For contributions to the foundations of decision analysis and its application.

**Salim M. Ibrahim,** consultant, Geneva, Switzerland. For advances in elasticized fiber technology.

**Donald L. Iglehart,** professor, engineering-economics systems and operations research, Stanford University, Stanford, Calif. For contributions to queuing theory, simulation methodology, inventory control, and diffusion approximations.

**Jeremy Isenberg,** president and chief executive officer, Weidlinger Associates, New York City. For contributions to designing and testing protective structures and detecting seismically vulnerable underground pipelines.

**Wilfred D. Iwan,** professor of engineering and applied mechanics and director, earthquake engineering research laboratory, California Institute of Technology, Pasadena. For research on seismic performance of structures, and for leadership in earthquake hazard mitigation and improvement of public safety.

**Sungho Jin,** supervisor, applied materials and metallurgy group, Bell Laboratories, Lucent Technologies, Murray Hill, N.J. For research on new magnetic materials and high-temperature superconductors.

**William L. Johnson,** Ruben and Donna Mettler Professor of Materials Science, Engineering, and Applied Sciences, California Institute of Technology, Pasadena. For the development of bulk metallic glasses as structural materials.

**Howard S. Jones, Jr.,** retired chief of microwave research, Harry Diamond Laboratories, U.S. Department of the Army, Adelphi, Md. For the invention and development of antennas and microwave components for missiles and spacecraft.

**Aravind K. Joshi,** Henry Salvatori Professor of Computer and Cognitive Science, University of Pennsylvania, Philadelphia. For contributions to natural language processing.

**William N. Joy,** founder and chief scientist, Sun Microsystems, Aspen, Colo. For contributions to operating systems and networking software.

**Stanley Kaplan,** chairman, Bayesian Systems Inc., Rockville, Md. For providing the framework of a general theory of quantitative risk assessment and development of synthesis methods in reactor physics.

**Hossein Kazemi,** manager, reservoir technology, Marathon Oil Co., Littleton, Colo. For contributions to understanding multiphase flow in fractured porous systems, and for developing techniques to manage complex petroleum reservoirs.

**Theodore C. Kennedy,** chairman, BE&K Inc., Birmingham, Ala. For leadership and innovation in advancing the nation's construction industry.

**Glenn F. Knoll,** professor of nuclear engineering and radiological science, University of Michigan, Ann Arbor. For contributions and technical leadership in the field of ionizing radiation detection and application.

**U. Fred Kocks,** professor, Los Alamos National Laboratory, Los Alamos, N.M. For advancements in the theory of strength, kinetics of plasticity of metals, and texture analysis.

**Frederick J. Krambeck,** advanced senior consultant, Mobil Technology Co., Paulsboro, N.J. For advancing the theory of complex reacting mixtures, and applying chemical reaction engineering principles to the design of commercial processes.

**Michael R. Ladisch,** professor of food service and agricultural and biological engineering, Purdue University, West Lafayette, Ind. For developing and scaling-up new approaches and materials for process chromatography, adsorptive bioseparations, and biocatalysis.

**Ronald K. Leonard,** retired director, John Deere Worldwide Tractor and Component Engineering, Galena, Ill. For contributions to the design and manufacturing of cotton harvesters, lawn and garden machines, and agricultural tractors.

**Paul A. Libby,** professor of fluid mechanics, University of California, San Diego. For contributions as a researcher, author, and educator who advanced knowledge of fluid dynamics, turbulence, and combustion through theoretical analyses.

**Kuo-Nan Liou,** professor and director, Institute of Radiation and Remote Sensing, University of California, Los Angeles. For contributions in the theories of radiation transfer and light scattering, with applications to remote sensing technology and climate modeling.

**Richard J. Lipton,** professor, department of computer science, Princeton University, Princeton, N.J. For application of computer science theory to practice.

**J. David Lowell,** principal, Lowell Mineral Exploration, Rio Rico, Ariz. For demonstrating relationships among geologic systems, metallogenic provinces, and hidden ore deposits.

**Nicky C. Lu,** founder and president, Etron Technology Inc., Hsinchu, Taiwan. For contributions to high speed dynamic memory chip design and cell array technology, and sustained technical leadership in the VSLI/memory industry.

