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THE NATIONAL ACADEMIES

National Academy of Sciences
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Editorial

Robert A. Frosch, a member of the National Academy of Engineering, is senior research fellow at the Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, and NAE senior fellow.

Facing Urbanization: The Engineering Challenges

American cities have generally been aging at the center and growing at the edges. In the center there are often problems with brownfields (polluted ex-industrial sites), poor housing stock, noise, and serious social problems. The infrastructure of central cities is aging—already quite old in some places—and often embodies engineering details that have been lost in history. New York City water is delivered through an underground aqueduct which is leaking 10 percent of the water, and has not been inspected in 40 years (you can't turn off the city's water to inspect the aqueduct). During the Boston "big dig," work has sometimes been delayed by the discovery of unsuspected geology, water, and infrastructure underground.

At the edges of the cities there are problems of urban spread into agricultural, forest, and prairie lands with concomitant developing environmental problems and conflicts. Everywhere in urban areas there are traffic congestion problems.

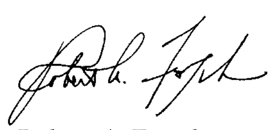
Many of these problems would be familiar to ancient Roman and medieval city residents and governments (although on a smaller, but similarly dense, scale), and like our earlier counterparts, we don't seem to have good engineering solutions, either. (In ancient Rome they attempted to deal with congestion by forcing delivery and pickup to nighttime hours, with resulting problems caused by noise and irate citizens. We, too, haven't done very well with this problem.)

Nevertheless, because of their employment, cultural, social, and business advantages, cities and their metropolitan areas remain popular and continue to grow in most parts of the world. As the World War I song has it: "How ya gonna keep 'em down on the farm after they've seen Paree?" Meanwhile, the population of the world is expected to about double in the next 50 years, adding another 5 billion people or so, most of them in the developing world. If recent trends continue, about 80 percent of these people will end up in cities. Approximately 80 million people a year are going into cities—the equivalent of 8 cities of 10 million people a year. How will these cities, or city extensions, come into being? How will they be designed and built? What will they be like to live in? Can they have a healthy and functioning infrastructure and population?

But be of good cheer: There is engineering work to do!

The NAE's Annual Technical Symposium, held in conjunction with the Annual Meeting, introduced these problems and examined some aspects of them. After a keynote address by John Porcari, secretary, Maryland Department of Transportation, we had four sessions with speakers on topics including urban growth, industrial ecology, sustainable communities, planning, transportation, information technology, cities of the future, and megacities. Four papers from these sessions are included in this issue of *The Bridge.* Each session concluded with questions from the floor with answers and some resulting discussions among the speakers. While not all aspects of the subject could be discussed in the one-day session, it was a lively forum.

In my view, this subject, the future development of cities and metropolitan areas, deserves more systematic attention from the engineering profession and could be a lively subject for programmatic attention by the NAE and its members.

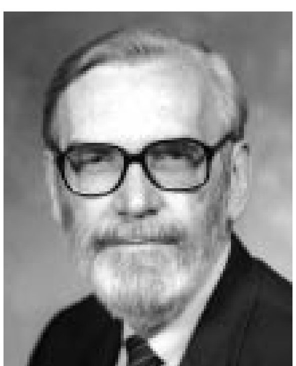


Robert A. Frosch

Wild Ideas in Future Cities

Joseph F. Coates

There is endless potential for science, technology, and engineering to enhance the quality of life for city dwellers, but there can be no progress without an agenda.



Joseph F. Coates is president of Coates & Jarratt, Inc., a futurist firm. This article is adapted from his talk given 5 October at the NAE Annual Meeting Technical Symposium.

The potential for science and engineering to enhance, alter, or radically change cities is real, but contingent upon social, political, and economic developments, and dependent upon the region of the world under consideration.

This paper presents a series of potential developments in the city, nominally in the next quarter century. All of these developments are scientifically plausible and potentially economically viable, and would bring great benefits to city dwellers, whether individual citizens, businesses, manufacturers, or government. While some of these concepts may seem wild, none should seem bizarre to the reader.

The first concept in the series is the notion of energy conservation as a design driver. Should greenhouse warming prove to be real and significant, the early stages of response will involve massive attempts to conserve energy, particularly in the use of petroleum and other fossil fuels. The consequences of this will show up strikingly in new housing. There already are numerous examples of housing, in all of the styles that Americans typically enjoy, capable of operating with today's scale of amenities and comfort while using only 10 to 30 percent of current energy consumption.

The move to wide-scale energy conservation will depend upon big changes in the invisible aspects of home design—better insulation and control of leakage of air in and out. New development will eventually move into aesthetically more radical designs from the ones that we are so familiar and comfortable with. Derivative of changes in new houses will be the need to retrofit the mass of housing that already exists. Businesses, particularly office buildings and commercial structures, will undergo a similar radical transformation.

The notion that these changes will involve great cost is misleading. One of the mainstays of a successful economy in the United States, as measured by traditional standards, is the housing sector. Innovations in that sector in the initial building and retrofit markets imply tremendous positive implications for gross national product, with, in many cases, extended payback from the long-term environmental and financial savings.

Rising Water

Another anticipated consequence of greenhouse warming will be more extreme weather, accompanied by a smearing of the seasons into each other. Because of warming, oceans may rise and, perhaps toward mid-century, cause the melting of the Antarctic ice cap and much greater ocean rise. Initially the rise will be in centimeters, and later in meters when Antarctica begins to melt down.

The consequences of ocean rise will lie in several dimensions. Will, for example, the city of New Orleans be the subject of the world's largest and most expensive revetment to hold back the flood? Will it become the twenty-first century Venice of the New World? Considering that public policy is all too often incremental, the response to the rising Gulf of Mexico and the Mississippi could lead to something like that. A better long-term strategic and economically more practical approach would be a plan to move New Orleans to high ground, perhaps moving it 200 or 300 miles from its present location. Similar changes will occur on the Gulf and along the East Coast. The need to have a long-term strategy for massive relocation, rather than incremental responses, will be extremely important. The undertaking of reconstructing cities and commercial centers on high ground is a truly exciting social and civil engineering prospect.

Domed cities—a favorite of science fiction—may appear on the landscape as construction techniques adapt to changing weather patterns. In principle, there is no reason why cities cannot be domed, but there are the practicalities of scale. It may be more practical to dome a city of 100,000 than one of 10 million, although the per-capita value of doing it with a city of 10 million might be greater. The domed city concept will get more attention as we have growing experience in the cold zones of the United States with the development, particularly in downtown areas, of enclosed passageways that link one building to another so that one can literally move as much as a mile from building to building without ever stepping outside. The logical extension of that would be to externally encapsulate those buildings and open the street level as well as the elevated enclosures to more weather-controlled living. Undoubtedly, domed cities will be more energy-conserving, make more effective use of infrastructure, and be capable of preserving the city from extreme weather.

Will New Orleans become the twenty-first century Venice of the New World?

Subsurface living also has a great deal of appeal from a technical point of view. Earth is outstanding insulation. It makes building construction easier, and it makes more effective use of land. We already have extensive experience with it in apartment houses and office buildings, and a great deal in industrial manufacturing and storage. The problem with subsurface dwellings is that the right amount of architectural and engineering design sense has not yet been applied to semi-subsurface structures in which some portions are below ground and others are not, or to questions of alternative ways of providing natural or artificial sunlight, or listening to the patter of rain, or witnessing a snowfall.

One important element of subsurface structures, particularly housing, will be central lighting. Today's lighting systems are grossly inefficient. Central systems using light pipes to carry light to all portions of the house should be a tremendous energy-conserving feature. A 3,000-watt central system able to light a whole house efficiently would create new design opportunities. In many parts of the country, central lighting could be handled by a solar collector backed up for night and cloudy days by a high-wattage lamp.

Much of the world is in need of basic improvements in housing.

Anticipating again that greenhouse warming will prove to be real and significant, the energy policy for the city, beyond massive energy conservation, is likely to see a felicitous marriage between photovoltaics and nuclear energy. The cost of photovoltaics is steadily falling as the materials technology improves, as the system costs go down with the effects of scale, and as we learn to determine the best places to put photovoltaics for distributed or central generators. The acute passion against nuclear power by a fraction of the population is likely to fade, as an older generation still mired in the fears of the dreadful consequences of World War II passes, and a younger generation less committed to their prejudices and fears thinks more cogently about energy alternatives. Other energy sources—geothermal, wind, and so on—will come along, but as it stands today, the two most attractive candidates as alternatives to fossil fuels are photovoltaics and nuclear. Wind is a solid third contender in many parts of the country.

In conjunction with new energy sources, much of the world is in need of basic improvements in housing. If one looks at the housing of the lowest-income 20 percent of the world's population outside the United States, it is radically alien to the design conditions familiar in the United States and other advanced nations. Typically, for a would-be homeowner with a family of four, one might have a total capital investment of $1,200, plus endless buckets of sweat equity, going into building a residence. Under those conditions, the West has little to offer, since effective housing for that bottom 20 or 25 percent is not Scarsdale with things left out. The housing has to be culturally appropriate, culturally responsive, and within the economic framework of the money and labor available. We see, however, that there is a potentially basic contribution for the West to make. Suppose one could count on a quarter of that housing budget—$300—what high-tech package could be put together to significantly enhance the quality of that housing for poor people? Would it involve a solar cell? Some reinforcing fibers for wall construction? Some devices for sanitizing water? Some technologies for reuse of human waste? It is unclear, but it would be worth exploring to see how the West could deal with that bottom of the heap and enhance the lives of 1 to 2 billion people over the next quarter century. Improvements in housing and sanitation would be a good place to start.

Indeed, the single largest public health problem in the world is microorganisms infecting people from their water or in their food. The cycle may be waste from other people or from animals, but the problem is the same. Western strategies of expensive fresh water and sewage systems cannot apply around the world. We need alternative approaches to bring engineering savvy to break the deadly cycle. In China and other countries night soil (human excrement used in fertilizer) is a positive ingredient in rural agriculture. Is it practical for night soil to become a positive feature in an urban environment, converted into garden feed or into some other appropriate use? The problem is there, the opportunity is enormous, but the path ahead is unclear.

Earthquake Prevention

We also have great opportunity in mitigating earthquake disasters. San Francisco Two without question will occur. The planning issue is whether we prevent San Francisco Three. The evidence is that we should be able to. A quake of the 8 to 8.3 range is likely to be catastrophic. To prevent that from occurring, the obvious solution is to convert an earthquake Richter 8 to an endless number of Richter 3 or 4 earthquakes. Can we induce those kinds of quakes? We have.

When Hoover Dam was first filled to create Lake Mead, it initiated quakes in dormant strata because of the tremendous hydrostatic pressure that lubricated faults. More recently, the Rocky Mountain Arsenal, which was the center for the manufacturing of nerve gas, attempted to cheaply get rid of toxic waste by deep-well injection. Quakes occurred after each injection. When plotted, the amount of injected liquid, in comparison to the quake frequency and intensity, provided marvelously parallel charts.

The concept for San Francisco, Los Angeles, and other quake areas would be to set up injection systems which continually induce low-level quakes that are marginally detectable by people and thereby continually release the stresses that normally build up to "the big one."

Dynamic Structures

In parallel, building technology will continue to improve. Throughout all of history, structures have depended on two fundamental principals, tension and compression—the one best exemplified by the Gothic cathedral, the other by the suspension bridge. Those are the ubiquitous principals in design, with a few minor exceptions, such as pneumatic buildings. We are, however, on the brink of a paradigmatic shift to dynamic buildings—structures that will respond to their environment in real time. Dynamic structures could be made of relatively low-density, high-strength structural members based on new composites, with steel cables placed over buildings and down to the ground, attached to motors controlled by a central processor. Sensors located around and throughout structures would identify earth shakes, wind pressure, and so on, enabling buildings to respond in real time by slackening and tensing the steel tendons that hold their skeletons together.

The advantages of dynamic structures will be flexibility in design and the ability to add or remove floors. Such structures may, for the first time, give us truly temporary buildings. Today, temporary buildings are ordinary buildings with amenities left out. Other advantages of dynamic structures may be lower cost and the reuse of structural elements.

Some of the most exciting things connected with the future of the city will be literally or figuratively invisible, and most significant among those will be simulation. Nothing from the new wine-bottle opener to the new housing development, skyscraper, or cruise ship will be built until it has been designed, planned, evaluated, and modified in cyberspace. Simulation technology will become routine, and will enable more and more would-be users to participate in testing and evaluating the design of structures.

Of course, simulation is only one small example of the anticipated advances in technology. The plummeting cost of telecommunications, coupled with the rapid expansion in the capabilities of computers and their shrinkage in size, will make it increasingly attractive to have every device, system, artifact, and component of our world made "smart." Smartness includes a system's capability to evaluate its own internal performance and the external function it provides, and if there is something wrong, to either initiate repair or call for help.

Smartness could radically alter physical infrastructure. Consider, for example, sewers. Here in Washington, the overflow of a sewer during a recent storm effectively polluted the whole Washington waterfront on the Potomac, making it unsafe for traditional uses. Throughout the Midwest we have had millions of tons of pure, fresh water dropped on the countryside and made almost instantly undrinkable because sewers overflow. I am not quite sure what a smart sewer would be like, but I am dissatisfied with the dumb ones. There seems to be, in principle, no reason why a smart sewer system could not respond to its own flow, moving and diverting the sewage into different places at different times. More importantly, it could respond to external changes and, if necessary, absolutely shut down, become watertight, and save the community from the health disaster of swimming in sewage.

Smartness could radically alter physical infrastructure.

Smartness will also enable our homes to become smarter, safer, more secure, more effective in identifying risks and other inputs, and more adept at responding to them, as exemplified by the automated kitchen. If you think about it, there are a number of low-intelligence "smart" devices in the kitchen—a dishwasher, a stove, a microwave oven, maybe even elements of the refrigerator—but they are all isolated from each other. When we link them together, we should be able to move from the present use of the kitchen to a situation in which a person will make a 15-second transit through the kitchen, talk to the appliances, express what is wanted for dinner and who will be there, and 20 minutes later have a four-course meal tailored to each person's preferences. The reason we do not have this now is that the two main sectors developing technology for the kitchen—the food sector and the appliance sector—have for decades ignored each other and are only now beginning to engage in any discussion about automation and integration. One can anticipate that food packages will come with their own chip that will talk to the equipment and tell it what it is and how it is to be prepared, and the equipment will know how to tailor the food to the residents of the house. Incidentally, the cleanup after the meal will run about six or seven minutes.

Automation will be a dominant feature throughout the house.

Robots running around the house along the model of R2D2 are unlikely, but automation will be a dominant feature throughout the house. For example, one might come home and announce to the chair, "Chair, this is Jane," and the chair will automatically whip itself to the configuration that it knows is most comfortable for Jane.

In industry, the robot was designed as an indoor labor-saving device in factories. Military and space research has led to mobile weatherproof robots, often with onboard intelligence, or the capability of being remotely manipulated. As those concepts move into the civil sector, we can anticipate much of the heavy work of building construction and maintenance being taken over and done more reliably by robots. Site preparation, construction, demolition, waste removal, and the repair, replacement, and maintenance of old roads, streets, and highways are likely to become routine robotic activities.

Robots will begin to play an increasing role in safety and security, in the removal of people from dangerous situations, and in the recovery of people in accidents. Robots might even find a place in the quick, danger-free removal of vehicles from congested streets when they are in violation of the law, as during rush hour. Robots will later move on to perform more prosaic functions for individual homeowners and businesses, such as reworking a lawn, repainting a building, or tackling other heavy-duty physical tasks.

Automation will also affect how we drive. The typical American automobile driver will spend one day a year waiting to make left-hand turns. Why? The traffic lights are either dumb, or they are arbitrarily set for one or two rush hours during the day. They are completely ignorant of the actual pattern of the traffic that they are managing.

It is fully within the scope of present capabilities to make each intersection smart, to identify the traffic at the intersection, run this all through a central processor covering areas of square miles or more, and change the stop light patterns to optimize traffic flow. One might consider this as an enormous improvement in traffic management, but that would be bringing an obsolescent concept to a revolutionary potential. One would not use the capability to just reset more sophisticated, arbitrary, and rigid patterns for traffic lights. One could convert the handling of traffic into a continuous open-ended experiment. That would be a radical enhancement in the handling of infrastructure. However, that concept should be broadened so that virtually any network or complex system in the urban scene could be converted into an open-ended, continuous, real-time experiment. Work done in the Star Wars program is already being considered for this kind of application.

Smart Cars

The current interest in intelligent transportation systems, formerly called intelligent vehicle highway systems, is moving to the stage of practicality. Geopositioning information is now routine in high-end vehicles, and it is reported to be useful and effective by many people. Off-the-road, to-the-road, to-the-vehicle, or to-the-driver communication will surely grow. There is the increasing likelihood of direct communication from vehicle to vehicle, as short-range radar informs the trailing car that the one ahead is slowing down, enabling the vehicle itself to safely reduce its own speed, responding faster than its human driver can. The car can operate by itself. Presumably, that will first occur on a practical scale on long stretches of road, and later move into increasingly congested areas of rural, suburban, and urban density.

