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The BRIDGE

LINKING ENGINEERING AND SOCIETY

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

The
BRIDGE

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The BRIDGE

LINKING ENGINEERING AND SOCIETY

Editor's Note

Features

NAE News and Notes

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Editor's Note

Julia M. Phillips

The Expanding Frontiers of Engineering

Every year, NAE sponsors a three-day U.S. Frontiers of Engineering (FOE) Symposium that brings together some 100 outstanding young engineers (ages 30 to 45) from academia, industry, and government laboratories to share ideas and learn about cutting-edge research on a wide range of engineering topics. The competitively selected, emerging engineering leaders who attend FOE symposia come from many backgrounds and have a variety of interests and talents. The symposium offers them a unique opportunity to learn about the latest research in engineering areas other than their own.

The thirteenth U.S. FOE Symposium, held September 24–26, 2007, at Microsoft Research in Redmond, Washington, encompassed five themes: engineering trustworthy computer systems; control of protein conformations; biotechnology for fuels and chemicals; modeling and simulating human behavior; and safe water technologies. Papers based on presentations from each session are included in this issue of *The Bridge*.

The session on the rise of intelligent software systems and machines was chaired by Annie Anton, of North Carolina State University, and John Dunigan, of Microsoft Research. The first speaker, Rebecca Wright, presented the two sides of the issue of proliferation of information about people, organizations, and their activities. The easy availability of information has led to valuable services, efficiencies, and convenience but has also raised serious concerns about privacy. Although some technological solutions are already available to mitigate the risks, this is an active area of research. Greg Morrisett, whose paper begins on p.5, outlined some common ways computers can be attacked, as well as ways of making such attacks less likely to succeed.

Diana Smetters described the challenges to developing computer-security technologies that are both usable and secure. These challenges include human limitations, such as an inability to remember more than a very small number of truly random passwords. In the final presentation in this session, Edward Felten addressed security and privacy challenges in information systems, specifically the ability to understand and access, discuss, repair, and modify commercial products after purchase. This capability poses not only engineering but also legal challenges, particularly if the product is, for example, a voting machine.

In the session on control of protein conformations, chaired by Donald Leo, of the Defense Advanced Research Projects Agency, speakers addressed how new techniques for observing, manipulating, and controlling biological systems have led to new methods of engineering biological systems. Rama Ranganathan outlined current efforts to systematically map, and then mechanistically understand, the global architecture of amino acid interactions. If these efforts are successful, they will dramatically advance our understanding and control of proteins and their evolution. Matthew Lang, whose paper begins on p.11, described how researchers are attempting to delineate the "mechanome," the general role of force, mechanics, and machinery in biology. Understanding the mechanome, he says, should lead to new strategies for fighting disease.

Richard Elander, of the National Renewable Energy Laboratory, and Vijay Singh, of the University of Illinois at Urbana-Champaign, chaired the session on biotechnology for fuels and chemicals. Sanjay Malhotra, whose paper begins on p.17, opened the session by describing advances in applications of corn-based chemistry. Although the public focus has been on the drive for ethanol from corn for transportation fuel, chemicals derived from corn have many other applications, ranging from polymers to drug-delivery systems and pharmaceuticals.

In the next presentation, Bruce Dien argued that, in light of the already strong demand for corn and corn-based derivatives, biofuel production should be based on lignocellulosic feedstocks. However, he explained, making lignocellulosic ethanol cost-competitive will require a great deal of research to overcome significant barriers. Carina Alles then described the current state of sustainability assessments for quantifying the overall impacts of biofuels, a necessary prerequisite for informed debate. Science-based methods, such as life-cycle assessments for quantifying environmental impacts throughout the value chain of a biofuel, are now more widely accepted as important to decision making.

The session on modeling and simulating human behavior was chaired by Christian Lebiere, of Carnegie Mellon University, and Robert Wray, of Soar Technology. Laurent Itti's opening presentation focused on visual cognition—an area in which human performance is generally vastly superior to computer performance. He described models of how humans and some animals notice things in a field of view. The ultimate goal of these models, which are increasingly successful at replicating actual behavior, is to integrate them with artificial-intelligence techniques. Kevin Gluck described efforts to model human performance and learning. Michael van Lent, whose paper begins on p.25, outlined his work on the development of a computational approach to incorporating cultural knowledge into models of human behavior.

The final session of the symposium on safe water technologies was chaired by Paul Westerhoff, of Arizona State University, and Carol Rego, of CDM, a consulting firm. In the first presentation, Karl Linden described the reemergence of the use of ultraviolet radiation for purifying drinking water. Amy Childress then discussed the growing challenge of desalinating water for human consumption, which is becoming increasingly important to the world population. Current methods are energy intensive and/or result in significant wastewater discharge, but new technologies promise significant improvements on both counts.

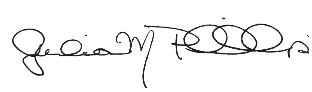
Jess Brown, whose paper begins on p.30, described biological treatments of drinking water, which have had longstanding success in some parts of the world. Although these treatments are very promising in terms of cost, effectiveness, and environmental effects, gaining widespread public acceptance for them will be a difficult challenge. Vanessa Speight concluded the session with a discussion of water-distribution systems, a behind-the-scenes, complex challenge in drinking water systems often ignored by researchers and the public.

The technical talks were followed by extensive Q&A sessions with enthusiastic participation by the audience. The program this year also featured 90-minute breakout sessions, during which attendees were divided into groups of 10 to 15 individuals who had previously indicated an interest in discussing a particular topic. The topics ranged from the societal responsibility of engineers to balancing career and personal life. The breakout sessions turned out to be highly interactive and very educational.

The dinner speaker, a traditional highlight of FOE programs, was Dr. Henrique (Rico) Malvar, managing director, Microsoft Research. He described the importance of research to the company as a whole, especially the engagement of Microsoft Research with the global science and engineering community.

The sponsors of this year's symposium were: Air Force Office of Scientific Research; U.S. Department of Defense (Defense Research & Engineering); Defense Advanced Research Projects Agency; National Science Foundation; Microsoft; and Cummins Inc.

FOE symposia are the most interdisciplinary, diverse, and stimulating gatherings I have attended. I hope the five papers included in this issue convey some of the excitement we experienced in Redmond in September. All of the presentations, summaries of the discussions, and the dinner speech will be included in the annual FOE volume published in February 2008.



Julia M. Phillips, chair
U.S. FOE Organizing Committee and Symposium

The more we rely on software, the more we need mechanisms to ensure that software is trustworthy.

Unifying Disparate Tools in Software Security

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Greg Morrisett

How much can you trust software? When you install a piece of code, such as a video game or a device driver for a new camera, how can you be sure the code won't delete all of your files or install a key-stroke logger that captures your passwords? How can you ensure that the software doesn't contain coding bugs or logic errors that might leave a security hole?

Traditional approaches to software security have assumed that users could easily determine when they were installing code and whether or not software was trustworthy in a particular context. This assumption was reasonable when computers controlled few things of real value, when only a small number of people (typically experts) installed software, and when the software itself was relatively small and simple. But the security landscape has changed drastically with advances in technology (e.g., the explosive growth of the Internet, the increasing size and complexity of software) and new business practices (e.g., outsourcing and the development of open-source architecture). Furthermore, the more we rely on software to control critical systems, from phones and airplanes to banks and armies, the more desperately we need mechanisms to ensure that software is truly trustworthy.

Attack Techniques

Malicious hackers have serious financial incentives to break into and control personal and business computers. Once they break into a machine, they can gather personal information (e.g., passwords, credit card information, and social security numbers) and use it to clean out bank accounts, apply for credit cards, or gain access to other machines on the same network. In addition, if attackers break into and control machines, they can use them to send "spam" (unsolicited e-mail advertisements), to store illicit digital goods (e.g., pirated music or pornography), or to launch denial-of-service attacks against other computing systems.

One technique attackers use to gain a foothold on a machine is to trick the user into thinking a piece of code is trustworthy. For example, an attacker may send an e-mail that contains a malicious program, but with a forged return address from someone the user trusts. Alternatively, an attacker may set up a website with a name that appears to be trustworthy, such as "*www.micr0s0ft.com*" (note that the letter "o" has been replaced by the numeral "0"), and send an e-mail with a link to the site suggesting that the user download and install a security update.

Even sophisticated users can be fooled. A clever attacker might contribute "Trojan horse" code to a popular open-source project, turning an otherwise useful program (e.g., a music player) into undetected mal-ware.[1] In short, it is relatively easy for an attacker to gain the trust of a user and get him or her to install code.

Even sophisticated users can be fooled by clever attackers.

Today we use a combination of digital signatures and virus scanners to try to stop these attacks. But digital signatures only tell us who produced the code, not whether it is trustworthy. And virus scanners, which look for snippets of previously identified mal-ware at the syntactic level, can be easily defeated through automated obfuscation techniques. Furthermore, virus scanners cannot detect new attacks. These relatively weak tools can tell us something about the *provenance* of software and its *syntax*, but they cannot validate the software's *semantics*.

Even Good Guys Can't Be Trusted

A second technique attackers use to gain control of a machine is to find a bug in an already installed program that communicates with the outside world. The classic example is a *buffer overrun* in a service, such as a log-in daemon, or a network-based application, such as a web browser. A buffer overrun occurs when a program allocates *n* bytes of memory to hold an input (e.g., a password), but the attacker provides more than *n* bytes. A properly written program will check and reject any input that is too long. Unfortunately, many programmers fail to insert appropriate checks, partly because commonly used programming languages (C and C++) make it easy to forget those checks, and partly because programmers often think that "no one will have a password of more than a thousand characters."

When programmers fail to put in a check and the input is too long, the extra bytes overwrite whatever data happen to be stored next to the input buffer. In many cases, the buffer is allocated on the control stack near a return address for a procedure—a location where the program transfers control once the input routine is completed.

A clever attacker will enter an input long enough to overwrite the return address with a new value, thereby controlling which code is executed when the input routine ends. In an ideal attack, the rest of the input contains executable instructions, and the attacker causes control to transfer to this newly injected code. In this way, the attacker can cause the program to execute arbitrary code.[2]

Attacks based on buffer overruns are surprisingly common; at one point, they accounted for more than half of the security vulnerabilities reported by the Computer Emergency Response Team (Wagner et al., 2000). But the failure to check input lengths is only one of a large number of coding errors attackers use to gain a foothold on a machine or extract private information. Other examples include integer overflows; format-string attacks; script-injection attacks; race conditions; bad, pseudo-random number generators; and improper use of cryptographic primitives.

Thus even well meaning software vendors cannot seem to produce trustworthy code. Part of the problem is that vendors must keep producing new features to sell new versions of software, which simply adds complexity to the code base. And part of the problem is that current development practices, including design, coding, review, and testing, cannot rule out simple errors,

[1] See Thompson (1984) for a particularly devious example.

[2] For a more detailed explanation, see *http://www.phrack.org/archives/49/P49-14*.

such as buffer overruns, much less deeper problems, such as the inappropriate use of cryptographic primitives or covert-information channels.

Preventing Bugs through Rewriting

One way to defend against attacks is to build tools that automatically insert checks at program locations where a policy violation might occur. For example, we might insert extra code at each buffer update to ensure that we do not write beyond its bounds.

Compilers for high-level, type-safe languages, such as Java and C#, already insert checks to prevent a large category of language-level errors, including buffer overruns. However, the vast majority of systems and application software, including security-critical operating-systems code, is still written in C or C++, so the compiler does not have enough information to insert appropriate checks.

Unfortunately, the cost of rewriting the millions of lines of code that make up big software systems (e.g., Windows or Oracle) is prohibitive, and doing so is likely to introduce as many bugs as it eliminates. Furthermore, because certain services, such as device drivers and real-time embedded software, need control over memory layout and timing, they are not suited to high-level languages.

Some effective tools for rewriting low-level legacy code are emerging. For example, the StackGuard tool (Cowan et al., 1998) and the Microsoft "/gs" compiler option rewrite C/C++ code to insert a secret "cookie" next to buffers allocated on the control-flow stack and check that the cookie has been preserved when a procedure is about to jump to a return address. In this way a buffer overrun can often be detected and stopped with relatively low overhead. Unfortunately, this technique does not protect against other forms of attack, such as overflowing a buffer allocated on the heap.

Another example of automated rewriting is the CCured compiler (Necula et al., 2002). CCured provides a strong type-safety guarantee by inserting extra metadata and run-time checks into C code. Metadata make it possible to determine, for instance, the size of a buffer at run time, and the checks ensure that *all* buffer boundaries and typing constraints are satisfied.

Although CCured can entail higher overhead costs than StackGuard, the security guarantees are much stronger. Nevertheless, the advantage of StackGuard is that it can be applied to almost any C program without change, whereas CCured requires a number of changes to the source code. In practice, the tool that is easier to use is almost always used first.

Many other tools also try to enforce security policies on legacy code through rewriting. These include software-based fault isolation (McCamant and Morrisett, 2006; Wahbe et al., 1993), control-flow isolation (Abadi et al., 2005), in-lined reference monitors (Schneider, 2000), and others. Each of these tools strikes a different balance among the expressiveness of the policies that can be enforced, the code base to which the techniques are applicable, and run-time overhead.

Rewriting code for big software systems is likely to introduce as many bugs as it eliminates.

Preventing Bugs through Static Analysis

Security-conscious companies are beginning to use tools that either prevent or detect a wide range of coding errors at compile time. Microsoft, for example, uses a static analysis tool called Prefast (based on an early tool called Prefix) that scans C and C++ code, looking for common errors, such as buffer overruns (Bush et al., 2000). Other companies, such as Fortify and Coverity, produce similar tools that can analyze software written in a variety of languages and support customizable rule-sets for finding new classes of bugs as they arise.

A static analysis tool attempts to symbolically execute all paths in the code, looking for potential bugs. Of course, a program with n conditional statements can have 2^n distinct paths, and a program with loops or recursion can have an unbounded number of paths. Thus the static analysis approach is both naïve and infeasible. Furthermore, the analysis does not know the actual values of inputs to the program, so it cannot always determine the value of variables or data structures.