**Richard G. Luthy,** Thomas Lord Professor of Environmental Engineering, department of civil and environmental engineering, Carnegie Mellon University, Pittsburgh. For leadership in the treatment of industrial waste waters, contaminated soils, and aquifers.

**James J. Markowsky,** executive vice president, power generation, American Electric Power Service Corp., Columbus, Ohio. For development and deployment of high efficiency, low emissions coal technologies including pressurized fluidized bed plants.

**Martin M. Mikulas, Jr.,** professor of aerospace engineering, University of Colorado, Boulder. For contributions to the development of advanced structural concepts.

**Marshall I. Nathan,** professor of electrical engineering, University of Minnesota, Minneapolis. For contributions to semiconductor lasers.

**John S. Newman,** professor, chemical engineering department, University of California, Berkeley. For contributions to applied electrochemistry and for their reduction to practice through advances in electrochemical engineering.

**Thomas J. O'Neil,** executive vice president, operations, Cleveland-Cliffs Inc., Cleveland. For contributions to the theory and practice of mining economics in mineral development and operations.

**Donald W. Peaceman,** consultant, Houston. For contributions to the development and usage of transient three-dimensional multiphase simulators for predicting performance of petroleum reservoirs.

**William T. Plummer,** director of optical engineering, Polaroid Corp., Cambridge, Mass. For contributions to optical science and engineering, and for leadership in high-volume manufacturing of precision optics.

**Gary A. Pope,** Texaco Centennial Chair in Petroleum Engineering and director, Center for Petroleum and Geosystems Engineering, University of Texas, Austin. For contributions to understanding multiphase flow and transport in porous media, and applications of these principles to improved oil recovery and aquifer remediation.

**Eugene M. Rasmusson,** senior research scientist, department of meteorology, University of Maryland, College Park. For contributions to understanding climate variability and establishing the basis for practical predictions of El Niño.

**Lee R. Raymond,** chairman and chief executive officer, Exxon Corp., Irving, Texas. For keeping a major oil company at the forefront of exploration and production technology.

**Bernard I. Robertson,** senior vice president, engineering technologies, and general manager, truck operations, DaimlerChrysler Corp., Auburn Hills, Mich. For technical contributions and leadership in the design and manufacture of highly reliable and affordable vehicles and their powertrains.

**B. Don Russell, Jr.,** associate vice chancellor for engineering and associate dean for research, Texas A&M University, College Station. For leadership in electric power engineering and contributions to power system protection.

**Jerald L. Schnoor,** University of Iowa Foundation Distinguished Professor, University of Iowa, Iowa City. For research and engineering leadership in development, validation, and utilization of mathematical models for global environmental decision making.

**Frieder Seible,** professor of structural engineering and chair, division of structural engineering, University of California, San Diego. For contributions to research, development, and applications in seismic analysis, and the design, construction, and retrofitting of bridges.

**Patricia G. Selinger,** IBM fellow and director, database integration, IBM Almaden Corp., San Jose, Calif. For leadership and contributions to relational database technology.

**Freeman D. Shepherd,** retired senior scientist for infrared arrays and sensors, Rome Laboratory, U.S. Department of the Air Force, Hanscom Air Force Base, Mass. For contributions to metal-silicide devices and infrared cameras.

**Peter G. Simpkins,** distinguished member of technical staff, Bell Laboratories, Lucent Technologies, Murray Hill, N.J. For contributions to the understanding and development of processes fundamental to the manufacture of low-loss, high-strength optical fiber.

**Katepalli R. Sreenivasan,** Harold W. Cheel Professor of Mechanical Engineering, Yale University, New Haven, Conn. For the application of modern nonlinear dynamics to turbulent flows.

**Rangaswamy Srinivasan,** president, UV Tech Associates, Ossining, N.Y. For ultraviolet laser processing of polymers and its extension to refactive surgery of the cornea.

**John P. Stenbit,** executive vice president, telecommunications, TRW Space, Defense, and Information Systems, Fairfax, Va. For contributions to the development and leadership in implementation of system architecture for complex military and communication systems.