The ultimate extension of this concept is to picture the automobile as a robot that in no way requires a human to be present. For example, imagine a homeowner talking to the car. “Mary, it is getting close to the end of the school day. Please go pick up Harriet and George at 3:05. Do not let anyone else into the car. On the way home stop at Safeway and tell Harriet to pick up two loaves of bread and a dozen eggs. Again, let no one else into the car. I look forward to you all being back here by 3:50. Should anything go wrong, I will be here. Mr. Smith is at his office this afternoon.” The car will go to do all its functions without a human operator. The auto industry seems not to have thought that far ahead, or has a bit of understandable timidity about suggesting that cars eventually become autonomous vehicles.

The City—the Center of Civilization

Throughout all of history, the city has been, and remains, the center of civilization. “Rural civilization” is a contradiction, and “suburban civilization” is an oxymoron. The keynotes of civilization in the city are museums, zoos, libraries, theaters, and other public centers of culture. Technology will radically alter all of them.

Museums will go high tech. As one sees an exhibit one will be able to press a button and get a level of detail appropriate for one’s age and one’s knowledge, in contrast to the museum today that pitches everything to the level of a bright 10-year-old. If you are interested in Picasso’s Blue Period, the museum will be able to call up on a beautiful screen a dozen other works from his Blue Period and give you whatever you want in detail about the history, the technical base, the aesthetic responses, critics’ comments over the years, and so on. Museums and art galleries will be turned inside out. Going into them will be a basic experience with the option of the infusion of knowledge in limitless amounts from the rest of the world.

Libraries, similarly, will continue with their repository function, but become the mechanism for electronic dissemination of information to clients anywhere. An emerging central problem for libraries in the age of information technology, more so than for museums, is funding. It is hard to believe that we will all want to work only from a national center, like the Library of Congress. There will be a place for libraries in the future, not only for traditional books, but audio books, video books, and books done in unprecedented media formats yet to be developed.

Zoos will continue to draw people, but developments in genetics will make the zoos of the future truly unusual. Within the next quarter century the woolly mammoth or mastodon will walk the earth again, the passenger pigeon will fly, and the dodo will waddle. Every museum is a repository of animals waiting to be resurrected through genetic technology. It is a conceptual hop, skip, and a jump from Dolly to the mastodon. That is not to demean or diminish the technical scientific steps along the way, but one can see the clear path. Mammoth flesh is found in large quantities in the Arctic. Pull viable DNA out of that flesh and insert it into a volunteered elephant’s egg. Re-implant the egg and after 18 to 22 months have a mammoth walking the earth. Any extinct animal, where flesh, feather, or perhaps even bone is available, will be a candidate for resurrection. We will also see the creation of interesting transgenic animals, and these will incidentally create issues in law and environmental management about whether they are indigenous species or not, and how we handle them.

Conclusions

Endless numbers of other things lie in the domain of science, technology, and engineering to enhance the quality of life for people living everywhere in cities, but where is the agenda? Without an agenda there can be no advocates, without advocacy, no funding, and without funding, there can be no progress.

If you of the Academy do not structure the agenda, who can, or will? I recommend that the NAE undertake a self-funded project to define a 25-, 50-, and 100-year agenda of specific engineering projects and developments for the United States and the world at large.

Industrial Ecology and the Ecocity

Thomas E. Graedel

Cities can be regarded as organisms, and analyzed as such, in an attempt to improve their current environmental performance and long-term sustainability.

Thomas E. Graedel is professor of geology and geophysics, School of Forestry and Environmental Studies, Yale University. This article is a revised version of his presentation given 5 October 1999 at the NAE Annual Meeting Technical Symposium.

A modern city is the place of residence of hosts of organisms, human and otherwise, and we can picture the metabolism of a city as the sum of the metabolism of its inhabitants (Newcombe, 1979). Ecologists generally study organisms by modeling the flows of nutrients and energy entering individual organisms, of resources being stored for later use, and of residues leaving. All these flows occur within cities as well. Accordingly, the city itself can be viewed as an organism with a metabolism that can be studied. If we examine a city's metabolic flows—nutrients, energy, storage, residue—from an environmental perspective, a further topic can be studied: the potential environmental impacts of the residues. Finally, since we evaluate cities at least partly from a policy point of view, metabolic studies can provide the basis for discussions of the desirability of changes in the scale or type of a city's metabolism, and how such changes might best be accomplished.

Investigating a city as an organism, and thinking about what characteristics and policy approaches might make a city environmentally superior (what we might term an "ecocity"), fall within the purview of the emerging specialty of industrial ecology (Graedel and Allenby, 1995). Industrial ecology is the study of the flows of resources in the technological environment, of the effects of those flows on the natural environment, and of the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources (White, 1994). Industrial ecology addresses itself to societal-level issues as well as to more directed topics such as pollution prevention and the design of products and processes in such a way that their environmental implications are minimal. In a clearly related societal issue, many groups worldwide are attempting to define what is meant by the engaging but fuzzy term "sustainable development." However sustainable development may be pictured, the tools and approaches of industrial ecology will be important in its implementation.

Thus, industrial ecology has the potential to speak to shorter-term issues such as our use of resources and our generation of residues, and to longer-term issues such as sustainability. These issues are not confronted only in cities, but it is in cities that their magnitude and impact are most striking, and where the potential for beneficial action is greatest.

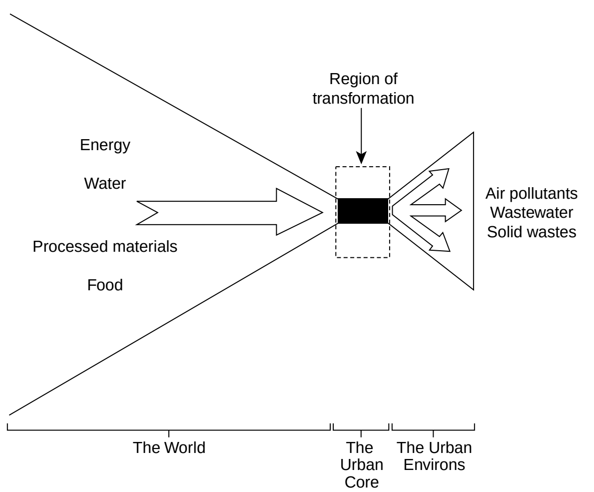


FIGURE 1 Generalized materials flows of urban metabolism. Materials are transported from throughout the world (a vast spatial scale) into the urban core, are transformed in order to sustain the human population, and are then released as wastes into the urban environs, a significantly smaller region adjacent to the urban core.

As centers of population and human activity, cities are also centers for flows of materials. The conceptual picture is shown in Figure 1. Cities gather resources of all kinds from near and far—steel beams from Indiana, porcelain from Europe, apples from New Zealand, coffee beans from Costa Rica. Some of this material is retained for long periods, such as the steel beams in multistory buildings. Other material—the New Zealand apple, for example—is transformed within a short time, and its residues discarded. Though wastes are seldom disposed of within the urban area itself, they generally move much shorter distances than the distances from which their progenitors were acquired. Cities are great attractors, but weak dispersers.

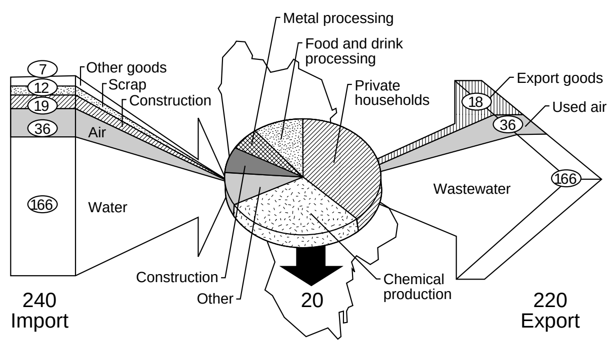


FIGURE 2 Urban metabolism. Flow of materials through the Bünz Valley, Switzerland, in metric tons per capita per year.
SOURCE: Brunner et al., 1994.

One of the few actual studies of the metabolism of an urban region was performed several years ago by Paul Brunner and coworkers at the Technical University of Vienna for the Bünz Valley in Switzerland (Brunner et al., 1994). Several features of the results, shown in Figure 2, are of particular interest. The first is the sheer magnitude of the flow: 220 metric tons per capita per year, on average. Also of note is that the most abundant resource flow, by far, is that of water. The water is not retained; it passes through the system in various uses, acquires a variety of contaminants, and leaves as part of the outflowing residue. The same is true, though at substantially lower throughput, for air used in combustion processes. The resource flows that have more complex fates are those of industrial chemicals and metals; of the 58 metric tons per capita that enter the region, 20 (more than a third) do not leave. Rather, they are added to the "built stock": roads, equipment, housing, and so forth.

Are there optimum flows of resources to an urban organism? Does the answer depend upon the size of the urban region, or its population density, or its culture? As yet, we have too few data on urban metabolism to answer these questions, but it is clear that the answers will relate not only to the urban organism itself, but also to its particular location, to the lifestyles of the inhabitants, and to its surrounding environment.

If we have a picture of resource and residue flows for a city, can we use that information to help determine the degree of environmental responsibility for the city? For the past two years, Gordon Geballe and I have directed a graduate seminar at Yale entitled "Designing the Ecocity," in which we have addressed this and related questions. A consensus of the research done for the seminars is that the following principles help define an ecocity:

- The city must be sustainable over the long term.
- The city must utilize a systems approach to evaluating its environmental interactions.
- The city design must be flexible enough to evolve gracefully as the city grows and changes.
- The open space of an ecocity must serve multiple functions.
- The city must be part of regional and global economies.
- The city must be attractive and workable.

Thus, stocks, flows, and metabolic analyses are an important part of the information relevant to a city's environmental performance, but only a part. To address the broader social and economic aspects of cities and environments, Megan Shane and I have developed an initial set of ecocity metrics and suggested appropriate criteria for rating city performance in each metric on a "high, medium, low" scale (Shane and Graedel, 1999). There are 10 metrics, divided among resource use, residue generation, human habitation, quality of life, and urban environmental management, as shown in Figure 3. Our preliminary assessment for Vancouver, British Columbia, the first application of this system, is also shown in Figure 3. Evaluated against the rating criteria, Vancouver did well in open space,

The city must be sustainable over the long term.

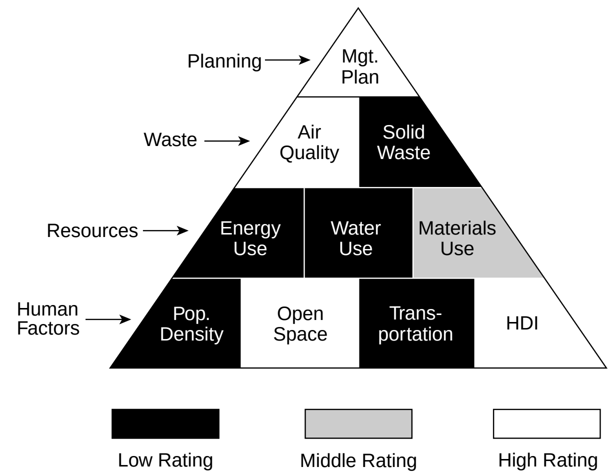


FIGURE 3 Ecocity metrics. The triangle shows the 10 metrics, and the shading shows a preliminary assessment, using those metrics, for Vancouver, British Columbia. HDI = Human development index, a measure of quality of life defined by the United Nations Development Programme.

air quality, quality of life, and environmental planning, but poorly in the use of water and energy, the generation of solid waste, sprawl, and reliance on private transportation. Overall, its ecocity assessment score was 9 points out a possible 20—a good start, but leaving plenty of room for further improvement.

While it is interesting to think of urban regions as organisms and ecosystems, and to devise ways to evaluate their environmental performance, such activities are more than merely intellectual exercises. Rather, they enable us to study the benefits to be derived from industrial and urban metabolic information. These benefits may be grouped into three categories, as indicated below.

Maintaining Human Systems. Urban complexes require that resources to support them be provided in sufficient magnitude and on a satisfactory time schedule. In the case of small urban areas, materials flows are seldom compromised by input or output capacity. As these organisms and ecosystems grow and evolve, limits to efficient connectivity often begin to emerge. In modern technological systems, especially those in densely populated urban areas, these limits are often related to infrastructure.

Urban infrastructure—roads, power lines, natural gas distribution systems, water supply systems, sewerage, etc.—has not traditionally been designed with flexibility and expansion in mind. Furthermore, it is customarily placed out of sight (and out of mind)—under streets, along railroad right-of-ways, within building walls—so that it is difficult to modernize. A recurring problem in growing cities is that infrastructure is unable to keep pace with growth in population and in industrial and commercial activity. By studying and predicting requirements for material flows, urban industrial ecologists can aid in accommodating needs or desires involving flows of resources of all types.

In a similar vein, urban industrial ecologists can evaluate and anticipate limits involving the management of residues. While infrastructure is still an issue here, knowledge of the assimilative capacity of the environments receiving the residues is crucial. Topics for study include the amount and characteristics of wastewater flows, the rate of generation of solid wastes, the disposal of toxic residues, and the like.

Implications for Population Density

It is interesting and unfortunate that we have little in the way of a clear idea of what the limits might be to resource supply and removal within densely populated areas. Might we be better able to reuse materials if population density is high? Will high population density be acceptable from a social point of view? From an infrastructure point of view? Can we reasonably hope to make cities more densely populated than Hong Kong (approximately 2000 people per hectare), and would we want to?

Urban industrial ecologists can respond to these issues not only by suggesting limits to supply and assimilative capacity, but also by working to develop alternative systems for delivering resources, for recycling materials within local metabolic systems rather than exporting them, and by finding ways to reduce flows while maintaining the services those flows now provide. These efforts may immediately determine the feasibility from a materials standpoint of reordering society for the purpose of improving long-term sustainability.

Maintaining Environmental Systems. The continued existence of a planet suitable for supporting life is clearly an important thing to think about; it is also clearly a function of the environmental stresses placed upon the planet by human activities. The levels of these stresses now and in the future can be informed by studies of urban metabolism, as the following examples show.

The air in the Los Angeles Basin of California was clear and healthy until the middle of the twentieth century. In the 1950s, however, a new phenomenon, photochemical smog, began to make the quality of the air progressively worse and worse. Although motor vehicles had been driven around Los Angeles for many years, there were finally enough of them and the tailpipe emissions were high enough that an environmental threshold had been exceeded. Future exceedences of this type may be able to be predicted, but only if the relevant environmental science is understood, the current residue flows have been determined, and future residence flows can be estimated.

Technological resources should cycle just as do nature's resources.

A second type of benefit from urban metabolic studies is the potential for determining the relative intensity of sources of residues. In a study of emissions of copper to the Swedish environment (Landner and Lindeström, 1999), neither industrial activity, nor mining, nor roof runoff proved to be the dominant source of copper, as was anticipated. Surprisingly, residues from automotive brake linings were the source of copper with the highest flow rate to the environment. With this information in hand, Sweden was able to place less emphasis on dealing with unimportant environmental flows of copper, and more on the crucial flows.

Redesigning Human Systems. Urban industrial ecology operates from the perspective that an ideal technological society is one in which materials, once extracted from their natural reservoirs, are retained in useful forms as long as possible through reuse and recycling. That is, technological resources should cycle just as do nature's resources. Such an achievement is only possible if considerable effort is made to enable it: products are designed to use recycled materials, materials are used in ways easy to recover, and so on.

Urban industrial ecology further contributes to resource cycling by identifying previously unappreciated or unmeasured reservoirs that may contain reusable material. A classic study of this type (Kimbrough et al., 1996), examined silver loss to the San Francisco Bay and the industrial and societal use of silver in the same area. Two important facts emerged:

- Most of the loss of silver to the bay occurred during X-ray film developing by small medical and dental offices. Once this silver source was identified, arrangements were made for regular pickup of discarded film developing baths. The result was an improved bay environment and the recovery of silver for future reuse.
- Approximately 10 percent of all silver used was retained on developed X-ray film in medical and dental offices. Since the information on those films can now be scanned into digital form and stored electronically, the X-ray film represents a significant stock of silver that can be "mined" in the future as needed.

Although research such as the silver study has thus far been rare, we can readily imagine that similar work will lead to information on other important but unappreciated reservoirs and on losses important to avoid in order to provide healthy environments.

Cities can be regarded as organisms, and analyzed as such, in an attempt to improve their current environmental performance and long-term sustainability. This is a relatively new area of study, and one where many more data need to be gathered before meaningful results will be derived. In addition, the topic of urban metabolism is not entirely within the purview of industrial ecology; fields such as urban planning, urban ecology, and social science have roles to play as well. Much work remains to be done.

Even though data are currently sparse, the demand for such data and for the revelations that will spring from it is increasing rapidly. The challenge of true sustainability for our fragile planet will be faced or avoided in cities more than in any other locale. We need promptly to determine how to define and develop ecocities, and then to act on our findings, or face what increasingly look to be unmanageable consequences.

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Sustainable Communities

Jonathan Lash

There are political challenges to be met regarding the connection between urbanization and our desire for sustainable communities.