Consequently, static analysis tools construct models of the program that abstract details and reduce the reasoning to finite domains. For example, instead of tracking the actual values that integer variables might take on, an analysis might track only upper and lower bounds. To ensure termination, the analysis might only consider a few iterations of a loop. More sophisticated techniques based on abstract interpretation (Cousot and Cousot, 1977) make it possible to determine an approximation of behavior for all iterations.

Although automated static analysis has improved tremendously, especially in the past few years, a number of problems remain to be solved. One problem, introduced by the necessary approximation described above, is false positives (i.e., potential errors may be indicated where there are none) or false negatives (i.e., errors that are not reported).

Automated static analysis often produces false positives and false negatives.

If the approximations are constructed so that the analysis is *sound* (i.e., no false negatives), programmers tend to be flooded with false positives, making it difficult to find and fix real bugs in the program. Therefore, few of these analyses are sound, and bugs can potentially sneak through. For example, a buffer overrun recently found in the Windows Vista custom-cursor animation code was not detected by Prefast.

Looking to the Future

One problem with static analysis tools is that, like optimizing compilers, they tend to be large, complicated programs. As a result, a bug in the analysis can mean that a security-relevant error goes undetected. Furthermore, because most tools operate on source code (or byte code), they must make assumptions about how the compiler will translate the program to machine code. Consequently, an inconsistent assumption or a bug in the compiler can result in a security hole.

An ideal static analysis would fit the following description:

- The analysis can operate at the machine-code level (to avoid having to reason about the compiler).
- The analysis is small, simple, and formally verified.
- The analysis is sound (i.e., no false positives).
- The analysis is complete (i.e., no false negatives).

Although these goals may seem unattainable, the *proof-carrying code* (PCC) architecture suggested by Necula (1997) comes remarkably close to satisfying them. The idea behind PCC is to require that executable programs come equipped with a formal, machine-checkable "proof" that the code does not contain bugs. By "proof" we mean a formal, logical argument that the code, when executed, will not violate a pre-specified (and formalized) policy on behavior.

The key insight of PCC is that constructing a proof is hard (generally undecidable), but verifying a proof is easy. After all, a proof is meant to be mechanically checkable evidence. Furthermore, assuming we have a sound, *relatively* complete logic for reasoning about program behavior, we can, in principle, accept precisely those programs that are *provably* safe.

The really nice thing about PCC is that, as a framework, it benefits both the user who is worried about the safety of installing a program downloaded from the Internet and the software producer who has outsourced the development of modules. With PCC, we are no longer dependent on *who* produces the code but on what the code actually does.

In practice, the problem with PCC is that someone, namely the code producer, still has to come up with proof that the code satisfies a given policy. Thus none of the difficult problems has really been eliminated. We still need other techniques, such as static analysis and rewriting, to find an effective way to construct the proof. However, with PCC we no longer have to trust the tools or compiler. Therefore PCC helps minimize the size of the trusted computing base.

One way to construct a proof that machine code satisfies a policy is by using a *proof-preserving compiler*. For example, if we start with source code and a proof that the source satisfies a policy, then a proof-preserving compiler can simultaneously transform the code and proof to the machine-code level. *Type-preserving compilers* are a particular instance in which the policy is restricted to a form of type safety (Colby et al., 2000; Morrisett et al., 1999; Necula and Lee, 1998).

Next-generation programming languages are incorporating increasingly sophisticated type systems that allow programmers to provide stronger safety and security properties through automated type checking. For example, the Jif dialect of Java lets programmers specify secrecy requirements for data, and the type system ensures that secret inputs (i.e., private fields) cannot flow to public outputs (Myers, 1999). Thus, when combined with a type-preserving compiler, the Jif-type system makes it possible for a third party to verify that a program will not disclose information that is intended to be private.

At an extreme, arbitrary policies can be captured with a *dependent type-system*, as found in emerging languages, such as ATS (Xi, 2004), Concoqtion (Fogarty et al., 2007), Epigram (McBride, 2004), and HTT (Nanevski et al., 2006). These languages make it possible to specify everything from simple typing properties to full correctness. The trade-off, of course, is that type checking is only semiautomatic. Simple properties can be discharged using a combination of static analysis, constraint solving, and automated theorem proving, but ultimately, programmers must construct explicit proofs for deeper properties.

Thus the success of these languages will be determined largely by how much can truly be automated. Nevertheless, for safety and security-critical software systems, these languages, in conjunction with PPCs and the proof-carrying code architecture, provide a compelling research vision.

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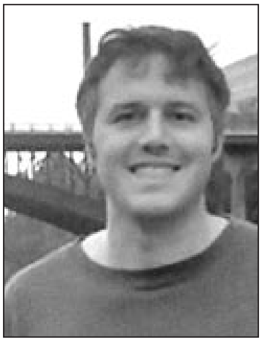
Understanding the role of force, mechanics, and biological machinery—the "mechanome"—will open the way to new strategies for fighting disease.

Lighting Up the Mechanome



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Matthew Lang

Genomics and general "omics" approaches, such as proteomics, interactomics, and glycomics, among others, are powerful system-level tools in biology. All of these fields are supported by advances in instrumentation and computation, such as DNA sequencers and mass spectrometers, which were critical in "sequencing" the human genome. Revolutionary advances in biology that have harnessed the machinery of polymerases to copy DNA or used RNA interference to capture and turn off genes have also been critical to the development of these tools. Researchers in biophysics and biomechanics have made significant advances in experimental methods, and the development of new microscopes has made higher resolution molecular- and cellular-scale measurements possible.

Despite these advances, however, no systems-level "omics" perspective—the "mechanome"—has been developed to describe the general role of force, mechanics, and machinery in biology. Like the genome, the mechanome promises to improve our understanding of biological machinery and ultimately open the way to new strategies and targets for fighting disease.

Many disease processes are mechanical in nature. Malaria, which infects 500 million people and causes 2 million deaths each year, works through a number of mechanical processes, including parasite invasion of red blood cells (RBCs), increased RBC adhesions, and overall stiffening of RBCs. As the disease progresses, it impairs the ability of infected cells to squeeze through capillaries, ruptures RBC membranes, and releases newly minted malaria parasites.[1]

Cancer, another leading cause of death, also progresses in many mechanical ways, such as the machinery of viral infection, which is responsible for hepatitis B, human papilloma virus, and related cancers. In addition, metastasis involves the detachment of tumor cells from the initial growth site, migration, circulation, and subsequent invasion through reattachment to new locations.

"Sequencing" the mechanome will lead to the discovery of the design features of biological motors.

Intracellular changes in cancerous cells bring about cell growth and proliferation, cell motility, and migration. These processes are currently targeted by Taxol, a potent chemotherapy drug that impedes the progression of cancer by stabilizing microtubules in a polymerized state, thus shutting down the machinery of cell division.

The human genome is contained in approximately 3 billion base pairs of DNA. If the pieces of DNA in our cells were connected end-to-end, the chain would be roughly as long as one's outstretched arms. Compared to other cellular filaments, DNA is quite flexible. To fit into cells, it is compacted in highly ordered structures through multiple hierarchical levels.[2] In addition to the conventional Watson and Crick base pairs, DNA forces and interactions include histone protein-DNA nucleosome complexes, chromatin fibers, chromatids, and, ultimately, 46 chromosomes. In general, our biological structures have many levels of structural hierarchy and are highly organized.

Molecular Machinery

From our DNA sequence, biological motors, including DNA and RNA polymerases and the ribosome, make RNA, and ultimately proteins, through coupled mechanical and chemical steps. This impressive machinery copies and translates with great accuracy. The ribosome, a huge motor spanning 20 nanometers (nm), which is actually composed of about 65 percent ribosomal RNA, assembles proteins from messenger RNA. Many antibiotics target the critical machinery of ribosomal translation in bacteria.

Other molecular motors, such as myosins and kinesins, run on different cytoskeletal tracks—actin filaments and microtubules, respectively.[3] Myosins, which are responsible for the contraction of skeletal and cardiac muscle, contribute to cell migration and cell-division processes, such as contractile ring closure. Similarly, kinesins, which are important in transport and cell division, are small, processive motors that run toward the plus (fast polymerizing) end of microtubules. In some cases, such as the kinesins that carry vesicles containing neurotransmitters along the sciatic nerve axon, this progress takes place over the length scale of about a meter and is a critical mechanism for cargo delivery.[4]

The design of biological motors can be classified by cataloging the motor's general structural features, fuel type, stepping distance, stall force, and other mechanical parameters. Detailed measurements of the motility cycles and underlying mechanisms for motility also provide information about how these mechanisms work.[5] Ultimately, "sequencing" the mechanome will lead to the discovery of the design features of biological motors in general, enabling us to catalogue them and outline the rules that govern their behavior.

Comparisons of the family trees of kinesins and myosins reveal a range of structural forms, including single-, double-, and tetramer-headed members of

[1] A red blood cell circulates in the body about half a million times in a 120-day period.

[2] Human cells are typically 10–30μm in diameter. The smallest, sperm, is only a few microns in diameter, and the largest, the egg, is ~100μm in diameter. The size of randomly packed DNA can be estimated from the radius of gyration ($b \cdot N^{1/2}$), where N is the number of segments and b is the length of each segment. DNA has a length of 0.3nm/bp, a persistence length of 50nm. An average chromosome may contain 1.3×10^8bp of DNA, yielding a radius of gyration of 44μm, larger than the typical cell size. Chromosomes were first observed by Karl Wilhelm von Nägeli in 1842.

[3] Mechanically, actin filaments have a Young's modulus of 2.3 GPa, and microtubules have a persistence length on the order of mm.

[4] Kinesin has a velocity of 800nm/s. Thus traveling the sciatic nerve might take more than two weeks. Diffusion alone would not be complete in a lifetime. This estimate can be obtained from the Einstein-Sutherland-Smoluchowski relation (a 1μm diameter cargo has a diffusion constant of $D = kT/6\pi\eta a = 2 \times 10^{-9}$ cm^2/s). Diffusion time is proportional to the distance squared $x^2/D = 7 \times 10^4$ years.

[5] Kinesin, for example, has been extensively characterized. It has a stepping distance of 8nm for each ATP molecule consumed. Steps occur upon ATP binding. Kinesin takes about 100 steps/second and runs at 800nm/second. After about 1μm, it loses hold of its track. Kinesin coordinates the action of the two heads, shuts down its hydrolysis in the absence of cargo, stalls at a load of about 5–6 pN, and walks much like we do.

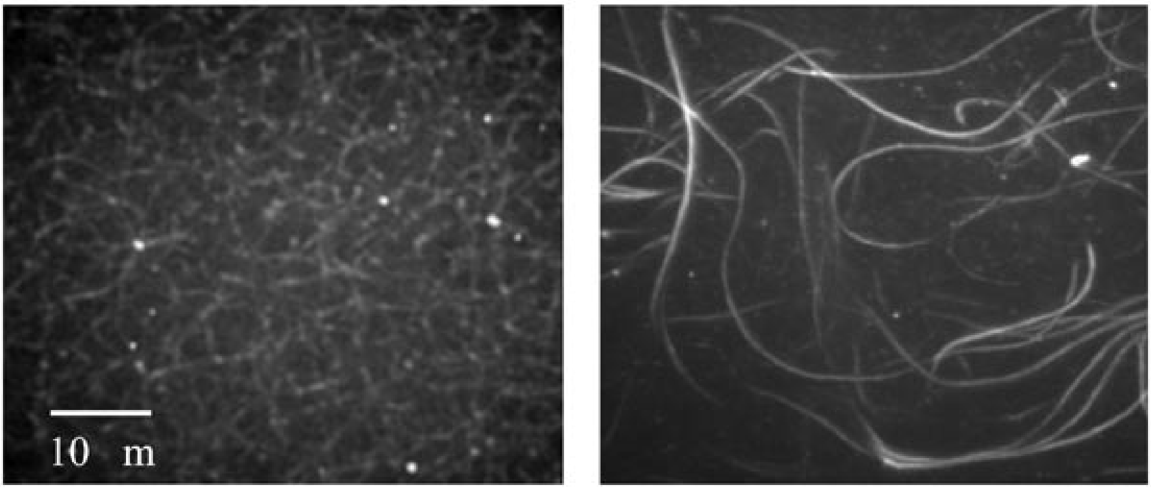

FIGURE 1 The images above show networks of actin filaments organized by different actin-binding proteins (ABPs). The ABP on the left, consisting of filamin, forms a meshwork arrangement of filaments. The ABP on the right, α-actinin, organizes actin filaments into bundles. Despite differences in network morphology, filamin and α-actinin have similar actin-binding domains. Source: Photos courtesy of Hyungsuk Lee and Jorge Ferrer, in collaboration with Prof. Roger Kamm's laboratory, Massachusetts Institute of Technology.

various lengths connecting the motor and cargo-binding domains. They also share some structural elements at the molecular level, such as the binding pocket for ATP (Vale, 1996), and both are fueled by hydrolysis of ATP. Another example of a common motor design is in AAA+ motors, which are similarly structured but run on a variety of track types (e.g., microtubules, DNA, and peptides) and are involved in a number of critical cellular processes (Ogura and Wilkinson, 2001). Nature, it appears, copies and pastes design elements for motors with similar roles and physical constraints. Despite different tracks and overall purposes for motility, all of the designs of common biological machines have been optimized.

Cellular Machinery

Cellular machinery (e.g., the processes of cell division, wound healing, and migration) can also be classified by general design principles. Forces originating from many sources (e.g., biological motors, polymerization of filaments, molecular conformational transitions, and fluid pressure) can act on structures, including cytoskeletal filaments, membrane barriers, receptor ligand linkages, and protein-complex adhesion sites. These interactions typically occur in cycles, such as migration, extension processes, adhesion, contraction, and detachment.

Highly tuned control over these forces and structures is orchestrated through mechanical and biochemical signals that initiate and terminate motility cycles. Mechanotransduction, a critical aspect of control, refers to the process whereby cells actively respond to mechanical signals through changes in morphology, signaling, and biochemical response.