**George Stephanopoulos,** A. D. Little Professor of Chemical Engineering, Massachusetts Institute of Technology, Cambridge. For contributions to the research, industrial practice, and education of process systems engineering, and for international intellectual and professional leadership.

**Lawrence D. Stone,** senior vice president and chief operating officer, Metron Inc., Reston, Va. For contributions to optimal search theory and practice.

**James R. Swartz,** professor of chemical engineering, Stanford University, Stanford, Calif. For contributions to the design, scale-up, and yield improvement of recombinant protein production systems.

**Frank E. Talke,** professor, Center for Magnetic Recording Research, University of California, San Diego. For work in tribology and mechanics of magnetic storage systems, ink-jet technology, and interferometric instrumentation, and for bridging industrial and academic research.

**Peter B. Teets,** president and chief operating officer, Lockheed Martin Corp., Bethesda, Md. For contributions to the nation's space and launch vehicle programs and for management of aerospace programs.

**Robert V. Thomann,** professor emeritus, environmental engineering department, Manhattan College, Riverdale, N.Y. For contributions to the prediction and management of water quality in streams, estuaries, lakes, and oceans.

**Charles R. Trimble,** president and chief executive officer, Trimble Navigation Ltd., Sunnyvale, Calif. For contributions to navigational systems.

**Pravin P. Varaiya,** professor, electrical engineering and computer science, University of California, Berkeley. For contributions to the theory of systems and control.

**Charles L. Wagner,** consultant, Export, Pa. For contributions to electric power system engineering and standards.

**Leo Young,** consultant, Bethesda, Md. For contributions to microwave technology and to the management of national security research.

### Foreign Associates

**Vitelmo V. Bertero,** professor emeritus of civil and environmental engineering, University of California, Berkeley. For contributions to improvements in seismic design and the construction of steel and reinforced concrete structures.

**Ghislain de Marsily,** professor of geology and director, Laboratoire de Géologie Appliquée, Universite Pierre et Marie Curie, Paris. For leadership in advancing the science and engineering of hydrogeology, especially in contaminant transport and nuclear waste isolation.

**Gilbert F. Froment,** professor emeritus of chemical engineering, Universiteit Gent, Belgium. For application of fundamental approaches in the analysis of complex, industrially important processes and reactors.

**Martin Grötschel,** vice president, Konrad-Zuse-Zentrum, Berlin. For contributions to combinatorial optimization and its applications.

**Julia S. Higgins,** professor of polymer science, department of chemical engineering, Imperial College, London. For application of neutron scattering and reflectivity to polymeric materials, and for service to the scientific community.

**Tsuneo Nakahara,** vice chairman, Sumitomo Electric Industries Ltd., Osaka, Japan. For contributions and leadership in the development and industrialization of materials for optical communications.

**Timothy J. Pedley,** G.I. Taylor Professor of Fluid Mechanics, department of applied mathematics and theoretical physics, University of Cambridge, England. For research on biofluid dynamics, collapsible tube flow, and the theory of swimming of fish and microorganisms.

**Amir Pnueli,** professor of computer science, Weizmann Institute of Science, Rehovot, Israel. For the invention of temporal logic and other tools for designing and verifying software and systems.

## Gibbons Joins NAE as Senior Fellow


*John H. Gibbons*

John H. Gibbons, former assistant to the president for science and technology, and former director of the White House Office of Science and Technology Policy, will join the NAE as senior fellow on 1 April 1999. Gibbons will work with the NAE president, other officers, members, and staff to identify emerging engineering and technology policy issues that the NAE and its sister organizations, the National Academy of Sciences and the Institute of Medicine, can address in a timely and productive manner. He will also provide guidance in developing implementation procedures, particularly with the executive and legislative branches of the federal government, for such activities.

Following his formal training in physics, Gibbons spent 15 years at Oak Ridge National Laboratory, where he studied the structure of atomic nuclei, specifically the role of neutron capture in the nucleosynthesis of heavy elements in stars. Beginning in 1970, he led studies on how to use technology to produce and use energy more efficiently and minimize the environmental impacts of energy production and consumption. In 1973, Gibbons was appointed the first director of the Federal Office of Energy Conservation. Two years later, he returned to Tennessee to direct the University of Tennessee Energy, Environment, and Resources Center. In 1979, he returned to Washington to direct the Congressional Office of Technology Assessment (OTA), which provided Congress with nonpartisan, comprehensive analyses on a broad spectrum of issues involving technology and public policy. He left OTA in 1993 to join the White House staff.