Jonathan Lash is president of the World Resources Institute. This article is a revised version of the talk he gave 5 October during the 1999 NAE Annual Meeting symposium, Facing Urbanization: The Engineering Challenges.

If you've read the program for today's symposium, you'll notice that I'm a lapsed litigator and a recovering regulator, which raises the question of what I'm doing in this group of engineers. Let me suggest that it may have something to do with the perception that, before the engineering challenges of urbanization can be met, there are political challenges to be met regarding the connection between urbanization and our desire for sustainable communities. That's what I'd like to address today.

The genius of our political system has always been seen as its protection of individual rights and liberties. Our economic system has prevailed virtually globally because it is so effective at responding to individual wants and needs. Our culture glorifies individual achievement, from the cowboy, who was so much a part of the iconography of my own childhood, to today's sports heroes. And yet most of the problems that concern people now are related to community. Indeed, I think that addressing those concerns is a fundamental challenge that we face as Americans.

I'll come back to that challenge later, but first I want to start with five premises from which the whole notion of the importance of sustainability comes. The first premise is that human well-being depends on the stability and productivity of interrelated natural systems, most importantly, the biosphere and the climate. The second premise is that, for the first time in human history, human activities are beginning to affect the stability and productivity of those natural systems.

Human well-being depends on the stability and productivity of interrelated natural systems.

Let me explain this second premise further. Human beings, in our miraculous performance of the last half century, producing enough food for a doubling of population, have extended agriculture across the face of the Earth to many places where it had never existed before. The United States has far more forest cover than it did 100 years ago. For example, in Vermont, where I lived for eight years, the land that was 80 percent open 100 years ago is now more than two-thirds forested. But if you look at the globe, 80 percent of the original forest has been cut since the beginning of human clearing of land. And although the world is now about 50 percent as forested as it was before human clearing, the 80 percent figure is critical, because second-growth forests are not the same as original forests in terms of their biological productivity, their diversity of species, and their resilience in the face of stress.

If you project current trends, by the time our grandchildren are talking about the issues we're talking about now, human use will have extended across the face of the Earth. Indeed, it is already true that there is nowhere on land, in the oceans, or in the atmosphere where you do not find the traces of human activity.

The climate, too, is being chemically destabilized. Whatever you may believe about global warming, it is beyond argument that human activity has sharply increased the concentration of greenhouse gases in the atmosphere, most importantly carbon dioxide, and that the chemistry of the atmosphere has historically had a sharp impact on climate. Indeed, projections are that during the century we're about to enter, if present trends continue, we will see sharp increases in temperature and sharp changes in precipitation patterns globally, and we are likely to see a greater number of intense storm events of all kinds, intense droughts of all kinds, and intense weather of all kinds.

The drivers of these changes are not mysterious; they are rapidly growing population and rapidly growing consumption. That's the third premise underlying the notion of sustainability. The first is that we're dependent on physical systems, the second is that we're affecting those physical systems, and the third is that the drivers are population and consumption. Indeed, our wonderfully productive and successful economy makes tremendous demands on natural systems—about 300 kilograms of material per $100 of gross domestic product.

Premise number four is that population will continue to expand for decades, regardless of policy, because most of the world's population is young. And premise number five is that economic growth will continue. It *must* continue—it is both politically and morally necessary that we continue to improve lives and expand opportunity.

A Solution for Sustainability

If you roughly accept those five premises, then there is a tension that we need to address. That tension is at the heart of the concept of sustainable development, and can be stated as such: Rather than choosing one or the other—reducing economic well-being in order to protect physical systems, or destroying physical systems in order to promote economic well-being—we need to find the solution that improves economic well-being in ways that protect physical systems. This isn't such an extraordinary premise in a society as technologically capable as this one, where we know more than enough about how to substitute information and knowledge for materials in the economic system. And that is the essence of the notion of sustainable development—that better lives and improved opportunity can be made available to more people with far less impact on the Earth by reducing throughput and increasing equity, and that knowledge is a key.

With those premises in mind, and that notion of sustainable development, let's look at urbanization. Globally, we are in the midst of a massive shift from a slow, fragmented, rural world to a fast, connected, urban world. Twenty-five years ago the world was two-thirds rural; 25 years from now it will be more than two-thirds urban, with the largest populations of the world living in megacities of over 10 million, mostly in countries we now call developing countries. The process of urbanization is growing the architecture for the global human economy. Decisions about the nature and process of urban life, or failures to decide, will shape outcomes beyond individual cities.

The Cost of Commuting

In the United States, the march of strip development, subdivisions, and greenfield industrial development outward from a dense core of cities is creating the irony of urbanization by dispersion. Indeed, one symptom of that process is how important a question *getting there* has become in our lives. I saw a few months ago a federal study that suggested that, in this region, two weeks are lost for the average worker per year waiting in traffic, at a cost of $1,055 per worker (Texas Transportation Institute, 1998). Just imagine for a moment what would happen if the Environmental Protection Agency proposed a new clean-air plan that was going to impose a cost of $1,055 per year per worker. There would be outrage across the land, yet we are doing it to ourselves in the way we are growing our urban areas.

In the developing world, urban areas are being formed not by plan but by accretion, as the turbulent currents of demographic and economic change swirl and drop their burden of people—people who seek something better than rural impoverishment, at least the possibility of occasional employment, and the dream of access to education and services. It may begin as a sudden bloom of squatter shacks outside of Bangkok or it may, as in Mexico City, be a process where squatter settlements climb further and further up the sides of mountains 10 miles outside the center of the city. This is a different kind of sprawl—first they build it, then they improvise crude services, then they bring utilities, and then they eventually demand the full range of services from the city, as the city spreads miles beyond them.

In China, urban areas are growing 10 times as fast as the population at large. Indeed, in several cities the rate is 20 times as fast. Despite the close regulation of human movement, illegal immigration to cities is one of the largest forces operating on the Chinese economy; again, because people are drawn by at least the hope of economic improvement.

Cities offer the possibility of huge economic energy and efficient delivery of services—but they also concentrate misery and intense pollution. For example, with urbanization there is a trend toward motorization. There are now 700 million vehicles in the world. This number is growing much faster than population, is concentrated in cities, and will soon reach 1 billion. Looking at China again, the government has launched an individual mobility strategy as an important part of their next five-year plan. It will result in a skyrocketing of automobile manufacturing, traffic, and pollution. If you have been in Beijing, you know that this last problem is an intense one. Premier Zhu Rongji recently said that, according to their estimates, the average person in Beijing loses five years of life as a consequence of vehicle-related pollution (Zhu, 1998). In most of the world, most of the air pollution in cities is the result of vehicles. Even in the developed world's wealthy cities, growing numbers of vehicles are overcoming the progress made in controlling pollution, and rates of health-threatening pollution are either remaining stable or growing again.

Most of the air pollution in cities is the result of vehicles.

Cities are growing because they are powerful economic engines. But people's dreams of a good life are woven of many strands—family, neighborhood, access to school and store—and beyond that, a set of amenities they want to have available—jogging, biking, walking, paddling, rock climbing. People expect those amenities in a just-in-time form. They don't want to travel three hours for the opportunity; they want it to be part of their life in a city.

The most important cause of injury and death among children in the United States is not murder or cancer or lung disease. It is accident, and accident is related to design. Accident has something to do with the livability of the places that we are creating, which brings me back to the underlying question I wanted to address, which is about politics. What can create the political support to change the direction of these trends?

My experience has been that one of the most intense forms of political change occurring now, one that is often below the radar of national politics, is taking place in cities and communities, because people understand that their problems are problems of *community*. This is true in the United States and globally, because people identify community as the level at which they can define and implement their aspirations.

The President's Council on Sustainable Development (PCSD), which I cochaired for six years, included CEOs of Fortune 500 companies, members of the President's cabinet, and leaders of environmental, tribal, labor, and civil rights organizations, all of whom participated in meetings held around the country. We started with a notion of approaching sustainable development through a set of global issues—resource and pollution issues—and ended up focusing more and more on communities as the place where the fundamental decisions that determine sustainability would be made.

The concept of sustainable communities is not simply a question of engineering choices, but is rather first about enabling people to coalesce around dreams. When the PCSD looked at communities seeking sustainability, we found seven things that seemed to mark those that have been most successful:

1. It is important that sustainability efforts serve, invest in, and respect people, recognizing that the crisis is one of vision and commitment, and that everything depends on empowered people and successful coalitions of common purpose.

2. It is essential to respect and invest in places, because place is the key to community, a unique and irreplaceable social asset.

3. It is essential to align with or create market forces for sustainability. Community sustainability is not an alternative to economic development, it is an advanced form of economic development and must succeed within the reality of our market.

4. It is essential to leverage ecological and social as well as economic assets of communities. Think of it this way: When you are thinking of moving into a new community, what do you look at? Is it solely a set of economic considerations?

5. It is essential to address issues of race and class to embrace the reality that we are an astonishingly diverse community, and to realize the potential strength that diversity can offer.

6. It is essential to build regional alliances. Sprawl has created interjurisdictional interdependence.

7. Successful alliances are locally created, led, and driven. They cannot be created from outside but they can be supported and catalyzed from outside.

Let me conclude with something I wrote with David Buzzelli of the Dow Chemical Company, then cochair of the PCSD, that I fervently believe in:

> The politics of mistrust are the greatest obstacle to the process of innovation and change that we all believe is necessary to achieve the goals we share. We believe that consensus will move America forward both faster and farther than confrontation. Moreover, we believe that consensus is the public's job, not the government's. Government is important in implementing what people agree on, but we all need to do the hard work of listening, learning, and finding common ground. Communities are the right place to start (PCSD, 1996).

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Megacities and the Developing World

George Bugliarello

The large urban agglomerates we call megacities are increasingly a developing world phenomenon that will affect the future prosperity and stability of the entire world.

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The concentration of the world's population in urban areas is growing at an enormously rapid rate, and within that phenomenon, projections call for even more rapid growth of megacities, currently defined by the United Nations (UN) as cities of over 10 million people.[1] From 1975 to 2015, the number of megacities will have grown from five—three of them in the developing world—to 26—all but four in the developing world (UN, 1998).

The definition of what is a megacity is clearly arbitrary, as the population concentration that differentiates megacities from other urban areas changes with time and context. In the ancient world, Rome, with its over 1 million inhabitants, was a megacity, and today, London or Chicago could be considered megacities, even if they fall below the 10 million UN threshold.

Although there are numerous examples in the developed world, megacities are primarily a phenomenon of the developing world. If one considers population projections for the 11 largest urban agglomerates in 2015 (Figure 1), in 15 years most of the largest cities of the world will be in the developing world, a significant change from the largest city populations in 1980 and 1994. Although Tokyo will remain the largest city in the world, New York, at second place in 1980 and 1994, is projected to be at the bottom of the list by 2015, while Mumbai will have climbed from sixth to second place, and Jakarta from last to fifth place. Both Tokyo and New York are experiencing relatively modest population increases, and a number of other large cities in the developed world are experiencing population declines. In contrast, the populations of developing world megacities are typically growing from one to five percent per year, although these rates are expected to abate somewhat in the next 15 years (UN, 1998). However, if all the megacities of the world—developed and developing alike—have one factor in common, it is the great diversity in many of their salient indices, from cost of living to mobility, that often reflects differing approaches to public policies (Parker, 1995).

Despite the fact that megacities are increasingly a phenomenon of the developing world, there are three major reasons why the developed world needs to pay attention to them. First, *what happens in the megacities of the developing world affects the rest of the world.* The combination of high population density, poverty, and limited resources makes the developing world megacity an environment which favors the incubation of disease, from cholera to tuberculosis to sexually transmitted infections, that in an age of rapid communication can almost instantaneously be propagated to the rest of the world. Vulnerability to terrorism, natural hazards, ecological disasters, war conditions, and food scarcity are also exacerbated in the megacities of the developing world. As recent episodes have shown, attacks against embassies, businesses, and travelers directly affect the developed world, particularly the United States.

Megacities, both in the developed and the developing world, are places where social unrest often originates, as demonstrated currently in Jakarta, and historically in Paris and St. Petersburg, the megacities of their time that sparked the French and Russian Revolutions. Such unrest affects the rest of the world, as do other phenomena of megacities, including the rate at which their residents emigrate to other areas, and the competitive challenge presented by their cheap labor forces. Last but not least, the ecological impacts of sprawling megacities extend to other regions of the world, as seen with the air pollution generated by millions of households burning soft coal, or with the disposal of waste, a universal problem epitomized by the odyssey of New York City's waste-laden barges.

The second major reason to pay attention to mega-

1980		1994		2015	
Tokyo	21.9	Tokyo	26.5	Tokyo	28.7
New York	**15.6**	**New York**	**16.3**	**Mumbai**	**27.4**
Mexico City	13.9	Sao Paulo	16.1	Lagos	24.4
Sao Paulo	12.1	Mexico City	15.5	Shanghai	23.4
Shanghai	11.7	Shanghai	14.7	**Jakarta**	**21.2**
Osaka	10.0	**Mumbai**	**14.5**	Sao Paulo	20.8
Buenos Aires	9.9	Los Angeles	12.2	Karachi	20.6
Los Angeles	9.5	Beijing	12.0	Beijing	19.4
Calcutta	9.0	Calcutta	11.5	Dhaka	19.0
Beijing	9.0	Seoul	11.5	Mexico City	18.8
Paris	8.9	**Jakarta**	**11.0**	**New York**	**17.6**
	131.5		161.8		241.3

FIGURE 1 Population of the 11 largest urban agglomerations (millions).
SOURCE: United Nations, World Urbanization Prospects, 1994.

cities is that *they are key instruments of social and economic development.* In a world concerned with the growth of the global population, megacities are strong indicators of both present and future conditions: they have become instruments for dramatic birthrate reductions in comparison to other regions of the countries in which they are situated; they are instruments to promote human genome diversity because they attract diverse populations; they are the site of cultural and educational institutions that promote social development; they often set the tone for a nation's social values; and they are powerful instruments of economic concentration (for example, today Karachi generates 20 percent of Pakistan's gross domestic product and provides 50 percent of government revenues).

A third reason to pay attention to megacities is that *they offer new market opportunities to both the developing and developed world alike,* as discussed further below.

Megacity Dynamics

To understand the role of the megacities in our world today, we need to understand their dynamics. A megacity is a complex organism and its development is largely a spontaneous process. It is not an entity that can be totally designed, as has been learned from a number of planning failures, exemplified by Brasilia, or, in New York and several other U.S. cities, by the so-called projects for low-income tenants. However, if it cannot be totally designed, the megacity can be guided in its evolution through realistic planning.

The first question, in terms of dynamics, is: Why do megacities attract? Why do such large populations flow to them and want to live in them? In the developing world, megacities attract those who are seeking a better life—a higher standard of living, better jobs, fewer hardships, and better education.

The second question is: Why, if they have such force of attraction, do megacities have what appears to be a formidable set of increasingly intractable problems? The problems of megacities include:

- Explosive population growth.
- Alarming increases in poverty that contradict the reasons why a megacity attracts (World Bank, 1991). A concentration of the poor and jobless occurs both in the developing world and, on a smaller scale, in the developed world, as evidenced by the number of unemployed in New York City.
- Massive infrastructure deficits in the delivery of telecommunications services, the availability of transportation, and the presence of congestion. For example, traffic congestion in Bangkok is so bad that the average commute now takes three hours (World Resources Institute, 1996).

Megacities are experiencing very rapid growth with which they cannot cope.

- Pressures on land and housing. China concentrates 5.7 persons per room, as compared to 0.5 persons in the United States.
- Environmental concerns, such as contaminated water, air pollution, unchecked weed growth due to the destruction of original vegetation, and overdrawn aquifers. For instance, Mexico City's aquifer is being overdrawn and is sinking by about 1 meter per year (World Resources Institute, 1996).
- Disease, high death rates, drug-resistant strains of infection, and lethal environmental conditions. For example, 12.6 percent of the deaths in Jakarta are related to air pollution causes (World Resources Institute, 1996).
- Economic dependence on federal or state governments that constrains the independence of megacity administrations.
- Capital scarcity, the factor that shapes the economy of the megacity and aggravates its other problems, from infrastructure to environmental deterioration.

These problems are increasingly intractable because megacities are experiencing very rapid growth with which they cannot cope. Coincident with rapid growth, these problems are occurring in environments where the populations, having flocked to the megacities in hopes of a better life, have ever higher expectations which are generally greater than the ability of a megacity to respond to them.

Megacity problems are exacerbated by what are usually serious deficits in the realm of knowledge. These are deficits in the generation of knowledge, such as the research necessary to address the problems of the megacity, and in the dissemination of knowledge, e.g., in the educational systems. Equally serious are deficits in the utilization of knowledge by the relatively poor and uneducated populations of the megacities. Since megacities are larger than many a nation, they need to address these crucial deficits in knowledge with the same seriousness with which nations address them, through research, education, and other instruments for the generation, diffusion, and utilization of knowledge.