Migration of the neuronal growth cone exhibits a range of interesting cell machinery. The main core structure of the growth-cone axon consists of bundled microtubules. At the tip of this bundle, actin filaments are structured in both bundled finger-like spikes (fillopodia) and web-like flattened sheets (lamellipodia). Actin filaments can be arranged in a variety of higher level structures coordinated by a series of actin-binding proteins (ABPs) (Figure 1).

The overall structures of ABPs vary widely, but many have a common actin-binding domain. In cell division, an actin-based ring-like bundle contracts to separate the cell into progeny cells. The design elements of this process, called cytokinesis, appear to be cut and pasted. For example, in cell division of higher plants, a similar process generates a microtubule-based structure at the cell-division locus (Jurgens, 2005). Even bacteria contain tubulin and actin homologues (FtsZ and MreB, respectively) that form higher level structures and machinery that resembles their counterparts, such as microtubules (MreB) and the formation of the cytokinetic ring in bacteria (FtsZ) (Erickson, 1998; van den Ent et al., 2001) (Figure 2).

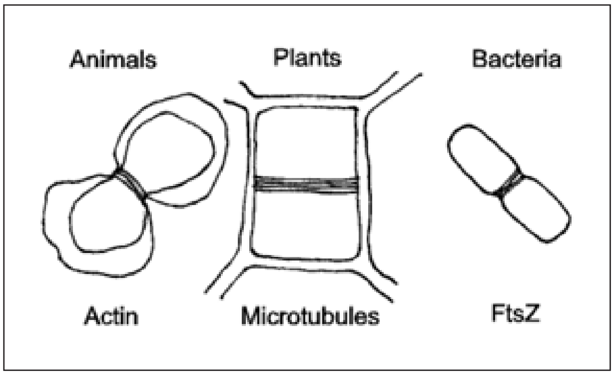

FIGURE 2 This cartoon shows similar stages of cell division in animal cells, plant cells, and bacteria. In all three, a common structural end point is achieved by ring formation through different types of filaments: actin filaments, microtubules, and FtsZ, respectively.

Tissue and Higher Level Machinery

Mechanical processes are critical, not only at the molecular level, but also at the tissue level and higher levels. In fact, the mechanics of the extracellular environment is an important factor in determining its fate. Stem cells plated on substrates of different stiffnesses differentiate into different cell types, taking on properties of tissues similar to their mechanical environments. For example, mesenchymal stem cells grown on a matrix with elasticity resembling that of tissues such as 1kPa brain, 10kPa muscle, and 100kPa bone differentiate into cells resembling neurons, muscles, and osteoblasts, respectively (Engler et al., 2006).[6]

The external environment of a cell contains many organized mechanical structures. A typical extracellular matrix is composed of cable-like collagen molecules, rubber band-like elastin molecules, and sponge-like proteoglycans. So, for example, tendons contain collagen organized into a bundle form with many levels of hierarchy, including mineralization. Tendons are designed to withstand low strain and fatigue and can sustain many cycles of loading and unloading over a long period of time. Tendon failure is a common sports injury.

In contrast to a tendon, the dense collagen network of the chorioamnion membrane surrounding a fetus is designed to eventually fail. Early failure in this structure is responsible for one-third of all premature births (Oyen et al., 2005).

Mechanical forces may also affect the organization of structures. Bone requires mechanical stimulation to maintain density, and collagen stress fibers in bone align in the direction of maximal load. Higher level mechanical systems include musculoskeletal, respiratory, cardiovascular, lymphatic, and integumental systems.

Measurements at the Molecular Level

With the advanced instrumentation and experimental methods described below, we are poised to measure the mechanome at the molecular level. For example, force microscopy, in which controlled loads are applied to structures while they are tracked with nanometer-level resolution, can be used to measure mechanical transitions in unfolding protein structures, the rupture of individual molecular interactions, and the motility of biological motors.

A huge range of forces are required to make these measurements. At the molecular level, a balance is obtained between stabilizing an interaction against thermal energy (kT) and maintaining the ability to break an interaction through transition-state barriers of a few kT. Given that kT is in the range of 4 pN-nm (or 4.1×10^{-21} J)[7], and typical transition distances are on the length scale of nanometers, forces ranging from 1 pN to a few tens of pN are ideal for probing molecular machinery.

ATP hydrolysis, the energy source for many biological motors, provides about 20 to 25 kT of energy. Unfolding proteins requires a force of tens to hundreds of pN. Furthermore, because cell-level machinery may involve many molecular interactions, force magnitudes on the scale of nN and more are sometimes required.

A broad range of complementary force-probe methods can meet these force requirements. These include the atomic force microscope (AFM), micropipette manipulation, magnetic traps, microfabricated cantilevers, and optical traps (Suresh, 2007). Combinations of these force probes, such as combined optical trapping and magnetic-particle manipulation, can extend the force range. The optical trap, which has been a mainstay technique in single-molecule biophysics research, is an ideal tool for probing the molecular interactions of biological motors and receptor-ligand interactions.

Fluorescence microscopy is another powerful method of observing single molecules. With advances in this technology, it can be used to track fluorophore-labeled biological motors with nanometer-level resolution (Yildiz et al., 2004). Energy-transfer methods using pairs of fluorophores (FRET) provide a fluorescence-

[6] kPA, or kilo-Pascal, is a unit of pressure defined as force for a given area, Newtons per meter squared.

[7] pN, or picoNewton, is a unit of force defined as 10^{-12} Newtons.

based ruler with a $1/r^6$ dependence,[8] on the length scale of nanometers, which is useful for monitoring conformational changes.

Recently, optical traps and FRET have been combined on a single platform (Tarsa et al., 2007). The combination marries the power of mechanical interrogation and control of structures with the ability to observe them with fluorescence. This combined method has been demonstrated using a model system consisting of a DNA-based hairpin that can be opened and closed with about 15 pN of force from the optical trap (Figure 3). A FRET pair placed at the base of the hairpin reported whether the hairpin was open or closed through high and low FRET states, respectively. Many additional advances, such as light-based methods of laser scissors, photobleach recovery, triggering, uncaging, and time-resolved measurements, can be integrated to produce powerful new tools.

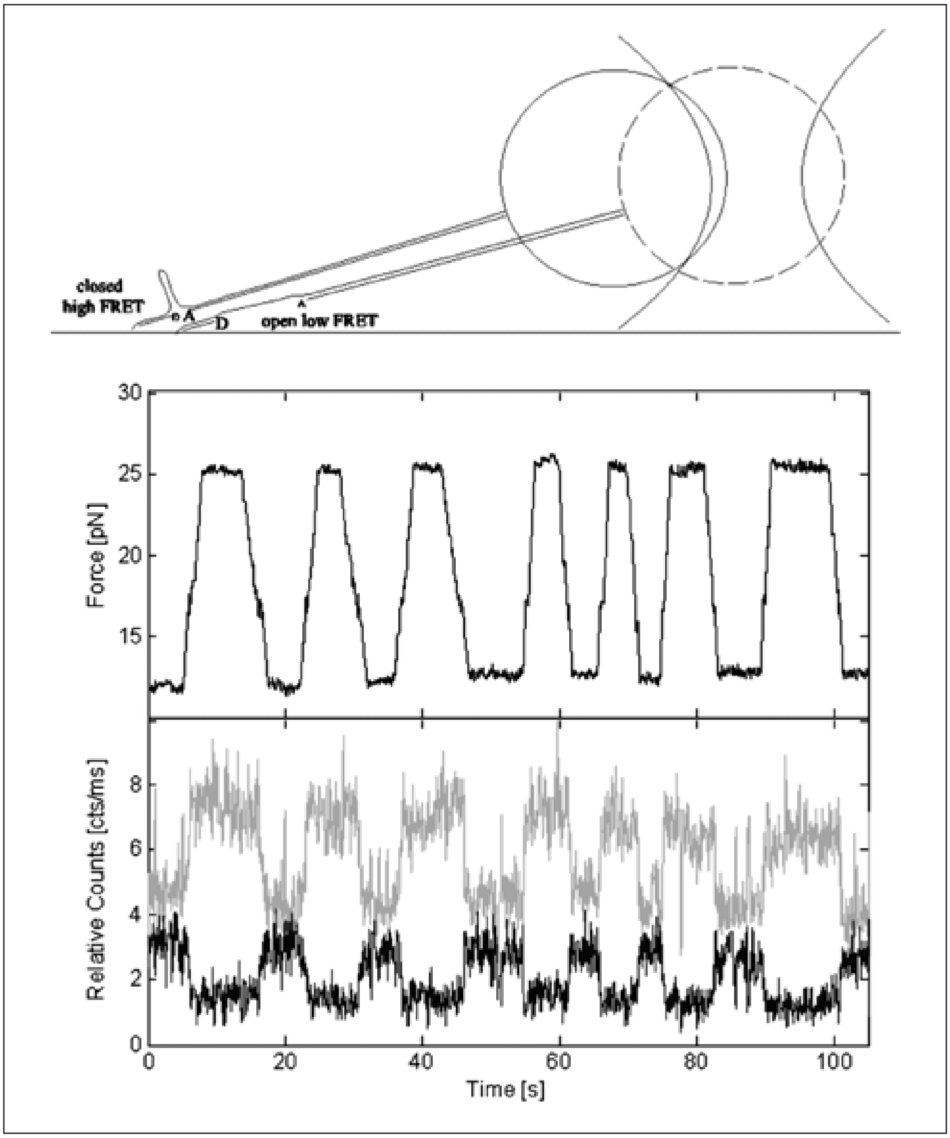

FIGURE 3 The upper frame is a cartoon showing the experimental design with open and closed states of a DNA hairpin complex controlled with force from an optically trapped bead. A donor and acceptor FRET pair is placed at the base of the hairpin to monitor whether it is open or closed. The middle frame shows how force on the hairpin is repeatedly transitioned from low to high with hairpin opening occurring at approximately ~18pN. The lower frame shows photon counts with donor (upper) and acceptor (lower) FRET signals changing simultaneously with the opening and closing of the hairpin.

Significant advances have also been made in assay technologies, molecular biology, and linkage chemistry. Molecular biology strategies, such as the encodeable green fluorescence protein (GFP), which can genetically label proteins, have advanced the field, as have new probes, such as enhanced organic dyes and quantum dots, which have enabled observations of single molecules over extended periods of time. Molecular biology strategies can also be used to create physical handles for the manipulation of molecules, thus exploiting, for example, the aptamer interactions and tethers based on the M13 phage (Khalil et al., 2007).

Conclusion

With the tools and advances in assays I have described, we are beginning to probe nature's machinery. Ultimately, we hope to gain a quantitative understanding of molecular and cellular machinery and to measure the forces and strength of the mechanical steps that underlie

[8] The separation, or distance, between fluorophores, *r*, is usually on the order of 5 nanometers, or 5×10^{-9} meters.

the mechanome. Once we understand the physical rules that govern biological systems and can measure nature's machinery, we should eventually be able to "sequence" the mechanome.

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Corn is replacing petroleum as a raw material in many industrial applications.

Applications of Corn-Based Chemistry

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The United States produces 44 percent of the world's corn. The largest crop grown in the United States, corn occupies some 70 million acres. This versatile, natural, biodegradable, and renewable resource has many commercial applications. As a raw material, it is replacing petroleum in many industrial applications, from plastic containers to clean-burning ethanol. One current goal is to produce 5 billion gallons of ethanol from corn annually. Corn components can also be found in thousands of other products, ranging from foods, drugs, cosmetics, and cleansers to adhesives and shoe polish. For example, corn oil is used in emollient creams and toothpaste,

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and corn syrup is used as a texturing and carrying agent in cosmetics.

The development of biodegradable polymers is a high priority from the standpoint of environmental preservation; biodegradable polymers from corn chemistry have a number of advantages over other synthetic materials. Polymers derived from starch (a component of corn) or other carbohydrates made from entirely renewable resources have been used in the manufacture of quality plastics, packaging materials, and fabrics (Koch and Röper, 1988), as well a variety of biomedical materials (e.g., bioMEMs, biochips, bioscaffolds etc.). This article focuses on new technologies arising from corn-based chemistry and their applications in the polymer industry and biomedicine, cosmetics and drug-delivery systems, and pharmaceuticals.

Biodegradable polymers from corn have a number of advantages over other synthetic materials.

Starch-Based, Biodegradable Polymers

Starch, a major component of corn, is a linear polysaccharide made up of repeating glucose groups with glycosidic linkages in the 1-4 carbon positions with chain lengths of 500 to 2,000 glucose units. There are two major polymer molecules in starch—amylose and amylopectin. Amylose, which has alpha linkage, is both flexible and digestible.

As the starch content of a polymer increases, it becomes increasingly biodegradable and leaves fewer intractable residues. Biodegradation of starch-based polymers is the result of enzymatic attack on glycosidic linkages between the sugar groups, which leads to decreases in chain length and the "splitting out" of lower molecular-weight sugar units (monosaccharides, disaccharides, and oligosaccharides) that can be readily used in biochemical pathways.

Biodegradable starch-based polymers are being investigated for potential use in several biomedical applications. For example, new processing techniques and reinforcement with various fillers have led to the development of materials with mechanical properties comparable to those of bone (Reis et al., 1997a). These polymers may be suitable for bone-replacement implants (Reis and Cunha, 1995), bone cements (Reis et al., 1997b), drug-delivery systems (Malafaya et al., 2001), and tissue-engineering scaffolds (Gomes et al., 2001).

Thermoplastic-Starch Products

When biodegradable thermoplastic-starch plastics, which have a starch (amylose) content of more than 70 percent, are combined with specific plasticizing solvents, they produce thermoplastic materials with good performance properties and inherent biodegradability. The hydrophilic nature of high-starch content plastics, which readily disintegrate on contact with water, can be overcome by blending and chemically modifying the material by acetylation, esterification, or etherification. Starch-based polymers are often plasticized, destructured, and/or blended with other high-performance polymers (e.g., aliphatic polyesters and polyvinyl alcohols) to provide useful mechanical properties for different packaging applications.

Starch-Aliphatic Polyester Blends

Blends of biodegradable, synthetic, aliphatic polyesters and starch are often used to produce high-quality sheeting and films for packaging. Approximately 50 percent of synthetic polyester (which costs approximately $4.00/kg) could be replaced with natural polymers, such as starch (approximately $1.50/kg). In addition, polyesters can be modified by incorporating different functional groups (e.g., hydroxy, amine, carbonyl, etc.) that are capable of reacting with natural starch polymers.