Dr. Gibbons was elected to the National Academy of Engineering in 1994 for his leadership in developing and communicating national policies for technological issues.

## NAS's Alberts Re-Elected

*Bruce Alberts*

The members of the National Academy of Sciences (NAS) re-elected biochemist Bruce Alberts to a second 6-year term as president of the Academy. Alberts's second and final term runs from July 1999 through June 2005. As president of the NAS, Alberts serves as a member of the council of the NAE.

NAS members also elected R. Stephen Berry as home secretary. Berry is James Franck Distinguished Service Professor, department of chemistry, University of Chicago. Elected as councillors at large were Brian J. L. Berry, University of Texas at Dallas; John I. Brauman, Stanford University, Stanford, Calif.; Kenneth I. Kellermann, National Radio Astronomy Observatory, Charlottesville, Va.; and Jane Lubchenco, Oregon State University, Corvallis.

Alberts, 60, was elected to membership in the NAS in 1981. He came to Washington in 1993 from the University of California, San Francisco. As president, Alberts also serves as chair of the National Research Council (NRC), the operating arm of the NAS and the NAE. The NRC conducts independent science, engineering, and health policy studies under a congressional charter with an annual budget of $180 million. NAE President **Wm. A. Wulf** serves as NRC vice chair.

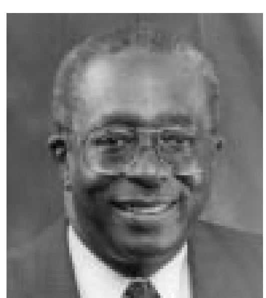
During his first term, Alberts focused heavily on science and mathematics education issues, helping to steer development of the landmark National Science Education Standards, currently being implemented in school systems across the United States. He also devoted considerable attention to the important role science policy plays in the international arena. Alberts spearheaded a drive to bring together academies of sciences from around the world to work on issues of mutual interest, including population growth, the environment, and agriculture. His interest in seeing more science incorporated into U.S. foreign policy decision making led recently to an NRC project for the State Department addressing the issue. That study, now under way, is due out later this year.

## Women in Engineering Update

NAE members **Jack Blumenthal,** TRW Space & Defense Sector, and **Julia Weertman,** Northwestern University, fielded questions on engineering careers from around the country in the NAE's first on-line discussion room, launched during National Engineers Week, 21–27 February. The discussion was part of the NAE project, Celebration of Women in Engineering (CWE), and included a live "Internet chat" on February 23 with middle school, high school, and college students. The discussion room and the Internet chat are firsts for the Academy and may become regular features of the CWE website, www.nae.edu/cwe. Weertman is a member of the CWE committee.

The Summit on Women in Engineering will be hosted by the NAE on 17–18 May. Part of the CWE project, the summit will draw broad, high-level national attention to the low numbers of women who become engineers or who remain in engineering throughout their careers. Chaired by **E. Gail de Planque,** former commissioner of the Nuclear Regulatory Commission, the summit will create a series of national partnerships intended to diversify the engineering workforce. Along with de Planque and Weertman, **M. Elisabeth Paté-Cornell,** Stanford University, serves on the steering committee for the summit.

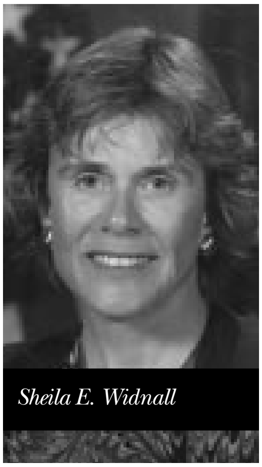
## Reed to Chair Diversity Committee



*Cordell Reed*

In support of NAE President Bill Wulf's efforts to focus attention on the issue of diversity in engineering, **Cordell Reed,** retired senior vice president, Commonwealth Edison Company, has agreed to chair the new NAE Committee on Diversity in the Engineering Work Force. The committee's first task will be to plan and convene a workshop to answer the question: Is there a business case to be made for diversity in the engineering work force? For further information, contact NAE Program Officer Victoria Friedensen (phone: 202/334-1605; e-mail: vfrieden@nae.edu).