Of all the challenges confronting the megacities, one of the most difficult and urgent for their stability, and for that of the rest of the world, is employment. Today there are 1.5 billion jobless people in the world. One billion more jobs will have to be provided in the next 25 years, a substantial portion of them in the megacities. This will be an enormous challenge, as it calls for a drastic transformation of the work picture in the megacities of the developing world. Today those megacities are characterized by substantial unemployment, low productivity among those who are employed, a large service sector, a small manufacturing sector, and a large and generally inefficient government sector. There is also a large informal sector of employment in family enterprises and small enterprises, from peddlers to small retail stores, which is quite different from the formal sector of large companies and the government.

Megacity problems are exacerbated by what are usually serious deficits in knowledge.

The employment difficulties are compounded by limited job mobility, inadequate transportation to jobs for poorer citizens, and the lack of legal protection for workers, particularly in the informal sector. This lack of jobs, coupled with the lack of housing and the conditions of life at the margins of the megacity, physically speaking in the barrios and favelas, and figuratively speaking in the lack of sufficient attention to needs, has led to the growth of a fundamentalism, the roots of which are mainly economic rather than religious.

To understand the dynamics of the megacities is also to understand their dilemmas. Dilemmas confront all large cities, but they are much more dramatic in the megacities of the developing world. The first set of dilemmas could be called "mayor's dilemmas"—how to balance growth and stability and how to avoid vicious circles in development. Balancing growth and stability entails questions of equity versus efficiency, efficiency versus jobs, and equity versus global competition. A megacity exists in a global market which, if the city is to get its share, constrains the ability to continue to offer economically inefficient jobs to the population—the very jobs that are needed to maintain internal stability.

Development Challenges

A vicious circle in the development of a megacity is that of attraction, growth, and disattraction, as exemplified by Bangalore, a city that offers a good base for growth in terms of a favorable climate, a skilled population, and a good transportation system (Niath, 1996). That base has led to a strong migration into Bangalore, which, in turn, has led to high real estate costs, the creation of slums, health care problems, environmental problems, and shortages of water and energy. This is not exclusively a problem of a developing world megacity. It is often encountered, in different ways, in developed world environments such as the Research Triangle Park in North Carolina. It is, however, far more serious in the developing world, if the hopes that major urban conglomerates be key instruments of social and economic development, rather than of despair, are not to be dashed.

The mayor's dilemmas are often exacerbated by an excessive dependence of the megacity—typical in the developing world—on central federal or state governments (World Bank, 1995). How to lessen that dependence is a challenge both for the megacity and for the nation in which it is embedded. A fundamental rethinking of the city-nation relationship is required, if the nation is to draw the maximum benefit from the megacity and the megacity is to attempt to solve successfully its key problems.

Another facet of this problem is the national dilemma of the balance of focus between a megacity and the rest of the country; that is, the extent to which megacities should receive the lion's share of attention, as often happens to the detriment of other urban areas and the rest of the country. A corollary question is how to slow down the growth of megacities in order to give them the breathing space necessary to provide adequate jobs and infrastructure to their existing populations. Part of the national dilemma is how to find alternatives to megacities by creating or strengthening smaller cities that would offer most of the advantages of a megacity but fewer problems, or by finding other ways of anchoring to the countryside the population that would like to migrate to the megacities. Many experiments to deflect growth from the megacities have failed, however, so the growth continues irrepressibly with serious social consequences—alienated populations that can find neither jobs nor adequate shelter. A recent example that does not seem to have worked as intended is the attempt by Turkey to create a number of new universities away from the major cities like Istanbul, Ankara, and Izmir, as instruments for catalyzing growth and anchoring population there (Organisation for Economic Co-operation and Development [OECD], 1995).

Keys to Solutions

The solutions to the problems and dilemmas of developing world megacities are complex. However, some approaches are essential, such as adopting "efficiency" policies, focusing on appropriate education, developing credit and capital, encouraging community participation, and focusing on technology.

Policies aimed at using more efficiently the resources of the megacities and at developing more efficient systems include the obvious fiscal discipline; the necessity to create financial reforms and to facilitate self-help activities and the work of entrepreneurs; the removal of institutional barriers such as those to home ownership; and the development of more efficient public-private interfaces. They also include the implementation of municipal service subsidies only for persons in need, instead of for services as a whole (usually a recipe for infrastructure deterioration); the deregulation, within limits that do not destroy social stability, of a highly regimented labor market; and essential cross-sectoral integrations, such as those of jobs and transportation and of land use and housing.

The importance of education, as well as of developing adequate credit and capital, is self-evident. The importance of intelligently designed community participation in decisions about the level, quality, and cost of services cannot be sufficiently stressed. Participatory planning does not mean that the community as a whole plans, but that it gets heard and involved in the planning process. This is a powerful, if often inadequately used, mechanism for avoiding costly solutions or solutions that fail to satisfy the needs of the population, for making the role of the megacity government more efficient, and, above all, for enabling the users of the megacity infrastructure, from transportation to schools to housing, to acquire a sense of ownership.

In solving the problems of megacities, technology is key.

In solving the problems of the megacities, technology is key to providing more choices, to making available better tools to address the challenges, and to generating new markets and thus new opportunities for economic development and employment (Bugliarello, 1994; OECD, 1992). In order to carry out this role, a set of issues needs to be addressed in a different context from that of the developed world. One such issue is the adoption of appropriate standards that provide for the sufficient safety and protection of the users and consumers, but that do not unduly inhibit economic development by forcing the adoption of approaches that are too costly. A second set of policy issues includes the extent to which new technologies are needed, as opposed to technologies that may be already in existence elsewhere but are locally new. That is, existing technologies can be provided in new packages to better respond to the needs of megacities, and locally produced technologies can be used instead of imported ones.

Policies are also needed to preserve the coexistence of new and older technologies (for instance, motorized transportation, bicycles, and animal transportation); to develop joint efforts with other cities to solve common problems that are beyond the capabilities of a single megacity; and to determine the appropriate balances between what can be done at a household level and what can be built at the city level (for instance, the extent to which housing can be built with self-help, rather than with large city intervention, or the extent to which energy can be generated, or waste can be processed at the household level, rather than through city networks). Policies must also decide on the balances between soft and hard solutions, for example, the extent to which human labor can be used instead of machines, or whether traffic instrumentation and controls can lessen the need for road construction. Other needed balances are between local and regional focus, such as suburban versus central city development, as well as between the needs of the residents and those of commuters, which often represent a substantial element of the daily population of the megacity (in Cairo, for example, there are 2 million commuters versus 11 million inhabitants [Rodenbeck, 1999]). Finally, policies need to establish an appropriate balance between free market activities and interventions, a balance difficult to attain because of its impacts on social stability.

An important aspect of the quest for a proper balance between efficiency and stability is the issue of subsidies. Experience in developing countries shows that subsidization of an entire service often leads to its deterioration when it overburdens a city budget and the city cannot maintain the service at an adequate level. Thus, both efficiency and sound technological development demand that users should pay for the services they receive, and only those users who cannot pay should be subsidized.

Policies need to establish an appropriate balance between free market activities and interventions.

In terms of technological needs, developing world megacities demand a philosophy for standards and specifications that is different from that of the developed world. In developing world megacities, standards and specifications should favor low-cost technologies that require little maintenance and are easy to repair, instead of more advanced, high-performance technologies. Too often, imports from the developed world fall rapidly into disrepair because they tend to require high maintenance and may be hard to repair. There is little point, for instance, to require air conditioning in transit vehicles if after a while the inability to adequately maintain it leads the passengers to open or even break the windows of the vehicles. "Good enough" technologies are called for, that is, technological solutions that are adequate for the needs of the megacities, but not so refined as to entail high engineering, construction, or operational costs.

A Different Equation

Technologies must also account for a different labor-machine equation than would be found in a highly developed economy. For instance, the sorting of material from urban waste is a significant and traditional source of employment in the poorer cities; it should be replaced by machines only when alternate and more favorable job opportunities are created. Until that occurs, mechanizing the process may be technically elegant and aesthetically pleasing, but could be socially destabilizing, even if it goes against the grain of a developed world engineering and social view. In brief, differences in social and physical environments and customs make it imperative to focus in appropriate ways on the social and environmental acceptability of a technology. Lastly, the export potential of a given technology introduced or developed in a megacity has to be considered; if there is a potential market for the technology, it could enhance the economic viability of the megacity.

Examples of needed technologies range from simpler vehicles with high local content to local energy transformers, cheap people-movers, and flexible multimodal systems for transportation, water supply, and waste removal. In each of these cases, the trunk systems—whether streetcars, gas pipelines, water mains, or sewers—need to be extended by flexible systems that provide services to those poorer segments of the population that are often concentrated at the margin of the megacity, as in the barrios or favelas. Those margins tend to expand more rapidly than the ability of the city to expand its trunk infrastructure—particularly water supply and sewage systems, as well as expressways and rail systems—to reach the periphery. In due time, some poor regions of a megacity improve economically and the trunk systems can be extended to them; but new marginal areas will arise that again will require flexible systems.

Given the importance of self-help initiatives, megacities need materials, supplies, methods, and organization to enable their citizens to help themselves. Finally, "per use" systems are needed to make it possible to charge those who are capable of paying for the use of expressways, water systems, and other services, while subsidies are provided only for those who cannot afford to pay the full rate.

Technologies and products to respond to the needs of the developing world megacities represent major market opportunities for both the megacities themselves and for the rest of the world. Those markets can be satisfied by products from inside the megacities or by products coming from anywhere else. However, for products coming from more advanced industrial economies, the market represented by developing world megacities cannot be viewed just as an extension of domestic markets, as seems often to be the case today. A megacity is a new kind of market that has new requirements, but also, given its large size, offers substantial opportunities to whomever, in either the developing or the developed world, recognizes it and has the skills and patience to pursue it. The market opportunities can be enhanced by aggregating the markets of several megacities, and by devising new appropriate technologies.

Global Market Strategies

Strategies that the developing world megacities need to consider in order to encourage these opportunities include creating effective interfaces between public and private sectors, providing incubators for new or locally new appropriate technologies, and developing joint efforts with other megacities to create a consolidated market, starting with a program of research and development to support the technology needs they have in common (World's Scientific Academies, 1996). An idea of the size and growth of the megacities market is conveyed by the size of the population of the 11 largest agglomerates in Figure 1, which is projected to go from 162 million in 1994 to 240 million in 2016—an increase of 80 million people in just those 11 cities.

An important element of a global market strategy for a megacity is the development of educational thrusts oriented toward that market. Computer education is already making many developing world megacities into sources of software for the developed world. Low labor costs give developing world megacities an advantage when it comes to people-intensive services such as tourism, maintenance, or even, possibly, some aspects of health care. There is no reason, for instance, why megacities could not become places for doing the labor-intensive tasks required to maintain technologies of the developed world, or for providing low-cost, personnel-intensive health care assistance for certain chronic diseases.

In conclusion, the large urban agglomerates we call megacities are increasingly a developing world phenomenon that will affect the future prosperity and stability of the entire world. It is important for both the developing world and the developed world to understand megacities' dynamics, their immense problems and needs, and the economic and market development opportunities they may offer. The evolution of megacities in the developing world will shape patterns of national and global economies, will continue to affect the settlement of vast populations, and will influence the social and political dynamics of the world. Although the megacities are not different in many respects from other urban concentrations, they play a key role on the global stage by virtue of their very size. The megacities of the developing world, confronted by nearly intractable problems, have a pervasive and crucial need for policies and socio-technological and socioeconomic approaches that must be devised in a different context than that of the developed world—a context with different settings, different needs, different challenges, and different opportunities.

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Notes

1. The literature on megacity issues is very large. The United Nations, The World Bank, and the Organisation for Economic Co-operation and Development are among the major sources of information on the subject. This paper has also drawn from an unpublished National Research Council study of megacities, for which I chaired the Synthesis Committee and Judith Bale was the project director.

NAE News and Notes

NAE Newsmakers

M. Robert Aaron, consultant, was awarded the 1999 **International Telecommunications Award** by the city of Genoa, Italy, in October 1999 for his work in the development of telecommunications networks, especially in the growth of digital systems and in packet communications. This award is given by Genoa in the name of Christopher Columbus to someone who has made contributions to telecommunications that have had a worldwide impact in bringing peoples together.

Ted Belytschko, Walter P. Murphy Professor of Mechanical Engineering, Northwestern University, was awarded the **Theodore von Karman Medal** of the American Society of Mechanical Engineers (ASME) in June 1999. Dr. Belytschko was honored for his contributions to engineering mechanics.

Erich Bloch, president, Washington Advisory Group, and founding chairman of the Semiconductor Research Corporation (SRC), received the **Robert N. Noyce Award** during the Semiconductor Industry Association's 23rd Annual Forecast and Award Dinner in San Jose, Calif. Mr. Bloch was recognized for his lifelong contributions to the semiconductor industry and his vision to address the technological competitiveness of the industry.

David B. Bogy, William S. Floyd, Jr., Distinguished Professor of Engineering and director, computer mechanics laboratory, University of California, Berkeley, received the **Mayo D. Hersey Award** in October during the joint ASME/Society of Tribologist and Lubrication Engineers Tribology Conference in Orlando, Fla. Dr. Bogy was recognized for dedicated service to ASME's Tribology Division and his pioneering research contributions.

Davis L. Ford, president, Davis L. Ford & Associates, was installed as president-elect of the American Academy of Environmental Engineers in November 1999.

Serge Gratch, professor emeritus, Kettering University, Flint, Mich., was honored in Ann Arbor, Mich., in October with the ASME **Internal Combustion Engine Award** for distinguished achievement in the field of automotive engineering.

Delon Hampton, chairman and CEO, Delon Hampton & Associates, was inaugurated as president of the American Society of Civil Engineers on 20 October 1999.

Stephen A. Holditch, president, S. A. Holditch & Associates, received the ASME International Petroleum Division's **Rhodes Petroleum Industry Leadership Award** on 5 May 1999 in Houston. He received the award for distinguished and meritorious contribution to the mechanical engineering profession within the petroleum industry.

Egor P. Popov, professor everitus of civil and environmental engineering, University of California, Berkeley, received the 1999 **George W. Housner Medal** from the Earthquake Engineering Research Institute for his outstanding contributions to the development of earthquake hazard reduction practices and policies through research, application of research in structural design and building codes, and service to professional societies.

Ponisseril Somasundaran, was elected to the **Indian National Academy of Engineering.** He is director of the National Science Foundation's Industry University Cooperative Research Center for Surfactants, and La Von Duddleson Krumb Professor, Columbia University.

Morris Tanenbaum, retired vice chairman and CFO, AT&T Corp., received the **Heritage Award** from Johns Hopkins University for his dedicated service to the board of trustees. He was especially commended for helping to guide the university's financial programs during his tenure as chair of the finance committee.

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The following members were honored by the ASME at the 1999 International Mechanical Engineering Congress and Exposition held 14–19 November in Nashville, Tenn.

H. Norman Abramson, retired executive vice president, Southwest Research Institute, received the **ASME Medal** for pioneering research in engineering dynamics, diverse activities in the field of technical communications, and dedicated service to the engineering profession.

W. Dale Compton, Lillian M. Gilbreth Distinguished Professor of Industrial Engineering and interim head, School of Industrial Engineering, Purdue University, received the **M. Eugene Merchant Manufacturing Medal** from the ASME and the Society of Manufacturing Engineers for his lifelong commitment to manufacturing excellence.

Michael M. Carroll, Burton J. and Ann M. McMurtry Professor of Engineering at Rice University, was awarded **Honorary Membership** in the Society for his dedicated service in ASME's Applied Mechanics Division, numerous research contributions and publications, and leadership in all aspects of engineering education.

Woodie C. Flowers, Pappalardo Professor of Mechanical Engineering, Massachusetts Institute of Technology (MIT), received the **Edwin F. Church Medal.** He was honored for promoting engineering education throughout the United States and for inspiring young people to experience science and design engineering.

John B. Heywood, director, Sloan Automotive Laboratory, and Sun Jae Professor of Mechanical Engineering, MIT, was honored with the **Soichiro Honda Medal** in recognition of his pioneering research contributions in the field of internal combustion engines and distinguished leadership at the largest university-based automotive laboratory in the United States.

John P. Hirth, professor emeritus, Washington State University, Pullman, and Ohio State University, Columbus, received the **Nadai Medal** for advancing the understanding of the behavior of materials at the atomic level.

Yu-Chi Ho, Gordon McKay Professor of Engineering and T. Jefferson Coolidge Professor of Applied Mathematics, Harvard University, was presented with the **Rufus Oldenburger Medal** for pioneering research achievements in control and optimization of engineered systems.

Anatol Roshko, Theodore von Karman Professor of Aeronautics, emeritus, California Institute of Technology, received the **Timoshenko Medal** for seminal studies on issues pertaining to fluid mechanics.

Ascher H. Shapiro, institute professor emeritus, MIT, was presented with the **Daniel C. Drucker Medal** for advancing the understanding of fluid flows in the human vascular system.

Charles R. Steele, professor of applied mechanics and mechanical engineering at Stanford University, was recognized with the **Warner T. Koiter Medal** for leading research accomplishments in solid mechanics and pioneering analytical work in the biomechanics of the inner ear.