Several products made of starch-based plastics are currently available commercially. These include films (e.g., shopping bags, bread bags, bait bags, overwraps, and backing materials for "flushable" sanitary products) and mulch film. One commercial product, the "BioBag," is produced from the Novamont resin (found in Italy), which has been around since 1994. The BioBag is made from cornstarch combined with fully biodegradable plastics or polylactic acid.

Other products are produced from starch-based foams. A well known example is water-soluble beads made from potato starch that can replace polystyrene-foam packaging beads. Starch-based beads, which are readily soluble and biodegradable, have created an early market for biodegradable plastics.

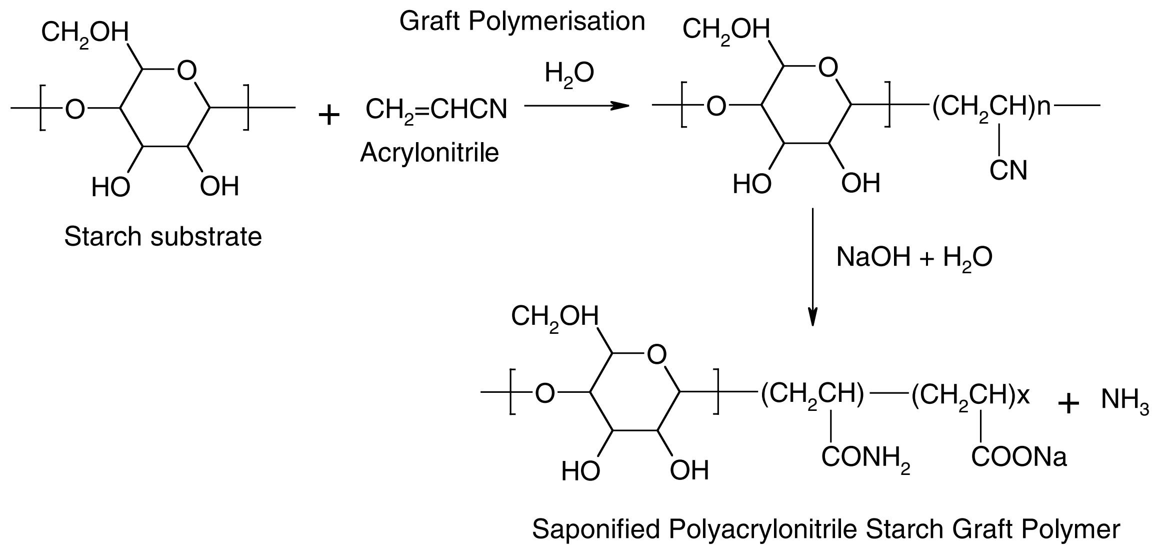

FIGURE 1 Synthesis of a starch-graft polymer.

Starch and PBS/PBSA Polyester Blends

Polybutylene succinate (PBS), polybutylene succinate adipate (PBSA), and other polyesters can be blended with starch to improve the mechanical properties of materials. Starch and PBS or PBSA blends produce biodegradable plastic sheeting that can be thermoformed into biscuit trays and other film products. The tensile strength of these blends is somewhat lower than that of polyester alone, but there is little significant further decrease in strength as the starch content increases, at least to a point. With a very high-starch content (>60 percent), however, sheeting can become brittle. To reduce brittleness and increase flexibility, plasticizers are often added.

Starch-Based Superabsorbent Polymers

Superabsorbent polymers (SAPs) are a unique group of materials that can absorb more than a hundred times their weight in liquid. In addition, SAPs do not easily release these fluids, even under pressure. SAPs were first developed in the 1970s by the U.S. Department of Agriculture in the form of starch/acrylonitrile/acrylamide-based polymers called "superslurpers." These products were originally used in agricultural/horticultural markets as hydrogels to help retain moisture in soil during the growing and shipping of crops and other plants (Yamaguchi et al., 1987).

There are two primary types of SAPs—starch-graft polymers and polymers based on cross-linked polyacrylates. Starch-graft polymers are prepared by graft-polymerizing acrylonitrile onto a starch substrate (Smith, 1972; Yamaguchi et al., 1987).

Saponification of a starch-graft polymer with an alkali yields a final product with nitrile, amide, and carboxyl functionalities (Figure 1). The hydrophilic groups on the composite can be adjusted by controlling the amount of sodium hydroxide and reaction time during the saponification process. The collaborative absorbent effect of -$CONH_2$, -COONa, and -COOH groups present in these polymers is superior to the absorbance capacity of other polymers containing a single -$CONH_2$, -COONa, or -COOH group (Wu et al., 2003).

Cross-linking during polymerization yields a networked polymer that is not only insoluble in water but is able to absorb and retain water under low load. A typical cross-linking agent is trimethylolpropane triacrylate in concentrations of 0.05 mol percent relative to the monomer. Cross-linking is also possible with ethylene glycol diglycidyl ether, which reacts with carboxyl groups on the polymer molecules to cross-link them.

Global demand for SAPs totaled an estimated 1.05 million tons in 2003, and the demand is expected to increase an average of 3.6 percent per year from 2003 to 2008. Globally, baby diapers account for an estimated 81 percent of SAP demand (Figure 2) (*http://nexant.ecnext.com/coms2/gi_0255-3047/Super-Absorbent-Polymers-SAP.html*). Adult incontinence garments make up the next largest segment of the SAP market

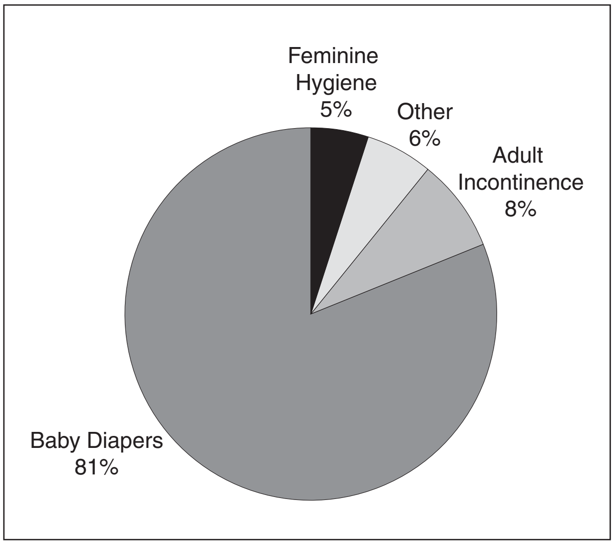

FIGURE 2 The market for superabsorbent polymers in 2003 (total 1.05 million tons).

(8 percent), followed by other applications (6 percent) and feminine hygiene products (5 percent). The "other applications" category includes de-watering agents for sewage sludge, drying agents for china-clay slurries and pulverized-coal slurries (Farrar et al., 1995), and a wide range of other uses.

Polylactic Acid or Polylactide

Polylactide (PLA) is a biodegradable polymer based on renewable resources with a range of applications similar to polyethylene terephthalate (PET). Uhde Inventa-Fisher, a German-based company, has been developing a PLA process for the last 10 years (*http://www.uhde-inventa-fischer.com*), and Cargill in the United States and Teijin in Japan are investing in large-scale production facilities for the manufacture of PLA.

The feedstock for PLA processes is glucose, which can be produced from hydrolysis of starch. Glucose first undergoes fermentation to produce sodium lactate and some impurities, such as proteins, cellular mass, and so on. After a number of purification steps, sodium lactate is transformed into lactic acid, which is then concentrated to remove residual water. This is followed by thermal polymerization (self-condensation), which yields a low-molecular weight PLA prepolymer, which is then thermally depolymerised to yield a distillable cyclic dimer (dilactide, or simply lactide).

Ring-opening polymerization of the purified dilactide with a suitable catalyst, often a tin salt (e.g., stannous octoate), produces high-molecular weight PLA (Figure 3). The final polymer is then granulated and further processed for the desired application. Because of PLA's good mechanical properties, it is used as packaging material (e.g., film, sheet, or bottles), textiles (e.g., filaments or fibers), engineering plastics, and medical polymers (e.g, surgical thread or implants).

1,4:3,6-Dianhydrohexitols-Based Polymers

Incorporating simple carbohydrates directly into polymer structures is difficult because both primary and secondary hydroxyl functionalities in carbohydrates interfere with the synthesis of well defined products. The problem can be circumvented by using 1,4:3,6-dianhydrohexitols.

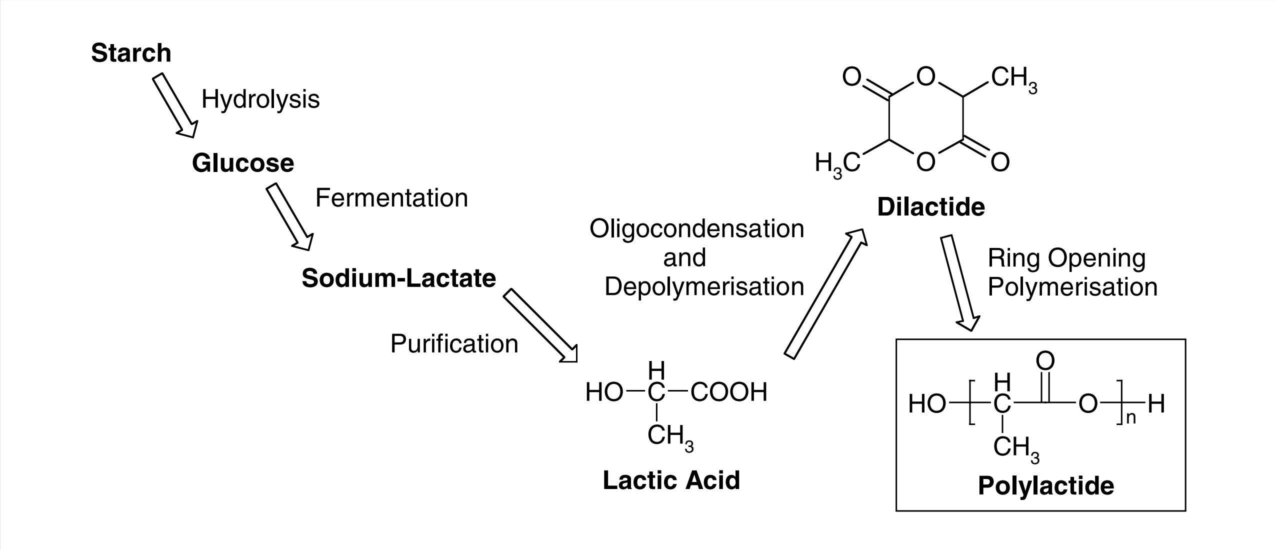

FIGURE 3 The Uhde Inventa-Fisher process of making polylactide from starch. Source: *www.udhe-inventa-fisher.com.*

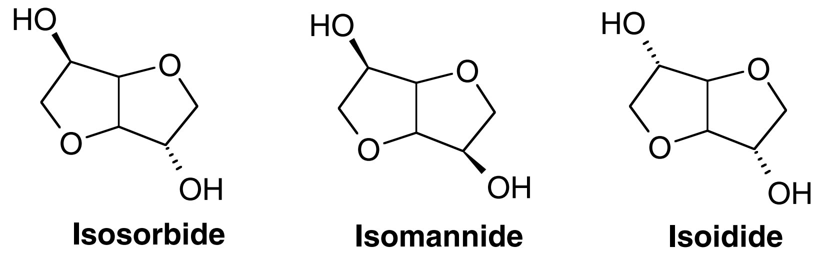

FIGURE 4 The three main isomers of dianhydrohexitols.

Dianhydrohexitols are well documented by-products of the starch industry obtained by dehydration of D-hexitols, which are made by a simple reduction of hexose sugars (Stross and Hemmer, 1991). About 650,000 tons of dianhydrohexitols are produced annually worldwide (Sheldon, 1993). These chiral biomass-derived products exist as three main isomers (isosorbide, isomannide, and isoidide), depending on the configuration of the two hydroxyl functions (derived from D-glucose, D-mannose, and L-fructose, respectively) (Figure 4). Isosorbide, which is produced from glucose via sorbitol, is the most widely available dianhydrohexitol.

Isosorbide

The Iowa Corn Promotion Board supports research on corn-derived products (notably isosorbide) in conjunction with the U.S. Department of Agriculture and U.S. Department of Energy and is partnering with the New Jersey Institute of Technology to identify and assess potential polymer applications for isosorbide. This biodegradable material is classified by the Food and Drug Administration as a "generally recognized as safe," or GRAS, material.

In principle, isosorbide can be incorporated directly into commercial polyesters, such as PET, which is widely used in a variety of food and beverage containers and has a current market of 4.4 billion pounds. Isosorbide, which has a rigid molecular structure, stiffens PET chains and raises the glass-rubber transition temperature (T_g) of PET resin to 85 to 90°C, depending on the level of incorporation. At that T_g, bottles made from these modified resins can be filled with pasteurized food products while they are still hot or with products that are so viscous they require heating to reduce filling time. Normal, unmodified PET bottles simply become distorted when hot-filled in this way. Preliminary cost estimates show that isosorbide produced by processing of starch is competitive with the cost of petroleum-based building blocks currently used to make plastics (Adelman et al., 2003; Kricheldorf and Gomourachvili, 1997).

Besides modifying PET, isosorbide has many potential uses in the polymer industry and can potentially reduce the amount of petroleum necessary to make plastics. The synthesis of numerous polymers, such as polyethers (Chatti et al., 2006; Kricheldorf and Al Masri, 1995; Majdoub et al., 1994), polyesters (Kricheldorf et al., 2003; Thiem and Lueders. 1984), polyurethanes (Bachmann et al., 1998; Cognet-Georjon et al., 1995; Thiem and Lueders, 1986), and polycarbonates (Kricheldorf and Gomourachvili, 1997), is already being investigated.

A few of the potential applications of dianhydrohexitol-based polymeric products are listed below:

- Isosorbide diglycidyl ether resins could replace bisphenol-A epoxies, which are used to line food and beverage cans. Bisphenol-A is a suspected xenestrogen, and replacing it with a naturally derived, biodegradable diol would have clear consumer advantages.