# NAE Thanks Donors


*Sheila E. Widnall*

The National Academy of Engineering has built a solid program of independent, self-initiated activities aimed at long-term national interests in technology and public policy. Whether in technological innovation, the environment, or public awareness, the NAE's program provides sound, credible guidance to the nation's leaders.

These independent studies, workshops, and symposia are made possible because of the generosity of the Academy's contributors.

This past year, the NAE, the National Academy of Sciences (NAS), and the Institute of Medicine (IOM) took an unprecedented step in the history of the National Academies by joining together on a capital campaign. The three organizations cooperate in governing the work of the NRC, but fundraising has historically been carried out by separate institution-specific development offices.

During 1998, the NAS/IOM and NAE development offices merged in order to nurture collaboration within the Academy complex, better serve our donors, and maximize resources. Having successfully met those objectives, the NAE is pleased with the progress made thus far.

The NAE's endowment stands at $55 million; the allocation from the endowment provides approximately $1.5 million each year, about half of the funds needed to support the NAE's programs. The balance is raised annually through restricted and unrestricted grants from corporations, foundations, and individuals. This 50-50 funding ratio means that the NAE must be accountable for its activities, since raising external funds depends upon the success of its programs. The NAE is, in essence, constantly testing its ideas in the marketplace.

At the same time, using funds from our endowment testifies to our belief in the value of our programs. It also gives the NAE important flexibility. We can seed new projects before outside support becomes available as well as undertake certain activities entirely free of funding that could appear to compromise the impartial role the NAE plays.

The NAE gratefully acknowledges the many members, individuals, foundations, and corporations that supported our programs and activities during the period January 1–December 31, 1998; a total of $6,545,623 was received. Every gift, whether new or renewed, individual or institutional, represents trust that our donors place in the Academy's work. We value the relationships built over the years with our supporters and audiences and pledge our continued dedication in providing technological leadership in service to the nation.

Sheila E. Widnall
NAE Vice President
Abby Rockefeller Mauzé Professor of Aeronautics
Massachusetts Institute of Technology

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Linda S. Sanford
Maxine Savitz
John A. Schey
Warren G. Schlinger
William R. Schowalter
Robert C. Seamans
Laurence C. Seifert
Robert J. Serafin
F. Stan Settles
Richard P. Simmons
Massoud T. Simnad
J. Edward Snyder, Jr.
Edgar A. Starke, Jr.
Richard J. Stegemeier
Dale F. Stein
H. Guyford Stever
William D. Strecker
Ben G. Streetman
Simon M. Sze
Chen To Tai
Morris Tanenbaum
Man-Chung Tang
Daniel M. Tellep
Leo J. Thomas
Gary L. Tooker
Hardy W.Trolander
R. Rhodes Trussell
Bernard A. Vallerga
Raymond Viskanta
Irving T. Waaland
Milton E. Wadsworth
Steven J. Wallach
Kuo K. Wang
John T. Watson
Walter J. Weber
Johannes Weertman
Julia R. Weertman
Robert J. Weimer
Max T. Weiss
Irwin Welber
Jack H. Wernick
John R. Whinnery
Robert M. White
J. Ernest Wilkins, Jr.
Ward O. Winer
Bertram Wolfe
Edward Woll
William. A. Wulf
John F. Yardley
Ben T. Zinn

**GOVERNMENT**

National Science Foundation*
United States Department of Defense*

*Denotes contributions restricted to support of specific NAE program activities.