Edward Wenk, Jr., professor emeritus of engineering, public affairs, and social management of technology, University of Washington, received the **Ralph Coats Roe Medal** for numerous lectures, articles, and books that have positioned him as a leading authority in the ongoing discourse between elected officials and the technical community on technology policy.

1999 Annual Meeting Report

On Saturday, 2 October, the NAE Annual Meeting began with the orientation of the Class of 1999 to the National Academies. That evening, the 88 newly elected members and foreign associates, along with their guests, were honored by the Council at a formal dinner in the Academies' Great Hall.

The public session on Sunday, 3 October, began with remarks by NAE Chair **Robert J. Eaton,** chairman of DaimlerChrysler. Mr. Eaton called attention to the fact that the NAE is at a crucial point in its history and must address essential areas pertinent to the advancement of engineering and society as a whole, such as the issue of technological literacy. Mr. Eaton stated that technological illiteracy "has a lot more to do with the increasing complexity of technology than the level of our IQs, but it's an issue that could have profound implications on how far we go from here, and how fast." (See p. 30 for the full text of his remarks.)

Following Mr. Eaton's remarks, President **Wm. A. Wulf** spoke about "Making A Difference." President Wulf discussed the impact that engineers and engineering have had upon society, and the need for the

NAE to expand the effectiveness of its programs. (See p. 34 for his remarks.) Dr. Wulf also announced an exciting development: the establishment of the Fritz J. and Dolores H. Russ Prize, a new biennial award that will recognize leaders in engineering with a $500,000 cash prize. (See p. 43 for more information on the Russ Prize.)

The induction of the Class of 1999, composed of 80 members and 8 foreign associates, followed Dr. Wulf's address. Next on the program, **Stephen D. Bechtel, Jr.,** chairman emeritus and director, Bechtel Group, Inc., received the Founders Award "for decades of exceptional accomplishments in civil engineering, corporate management, and civic, educational and professional development, all of which have been of great benefit to people in the United States and around the world." (See p. 41 for the full text of his remarks.)

H. Guyford Stever, former president of Carnegie Mellon University and former head of the National Science Foundation (NSF), then received the 1999 Arthur M. Bueche Award "for a lifetime of exceptional service to engineering and society as a researcher, university president, and government official, and for the style of leadership that has made him a preeminent U.S. statesman in science and technology." (See p. 39 for his remarks.)

Concluding the awards program, **Charles K. Kao, Robert D. Maurer,** and **John B. MacChesney** were presented as the 1999 recipients of the Charles Stark Draper Prize. They received this honor in recognition of their individual contributions to "the conception and invention of optical fiber for communications and for the development of manufacturing processes that made the telecommunications revolution possible." (Learn more about the Draper Prize and its recipients on p. 42.)

After the awards program, guest speaker Joseph Bordognd, deputy director, NSF, discussed the nature of challenges in science, engineering, and technology policy. A reception in honor of all award recipients was then hosted in the National Academies' Great Hall.

On Monday, 4 October, a number of briefings on topics of interest to members were held. Discussions included advanced engineering environments, diversity in the engineering workforce, estate planning, teacher education and curriculum development in science and math, materials science and engineering, and sustainability.

Those who attended the spouse/guest program enjoyed a lunch briefing at the Rayburn House Office Building on "Diversity in the Engineering and Technology Workforce." Ms. Terri Fish, staff member for the U.S. House of Representatives Committee on Science and its Subcommittee on Technology, led the discussion on the history of the law that created the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology. A tour of the Library of Congress followed and included a private showing of the recently opened National Digital Library Learning Center.

While spouses and guests were treated to the private tour, members and foreign associates participated in the NAE section meetings. The section meetings provide attendees with an opportunity to cover topics that are of critical importance to their respective fields of interest and to their chosen membership classification.

This year's section chairs are:

Aerospace Engineering
Steven D. Dorfman, Hughes Electronics Corporation (retired)

Bioengineering
Van C. Mow, Columbia University

Chemical Engineering
L. Louis Hegedus, Elf Atochem North America Inc.

Civil Engineering
Loring A. Wyllie, Jr., Degenkolb Engineers

Computer Science and Engineering
Robert E. Kahn, Corporation for National Research Initiatives

Electric Power/Energy Systems
John F. Ahearne, Sigma Xi, The Scientific Research Society

Electronics Engineering
Frederick H. Dill, IBM Thomas J. Watson Research Center

Industrial, Manufacturing, and Operational Systems
Joe H. Mize, Oklahoma State University (emeritus)

Materials Engineering
Praveen Chaudhari, IBM Thomas J. Watson Research Center

Mechanical Engineering
H. Norman Abramson, Southwest Research Institute (retired)

Petroleum, Mining, and Geological Engineering
Robert J. Weimer, Colorado School of Mines (emeritus)

Special Fields and Interdisciplinary Engineering
John B. Mooney, Jr., J. Brad Mooney Associates Ltd.

The social highlight of the Annual Meeting was the reception and dinner dance, held Monday evening at the J.W. Marriott Hotel, with entertainment provided by the Blues Alley Big Band.

The theme of this year's technical symposium, held on Tuesday, 5 October, was "Facing Urbanization: The Engineering Challenges." This area of critical importance was considered in depth. While people are attracted to what city life has to offer, keynote speaker John Porcari, secretary, Maryland Department of Transportation, pointed out that the "vital systems of our cities are old and the associated infrastructure is crumbling." Porcari and other symposium speakers discussed trends in urban growth, sustainable communities, travel and transportation, technology's transformation of cities, and the future of urbanization. Articles based on the presentations by Joseph Coates, Thomas Graedel, Jonathan Lash, and George Bugliarello are presented in this issue of *The Bridge.* Following the symposium, the Annual Meeting adjourned with a reception in honor of all attendees.

This year the Annual Meeting was attended by 813 members, foreign associates, and guests. Mark your calendars now for the next Annual Meeting, 22–24 October 2000. See you there!

NAE Chair's Remarks

Robert J. Eaton is chairman of DaimlerChrysler. He delivered these remarks 3 October at the 1999 NAE Annual Meeting.

Good afternoon. Let me again add my congratulations to our new members. We're happy to have you with us. And I'm glad you could make this meeting.

I say that because I *missed* my induction. I was living in Zurich at the time. I packed my best bib and tucker for the event, and headed for Washington with a stop in London. Well, I got to London but my bags didn't. Since my bags missed the plane in Zurich, the Swiss authorities decided to quarantine them in a bomb shelter for 24 hours. So I turned around and went back. It was a rocky start, but I have thoroughly enjoyed my experience with the Academy since that day, and I'm sure you will also.

As I hope you are able to see from our new strategic plan, which will be distributed starting this week, NAE plans to be an even bigger influence in the future than it has been in the past, and we will be counting on you to help make that happen. You are coming aboard at a time when the whole world, not just NAE, is planning a new future.

The millennium is on everybody's mind these days. Just the T-shirt concessions must be worth a king's ransom. Why all the fuss about 2,000? After all, it's just another number. It's just another trip around the sun like the millions and millions before it.

Well, about 3,000 years ago Hindu mathematicians in India taught the world to count things by tens. If you're getting tired of all the hype, blame them.

The millennium, however, is a convenient ledge from which to rest a minute and look out ahead at what's coming. We can't see that future very clearly, of course. Most of what will happen in the years ahead, like most of what's happened in the past, will surprise us. That's particularly true of technology. But there are a few broad issues we need to deal with before we get too carried away with the specifics.

I want to talk about three of them this afternoon. One is the level of technological illiteracy that exists today. A second is the role of policymakers (in both public and private sectors). And a third is a problem that is growing within the technology community.

The several generations that will welcome the new millennium are the first in the history of humankind that do not know how their machines work. That has a lot more to do with the increasing complexity of technology than the level of our IQs, but it's an issue that could have profound implications on how far we go from here, and how fast.

I knew how a car worked before I was old enough to drive one. I took one apart and put it back together when I was 12. It wasn't very hard. Many other kids could do the same thing.

I've been an engineer in the auto industry for more than 36 years. Like all of you, I'm sure that my overall level of technological literacy would put me well into the top percentile of all Americans. But you know what? I couldn't go out in my garage today and take my car apart and put it back together like I did when I was 12. Oh, I could handle the mechanical parts, but cars today are full of black boxes—electromechanical devices and electronic control systems. To deal with technology today, it takes more technology.

When I was a kid in Kansas I knew how a radio worked because for a couple of bucks I could put together a crystal set and tune in stations all the way from Des Moines to Denver. Today my TV signals are bounced off a satellite 22,500 miles in space. If they don't get to me, I reach for the phone, not my toolbox.

People today rely more than ever on machines they cannot fix and technologies they do not understand. They operate largely on faith. It's an almost theological dependence on our machines to feed us, protect us, entertain us, cure our diseases, or take us across the country or around the world. But it's a faith that—when breached—has serious consequences for those of us trying to manage the development of technology.

We get sued, for one thing. We get sued because the car or the airplane or the boat or the snowmobile didn't live up to expectations—expectations that usually border on perfection. We also get sued because a certain segment of the bar has created a lucrative industry in technology torts and protected it with massive political contributions. They also bank on the technological illiteracy of juries. Juries that don't understand technological limitations are easy to manipulate. Lawyers routinely convince them that every tragedy must have a villain. Someone has to pay!

Every new technology involves risk—some greater than others. The chilling effect of the liability environment we have today will make sure that some technologies never get out of the laboratory. Technological illiteracy is also the raw material for demagoguery on issues ranging from climate change to air quality to whether or not an ABM system will work. Because so few in the general public are able to comprehend the particulars, the protagonists rely on polls and PR gimmicks, instead of scientific evidence and logical arguments.

Now, if I can't tear down and rebuild my own car—one that my own company made—it's obviously unreasonable to expect John Q. Public to make an informed judgment about, say, the safety of our nuclear waste program. At least without some help. And that puts a heavy burden on those who create, manage, and regulate technology today.

Technology policy is made by business people looking to maximize their profits and politicians looking to maximize their influence. That may be a pretty crass way to put it, but it saves a lot of words.

I don't mean to imply, however, that either the business leaders or the political leaders do not act responsibly. They do. Or at least they try. But they are pushed and pulled by many conflicting demands.

Last year when we merged Chrysler and Daimler-Benz, technology was a major factor in the decision to combine our efforts. Other companies are doing the same thing. Consolidation in the global auto industry is a fact of life, and will be for a number of years to come as companies realize that it's the only way they'll be able to afford the new technologies that the public—and governments—are demanding. This can have some serious consequences to innovation, of course.

Would it be better to have 25 or 30 auto companies around the world all chasing these new technologies independently? Would good old-fashioned competition work better than consolidation? Maybe—if each of them had unlimited financial resources. But they don't, and they won't. If governments mandate that cars become more and more environmentally benign (and I assure you I agree with that), then they must accept that competition will be one of the trade-offs.

But I don't want to overstate it. I don't think the auto industry will go as far as the aviation industry where you now have essentially two companies making airliners. I don't think that level of consolidation is necessary. We aren't going to get down to two independent auto companies—but there aren't going to be 25 or 30 either.

And I think the antitrust laws in the United States and the competition laws in Europe will ensure that there are enough companies still going head-to-head that creative new technologies will be developed to serve the public.

The public policies that are changing the makeup of my industry are having an equal impact on many others. We began this century with Teddy Roosevelt busting trusts and yellow journalists exposing the horrible things going on in meat-packing plants and coal mines. We got some needed regulations that protected the public. But in all things, we tend to go too far, and we're ending the century with a penchant to regulate almost everything.

Let me use the Internet as an example because it is notoriously unfettered now but has some regulators drooling to get at it. There are some important issues involved—issues of privacy and freedom of speech. Issues of intellectual property rights and criminal liability. Who can do business on the Internet and how? Who has jurisdiction over it? And the big one—how do you tax this thing?

That will be the big fight—how to tax it. I don't want to sound too cynical, but it's almost inconceivable that we can get all this free stuff forever. It is the natural order of things for government to want its take. Somebody in this town is just steaming right now that I can send mail without a stamp and get it there in a nanosecond instead of three days.

To their credit, most of the potential regulators, including the FCC, have wisely tried to keep out of the Internet's way. But I'm afraid that the widespread use of the Internet, the abuse of it by some, and the possible tax revenues, will bring more and more pressure for government to get more involved. And that could stunt the development of the most important communication tool since moveable type.

The Internet is in its infancy. It hasn't learned much discipline or picked up a lot of manners yet. I don't know what the Internet will grow up to be. I have high expectations. But if it's going to reach its full potential, I know we have to watch it stumble for a while. We have to nurture it and encourage it. We have to protect it. And we have to resist the temptation to saddle it with so many rules, regulations, and responsibilities that it chokes.

So far we're dealing with a population that is technologically illiterate and policymakers who are not always motivated purely by the advancement of science and human knowledge.

The third problem lies within ourselves—within the technology community itself. We are completing a millennium that began with the longbow and ended with smart bombs. We're completing a century that began with streetcars and ended with space stations. And ironically, the very second that the clock turns over, we'll all be holding our breath that the most colossal technological blunder of all time won't shut down virtually everything we've taken a hundred years, a thousand years, to build. It's an irony that only a poet could imagine.

A body of technology so powerful and yet so fragile that leaving two digits off a date can crash it. This would have been great science fiction 20 years ago. It's a reality today. And an embarrassing one. It's embarrassing because the very term "Y2K" could have symbolized a new millennium full of hope for peace and prosperity in a world that finally has the tools to feed all its people. But it has instead come to symbolize the vulnerability and the failure of modern technology. How could a problem so simple and so obvious be ignored by so many for so long? Because we are human beings, with human failings that we can engineer out of our machines but not out of ourselves.

With all the preparations and with all the billions and billions of dollars spent, I think Y2K will turn out, at worst, to be a major inconvenience. For most of us, I don't even think the lights will go out. I even have the slightly perverse notion that it's a good thing. Maybe we've become a little too full of ourselves because of the technologies we've created. Entering the new millennium humbler and wiser will be a good thing.

But we'll have some missionary work to do with the laity. I mean those who depend on technology but don't understand it. The millions who stare into a computer screen all day but have only a broad and hazy idea of how it works. The customer who pays extra for antilock brakes on faith, because he doesn't know how they work. The passenger on the airplane, the patient on the heart-lung machine, the kid doing his arithmetic on a handheld calculator.

All of them have lost some of the confidence they had in technology. There will always be that kernel of doubt, that queasy feeling that somebody paid too little attention to some tiny issue, and we're all going to get an unpleasant surprise as a result. And, of course, Congress will probably investigate.

By the way, I don't want to embarrass our new inductee, Lou Gerstner, by pointing the finger at the computer industry. Maybe not as visibly as this one, but we all have our Y2K bugs, don't we? No matter what industry or what field we're in, some minuscule overlooked detail comes back to haunt us. We certainly have our share in the auto industry.

Automobiles have never been so sophisticated, so safe, so reliable, so comfortable, and believe it or not, so cheap, measured against inflation. And yet almost every month each of the auto companies has to send out recall notices. Never for something big. We spend hundreds of millions each year fixing 10-cent mistakes.

It is now *technologically* possible to have zero defects. So far, however, it hasn't proved to be *humanly* possible. And it probably never will.

It's important that our customers have realistic expectations—high, but realistic. It's important that the policymakers here in Washington and in the state capitals also have high but realistic expectations. It's important that we're able to share information. It's important that technology gets less and less mysterious to those who use it day in and day out.

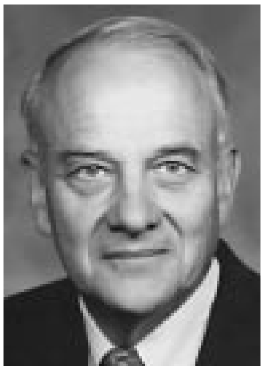
Our new strategic plan puts more emphasis than ever before on communication. The mission statement says that by 2005, NAE will be recognized as the preeminent organization responsible for identifying important technological issues facing society, and advising on their resolution.

Near the top of the list of critical activities is raising the awareness of NAE. We are aiming to have the NAE president testify more often on the Hill, to have more of our positions cited in the Supreme Court, and to have the news media regularly coming to NAE for guidance.

I would like to see our political leaders rely on the Academies for science and technology the way they do the Congressional Budget Office for fiscal advice. If we are going to be effective, we have to be heard. We have to improve our response time. And we can't wait to be summoned, we have to be proactive in seeing issues coming and sharing our advice.

In closing, it is a dangerous world in which the public and its policymakers don't understand the machines they regulate or influence. They don't have to be able to take them apart and put them back together, but they need to understand what these technologies can do—and, perhaps even more importantly—what they *cannot* do. It will be a high priority of NAE as we head into the next millennium to help them do that.

President's Address: Making a Difference



Wm. A. Wulf is president of the National Academy of Engineering. This article is a revised version of the talk he gave 3 October at the 1999 NAE Annual Meeting.

I have a very pleasant announcement to make. As you know, later this afternoon we will announce the winners of the Charles Stark Draper Prize. This $500,000 prize is one of the largest and most prestigious in the engineering profession. Until this year we awarded it once every other year. Last year, however, we announced that, through a generous gift from Draper Laboratory, we are now able to award this prize annually. It has been a source of frustration to many of us that the Draper Prize—this recognition of engineering achievements that have contributed so much to the well-being and freedom of humanity—is not more widely recognized by the public. The experts tell us that one reason for this has been how infrequently we awarded it. People forget! The fact that we will now award the prize annually should help with that part of the problem, and my announcement today should help even more.