- Isosorbide and dianhydroiditol polycarbonate resins could be used as molding plastics with high T_g, transparency, and UV-resistance to replace bis-A polycarbonates in CD blanks.

- Chiral separation resins (amorphous, insoluble polyurethanes based on isosorbide) have great potential value in the pharmaceutical and fine-chemicals market for resolving enantiomeric molecules. These isosorbide-based materials exploit the basic chirality of anhydrosugar molecules.

- Isosorbide/isoidide-ester copolymers of controlled stereochemistry could lead to high-performance fibers and engineering resins and the creation of new classes of controlled-performance, cost-effective polyesters through the control of polymer chirality along the chain.

- Potential applications of polyester resins from isosorbide with terephthalic and isophthalic acids and copolymers with monomers (e.g., L-lactide, caprolactone, etc.) range from environmentally friendly molding resins to drug-release and degradable-suture materials.

Cosmetics and Drug-Delivery Applications

Dimethyl isosorbide (DMI) is a water-white liquid with excellent solvent properties that can be easily synthesized by methylation of isosorbide using dimethyl sulfate and aqueous alkali. DMI can be formulated with standard equipment and requires no special materials, such as flammables, in its production.

Used as a sustainable solvent in skin-care products and drug formulations, DMI facilitates the penetration of active ingredients through the epidermis, enabling targeted delivery of self-tanners, makeup removers, anti-acne treatments, and other transdermal products (*http://www.bulkactives.com/dimethylisosobide.htm*). DMI can transport water-soluble active agents into the skin without recrystallizing them and causing skin irritation. And, most important, it does not promote penetration of the ingredients into the bloodstream.

Materials made with DMI require a lower concentration of aggressive active agents, such as salicylic acid, vitamin C, lactic acid, hydrocortisone, and hyaluronic acid, thus reducing the formulation cost of finished products. Other advantages include longer shelf life (particularly for formulations susceptible to hydrolysis or trans-esterification); miscibility with most organic solvents and non-ionic surfactants; and compatibility with many product forms, including clear gels.

All of these properties make DMI a potential choice for transdermal or topical delivery of a variety of drugs. Preliminary studies indicate that DMI is practically nontoxic. Thus, when used internally, it is predicted that DMI will be metabolized to form isosorbide. DMI has already been used successfully for stable liquid formulation of aspirin (Luzzi and Joseph, 1980), which has been a long-standing problem because of the instability of aspirin in other solvents.

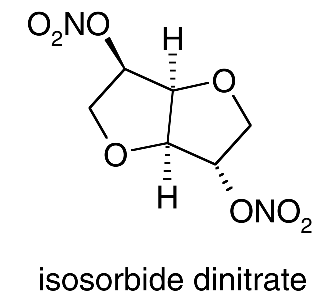

FIGURE 5 Chemical structure of the isorbide dinitrate molecule.

Pharmaceutical Uses of Dianhydrohexitols

The mono- and dinitrate esters of isosorbide and isomannide, both active NO-releasing drugs, are widely used in the pharmaceutical industry as vasodilators. Figure 5 shows the configuration of isosorbide dinitrate

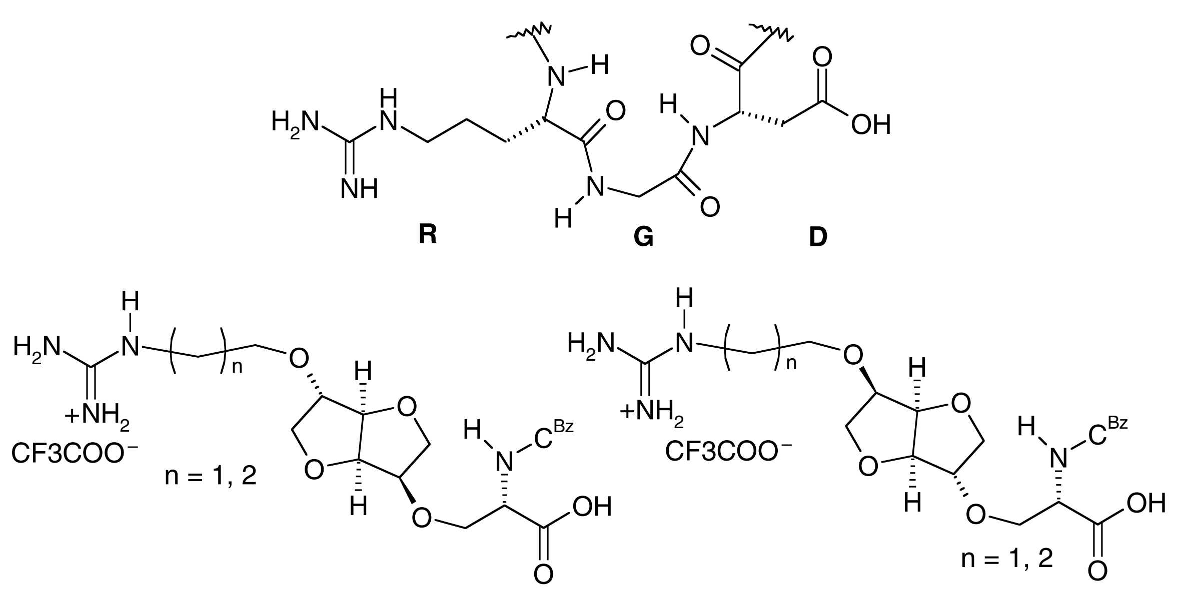

FIGURE 6 RGD-mimetics derived from isosorbide and isomannide.

(sold under the brand names Isordil® and Sorbitrate®), which is used as a vasodilator in various formulations that work by different routes for the management of angina pectoris and congestive heart failure (Bidoggia, 1987; Marten et al., 1984). Many pharmaceutical preparations of these compounds are trade products.

Isosorbide and isomannide have also been successfully used as templates for RGD-mimetics[1] (Figure 6) in the development of integrin antagonists[2] (Osterkamp et al., 1999). Because RGD mimetics can inhibit cell attachment and consequently induce apoptosis, they might someday be used as drugs against angiogenesis, inflammation, and cancer mestastasis.

Conclusion

Corn is a versatile, natural, biodegradable and renewable resource that has many commercial applications. Corn-chemical and biotechnological processes have led to the development of a wide range of products, from polymers to biofuels and vitamins. In the past decade, numerous consumer products based on the results of research have demonstrated the potential of biorenewable sources being used instead of petroleum-based products. With continued work and technological advances, we may soon achieve this potential.

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Computational models that incorporate the sociocultural layer of human behavior present serious challenges and promising opportunities.

Modeling of Culturally Affected Human Behavior

Michael van Lent, Mark Core, Steve Solomon, Milton Rosenberg, Ryan McAlinden, and Paul Carpenter

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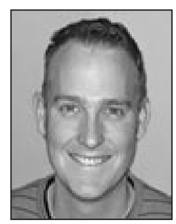

Ryan McAlinden

Paul Carpenter

One major textbook divides artificial intelligence (AI) systems into two categories, those that are meant to think and act rationally and those that are meant to think and act like people (Russell and Norvig, 2003). Developers of systems that focus on rational behavior seek to maximize expected rewards based on the agent's goals; they do not attempt to account for the many social or cultural factors that influence human behavior. Even systems with human-like behavior as their goal, such as ACT-R (Anderson and Lebiere, 1998) and SOAR (Laird et al., 1987), generally focus either on passing the Turing test or simulating detailed aspects of cognition and/or neural physiology. These models are becoming more like intelligent software agents and are advancing our understanding of the neural and cognitive layers of human thought. However, very few AI systems explore the sociocultural layer of human thought.

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For decades, the so-called "soft sciences" (psychology, sociology, and anthropology) have focused on the behavioral phenomena that "make us human," such as emotion, personality, and culture. Not surprisingly, however, these investigations have generated many competing, hotly debated theories but few clear answers.

A few brave AI researchers have waded into the fray by selecting individual theories and attempting to model them computationally in combination with agent-based AI methods. For example, the PsychSim system is a multi-agent-based computer program that lets social psychologists and sociologists run experiments in simulation (Pynadath and Marsella, 2005). PsychSim draws on theory of mind (Nichols and Stich, 2003) from the social sciences and combines it with standard AI approaches, such as decision theory and partially observable Markov decision processes, to create a system of agents that can model and reason about each other.

Similarly, the emotion-modeling and adaptation, or EMA, model (Marsella and Gratch, 2006) combines appraisal theory (Scherer et al., 2001) with standard AI plan representations to model relationships between an agent's goals and emotions. Finally, the cultural-cognitive architecture (Taylor et al., 2007) builds on schema theory (D'Andrade, 1992) and uses the SOAR architecture to model culturally specific behavior schemas or scripts.

Culture is the aspects of physical appearance, internal knowlege, and external behavior common to a cultural group.

Culture is one of the more complex and interesting elements of human social behavior. Even the definition of the term "culture" is hotly debated. Geert Hofstede (1994), a widely known researcher of culture, defines it as "the collective programming of the mind that separates one group of people from another." Following in this vein, we define culture more specifically as the aspects of physical appearance, internal knowledge, and external behavior common to a cultural group. A cultural group is defined as a group of people who identify with the group through a shared trait, such as gender, race, ethnicity, religion, nationality, "regionality," age, economic status, social class, education, or occupation.

Individuals belong to many different cultural groups simultaneously. Current theories of culture propose that, in any given situation, an individual selects a dominant cultural identity trait, which plays a primary role in influencing his or her behavior (DiMaggio, 1997). In the Culturally Affected Behavior (CAB) Project at the University of Southern California, we distinguish between culture and personality. Culture denotes the aspects of appearance, reasoning, and behavior that are common to a group; personality denotes the aspects of appearance, reasoning, and behavior that are specific to an individual and by which that individual defines his or her identity within the group.

Previous research on culture in the fields of psychology, sociology, and anthropology can be divided into two general categories. In one category, researchers (e.g., Hofstede) attempt to identify the high-level cultural parameters (such as power distance, individualism, masculinity, uncertainty avoidance, long-term orientation) that characterize a culture. This is the cultural equivalent of the Myers-Briggs personality test (Myers, 1962). Researchers in the second category focus on detailed aspects of culturally influenced behavior (such as greetings and polite or impolite gestures) (D'Andrade, 1992; DiMaggio, 1997).

Unfortunately, it is not feasible to derive low-level details of culturally influenced behavior solely from high-level cultural parameters. Hofstede's five dimensions of culture do not provide enough information for us to derive, for example, that in Muslim cultures women should not initiate a handshake when greeting a man. However, Hofstede's masculinity dimension (which is generally very high in Muslim cultures) could be used as an indicator that culturally important details are involved in a woman greeting a man. The masculinity dimension might also suggest that Hindu cultures, which have similar masculinity values, might share many details in this area with Muslim cultures.

Thus high-level theories can provide useful indicators and parallels that could make it less difficult to create cultural-behavior "modules" that encode the details of culturally influenced behavior. At the very least, high-level theories indicate areas of behavior that are likely to have culturally specific aspects and/or suggest commonalities among cultures, suggesting that detailed cultural information might be reusable.

The Culturally Affected Behavior Project

At the CAB Project, we draw on the schema theory and theory of mind (mentioned above), plus shared symbol theory (D'Andrade, 1984), to develop a computational approach for representing, encoding, and using cultural knowledge at the individual and aggregate levels. A number of aspects of this problem are described in more detail below.

Computational. Unlike most research in sociology, anthropology, and psychology, we are attempting to develop cultural models and representations that can be integrated into an AI system that operates in an educational game. To be implementable in a computer simulation, the approach to cultural modeling must be computational. Although this approach must be fairly formal, models can still have significant uncertainties and approximations.

Approach. The goal of the CAP Project is not to develop a specific software implementation but to develop a conceptual approach that can be implemented in a variety of ways using general programming languages or AI.

Representing. One of our primary challenges is to create a representation that is not only easy to author and modify, but is also capable of supporting changes to an AI character's cultural model without requiring that the character's entire behavior set be re-authored.

Encoding. In addition to defining the representation of cultural knowledge, we will explore how these cultural representations can be created. One potential advantage of the modular approach to cultural representation is that it supports easier authoring of cultural models. In addition to direct authoring, encoding includes acquiring cultural knowledge from other sources, such as machine learning and data mining from databases compiled by sociologists and anthropologists.

Using. Exploring the representation and encoding aspects of cultural models requires considering how these models might be used to affect the appearance, reasoning, and behavior of AI agents. As part of the CAB Project, we are investigating a variety of ways modularized cultural models can affect agent behavior, including (1) selecting which aspect of an agent's cultural identity should be most important in a given situation, (2) filling in details about another agent or human avatar's cultural identity, (3) establishing opinions and attitudes toward others, (4) influencing the selection of goals and objectives, and (5) selecting culturally specific behaviors and actions for achieving those goals.

The CAB Approach

Our goal is to combine established theories from the social sciences with computational methods from AI. However, we also draw inspiration from many social-science theories and focus on swappable culture "modules" that allow a virtual character in an educational computer game to look, sound, and act differently based on the currently loaded culture.

A primary hypothesis of the CAB Project is that it is possible to separate cultural knowledge from task or domain knowledge. This means an AI character's culture can be changed without changing the character's entire knowledge base. We are trying to modularize the cultural model into a "chunk" of knowledge that affects the AI agent's appearance, reasoning, and behavior but is as separate from the rest of the agent's behavior model as possible.

A primary hypothesis is that cultural knowledge can be separated from task or domain knowledge.

Major Challenges

A central challenge is to determine the extent to which cultural knowledge, which obviously has a pervasive influence on behavior, can be modularized. Some aspects of a game character, such as appearance, can be changed very easily by switching the 3D character model and texture or "skin" on that model. Slightly more challenging is modifying a character's animations (how the character moves) and voice model (how the character sounds, including accent).