## NAE Calendar of Meetings

**1999**

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| 12 March | NAE Congressional Luncheon |
| 19 March | NAE Regional Meeting<br>University of California at Berkeley |
| 31 March | Task Group on the Election of Officers and Councillors |
| | NAE Regional Meeting<br>Cambridge, Mass. |
| 8–10 April | Second German-American Frontiers of Engineering<br>Beckman Center, Irvine, Calif. |
| 13 April | NRC Governing Board Executive Committee |
| 19–20 April | NAE Council Strategic Planning<br>Chicago, Ill. |
| 21–22 April | Latino Science and Engineering Consortium |
| 27 April | NAE Regional Meeting<br>Wilmington, Del. |
| 28 April | NAE Regional Meeting<br>Palm Beach, Fla. |
| 29–30 April | Workshop on the Potential of Promoting Technological Advance through Government-Sponsored Prizes and Contests |
| 3–4 May | Convocation of Professional Engineering Societies |
| 11 May | NRC Governing Board Executive Committee |
| 11–12 May | NRC Governing Board |
| 12 May | NAE/CSMEE Committee on Technological Literacy<br>(Planning meeting) |
| 13 May | NAE Audit Committee |
| 13–14 May | NAE Council Meeting |
| 17–18 May | Summit on Women in Engineering |
| 24–28 May | Thirteenth CAETS Convocation<br>Sophia-Antipolis, France |
| 11 June | NAE Regional Meeting<br>Seattle, Wash. |
| 14 June | NAE Regional Meeting<br>Argonne, Fla. |
| 17 June | NRC Governing Board Executive Committee |

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

# In Memoriam

**FRED W. ALBAUGH,** 85, retired director, Pacific Northwest Laboratory, died on 22 February 1999. Dr. Albaugh was elected to the NAE in 1978 for leadership in many areas of research and development, particularly in applying nuclear energy to defense and civilian needs.

**BERNARD BUDIANSKY,** 73, Gordon McKay Professor of Structural Mechanics, emeritus, and Abbot and James Lawrence Professor of Engineering, emeritus, Harvard University, died on 23 January 1999. Dr. Budiansky was elected to the NAE in 1976 for contributions to the understanding of buckling phenomena, materials behavior, and new mathematical analyses of structural response.

**FRANKLIN S. COOPER,** 90, retired president, Haskins Laboratories, died on 20 February 1999. Dr. Cooper was elected to the NAE in 1976 for originality in speech instrumentation and its application to human communication, including aids for the handicapped.

**HARMER E. DAVIS,** 93, professor emeritus of civil engineering and director emeritus, Institute of Transportation Studies, University of California, Berkeley, died on 24 December 1998. Professor Davis was elected to the NAE in 1967 for conception and development of transportation engineering programs.

**HOWARD W. EMMONS,** 86, Gordon McKay Professor of Mechanical Engineering, emeritus, Harvard University, died on 20 November 1998. Dr. Emmons was elected to the NAE in 1965 for his contributions to aerodynamics.

**JAMES P. GOULD,** 75, retired partner and consultant, Mueser Rutledge Consulting Engineers, died on 25 December 1998. Dr. Gould was elected to the NAE in 1988 for major contributions in the application of geotechnical theory to design and construction of underground works.

**MEREDITH C. GOURDINE,** 69, president, Energy Innovations, died on 20 November 1998. Dr. Gourdine was elected to the NAE in 1991 for outstanding contributions in the field of electro-gas dynamics and the development of practical devices derived therefrom.

**GEORGE R. IRWIN,** 91, professor emeritus of mechanical engineering, University of Maryland, died on 9 October 1998. Dr. Irwin was elected to the NAE in 1977 for invention of modern fracture mechanics and its innovative application to engineering design.

**CLARENCE E. LARSON,** 89, retired commissioner, U.S. Atomic Energy Commission, died on 15 February 1999. Dr. Larson was elected to the NAE in 1973 for the development of processes for recovery and purification of uranium and leadership in nuclear plant design.

**IAN McLENNAN,** 88, retired chairman, Broken Hill Proprietary Company, Ltd., died on 25 October 1998. Dr. McLennan was elected a foreign associate of the NAE in 1978 for the introduction of advanced technologies into the Australian iron and steel industries.

**RYOICHI NAKAGAWA,** 85, retired corporate officer, Nissan Motor Company, Ltd., died on 30 July 1998. Dr. Nakagawa was elected as a foreign association of the NAE in 1990 for outstanding leadership and achievements in the development of high-performance aircraft and automotive engines, emission control systems, and electronics.