Through the generosity of Fritz and Dolores Russ of Dayton, Ohio, and the cooperation of Ohio University, we are adding another biennial prize to what we hope will be a growing family of ways that we recognize the contributions of engineers to society. The Fritz J. and Dolores H. Russ Prize will have a $500,000 honorarium like that of the Draper Prize, and the first honoree(s) will be announced in 2001.

The Russes have made this generous gift to recognize outstanding achievement in an emerging engineering field that is currently of critical importance, and that contributes to the advancement of the human condition through widespread use. By doing this, the Russes hope to increase the public's awareness of the impact of engineering and technology on our quality of life. In its initial years, the prize will recognize achievements in bioengineering.

The Russes are marvelous, gentle people who are dedicated to both engineering and education. Their story is both classic and touching. Fritz was the engineer and entrepreneur and Dolores the bookkeeper and receptionist who together founded Systems Research Laboratory in 1955. They told me a story when I saw them last week that perhaps typifies my impression of them. They cut a hole in the wall between their offices so when she answered the phone she could hand it to him through the wall, thus saving the cost of having two telephones. Well, from that sort of frugal beginning they built a great engineering company, and now they want to "give back," and they are doing so very generously. I feel quite blessed to have had the opportunity to get to know them over the last two years.

Just in case it isn't clear, let me make the point again. Until today, we were awarding one $500,000 prize every two years. We will now award three $500,000 prizes every two years—two Draper Prizes and one Russ Prize. I think this is a marvelous recognition of engineering, and I am very hopeful that this will draw significantly more attention to engineers and their contributions.

Now I want to turn to the topic of my address, "Making a Difference." We have just completed our strategic plan, an exercise you've heard me talk about for the last two years. Now that we're done, the question on the table is this: How do we make a difference?

Engineers, of course, have always made a difference. If you think about the lifestyle of the average person in 1899, entering the twentieth century, and compare it to the average lifestyle today, entering the twenty-first century, there are tremendous differences. Almost all of those differences are due to engineering and technology—to engineered artifacts and processes.

In fact, few aspects of the ways we conduct our lives, our government, and our commerce could have been supported by the technology that existed 100 years ago. Even the increase in life span in this century, from 46 to 76 years, is principally due to improvements in public health, and it's estimated that two-thirds of those improvements are attributed to clean water and sanitary sewers—both products of engineering.

Clearly, engineers *do* have an impact, but we need to expand that impact to include civic and social issues. We have a responsibility to do so. When I say *we,* I mean we the profession of engineering, and more specifically, the National Academy of Engineering. So, that's my topic today—how do we, the National Academy of Engineering, increase our impact? How do we make a difference?

Note that there's a presumption in the question that either we're not making a difference now, or at least we're not making enough of a difference. And that poses some additional, uncomfortable questions. Why aren't we making enough of a difference? What should we be making a difference about—just engineering things, or much broader societal issues? What should we, the Academy, be doing differently in order to make a difference? Are there things we should stop doing? How do we change and not lose our credibility?

I am going to posit a model for change to address these questions—a model for a new *kind* of activity to complement those that we already engage in. But first let me describe the kinds of things we already do.

Our first task is to respond to requests from the government. That's the mandate of the congressional charter that we operate under. It is, and always must be, our top priority. We can and should improve how we do that to make our work more timely, less expensive, and more effective.

Second, we address a class of specific "must do" issues—issues where the leadership of the Academy is crucial to setting the tone for the engineering profession. Last year I devoted my talk to the issue of diversity in the engineering workforce, which I think is one of those on which the NAE must lead. Another such issue is the technological literacy of the general public. In real life I was a professor at the University of Virginia, which was founded by Thomas Jefferson. Jefferson felt that you couldn't have a democracy without an educated and informed citizenry. I fear that we have a citizenry that is technologically illiterate, meaning that our citizens, and the representatives they elect, make decisions every day which depend upon a degree of technological literacy they simply don't have.

Other areas where I think the Academy's leadership is crucial include

- engineering education,
- public awareness and understanding of engineering,
- the international dimensions of engineering, especially in the face of the globalization of industry,
- engineering and technology and their effects on our economy, and
- engineering and technology as it affects the environment.

All of these are issues where the Academy must take a leadership role. These are the kinds of things we've done in the past and we'll continue to do them, albeit perhaps in evolved ways that are more effective.

I won't go into detail about our existing programs now because I want to spend some time talking about new things. But I will mention one project that you probably haven't heard of with relationship to our Pubic Understanding of Engineering program—the Greatest Engineering Achievements of the Twentieth Century.

We're collaborating with more than 60 professional engineering societies to identify the engineering achievements that have had the most significant impact on quality of life in the twentieth century. Note that the emphasis here is on societal impact. We are not interested in just technological "gee whiz." Rather, we are interested in those achievements that are of most importance and interest to the general public. Each engineering society has until the end of October to submit their own top five nominations, and then an anonymous NAE selection committee will select the top 20 achievements from among them. These 20 will be announced at a press event during National Engineers Week next February. We envision that we'll use the stories of the greatest achievements as the basis for a wide variety of education and media materials over the next few years.

Programs like this have long-term impact in ways that are hard to measure, but are nonetheless very real. But, as I said at the beginning, we need to complement them with another kind of activity. Before I discuss that new kind of activity, I want to set two pieces of context.

The first piece of context has to do with the role of the National Academies, and the nature of our credibility. Collectively the Academies *do* have an impact, and it's important to understand that we have that impact *not* just because of who we are, not because we are some of the country's best engineers and scientists. Much of that impact is due to our reputation for unbiased, authoritative analysis, which is due in no small measure to the *process* used by the Academies. This process involves careful question formulation, balanced and unconflicted committee selection, and fact-based, not opinion-based, logic in reports. We are never advocates! We are never just another special interest group!

We have a saying at the Academies that I'm particularly fond of—what the Academies do is "tell truth to power." As we think of new ways of doing business, we need to be sure we retain that absolutely authoritative, unbiased reputation. Reputation is a slippery slope—it's very easy to lose, and very hard to gain back.

The second bit of context is related to the accelerating pace of technological change. That acceleration poses at least two problems for our traditional mode of responding to governmental requests. The first problem has to do with the time crunch. The time between the development of a technology and its deployment is decreasing. Everyone in industry knows this and feels it in their daily work. In parallel, time is also decreasing between the initial recognition of a policy issue posed by an emerging technology, and the need for a response to that issue. Indeed, the greatest complaint about the Academies' reports—they take too long. It's not that somehow our process has gotten worse; rather, it is that the need for quicker response is driven by the pace of technological change. The pressure for greater speed in doing what we do is enormous, and frankly, it is seriously in tension with the need for the quality on which our reputation depends. There's a point beyond which, if you go any faster, you will sacrifice quality.

The second problem has to do with the framing of technology-related issues. Too often, by the time an official recognizes the existence of an issue, the debate about the problem has already been framed in terms that preclude the "right" answer. This is a manifestation of the first problem, but it is an especially frustrating one. For example, I have spent a significant amount of time over the last three years trying get the right kind of intellectual property protection for databases. Unfortunately, before I got involved, the problem had been defined, or framed, as a purely *legal* issue. Computer security is one of my research areas, and I *know* that the right solution involves more than law; it must be coupled with appropriate technology. But technology is simply not on the plate as a possible ingredient of a solution for this problem. It has been framed as purely a legal problem, and it's the only way that the people on the Hill are willing to think about it.

So, the two pieces of context are (1) the important role of process in the credibility of the Academies, and (2) the implications of rapid technological change. Perhaps by setting up these two pieces of context I have telegraphed what I think we need to do, and what has come out of our strategic planning process. The new mode of operation I suggest is one in which we *do the study before we're asked.*

This won't work in all cases, but in many cases I believe we can

- anticipate what changes are enabled by new technologies;
- anticipate the social implications of those technologies and the policy issues that may arise from those implications;
- proactively lay out the options that policymakers will have in addressing those issues; and
- prepare the groundwork for the future debate on those issues to enable the body politic to hold an *informed* discussion.

Where we can do this, we address both of the problems mentioned above. Because we have anticipated the issue we will have enough time to ensure the quality of work and still provide the answers in time, and we'll contribute to framing the question and debate.

I am often asked whether the positions put forward by the Academies really have an impact. The answer is that they *do,* but only if the issue hasn't already reached the "bumper sticker" stage. That is, once an argument has been politicized to the point that it can fit on a bumper sticker, it's too late for us to be effective. We need a mode of operation that lets us get out in front of the bumper sticker stage.

Let's consider some examples of the kind of issues that might be appropriate for this sort of activity. Examples like this, I hope, will suggest two things: first, that at least some of the issues are very deep and fundamental for our democracy, and second, that some of the issues *can* be anticipated. And if we *do* anticipate them, we really can make a difference.

I've chosen my examples from information technology because that's the field I know best. I could have chosen energy, urbanization and infrastructure, micro- and nano-technologies, agriculture, or a host of others, but I just don't have as much insight into those fields. I encourage each of you, though, to think about analogous issues from your own field.

My first example is the Microsoft antitrust lawsuit. I hope all of you realize that the economic models underlying our current antitrust laws, first of all, are about a hundred years old, and second, simply do not explain the software industry.

There is a set of basic assumptions in those economic models that just don't apply—the scarcity assumption, for example. Information is one of those commodities which doesn't lose value by being shared. In fact, it frequently increases its value by being shared. Another assumption is the balance of design cost to manufacturing cost. In the software world the traditional balance is reversed—manufacturing cost is nominal, and design cost is high.

The assumptions also fail to account for the "networking effect." The networking effect states that if I have something alone it is of little or no value, and that the more of us who have it, the greater its value becomes. Standard economic theory says otherwise, but the telephone is a classic example of this. If you're the only person in the world who has a telephone, it really isn't of much value. The more people who have telephones, the more value it gives to you.

All three of those assumptions are upside down in the economic models underlying the antitrust laws. I'm not saying that Microsoft is a bunch or angels, or, for that matter that they're devils. What I am saying is that they are being tried under laws whose assumptions do not apply to the situation at hand, and thus the remedies available to the judge may not serve the greater public interest.

As it happens, many of us saw this problem coming and tried to have some scholarship done five years ago, but we couldn't get a study funded. I'm not a lawyer and I'm not an economist; I couldn't do the study. But we, the NAE, could anticipate that the problem would arise, and, if we had done something about it even five years ago, we might be having a more rational discussion today.

My second example is from Monday's *USA Today.* It seems that almost every day I see articles that make me think we should have thought about that and done something about it two years ago. On Monday the article was about "virtual child pornography." Can something be defined as child pornography if it involves a child-like looking entity—but that is not a child? I don't know. The point is this: our ability to manipulate digital images is so good now that, in effect, we can create undetectable photos of scenes that never existed. In this case the technology was used to create a pornographic film that appeared to involve children, but in fact did not.

The ability to alter photos raises question about their use as legal evidence. It is simply not clear that you should trust a photograph as ever having depicted a real event. And this state of technology was easily predictable 10 years ago.

My third example is *posse comitatis.* The distinction between national security and law enforcement is blurring in the Internet. A law that was passed in the middle of the 1880s, called *posse comitatis,* is a cornerstone of civilian control of the military in the United States. One only need look to East Timor to understand what could possibly happen when you don't have civilian control of the military. *Posse comitatis* says something very simple: The U.S. military operates outside the borders of the United States, and law enforcement agencies operate inside the borders. A simple rule. But in the Internet, where is "outside" and where is "inside?"

Suppose the 911 number in Atlanta isn't working. And a bank is under attack in Seattle. And the power system fails in Chicago. Are we under attack by Iraq? Or a teenage hacker in Des Moines? Or a state-sponsored terrorist group somewhere? Is this a national security issue or a law enforcement issue? For that matter, would anybody even know that all three of these things were happening at the same time? And whether the efforts were coordinated? Who has the command authority to do anything about it? And what are the rules of engagement? And in answering those questions, how do we retain the equivalent of civilian control of the military?

My fourth example is jurisdiction. I am told there are a handful of philosophical bases for legal systems around the world. The philosophical basis for Islamic law, for example, is very different from the basis for ours. All of these systems, however, share a few common attributes—one of which is the notion of jurisdiction, the notion that laws apply in a place. Guess what about cyberspace, about the Internet? There is no place there. There's no *there* there, in the words of Gertrude Stein.

The problem of jurisdiction is illustrated by a case that came up in Tennessee a number of years ago. A prosecutor from Nashville indicted some people from California for hosting a pornographic website. As you know, pornography is defined by "community standards," and as I understand it, the site was pornographic by Nashville standards, but not by California standards.

Whose laws apply? Where is the jurisdiction? I personally hope that a notion this fundamental, a piece of the philosophical underpinning of our legal system, is not decided in a case dealing with pornography on the Internet.

You'll notice that all of the examples I just discussed have a common characteristic. For the most part, NAE members are not the experts who would address the issue. Rather, NAE members are the experts on the technology that enables the situation that *creates* the policy issue, and possibly, as in the case of intellectual property in databases, the technology that could be part of the solution to the problem.

NAE's "value added" is not in addressing the issue—we need to involve other disciplines in that—but rather in recognizing that the issue needs to be addressed. The new model for NAE activity, the model added to the kinds of things we now do, involves the NAE more in

- identifying socially relevant, often fundamental, "future" issues raised by the technologies we are developing;
- engaging the right entities to explore the implications, and providing proper engineering input to the discussion;
- managing a portfolio of such projects; and
- ensuring that the right product reaches the right target audiences in a timely way.

I said I wasn't going to talk about our traditional activities, but I want to note that this last point—ensuring that the right product reaches the right target audiences—is something we need to do better in all of our activities, including our traditional ones. We must identify up front the audience that can effect change, and we need to tailor the product and its dissemination to that audience.

The new type of work I've just described raises a number of issues. First, I think it was Niels Bohr who said "prediction is hard, especially about the future." We won't get it right all of the time, but we need to get it right often enough.

Second, we need to get the time frame right. It's fun to speculate about the long distant future, but I think the issues we're talking about are ones that will come to the fore in two to three years. In essence, what I'm suggesting is just-in-time delivery of advice.

Third, we may sometimes have fewer facts, and that will raise quality control issues. The scholarship on which we base our advice may not be as thorough. We may end up reviewing the various options and delineating their consequences, rather than making a particular recommendation. We may even have to commission scholarship sometimes.

Fourth, and perhaps the most challenging of all, is funding. I'm almost certain that, at least at the beginning, the federal government will not be willing to fund these activities. Too many of the issues will appear "not to be on the watch" of the current office holders. That's the problem I had with getting a study on the economic models underpinning the antitrust laws. One of the main goals I have for the capital campaign is to free up our ability to fund such projects. It's not easy to break the mold that you have operated in for many years.

To conclude, Kettering said something to the effect that he was very interested in the future because he was going to spend the rest of his life in it. Well, the technologies that engineers create enable many different futures. Which of those futures we and our children actually experience depends on a lot more than technology. Specifically, it depends on the legal, regulatory, and policy environment in which those technologies are fostered, impeded, developed, or exploited.

The Academies have been trustworthy advisors to the government on just such issues, but at a time when our advice is increasingly critical, our traditional approach to providing that advice is being strained because of the pace of technological change.

In at least some cases we can anticipate issues. Wayne Gretsky, probably the best hockey player who ever lived, said that he didn't skate to where the puck is, but to where it *will be*. That's what we need to do as well.

Bueche Awardee Remarks

Bueche Award recipient H. Guyford Stever, with NAE President Wm. A. Wulf, NAE Chair Robert J. Eaton, and Earl Dowell, chair of the awards committee. Stever gave these remarks 3 October 1999 at the NAE Annual Meeting.

I am honored to receive the 1999 Arthur M. Bueche Award of the National Academy of Engineering, for which I thank my peers on the Council, on the awards committee, and in the NAE membership.

I am particularly pleased to receive this award at this time because it gives me an opportunity to put on a long, flowing white beard to act out the role of Father Time, closing out the year 1999, as well as closing out the twentieth century, even closing out the second millennium, though I think I should modestly limit my remarks simply to the year and the century in which I have had a ringside seat. But the material in the Bueche Award citation only takes my life back to my college days. In my new role as Father Time for the twentieth century, I must go back as far as I can.

I had an early technology interaction in 1920 when I was about four years old. A friend of mine and I dragged a tricycle and a four-wheel cart to the second floor of my home to race each other down the stairs, with, needless to say, disastrous results. Going farther back in the century, to my birth, when the obstetrician whacked me on my bottom to get me started, I bellowed, "We need more money for basic research!" It was a defining moment in my life.

It is a privilege to join the previous 16 award recipients, with all of whom I have had varying interactions in engineering, science, technology, and education, working from a mix of institutional bases in academe, industry, and government. My acquaintances with many of this group go way back to World War II where, as young engineers and scientists, we had great opportunities to participate in rapidly emerging fields of technology. The federal government became a fertile field for the growth of new departments and agencies based on new technologies and related societal needs. Each of these agencies had a plethora of science policy issues, so we, both as advisors and participants, have had many continuing opportunities.