The greatest challenge, however, is modifying how a character thinks and reacts in interpersonal situations. We model a set of interlinked "sociocultural norms," such as "is-observant-of-Islam," "avoids-alcohol," and "is-not-corrupt," each of which has (1) a culturally dependent weight based on the importance of that norm to the target culture and (2) a situation-dependent degree based on how much the agent feels the current situation supports or challenges that norm. Many sociocultural norms represent "shared symbols" in that they reflect common attitudes toward specific objects, gestures, and concepts in the character's environment.

In any given situation, the weighted sum of degrees across all sociocultural norms represents the character's "sociocultural comfort level" with that situation. For example, Farid, the Iraqi police officer, might have a high weight for the "is-observant-of-Islam" sociocultural norm, which necessitates a high weight for the "avoids-alcohol" norm. If the human player were to offer Farid alcohol as a gift, the weight of the "avoids-alcohol" norm would decrease, and Farid would be less comfortable.

However, Fritz, the German police officer, might have a zero weight for both the "is-observant-of-Islam" norm and the "avoids-alcohol" norm. Thus offering a gift of alcohol to Fritz might seem to be a positive relationship-building action. However, if Fritz has a high weight for the "is-not-corrupt" norm, offering him any gift might be interpreted as an attempted bribe, which would challenge his "is-not-corrupt" norm and consequently decrease his sociocultural comfort level.

By weighting norms, every character, no matter what his or her culture, can include the entire set of sociocultural norms. If a norm is not relevant to a character's specific culture, it can be "turned off" by setting the weight to zero (as with the "is-observant-of-Islam" norm for Fritz). Therefore, changing a character's culture is simply a matter of changing the weights on the sociocultural norms rather than significantly restructuring the character's knowledge base.

Applications

The ELECT BiLAT immersive-training application shows the advantages of the CAB cultural-behavior modules. The ELECT BiLAT application (see Figure 1) will give students an opportunity to prepare for and conduct meetings and negotiations in cross-cultural settings. At present, the cultural behaviors being developed for the ELECT project are specific to Iraqi culture. Thus the elements of Iraqi culture are not structured as a swappable module in the system but are dispersed throughout the system in both explicit and implicit ways. As a result, moving the ELECT BiLAT application to a new culture will require re-authoring much of the system rather than just re-authoring the parts specific to culturally affected behavior.

Nevertheless, by exploring the challenges to representing and authoring cultural behavior modules, the CAB Project might make it possible to adapt systems like ELECT BiLAT to a wide variety of cultures without requiring the creation of completely new databases of behavior knowledge. We are currently working on a modified version of ELECT BiLAT that can support a meeting with either Farid, the Iraqi police officer, or Fritz, the German police officer, by modifying the weightings of the character's sociocultural norms and changing the character's appearance, animations, and voice model.

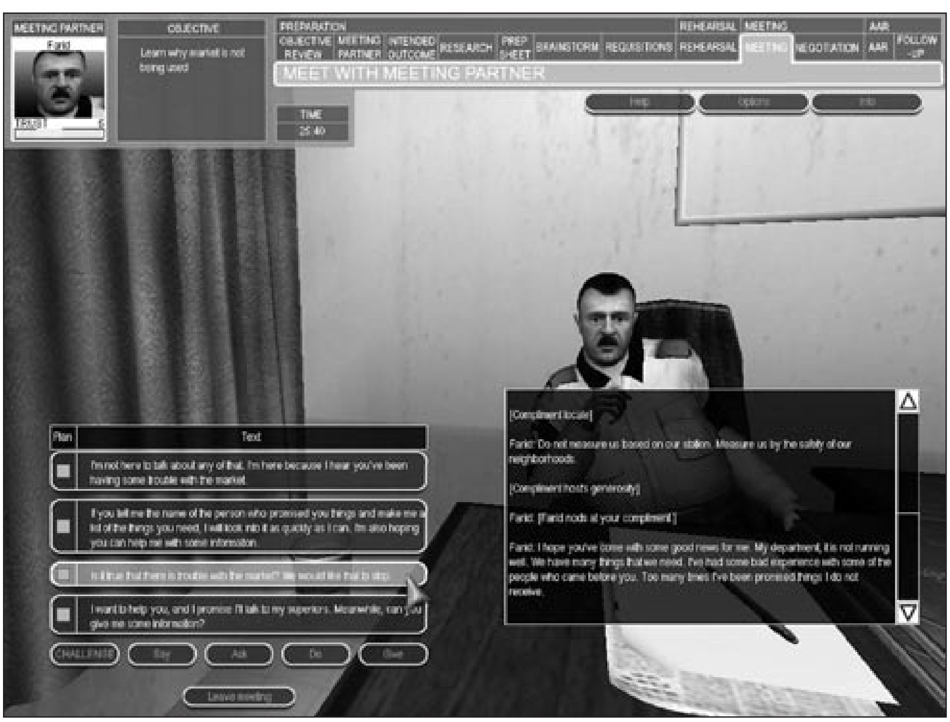

FIGURE 1 A screen shot from the ELECT BiLAT application, which can help students prepare for conducting meetings and negotiating in cross-cultural settings.

This example shows how cultural information might influence the behavior of a single entity. The approach works well for modeling the influence of culture at the individual level and for small groups of individuals and enables users to interact with those groups or individuals in real time. However, at the macro-level, which involves the behavior of large groups and populations, the models must apply not to individual entities but to trends in behavior across interacting cultural groups. An example of culturally affected behavior at this level is the social structure of traditional tribes, which varies from culture to culture. So far, our efforts have been focused primarily on cultural behavior at the individual level, but we will also investigate macro-level cultural behaviors.

Metrics for Evaluating the System

The first challenge to defining metrics for success in the modeling of culturally affected behavior is determining exactly what should be measured. We have attempted to evaluate four aspects of the system. First, to ensure that the system can support an immersive user experience and that it acts in a culturally appropriate way, we must evaluate the believability (also called observational fidelity) of the generated behavior. Second, to ensure stability, we evaluate the functional validity of the system (i.e., its ability to run without bugs or crashes).

Third, to ensure that new cultures can be rapidly encoded, we measure the "authorability" of the cultural knowledge modules. Finally, we evaluate the explanatory fidelity of the system (i.e., its ability to explain why the system is behaving in a given way). Metrics for believability, authorability, and explanatory fidelity will be based on acceptance tests with users. Functional validity can be measured through unit and functional testing.

Conclusion

The development of computational models of the social layer of human behavior is a challenging goal. Projects like CAB require teams of researchers and authorities in disciplines that have not traditionally worked together. Fortunately, we can draw on the experiences of previous generations or researchers who have created new fields of study on the boundaries between established scientific disciplines. For example, cognitive modeling, the computational modeling of human cognition, requires expertise in cognitive psychology, computer science, and computational linguistics (the study of language using computational models). Following in the footsteps of these pioneers, computational social science has the potential to grow into a mature field of study that supports further research investigations and has important practical applications.

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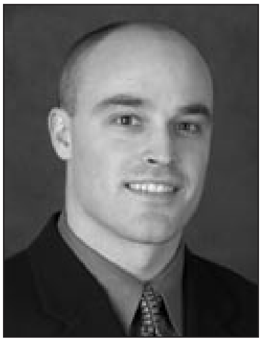
Systems that use bacteria to treat drinking water have been shown to be highly efficient and environmentally sustainable.

Biological Treatments of Drinking Water



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Jess C. Brown

Microbial biomass has been used since the early 1900s to degrade contaminants, nutrients, and organics in wastewater. Until recently, the biological treatment of drinking water was limited, particularly in the United States, but recent developments may mean that biological drinking water treatment may become more feasible and more likely to be accepted by the public. These developments include (1) the rising costs and increasing complexities of handling water-treatment residuals (e.g., membrane concentrates); (2) the emergence of new contaminants that are particularly amenable to biological degradation (e.g., perchlorate); (3) the push for green technologies (i.e., processes that efficiently destroy contaminants instead of concentrating them); (4) regulations limiting the formation of disinfection by-products (DBPs); and (5) the emergence of membrane-based treatment systems, which are highly susceptible to biological fouling.

Process Fundamentals

Bacteria gain energy and reproduce by mediating the transfer of electrons from reduced compounds (i.e., compounds that readily donate electrons) to oxidized compounds (i.e., compounds that readily accept electrons). Once electrons are donated by a reduced compound, they travel back and forth across a cell's mitochondrial membrane in a series of internal oxidation-reduction reactions. Ultimately, the electrons are donated to the terminal electron-accepting compound. This series of reactions, which is cumulatively known as the electron-transport chain, creates an electrochemical gradient across the cell membrane that bacteria use to generate adenosine triphosphate, also known as energy (Madigan et al., 1997).

As compounds gain or lose electrons, they are converted to different, often innocuous, forms that are thermodynamically more stable than the original compounds. The example below illustrates the microbially mediated oxidation-reduction reaction between acetate (an electron donor) and dissolved oxygen and nitrate (two environmental electron acceptors).

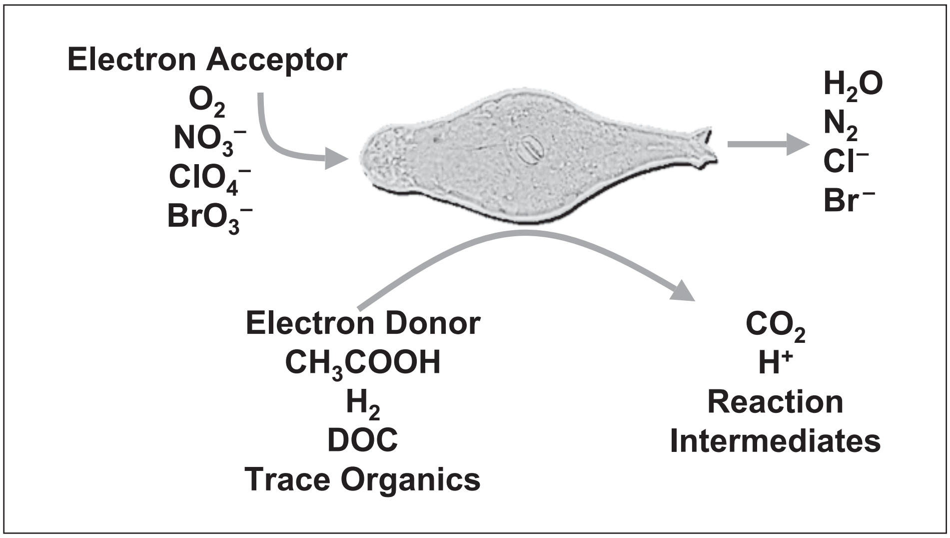

FIGURE 1 Microbially mediated oxidation-reduction reactions.

- $CH_3COO^- + 2O_2 \rightarrow 2HCO_3^- + H^+$
  $\Delta G^{o\prime} = -844$ KJ/mol acetate
- $CH3COO^- + {}^3/_5NO_3^- + {}^{13}/_5H+ \rightarrow 2HCO_3^- + {}^4/_5H_20 + {}^4/_5\,N_2$
  $\Delta G^{o\prime} = -792$ KJ/mol acetate

Notice that nitrate, a common contaminant in drinking water, is converted to innocuous nitrogen gas. The Gibb's free-energy values for the overall reactions are shown below the equations (Rikken et al., 1996). The more negative the Gibb's free-energy value, the more thermodynamically unstable the reaction and the greater the energy yield for the bacteria mediating the reaction. Electron transfer in the overall reactions can be observed only by evaluating the oxidation states of individual atoms.

Biological drinking water treatment processes are based on the growth of bacterial communities capable of mediating oxidation-reduction reactions involving at least one target contaminant (Figure 1). Heterotrophic biological processes use an organic electron donor (e.g., acetic acid). Autotrophic biological processes use an inorganic electron donor (e.g., hydrogen).

Contaminant Applications

Biological processes can be used for a wide range of organic and inorganic contaminants (Table 1) in both surface water and groundwater.

Technology Configurations

Numerous forms and configurations of biological treatment processes are used to degrade contaminants in drinking water. Most are operated as fixed biofilm systems, meaning that the process includes a biogrowth support medium on which bacterial communities attach and grow (e.g., granular media). A smaller number of technologies operate as suspended growth systems, in which free-floating bacteria are hydraulically maintained within a reactor. Biological reactors can be inoculated with an enriched bacterial community or can simply be acclimated by the organisms indigenous to the water source being treated. Examples of biological treatment configurations are described below.

Fixed-Bed Processes

In fixed-bed (FXB) biological processes, biofilms develop on a stationary bed of media, such as sand, plastic, or granular activated carbon (Figure 2). The granular media bed can be contained in pressure vessels or open basins. In pressure-vessel systems, water is pumped up-flow or down-flow across the biological bed; in open-basin systems up-flow requires pumping, but down-flow occurs by gravity. As water is treated, biofilms increasingly restrict flow and cause head loss across the bed. If unchecked, the loss eventually exceeds the available driving pressure or causes short-circuiting through the bed. To avoid these complications, FXB systems are routinely taken off line and backwashed to remove excess biomass from the system (Brown et al.,

TABLE 1 Contaminants Amenable to Biological Treatment[1]

Contaminant Category	Removal Application	Description
Natural organic matter (NOM)	• Regrowth substrate • DBP precursors • Color • Membrane foulants	• The biological oxidation of carbonaceous organic matter to CO_2 can minimize potential regrowth in distribution systems, decrease the production of DBPs, remove color, and improve transmembrane fluxes without chemical additives. Ozone is often used before a biological process to increase removal of NOM.
Trace organics	• 2-methyl-isoborneol (MIB) • Geosmin • Algal toxins • Endocrine disruptors and pharmaceutically active compounds • Pesticides	• Biological oxidation to CO_2, often degraded as a secondary electron donor (i.e., does not yield the requisite energy to support cell maintenance and growth), requires the presence of a primary substrate, such as NOM.
	• Methyl tertiary-butyl ether (MTBE)	• Biological oxidation to CO_2.
Halogenated organics	• Perchloroethylene (PCE) • Trichloroethylene (TCE) • Dibromochloro-propane (DBCP) • Chloroform	• Biological reductive dechlorination produces innocuous ethane or CO_2.
Inorganics	• Perchlorate • Chlorate • Nitrate • Nitrite • Bromate	• Biological reduction produces innocuous end products (Cl^-, N_2, Br^-, H_2O), thus eliminating the generation of a contaminated concentrate stream.
	• Selenate • Chromate	• Biological reduction produces insoluble species that can be readily filtered or settled out of water, thus eliminating the need for chemical reduction.
	• Ammonia	• Biological oxidation of ammonia to nitrate provides an alternative to chemically intensive break-point chlorination.
	• Iron • Manganese	• Biological oxidation of soluble species (Fe^{2+}, Mn^{2+}) to insoluble species (Fe^{3+}, Mn^{4+}) eliminates the need for chemical oxidation prior to filtration or settling.