**ELBURT F. OSBORN,** 86, vice president for research, emeritus, Pennsylvania State University, died on 19 January 1998. Dr. Osburn was elected to the NAE in 1968 for advances in ceramic, slag, mineral, and steel technologies.

**WILBUR L. PRITCHARD,** 66, president, W.L. Pritchard & Co. Inc., died on 18 March 1999. Dr. Pritchard was elected to the NAE in 1995 for contributions to microwave and satellite technology as applied to communication and direct broadcast.

**JOSEPH F. SHEA,** 72, retired senior vice president, Raytheon Company, died on 14 February 1999. Dr. Shea was elected to the NAE in 1971 for personal leadership in the development of ballistic missile technology and advancement of manned spaceflight.

# National Research Council Update

## Reducing Disaster Losses

A new report from the National Research Council's Board on Natural Disasters, *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. The report says that the network should be designed to provide timely data in formats most useful for those who will make decisions in emergency situations. Once a national network is proved effective, it could be expanded to include other countries, it notes.

New sensors, communication technologies, and modeling programs have greatly improved efforts to monitor earthquakes, storms, and other natural events; identify hazard areas; and take inventory of critical infrastructure such as buildings, roads, and power systems. However, emergency managers often are called on to make decisions with incomplete information, the report says. Many regional or local agencies may not have access to costly, sophisticated computers and other technologies. In some cases, critical data are not widely available because of technological limitations. In addition, data are generated by a variety of different sources with inconsistent standards for presenting the information, making it difficult to interpret and use.

To overcome these obstacles, the report suggests the national disaster network should

- combine data from different sources into timely, mean ingful information for decision-makers;
- ensure that information is accurate and reliable;
- develop an effective plan for disseminating data; and
- obtain resources and commitment from data users.

NAE member **Lloyd S. Cluff,** Pacific Gas and Electric Co., served on the study committee.

# 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, D.C. 20055. For more information or to place an order, contact NAP on-line, http://www.nap.edu. To place an order by phone, contact NAP at (202) 334-3313 (in the Washington metropolitan area) or (800) 624-6242 (outside the Washington metro area). *(Note: Prices quoted by the National Academy Press are subject to change without notice. On-line orders receive a 20 percent discount. Please add $4.00 for shipping and handling for the first book ordered and $0.50 for each additional book. Add applicable sales tax or GST if you live in CA, DC, FL, MD, MO, TX, or Canada.)*

**Advanced Technologies for Human Support in Space.** Argues that NASA research related to living and working in space would benefit from better internal evaluations and periodic external reviews. Recommends research to determine optimal crew schedules, workloads, distribution of tasks, and training procedures for long missions. Hardbound, $35.00.

**Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering.** Third in a series on science and engineering education and careers, this guide features a list of the fundamental practices of a successful mentor, vignettes that illustrate good and bad examples of mentoring, advice for new mentors, and pointers on the different kinds of guidance needed by undergraduate, graduate, and postdoctoral students as well as junior faculty. Paperbound, $7.95 (prepaid).

**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.

**Engineering within Ecological Constraints.** Presents a rare dialogue between engineers and environmental scientists about the many technical and legal challenges of ecologically sensitive engineering. The volume looks at the concepts of scale, resilience, and chaos as they apply to the interactions between ecological systems and technology. Hardbound, $37.95.

**Exposure of the American People to Iodine-131 from Nevada Atomic Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications.** Finds a higher risk of thyroid cancer among those exposed to radioactive iodine during nuclear bomb tests but says there is no evidence that health benefits would be achieved by instituting government-sponsored screening efforts. Hardbound, $34.00.

**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.

**Policy Options for Intermodal Freight.** Recommends guidelines to help governments evaluate proposals for public investment in freight facility projects and to select financing arrangements. Copies available through the NRC's Transportation Research Board, (202) 334-5519.

**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.

**Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology.** Asserts that major changes in U.S. transportation policies, technologies, and practices may become necessary to reduce motor vehicle emissions and the subsequent risk of global warming during the next century. Copies available through the NRC's Transportation Research Board, (202) 334-3214.