In the early 1970s there was an awakening to the rising industrial prowess of Japan and Europe. In 1972, with the publishing by the National Science Foundation (NSF) of the first *Science Indicators,* major interest emerged in the comparison of our science and technology policies and budgets with those of leading nations in the industrialized world. Very soon, led by Bruce Hannay and Ralph Landau, thorough NAE studies on international comparisons of relative industrial strengths showed the true nature of our growing international competitive problems in R&D. Clearly, we needed a stronger university-industry-government relationship in R&D.

Along that line of university-industry-government relations, I honor Art Bueche himself as the very model for this award. I particularly valued my associations with Art in the four years when I was science advisor for Presidents Nixon and Ford, in that important transitional period in science and technology policy for the highest levels of the executive branch. At the time the NSF, the temporary home for the top science and technology policy office, had strong funding capability to handle the growing interest in both academe and industry to participate in government science and technology policies and programs. Also, there was strong activism in those days directed towards making research and development more relevant to societal issues. Perhaps the biggest of such issues emerged when the October 1973 oil embargo was established by OPEC, resulting in confusion and near panic. For three years we had our hands full with energy R&D programming and budgeting. Art helped us immeasurably.

I recall teaming with Art in the spring of 1976, our nation's bicentennial year, to open the testimony to a congressional committee, chaired by the Honorable Ray Thornton, on the subject of federal research and development and the national economy. Speaking for the administration, I seized the opportunity to give my thoughts on the broad range of benefits of federally supported R&D, especially the many programs relating to the economy. Then Art, speaking as General Electric R&D vice president, and president of the Industrial Research Institute, added his view of all the areas where leadership was required for success: "First, a knowledge base—generated by ourselves or by other nations—and then discovery, invention, development, manufacture, marketing, distribution, and sales."

That spring of 1976 was a high point in the development of science and technology policy, with the signing by President Ford of The National Science and Technology Policy, Organization, and Priorities Act of 1976. This returned to the White House, by act of Congress, the entire science structure which had been shifted to the NSF in 1973 by President Nixon. The White House structure for science, engineering, and technology has flourished ever since.

As I look back, I think, "What a time we have had!" There have been so many new technology ages and science revolutions that are credited to our century. One can hardly turn on the TV without getting a program describing one of many new technology ages. They all seem to run together and are, as the Vermont farmer says, "inextricably intertwingled." For example, electronics begat radio, radio begat radar, radar begat TV, and then they joined telephony, the solid-state component, and the computer to develop our modern communications systems. Then came the Internet and we have the information age, which sometimes is aggrandized into the knowledge age. Perhaps an even more spectacular example is in the life sciences, with the ages of microbiology, genetics, biochemistry, biophysics, bioengineering, biotechnology, biomaterials, and, especially, the biocomputer.

My Father Time role is running out of time, so I turn to worrying about Baby Time 2000. Change is needed. In past New Years, each new Baby Time was a cherubic boy. Why not double the workforce and have non-identical twins, one boy and one girl? At birth, the Twin Babies Time 2000 will need some extra strength just saying, "We told you so on Y2K."

But that is not the only change needed. Previous winners of this award have all come from the technology fields with physical science bases. We now know that the life sciences will play a preeminent role in the twenty-first century. In fact, they already have for some time. Now we have no excuse not to pick up the most promising areas in the technologies based on the biological, social, behavioral, and computer sciences. Why not have one of the Twin Babies Time represent the life sciences, and the other the physical sciences? Make it a family affair, for it really has become one.

I will not bore you with my predictions of the new technologies which will emerge in the twenty-first century. My favorite quotation about the future is the one from Antoine de Saint-Exupery: "Your task is not to foresee the future, but to enable it." The engineers and scientists of our twentieth century have indeed provided plenty of enabling information for the twenty-first century.

But there is one hope and expectation I have for the coming century. Society is faced with an almost doubling of the world population from its present 6 billion humans to about 11 billion by the year 2100. We must provide twice the amount of food, energy, land, clean air and water, and shelter. Just think of the problems of building all those structures and furnishing all the infrastructure needed to make them work. Engineering and engineering systems problems have already started beckoning the engineers, their professional societies, and their home institutions.

With these optimistic though challenging thoughts, again thank you for the honor of the 1999 Bueche Award.

Founders Awardee Remarks

Stephen D. Bechtel, Jr., takes a look at his new Founders Award medallion with his wife Betty.

Dr. Wulf, Dr. Dowell, members of the Academy: Thank you very much for this honor. Thank you, too, to my wife, Betty, for her support over many decades of frequent travel and long, strenuous hours. Thank you, also, to my associates in Bechtel whose outstanding work over the years has made our company's accomplishments possible.

This recognition by the NAE gives me one of the greatest satisfactions of my life. Like every member of this Academy, through engineering I've been privileged to lead a very interesting, stimulating, and, I hope, constructive life. In my case, it was the challenge and excitement of expanding a family business globally, honing not only the company's engineering expertise, but also our management processes and skills.

In 1960, when I took on the presidency of Bechtel, we booked $500 million in new work. That year, there were 10,900 Bechtel people working on 320 projects in 30 countries. In 1990, the year I retired as CEO, we booked $4.8 billion, and we had 32,500 Bechtel people working on 1,700 projects in 77 countries.

Those years were dynamic. They brought first-of-a-kind, pacesetting engineering/construction projects: from oil platforms in the turbulent North Sea to a gold mine atop a dense jungle mountain in Papua New Guinea; from Palo Verde, the largest U.S. nuclear power plant, to Algeria's first large-scale liquefied natural gas plant; from Jubail, a 360-square-mile industrial city in Saudi Arabia, to the James Bay hydroelectric complex stretched across an area in Quebec larger than New York State; from the Trans-Turkish Motorway, to Boston's Central Artery, to the realization of Napoleon's dream—the Channel Tunnel connecting England and France.

There has never been a dull moment. But those years also involved something else that was to prove very interesting, and ultimately challenging and extremely satisfying: my membership in the NAE. I was privileged to have been elected NAE's first chairman. It was a welcome opportunity to help this great organization focus on making progress in its immensely important mission.

Today, we stand a short three months away from a new millennium. We can look back over a thousand years to when medieval Europe embraced a new labor-saving technology—water power. Succeeding centuries brought the scientific revolution, the industrial revolution, and the information age, all leading to the highest standard of living the world has yet seen. This progress has had global reach, contributing to emerging economies around the world and applying its tools to preserving the environment.

Now, as we look to the future, despite some skeptics who actively promote contrary views, I believe that the next millennium will add substantial progress and benefit to mankind. It is our responsibility to help make sure this progress happens.

Today I'd like to put a challenge to you, the members of this Academy. You represent the leadership of all disciplines of the engineering profession—in the private sector, in public service, and in education. And, through you, let's extend the challenge to every engineer in our country.

The challenge is to further educate the public, particularly young people in grammar school and junior high school, about how engineering has benefited people around the world, and about the work yet to be done. The challenge is to help build more understanding and appreciation for the role of engineers in society. The challenge is to help interest young people in taking studies that keep their options open for enrolling in engineering colleges and pursuing careers in which they can make a unique contribution to society. To meet these challenges, the engineering community must be fully involved. Our profession should also reach out to the underrepresented minorities and to women.

I am immensely proud of our profession's success on several fronts. One is National Engineers Week. We now have 35,000 engineers going into elementary, junior, and senior high schools across the country telling more than 4 million students what engineering is all about. Then, there is the Junior Engineering Technical Society. JETS, now 50 years old, encourages and helps high school students develop their aptitude for engineering, math, and science. Each year, its programs reach more than 250,000 students spread throughout the 50 states.

These are just two of the activities that our Academy fosters. There are other very constructive things the NAE does to educate people on important developments and opportunities in engineering. But there is more to be done. At this point, it is not clear to me what the focus should be for that effort. I encourage every one of us to think about it.

While our collective action is extremely important, let's not forget what we can do individually, too. Looking back to my younger years, I was lucky enough to learn from some of the finest engineers and managers in their fields.

Today, you are the leading engineers in our country, and there are many young people out there who could be attracted to engineering and whose professional lives could be strengthened by your sharing with them some of the stimulating and rewarding activities available in our profession. Many of us are involved now; but I challenge you to do more.

Thank you all. It is an honor to be in your company, and a very great privilege to receive this Founders Award.

Fiber Optic Developers Receive Draper Prize

Left to right: May-Wan Kao and Charles Kao, John MacChesney and Janice MacChesney, Barbara Maurer and Robert Maurer.

On 3 October 1999, the National Academy of Engineering announced that **Charles K. Kao, Robert D. Maurer,** and **John B. MacChesney** are the recipients of the 1999 Charles Stark Draper Prize for their work in developing fiber optic technology, a watershed event in the global telecommunications and information technology revolution.

The Charles Stark Draper Prize, endowed by Draper Laboratory, Cambridge, Mass., was established in 1988 to recognize individuals whose outstanding engineering achievements have contributed to the well-being and freedom of humanity. The once biennial prize will now be awarded annually. This year's award celebrates fiber optic technology, which uses light to carry information through silica fiber material. Its low manufacturing cost and ability to transmit vastly more information than copper wire has fueled the explosion in global communications.

Dr. Kao, who was working at ITT's Standard Telecommunications Laboratories in the 1960s, theorized about how to use light for communication instead of bulky copper wire, and was the first to publicly propose the possibility of a practical application for fiber optic telecommunications. Dr. Maurer led a team of engineers at Corning Inc. that included co-inventors Donald Keck and Peter Schultz, who designed and produced the first optical fiber in 1970. Dr. MacChesney and his colleagues at Bell Laboratories—formerly part of AT&T and now the research and development arm of Lucent Technologies—followed in 1974 with the modified chemical vapor deposition process, which provided a path to the practical mass production of high-quality optical fiber.

During National Engineers Week in February, each of the three Draper recipients will receive a medallion, a certificate of recognition, and their share of the $500,000 cash award.

NAE Announces Major New Engineering Award

At the NAE Annual Meeting on 3 October, NAE President Wm. A. Wulf announced the establishment of a major new award for engineering achievement—the Fritz J. and Dolores H. Russ Prize. This award is named after Fritz Russ, an esteemed engineer and founder of Systems Research Laboratories, and his wife Dolores, a long-time supporter and benefactor of the engineering industry.

Endowed by the Russes through Ohio University, Athens, the biennial Russ Prize is designed to recognize outstanding achievement in an engineering field that is currently of critical importance and that contributes to the advancement of the human condition through widespread use. In its initial years, the prize will recognize achievements in bioengineering.

The Fritz J. and Dolores H. Russ Prize will recognize leaders in engineering with a $500,000 cash award, a gold medallion, and a certificate of recognition. Award nomination forms are now available, and the first recipients will be announced in 2001.

2000 Call for NAE Award Nominations

Each year the National Academy of Engineering salutes leaders in engineering for lifetime dedication to their field and for commitment to advancing the human condition through great engineering achievements. By recognizing these leaders, the NAE hopes to bring better understanding of the importance of engineering to society.

The NAE currently presents four awards for engineering achievement—the Arthur M. Bueche Award, the Charles Stark Draper Prize, the Founders Award, and the Fritz J. and Dolores H. Russ Prize. The first three awards are presented annually, and the newly established Russ Prize will be presented biennially.

Materials are now available for nominating potential recipients of NAE awards in 2000. The deadline for submitting all nominations is 3 March 2000. For information pertaining to NAE awards or to receive the 2000 nominations packet, contact Daniel Whitt, NAE awards administrator, at (202) 334–1237 or awards@nae.edu. The nomination form is also available online at www.nae.edu.

1999 Frontiers of Engineering Symposium

Speaker Tom Albrecht of IBM Almaden Research Center makes a point during his talk on magnetic data storage technology.

The data storage technology of magnetic recording, applications of DNA array technology, deregulation of electric utilities, and optical applications of MEMS were some of the exciting topics covered at the NAE's fifth Frontiers of Engineering Symposium, held at the Beckman Center in Irvine, Calif., 14–16 October. The 100 engineers who attended this year's meeting learned about leading-edge engineering research and technical work in sessions titled "Drowning in Data," "Making Sense of the Human Genome," "Engineering Novel Structures," "Energy for the Future and its Environmental Impact," and "Optics." The four speakers in the session on data, for example, covered the topics of technical challenges in disk materials and magnetics, the evolution and future of multiprocessor servers, network survivability and information warfare, and the future of Web search engines. The energy session included talks on engineering challenges associated with the deregulation of the electric power industry, the future of nuclear energy, and the outlook for renewable energy technologies, such as biomass, geothermal, wind, solar, and photovoltaics.

As with past Frontiers of Engineering symposia, one of the high points of the meeting was the dinner speech given on the first evening of the symposium. This year's speaker was NAE member **Kent Kresa,** chairman, president, and CEO of Northrop Grumman Corporation, who spoke about the challenges of rapid change and the importance of a diverse and well-educated engineering workforce. NAE member **Robert H. Wagoner,** professor of materials science and engineering at Ohio State University, chaired the organizing committee and the symposium.

The NAE has hosted an annual Frontiers of Engineering meeting since 1995. The meeting brings together some of the country's best and brightest engineers from industry, academe, and government at a relatively early point in their careers, with all participants being 30 to 45 years old. Frontiers provides an opportunity for them to learn about developments, techniques, and approaches at the forefront of fields other than their own, something that has become increasingly important as engineering has become more interdisciplinary. The meeting also facilitates the establishment of contacts and collaboration among the next generation of engineering leaders.

As one can imagine, developing a presentation for this audience is quite a challenge. While most of the participants have Ph.D.s in an engineering field, they are not necessarily experts in the fields being covered at the symposium. As a result, speakers are asked to give a brief overview of their topic before discussing a specific technical problem, its solution, and its impact on research or industry. Speakers are also asked to talk about challenges and/or controversies in their fields, to summarize open research or applications questions,

Participants Marvin Theimer, Microsoft Research (left), and Rakesh Nagi, State University of New York, Buffalo (right), talk with Khourosh Gharachorloo, Compaq Computer Corp. (center), during one of the breaks.

and to provide a view on what will be the exciting frontiers in the next 5 to 10 years. Typically, speakers embrace this challenge, with the result being that discussions are very lively and participants leave with some ideas for their own work.

The NAE was pleased to welcome to the U.S. Frontiers meeting the Japanese and American members of the organizing committee for the first Japan-America Frontiers of Engineering Symposium (JAFOE), which will be held in Japan in November 2000. JAFOE will be the second international Frontiers venture for NAE, joining the German-American Frontiers of Engineering, which will hold its third meeting in May 2000 and is transitioning to a European-American Frontiers of Engineering Symposium.

Audio files of the presentations and text of the speakers' papers are available on the NAE's website at www.nae.edu. In February 2000 the NAE will publish a symposium volume containing extended summaries of the presentations. An organizing committee, chaired by NAE member **Michael L. Corradini,** associate dean for academic affairs and professor of engineering physics at the University of Wisconsin, Madison, has begun planning for the sixth Frontiers meeting, to be held 14–16 September 2000 at the Beckman Center.

Funding for this year's U.S. Frontiers of Engineering Symposium was provided by the Alcoa Foundation, the Defense Advanced Research Projects Agency (DARPA), Department of Defense Research and Engineering (DDR&E), the National Aeronautics and Space Administration (NASA), Parsons Brinckerhoff, and Science Applications International Corporation (SAIC).

For more information about the symposium series or to nominate an outstanding engineer to participate in the 2000 meeting, contact Janet Hunziker in the NAE Program Office at (202) 334-1571 or jhunzike@nae.edu.

Committee on Engineering Education

In August 1999 the NAE established a new standing Committee on Engineering Education (CEE). The mission of this new committee is to strengthen the National Academies' (NAE, NAS, IOM, and NRC) collective voice and service to the nation on issues pertaining to the vitality and currency of engineering education in the United States. As a standing committee, the CEE consolidates the membership, functions, and ongoing activities of two former boards—the NRC Board on Engineering Education (BEEd) and the NAE Academic Advisory Board (AAB)—thus bringing the Academies' efforts in the area of engineering education into closer affiliation with the Office of the NAE President. NAE member **Stephen W. Director,** dean of engineering at the University of Michigan, chairs the 23-member CEE, which includes 13 other NAE members on its roster.

The CEE has adopted three initiatives, first formulated by its predecessor boards (BEEd and AAB), for further development. These include proposals for a project that seeks to improve articulation of engineering education programs between two- and four-year colleges; an initiative to explore how new findings from advanced research in education and cognitive psychology might be harnessed to improve the teaching of engineering at the undergraduate level; and a workshop to develop a shared vision of engineering work and the engineering workforce in the year 2020, as well as the associated implications for engineering education.

Proposals for the first two of these initiatives and for funding the standing committee's core activities have been submitted to prospective sponsors. It is expected that the projects mentioned above will be funded and launched in early 2000. For further information concerning the CEE, please contact Proctor Reid, associate director, NAE Program Office, at (202) 334–2467 or preid@nae.edu.