[1]Source: Adapted from personal experience and Bouwer and Crowe, 1988; Brown, 2006; Brown et al., 2005; Dahab and Woodbury, 1998; Herman and Frankenberger Jr., 1999; Kirisits et al., 2002; and Lauderdale et al., 2007.

2005; Kim and Logan, 2000). FXB is often coupled with pre-ozonation to improve the removal of organic material, which reduces regrowth potential and DBP formation in distribution systems.

Fluidized-Bed Processes

Fluidized-bed reactors (FBRs) also use granular media to support biogrowth. Contaminated water is pumped up-flow through the reactor at a high rate to fluidize the granular media bed and reduce resistance to flow. Typically, the fluidization rate is controlled to maintain a 25 to 30 percent bed expansion over the resting bed height. Feed flow is supplemented with recycle flow to provide the appropriate up-flow velocity for fluidization (Green and Pitre, 1999; Guarini and Webster, 2004). Excess biomass is removed from FBR systems by

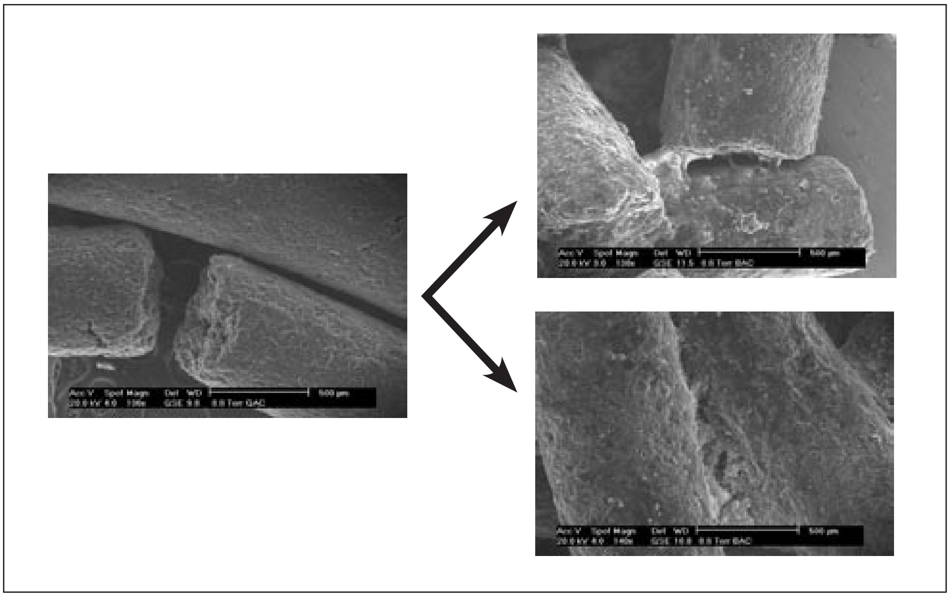

FIGURE 2 Electron micrographs showing (a) the surface of virgin granular activated-carbon media and (b) and (c) biofilm-covered granular activated carbon that was used for three years in a biological drinking water treatment reactor. Source: Reprinted with permission from *WaterWorld*, April 2007.

(1) shear forces generated by the high feed-pumping rates and/or (2) in-line mechanical shearing devices. Therefore, although FBRs require higher feed-flow capacity, they do not require an off-line backwashing step.

Membrane Bioreactors

Conventional Systems

Membranes can also be coupled with biological systems to improve the treatment of drinking water. In one approach, ultrafiltration membranes are submerged in a reactor basin that contains suspended biomass. The reactor basin provides the detention time necessary to achieve effective biological treatment. Treated water is drawn through the membranes by vacuum and pumped out to permeate pumps for further processing.

Airflow introduced at the bottom of the reactor basin performs several functions. First, it creates turbulence that scrubs and cleans the outside of the membranes and reduces the accumulation of solids on the membrane surface. Thus the membrane can operate for extended periods of time at high permeate fluxes. Second, the air has the beneficial side effect of oxidizing iron, manganese, and some organic compounds that may be present. Third, air ensures mixing in the process tank to maintain suspension of the biomass. Periodic backwashing of the membranes is done by passing permeate through the membranes in the reverse direction to dislodge solids from the membrane surface.

Biofilm Reactor Systems

A different approach to the "conventional" membrane bioreactor (MBR) uses hollow-fiber membranes to deliver hydrogen gas (an electron donor) to biofilms that grow on the outside of the fibers. When the hollow-fiber membranes are submerged in a reactor vessel through which contaminated water passes, contaminants diffuse from the bulk water into the biofilms and are degraded (Nerenburg et al., 2002). Occasionally, the membranes are chemically cleaned to remove excess biomass.

Ion-Exchange Membrane Systems

Yet another MBR method involves a reactor with two treatment chambers separated by an ion-exchange membrane. One chamber contains suspended biomass plus nutrients; the other chamber contains raw water. As raw water enters the system and moves through one chamber, ionic contaminants diffuse across the membrane into the biological treatment chamber where they are degraded. The objective of this approach is to separate the active biomass from the raw and treated water (Liu and Batista, 2000).

Bank Filtration Systems

Bank filtration wells, drilled near rivers and lakes, draw surface water through soil and aquifer material, which act as a passive treatment reactor. As the surface water moves through the aquifer, it is subject to filtration, dilution, sorption, and biodegradation processes (Gollnitz et al., 2003; Ray et al., 2002; Weiss et al., 2003a,b). Bank filtration, which has been used for more than 130 years in Europe, has aroused a great deal of global interest for use in reducing organic and particulate loads to drinking water treatment plants.

One of the oldest bank filtration systems draws water from the Rhine River in Germany and is part of the Düsseldorf Waterworks. This system has been in operation since 1870, and until about 1950, it was the only treatment process used at that facility.

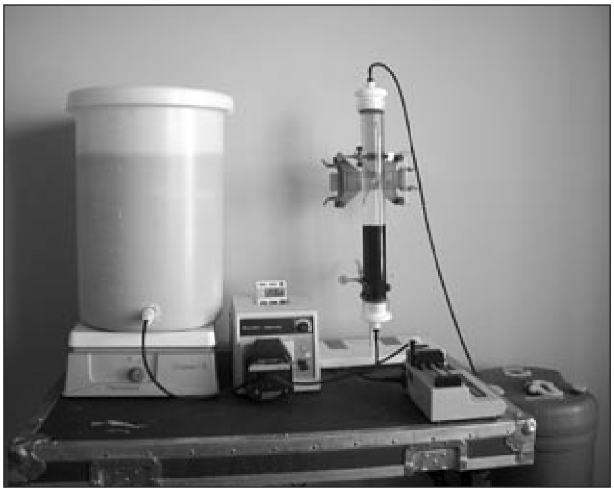

FIGURE 3 Bench-scale biological-treatment testing apparatus.

Process Optimization

Various tools are available to facilitate the optimization of engineered biological treatment systems. Bench-scale reactors (Figure 3) and pilot-scale reactors (Figure 4) are often used in conjunction with mathematical models to isolate the impacts of various water quality conditions and operating parameters on overall system performance.

Commercial Models

Available commercial models can be tailored to a specific treatment application and process configuration. Typically calibrated using results from bench- and/or pilot-scale testing, these models can simulate steady-state or dynamic conditions and account for hydraulic-flow regimes from plug-flow to complete mixing.

The models incorporate a wide range of parameters, such as feed-water quality and temperature, substrate and nutrient loading rates, contact time, biofilm thickness, specific surface area of reactor media, and biomass detachment. Not only can they predict bioreactor performance for a given set of environmental conditions, they can also elucidate observed phenomena in bioreactor systems. In other words, they can eliminate the “black box” perception of bioreactor processes.

Culture-Based Microbiological Analyses

Microbiological analyses provide another optimization tool. Using a targeted nutrient medium in conjunction with specific incubation conditions, pure cultures can be isolated from the mixed community of bacteria comprising a bioreactor. An enrichment of each pure culture can then be tested to identify optimal environmental conditions for that classification of bacteria. The information can then be used to tweak the operation of or nutrient loading to a given bioreactor to favor the activity and growth of key contaminant-degrading microorganisms.

Molecular Microbiological Techniques

A complement to culture-based techniques, molecular microbiological techniques can be used to identify, quantify, locate, and track specific classes, families, genera, or species of bacteria. These techniques rely on the extraction, amplification, and sequencing (i.e., order of

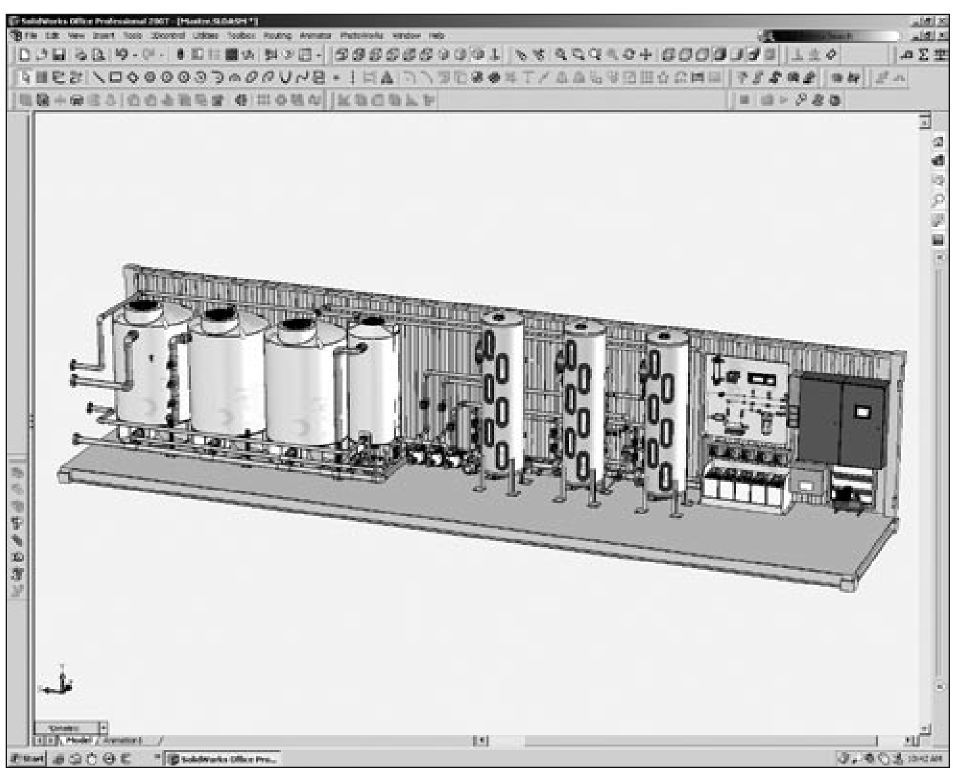

FIGURE 4 Illustration of a pilot-scale biological-treatment testing apparatus.

nucleic acid bases A, T, C, and G) of bacterial community DNA.

Once DNA sequences have been identified for a mixed community, they can be compared against large libraries of known bacterial DNA sequences to identify specific bacteria in a given treatment system to provide a "fingerprint" of the mixed microbial community. Nucleic acid probes, which are constructed using DNA sequence data to target specific bacteria, can then be used to quantify and track changes in a microbial community's fingerprint as a function of operational conditions or water-quality characteristics.

As environmental conditions change, the composition of a microbial community also changes. Molecular microbiological techniques can rapidly identify the environmental conditions that favor the growth and activity of the key contaminant-degrading bacteria in a bioreactor.

Summary

Given that a key objective of treating drinking water is the inactivation or removal of microorganisms from raw water, using bacteria to help produce potable water would seem to fly in the face of conventional wisdom. However, biological drinking water treatment processes, which use indigenous, nonpathogenic bacteria, are always followed by downstream processes, such as final disinfection. Consequently, well designed biological treatment systems pose no significant, inherent threats to the health or safety of distributed water. On the contrary, they can often provide an alternative to conventional processes that has several potential advantages:

- low operating costs
- high water-recovery rates
- destruction, rather than sequestration or concentration, of contaminants
- simultaneous removal of multiple contaminants
- minimal sludge production
- no hazardous waste streams
- minimal or no added chemicals
- robustness over a wide range of operating conditions and water qualities

Overall, biological drinking water treatment is highly efficient and environmentally sustainable. As green water treatment philosophies gain traction and as regulatory and residuals-handling constraints continue to tighten, the use of biological drinking water treatment technologies and processes will likely continue to expand around the globe.

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NAE News and Notes

NAE Newsmakers

Robert K. Brayton, Cadence Distinguished Professor of Electrical Engineering and Computer Science, University of California at Berkeley, received the **Phil Kaufman Award for Distinguished Contributions to Electronic Design Automation** on November 1 during the 14th annual Kaufman Award dinner in Santa Clara, California. The award is sponsored jointly by the Electronic Design Automation (EDA) Consortium and the IEEE Council on EDA and has been presented annually since 1994 to individuals who have had a demonstrable impact on the field of EDA. Dr. Brayton's seminal contributions to logic synthesis were critical to the design of application-specific integrated circuits (ASICs) and the development of CAD products that use logic synthesis software. He is also codeveloper of the sparse-tableau approach and backward-differentiation formulas, implemented as early circuit-simulation software, which influenced the development of SPICE, HSPICE™ and Spectre®.

Wayne Clough, president of Georgia Tech, was honored by the Council on Competitiveness for his leadership of the National Innovation Initiative, which is credited with "paving the way for the America COMPETES Act" recently signed into law by President George W. Bush. The new law increases funding for math and science education and for research.