Technological Literacy Update

The Committee on Technological Literacy, a joint activity of the NAE and the NRC Center for Science, Mathematics, and Engineering Education, met for the third time on 16–17 December. The bulk of the meeting was devoted to committee discussion of the project report, which is in early draft form. The project's goal is to raise the importance of technological literacy on the national agenda. NAE member **Tom Young,** Lockheed Martin (retired), chairs the committee. The committee will meet several more times before issuing its report in fall 2000.

The NAE is wrapping up its two-year involvement in reviewing the set of K–12 technology education standards being developed by the International Technology Education Association (ITEA). The NAE committee reviewing the standards, chaired by member **George Bugliarello,** Polytechnic University, is expected to meet for the last time in early January 2000. An NRC committee, chaired by NAE President **Wm. A. Wulf,** also has been reviewing the standards. The NRC group is expected to complete its work in late December, at which time it will release a final letter report on the standards. ITEA will release the standards publicly in March 2000.

The NAE will begin a new collaboration in early 2000 with the National Science Resources Center (NSRC), which is operated jointly by the Smithsonian Institution and the National Academies. The collaboration will focus on involving the engineering education community in science and technology education reform at the K–8 level. NSRC has a long and successful track record developing instructional materials and conducting leadership training for science education reform.

For more information on the NAE's technological literacy efforts, contact Greg Pearson in the NAE Program Office at (202) 334-2282 or gpearson@nae.edu.

NAE Welcomes New Fellow


Kristin B. Zimmerman

The NAE is pleased to announce that Kristin B. Zimmerman has accepted a one-year fellowship to assist in the Academy's efforts to promote diversity within the engineering workforce. In her new role, Dr. Zimmerman will staff the new Forum on Diversity in the Engineering Workforce (see next article), an industry-university-government partnership created by the NAE to focus national attention on workforce diversity issues.

Dr. Zimmerman, currently an engineer at General Motors Corporation (GM), is also a member of GM's Advanced Portfolio Exploration Group. Dr. Zimmerman joined GM in 1993 to create and implement the company's Global Academic Partnerships Program. The program is responsible for linking technical expertise from the academic sector with that of GM's research portfolio.

Dr. Zimmerman earned a B.S. in physics and mechanical engineering and her M.S. and Ph.D. in engineering mechanics from Michigan State University.

New Committee and Forum to Address Diversity in Engineering

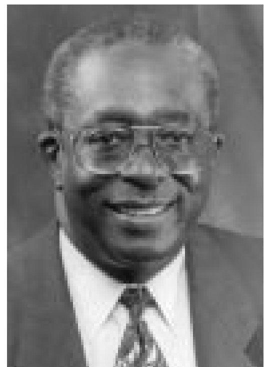
As part of its ongoing efforts to address the low numbers of women and underrepresented minorities in the engineering workforce, the NAE has created the Program on Diversity in the Engineering Workforce. The program efforts will involve two new groups: the Forum on Diversity in the Engineering Workforce and the Committee on Diversity in the Engineering Workforce.

The Forum on Diversity in the Engineering Workforce is an outcome of last spring's Summit on Women in Engineering (see *The Bridge,* Summer 1999), and is an informal partnership of industry, government, university, education, and outreach organizations, created to provide a unique dialogue among top leaders in the national engineering and technological enterprise.


Linda S. Sanford


John B. Slaughter

Chaired by NAE members **Linda S. Sanford** and **John B. Slaughter,** the Forum will meet for the first time in January 2000. The Forum will include approximately 60 members, who will determine the group's activities. The goals of the Forum include efforts to expand the dialogue on the engineering workforce to the regional and local level and to widen the range of public- and private-sector leaders engaged in actively pursuing and attaining diversity in the engineering workforce.


Cordell Reed

The Committee on Diversity in the Engineering Workforce is a traditional Academy study committee. Chaired by **Cordell Reed,** the committee will further understanding of the underlying causes that have limited the diversity of the engineering workforce and provide guidance on resolution of those causes. The committee's first task is to examine the factors that contribute to the retention and advancement of women and underrepresented minorities within organizations. The committee, in order to develop a coherent program to address these issues, will

- convene a workshop on Best Practices in Retaining and Advancing Women and Underrepresented Minority Engineers;
- oversee the continued development and evolution of the Celebration of Women in Engineering website;
- continue to develop focused areas for the NAE's participation, such as engineering in K–12 education or the engineering workforce as a national security issue; and
- provide guidance to the Forum and initiate contacts within the national policy community.

For more information on the NAE's diversity efforts, contact the program officer, Victoria Friedensen, at (202) 334–1605 or vfrieden@nae.edu.

National Engineers Week Events Planned for February

National Engineers Week (E-Week) celebrates the positive contributions engineers make to all aspects of our lives. Scheduled next year for 20–26 February, E-Week has become the largest national volunteer effort conducted by the engineering profession, supported by more than 70 engineering societies and government agencies, as well as by more than 40 major U.S. corporations. This marks the eleventh year that the NAE has supported National Engineers Week.

During E-Week, tens of thousands of engineers throughout the United States will help promote public understanding of the engineering profession through school teach-ins, technology fairs in shopping malls and libraries, student competitions, and awards and recognition programs. The focus of E-Week 2000 will be on the contributions of engineers to improve the environment.

Among the projects this year designed to spread the message of engineering's importance to society will be the selection of the "Greatest Engineering Achievements of the 20th Century," to be announced at a National Press Club luncheon in Washington. Considering the staggering engineering accomplishments of the past 100 years, the selection is certain to challenge the team of experts—an anonymous NAE committee—who will select the top 20 achievements.

Some of the products and events associated with E-Week 2000 include:

- A CD-ROM for high school students to encourage interest in engineering through environmental action. The CD-ROM emphasizes that promoting sustainable development and safeguarding dwindling natural resources are engineering concerns and offer great career opportunities.
- A video, *The Invisible World,* that shows how bridges are built and explains the different types of bridges, what happens when a bridge is built incorrectly, and what makes bridges stand.
- The National Engineers Week Future City Competition, which will be held in 20 regional sites. The competition requires seventh- and eighth-graders to design a city of the future, first on computer and then in a large three-dimensional model, and defending their solutions to a panel of engineers.
- The National Engineering Design Challenge, for high school students, sponsored by the Junior Engineering Technical Society (JETS). Now in its eleventh year, this year's challenge requires students to create, build, and demonstrate a working model of a temporary, portable, inexpensive shelter.

For more information about National Engineers Week programs, access the E-Week website at http://www.eweek.org.

Symposium Planned on Space Program and Microgravity

The NAE will convene its National Meeting on 11 February 2000 at the Beckman Center in Irvine, Calif. The morning session will be devoted to a symposium honoring **Simon Ostrach,** who has served as NAE home secretary for the past eight years. Dr. Ostrach will retire from this post in June 2000, and the symposium is planned to express the Academy's gratitude for his substantial contributions.

Dr. Ostrach is Wilbert J. Austin Professor of Engineering at Case Western Reserve University, and director of the National Center for Microgravity Research on Fluids and Combustion, established by the National Aeronautics and Space Administration (NASA) at the Case School of Engineering. The symposium topic will be "The Space Program and Microgravity Research," reflecting Dr. Ostrach's long association with NASA and his current research interests. Symposium speakers will include **Daniel S. Goldin,** administrator, NASA; Eugene Trinh, director, Microgravity Research Division, NASA; **Martin E. Glicksman,** John Tod Horton Distinguished Professor, Rensselaer Polytechnic Institute; and Charles Walker, senior manager, Space and Communications Group, The Boeing Company.

Davis Receives Defense Manufacturing Excellence Award


Lance A. Davis

NAE Executive Officer **Lance A. Davis** received the 1999 **Defense Manufacturing Excellence Award** on 30 November 1999, in recognition of his substantial and lasting contributions to furthering manufacturing technology in the Department of Defense (DOD) and in the U.S. industrial base. The award was presented at the 1999 Defense Manufacturing Conference in Miami, Fla.

Dr. Davis served as director of the Office of Technology Transition within the Office of the Under Secretary of Defense for Acquisition and Technology from 1994 through May 1999. In this capacity he was instrumental in the continuous improvement of the DOD Manufacturing Technology (ManTech) program. He led the program's review and assessment process, and crafted a set of recommendations and program management guidelines that will have a lasting positive effect on ManTech projects for years to come. Dr. Davis also established and chaired the Science and Technology (S&T) Affordability Task Force, where his efforts resulted in improved communication between laboratory and weapon system program managers, the development of improved training programs for S&T managers, and more focus on affordability in the DOD development community.

The annual Defense Manufacturing Excellence Award is sponsored by the Multi-Association Industry Affordability Task Force, a volunteer group of industry associations created in 1993 to pursue studies in affordability for the Department of Defense. The task force represents nine industry associations, including the Aerospace Industries Association, the Armed Forces Communications Electronics Association, and the National Association of Manufacturers. The National Center for Advanced Technologies (NCAT) acts as secretariat and agent for the task force. NCAT is a nonprofit research and education foundation that provides a bridge between government, industry, and academia and encourages cooperative efforts on technology development.

NAE Calendar of Meetings

2000

13 January	Program Advisory Committee
18–19 January	Forum on Diversity in the Engineering Workforce
2 February	Election Peer Committee Chair Workshop
9–10 February	NAE Council Irvine, Calif.
11 February	National Meeting Irvine, Calif.
20–25 February	National Engineers Week
22 February	Draper Prize Presentation Dinner, U.S. Department of State, Washington, D.C.
28 February	Membership Policy Committee
16–17 March	Committee on Diversity in the Engineering Workforce
27–29 March	CAETS Strategy Task Group Paris, France
13–15 April	German-American Frontiers of Engineering Symposium Bremen, Germany

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

In Memoriam

ARNALDO M. ANGELINI, 90, honorary president and consultant, National Electric Power System of Italy, died on 25 August 1999. Dr. Angelini was elected a foreign associate of the NAE in 1976 for contributions in the development of nuclear generating stations, as well as hydro and pumped hydro stations, and the improvement of Italy's transmission and distribution systems.

JEROME B. COHEN, 67, Frank C. Engelhart Professor of Materials Science and Engineering, Northwestern University, died on 7 November 1999. Dr. Cohen was elected to the NAE in 1993 for contributions to X-ray diffraction of materials, including residual stress, and atomic arrangements in alloys, ceramics, and catalysts.

JAI KRISHNA, 87, engineering consultant, died on 27 August 1999. Dr. Krishna was elected a foreign associate of the NAE in 1979 for contributions in engineering education and research in civil engineering design and earthquake engineering.

W. D. MACDONNELL, 87, retired chairman and CEO, Kelsey-Hayes Company, died on 3 August 1999. Mr. MacDonnell was elected to the NAE in 1968 for methods of increasing the efficiency of steel production.

JACOB RABINOW, 89, consultant, National Institute of Standards and Technology, died on 11 September 1999. Mr. Rabinow was elected to the NAE in 1976 for inventions and development of devices in computers, power transmission, and post office automation.

HENRY E. SINGLETON, 82, cofounder of Teledyne, Inc., died on 31 August 1999. Dr. Singleton was elected to the NAE in 1979 for contributions to lightweight inertial navigation systems.

M. E. VAN VALKENBURG, 75, dean emeritus, college of engineering, University of Illinois, Urbana-Champaign, died on 19 March 1997. Dr. Van Valkenburg was elected to the NAE in 1973 for contributions to circuit theory, beacon antennas, servomechanisms, and computer science.

PAUL WEIDLINGER, 84, retired principal, Weidlinger Associates, died on 5 September 1999. Mr. Weidlinger was elected to the NAE in 1982 for innovative contributions to structural engineering and outstanding contributions in the design of steel and reinforced concrete structures.

National Research Council Update

New NAE Report Assesses Inducement Prize Contests for Innovation

Traditionally, the U.S. federal government has relied on two primary methods to fund technological research and development: grants and procurement contracts. On 30 April 1999, the NAE hosted a workshop to look at a third method, the inducement prize contest.

The workshop was convened at the request of the White House National Economic Council, and funded by the National Science Foundation (NSF). It was organized by a five-member steering committee comprised of **Erich Bloch,** president, Washington Advisory Group; **Paul G. Kaminski,** chairman and CEO, Technovation, Inc.; **Daniel M. Tellep,** retired chairman, Lockheed Martin; David Mowery, Milton W. Terrill Professor of Business, University of California, Berkeley; and former Congressman Robert S. Walker.

Inducement prize contests are designed to encourage progress toward or achievement of a specific objective. In the past, they have been sponsored almost exclusively by private entities. However, the history of such contests and the growing body of research on ways to encourage and support technical innovation suggest that prize contests might be a valuable tool for the federal government.

In the report, the steering committee recommends that Congress encourage federal agencies to make more use of inducement prize contests to advance technology research and development toward specific societal ends. When compared to traditional grants and procurement contracts, inducement prize contests appear to have several strengths, including

- the ability of prize contests to attract a broader spectrum of ideas and participants by reducing the costs and other bureaucratic barriers to participation;
- the ability of federal agencies to shift more of the risk for achieving or striving toward a prize objective from the agency to the contestants;
- the potential of prize contests for leveraging the financial resources of sponsors; and
- the capacity of prizes for educating, inspiring, and occasionally mobilizing the public with respect to particular scientific, technological, and societal objectives.

The steering committee views inducement prizes as a potential complement to, but not a substitute for, the types of grants and procurement contracts that are used now to provide direct federal support of research and innovation. In particular, the steering committee believes such prizes might be used to identify new or unorthodox ideas or approaches to particular challenges, to demonstrate the feasibility or potential of particular technologies, to promote the development and diffusion of specific technologies, to address intractable or neglected societal challenges, or to educate the public about the excitement and usefulness of research and innovation.

To encourage agencies to experiment with inducement prize contests, the committee recommends that Congress consider providing explicit statutory authority and, where appropriate, credible funding mechanisms for agencies to sponsor and/or fund such contests. If such a policy experiment is initiated, it should be time-limited, and the use of prizes and contests should be evaluated at specified intervals by the agencies involved to determine their effectiveness and impact.

The report is titled **Concerning Federally Sponsored Inducement Prizes in Engineering and Science.** The report can be read online at www.nap.edu/catalog/9724.html. For more information, contact Proctor Reid, associate director, NAE Program Office, at (202) 334-2467 or preid@nae.edu.

Publications of Interest

The following publications result from the program activities of the National Academy of Engineering or the National Research Council. Except where noted, each publication is for sale (prepaid) from the National Academy Press (NAP), 2101 Constitution Avenue, N.W., Lockbox 285, Washington, DC 20055. For more information or to place an order, contact NAP online at http://www.nap.edu or by phone at (888) 624–8373. *(Note: Prices quoted by NAP are subject to change without notice. Online orders receive a 20 percent discount. Please add $4.50 for shipping and handling for the first book ordered and $0.95 for each additional book. Add applicable sales tax or GST if you live in CA, DC, FL, MD, MO, TX, or Canada.)*

Concerning Federally Sponsored Inducement Prizes in Engineering and Science. Reviews the use of inducement prize contests to advance technical innovation. Recommends that Congress encourage federal agencies to experiment with using inducement prize contests to support technology research and development. Paperbound, available from the NAE Program Office (202-334-1579).

Hardrock Mining on Federal Lands. Reviews existing law and the roles of the Bureau of Land Management and U.S. Forest Service in protecting the environment. Concludes that state and federal laws are generally effective in providing environmental protection, but some regulatory gaps need to be addressed and improvements are needed in implementing the laws. Paperbound, $33.00.

Improving Project Management in the Department of Energy. Calls into question DOE's project management procedures and recommends the establishment of a new office to oversee them and provide support services. Paperbound, $33.00.

Improving Surface Transportation Security: A Research and Development Strategy. This report recommends a long-term R&D strategy for improving the security of the U.S. surface transportation system, which includes public and private roads, railways, waterways, and pipelines. Paperbound, $18.00.

Industrial Environmental Performance Metrics: Opportunities and Challenges. Examines metrics used to assess industrial environmental performance, based on a study of four industries: automotive, chemicals, electronics, and pulp and paper. Recommends ways to improve the measuring and reporting of corporate environmental performance. Paperbound, $54.95.

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

New Strategies for New Challenges: Corporate Innovation in the United States and Japan. This report explores challenges facing U.S. and Japanese companies and examines the implications for policymakers in the two countries. Paperbound, $18.00.

Our Common Journey: A Transition Toward Sustainability. Identifies the greatest threats to sustainability and outlines several priorities for action in five key areas. Paperbound, $49.95.

The Pervasive Role of Science, Technology, and Health in Foreign Policy: Imperatives for the Department of State. Recommends 13 ways the State Department could integrate science, technology, and health awareness into U.S. foreign policy. Paperbound, $29.00.

Science for Decisionmaking: Coastal and Marine Geology at the U.S. Geological Survey. This report reflects conclusions and recommendations drawing on discussions with the USGS and input from potential users, clients, and collaborators of the Coastal and Marine Geology Program on responsible management of fragile coastal and marine ecosystems. Paperbound, $28.75.