Ronald L. Rivest, professor of computer science, Massachusetts Institute of Technology, and cofounder of VeriSign, was honored as the **Marconi Fellow for 2007** at the Marconi Society's annual award dinner in Menlo Park, California. Dr. Rivest was honored for the development of computer technologies that are essential to the digital infrastructure for E-commerce, Internet-based online banking, stock trading, and online credit card transactions. The award includes $100,000.

At a ceremony at the Low Library Rotunda at Columbia University on October 13, 2007, the Columbia Alumni Association and Asian Columbia Alumni Association bestowed the **2007 Columbia University Distinguished Achievement Award** to **Ponisseril Somasundaran**, LaVon Duddleson Krumb Professor, School of Engineering and Applied Science, Columbia University. Janice Min, editor-in-chief of *Us Weekly*, and Margaret Fung, a cofounder and executive director of the Asian American Legal Defense and Education Fund, presented the award. Professor Somasundaran was cited for his outstanding achievements and commitment to excellence.

Albert R.C. Westwood, Vice President Emeritus, Research and Technology, Sandia National Laboratories, was the recipient of the **2007 Herbert B. Chermside Award** of the Society of Research Administrators International for distinguished contributions to the field. Dr. Westwood was cited for his expertise in research administration and his many contributions to the research community in the United States and abroad. The award was presented at the annual meeting of the society in Nashville, Tennessee, on October 16, 2007.

On October 17, SEMI, a global industry association serving companies that provide equipment, materials, and services used to manufacture semiconductors, displays, nanoscale structures, microelectromechanical systems (MEMS), and related technologies, presented the **2007 SEMI Award** to **C. Grant Willson**, Rashid Engineering Regents Chair, Department of Chemical Engineering, University of Texas at Austin. Dr. Willson was recognized for his work on chemically amplified resists, which increased productivity in lithography The association also presented the **SEMI Lifetime Achievement Award** to **Bernard S. Meyerson**, vice president for strategic alliance and chief technologist, IBM Systems and Technology Group. Dr. Meyerson was cited for his many contributions to industry and for innovation throughout his professional career.

2007 NAE Annual Meeting

Craig R. Barrett, Stanford Sol Penner, Charles M. Vest, and Nicholas J. Garber.

Nicholas J. Garber, Craig R. Barrett, Jordan J. Baruch, and Charles M. Vest.

NAE members, foreign associates, and guests gathered in Washington, D.C., this September for the 2007 NAE Annual Meeting. The meeting began on Saturday afternoon, September 29, with an orientation session for new members. This was followed by the NAE Council dinner in the Great Hall of the National Academies Building in honor of the 64 new members and 9 new foreign associates.

NAE chair **Craig R. Barrett** opened the public session on Sunday, September 30, with brief remarks on "How the NAE Influences National Policy" (pp.41–42). President **Charles M. Vest** then gave a provocative talk on NAE's mission to provide leadership, the importance of engineering to national competitiveness, and facing the difficult challenges of the 21st century (pp.42–46). The NAE Class of 2007 was then inducted, with introductions by NAE Executive Officer **Lance Davis**.

The program continued with the presentation of a certificate issued by the NAE Council naming **Wm. A. Wulf** NAE President Emeritus. Next the 2007 Founders Award was presented to **Stanford Sol Penner**, University Professor, University of California San Diego, "for pivotal studies on thermal radiation, propulsion, combustion, and energy systems; directing government studies; founding a university department and energy center; and training future leaders." The Arthur M. Bueche Award was then presented to **Jordan J. Baruch**, Jordan J. Baruch Associates, "for the promotion of innovation and management of science and technology nationally and internationally, thereby enhancing the economy of the U.S. and developing nations." Acceptance remarks by Drs. Penner (see pp.47–49) and Baruch (see pp.49–50) followed.

Arthur W. Winston, director, Master of Science in Engineering Management (MSEM) Program, and research professor of electrical engineering, Tufts University, a member of the team that received the 2007 Gordon Prize, delivered a lecture on the winning MSEM Program at Tufts. The team also included Harold S. Goldberg, retired associate dean of the MSEM Program, and Jerome E. Levy, consultant, Northeastern University. (Dr. Winston's acceptance speech appeared on pages 53–54 in the summer 2007 issue of *The Bridge*.)

After a break, **John A. Armstrong**, retired vice president for science and technology at IBM, introduced the Armstrong Endowment for Young Engineers: Lillian M. Gilbreth

Lectures which are given by outstanding young engineers based on their presentations at a Frontiers of Engineering Symposium. Brian Witten, senior director of government research, Symantec Research Labs, Symantec Corporation, spoke on "Cybersecurity: The Transition from Art and Science to Engineering." Muriel Médard, associate professor, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, spoke on "New Directions in Wireless Communications."

The final speaker was Professor **Xu Kuangdi**, president of the Chinese Academy of Engineering, who spoke on "Relying on Scientific and Technological Progress to Transform China's Economic Development Model." The day ended with a reception for members and guests.

At the Annual Business Session on Monday morning, Dr. Vest shared his observations on NAE based on his early experiences as president and the responses from NAE members and foreign associates to an e-mail asking for "the most important things NAE should do to

Charles M. Vest, Brian Witten (Gilbreth Lecturer), and John A. Armstrong.

Charles M. Vest, Muriel Médard (Gilbreth Lecturer), and John A. Armstrong.

Class of 2007

Presidents at the Saturday evening reception. From left to right: Bruce Alberts, past president of NAS; Ralph Cicerone, NAS president; Charles M. Vest, NAE president; Robert C. Seamans, past president of NAE; Wm. A. Wulf, NAE President Emeritus; and Harvey Fineberg, IOM president.

Xu Lena, Charles M. Vest, Xu Kuangdi (NAE foreign associate and guest speaker), Wm. A. Wulf, and Xu Luoping.

Presentation of Council certificate to Wm. A. Wulf naming him NAE President Emeritus during the awards ceremony held September 30.

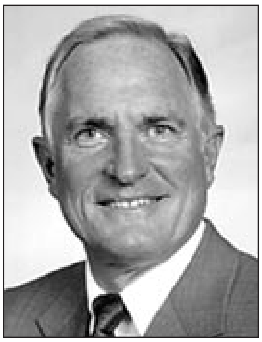
promote the nation's technological welfare" and "other matters" of interest.

The business session was followed by a symposium, "Health Care as an Adaptive Enterprise: An Engineering Challenge," held in honor of **W. Dale Compton**, NAE home secretary. Speakers included Christopher Meyer, chief executive, Monitor Networks; **William B. Rouse**, executive director, Tennenbaum Institute, Georgia Institute of Technology; W. Mark Saltzman, Goizueta Foundation Professor of Chemical and Biomedical Engineering, Yale University; Jerome H. Grossman, director, Harvard/Kennedy School of Health Care Delivery Project; and Paul Levy, president and CEO, Beth Israel Deaconess Medical Center. Articles based on these presentations will be published in the March 2008 issue of *The Bridge*.

On Monday afternoon, members and foreign associates participated in NAE section meetings at the Keck Center. The final event, that evening, was a reception and dinner dance at the Ritz-Carlton, Washington. Music was provided by the Radio King Orchestra.

The next annual meeting is scheduled for October 5–6, 2008.

How NAE Influences National Policy
Comments by NAE Chairman Craig Barrett



Craig R. Barrett

These remarks were delivered at the NAE Annual Meeting on September 30, 2007.

The National Academies, of which the National Academy of Engineering is a part, has two separate and distinct missions. One mission is to publicly recognize excellence and capability, which is why we are here today, to recognize the members of the Class of 2007 and their professional accomplishments. I think the new members should be very proud, because there is nothing better in the world than the recognition of one's peers. That is precisely how our process works. New members are elected by the membership in recognition of their accomplishments. I think that is an excellent way to maintain the quality and stature of the academy in the future.

The parallel mission is stated in the academies' founding charter. The National Academies was created to provide advice to the U.S. government on matters related to science, technology and engineering, and medicine. The three member academies, the National Academy of Engineering, National Academy of Sciences, and Institute of Medicine, are chartered to do that. And we, in fact, do a rather good job of it. A substantial technical report by noted academics and industry experts in various fields is published by the academies almost every working day of every year.

There is probably no better time (and certainly no more complicated time) than now to face the problems all around us. Most of the problems are related to the competitiveness of the United States, climate change, the future of energy, educational institutions and what to do about them, and K–12 education. These are very, very complex problems, and solving them will require sound foundations in fact and what we like to call good engineering problem solving.

As you sit at home and watch television, you see 15-second sound bites by our politicians, the 200 or 300 who are running for president. If you watch the presidential debates, you don't hear arguments based on sound engineering research or engineering problem solving. You hear 15-second sound bites.

Our charter provides some sanity in this debate. We say that, if you are going to decide on a policy, then you really should consider the facts. You should consider the foundations of the problem before you decide upon a solution. In Washington, it seems, it is always more fun to do it the other way around.

A wonderful example of the academies' work was the report put out about two years ago, *Rising Above the Gathering Storm*, which was a study of the competitiveness of the United States and what we should do in research and development and education to make the environment more favorable for investment in innovation. That was a seminal report in terms of catalyzing the debate, not only influencing President Bush to include the American Competitive Initiative in his State of the Union address but also influencing both houses of Congress to pass the America COMPETES Act, which is soundly based on the data and suggestions in that report.

That was just one report by the academies that has had a major influence on policy. The academies are also currently working on reports in other areas, such as climate change and what to do about energy. When you hear people propose fast, easy solutions to reducing America's energy dependence, such as planting more rows of corn in Iowa, it is useful to also look at the potential of various alternate energy sources, including their financial basis and how much energy you might expect them to generate.

Academies reports are extremely important. They can influence the solutions to the problems we face. In a sense, National Academies reports provide a bridge between the complex problems we face and the public debate on how to solve them. We are not a policy organization. We are an organization dedicated to providing a sound, factual basis for carrying the debate forward and making good decisions.

If we are, in fact, a bridge to the future, it is useful for us to talk about bridges. Here on the podium in front of me is the symbol of the National Academy of Engineering, which is a bridge. A bridge can represent a number of things. It can represent engineering excellence and engineering achievement. In fact, from the physical standpoint, that is precisely what it represents. But it can also represent a bridge for solving problems, a bridge between the underlying, basic causes of problems and public policies that drive solutions forward.

I want to leave you with a thought about bridges, what I think is a very powerful message. It may seem rather strange for me, educated as an engineer, to stand before you and read a poem. Engineers don't usually read poems, I know. Poetry is not us. But I am going to read one.

This poem, entitled *The Bridge Builder*, was written by a late nineteenth-century poet, Will Allen Dromgoole. Despite the name, Will Allen was actually a woman. I read *The Bridge Builder* to you because I think it sends a very important message about what we can all do as members of the academies and as members of society.

The Bridge Builder

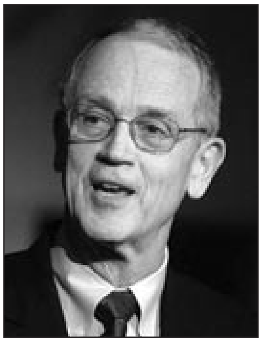
An old man, going a lone highway,
Came at the evening, cold and gray,
To a chasm, vast and deep and wide,
Through which was flowing a sullen tide.
The old man crossed in the twilight dim;
The sullen stream had no fears for him;
But he turned when safe on the other side
And built a bridge to span the tide.

"Old man," said a fellow pilgrim near,
"You are wasting strength with building here;
Your journey will end with the ending day;
You never again must pass this way;
You have crossed the chasm, deep and wide—
Why build you the bridge at the eventide?"

The builder lifted his old gray head:
"Good friend, in the path I have come," he said,
"There followeth after me today
A youth whose feet must pass this way.
This chasm that has been naught to me
To that fair-haired youth may a pit-fall be,
He, too, must cross in the twilight dim;
Good friend, I am building the bridge for him."

I think that captures accurately and eloquently the charter of this organization and the charter of the members in the National Academy of Engineering. To the Class of 2007, I welcome you, and I hope you will help us continue to build bridges to the future.

NAE's Mission to Provide Leadership
Address by NAE President Charles M. Vest



Charles M. Vest

These remarks were delivered on September 30, 2007, at the NAE Annual Meeting.

It is a great pleasure to participate in my first induction ceremony as president of the National Academy of Engineering (NAE), and a particular privilege to welcome the families, friends, and guests of those who are being inducted today as members or foreign associates of our academy. Your election to NAE signals that our members, through a very rigorous process, concluded that you are among the most brilliantly accomplished and distinguished members of your profession. We all hope that this is a deeply meaningful event in your personal and professional lives.

It is a beautiful day in Washington, the kind of day when it is refreshing and wonderful to be in this great city. Every time I think about Washington, D.C., my mind goes back to an incident recounted in Doris Kearns Goodwin's book, *Eleanor and Franklin*. During World War II, Winston Churchill traveled to this city to meet with President Roosevelt. London had been under a blackout since 1939, and Washington had been blacked out since a few days after Pearl Harbor. When Churchill's plane came in to land, Roosevelt ordered that all the lights in the city be turned on. I can only imagine the stunning effect of seeing this beautiful city suddenly light up. I cannot duplicate that feat for you, but we have gathered the great lights of engineering in the United States and are very proud to welcome all of you.

Election to NAE is a rare and singular honor, but membership is also an opportunity for national service. Indeed, it is a call to national service. We are chartered by the U.S. Congress, together with the National Academy of Sciences, the Institute of Medicine, and our joint operating arm, the National Research Council, to provide independent, objective advice to the federal government on matters of science, engineering, and medicine.

We are not a government organization, not part of the federal government. We are an independent, nonprofit organization that can be thought of as a grand think tank. In return for providing the objective, nonpolitical analyses and advice of the nation's most accomplished engineers, we have been granted a special, respected role as advisers to the nation.

We fulfill our function largely by conducting rigorous studies of specific issues, either requested by the government or, from time to time, by initiating a study ourselves of an issue we believe is especially important. Of course, we call on our members to provide leadership for these studies. This is a primary service we will expect of you.

When I was elected to NAE in 1993, I received a note from John Armstrong, who is with us today. John was then vice president for science and technology at IBM. His note said, "Dear Chuck, congratulations on your election to NAE. I just can't wait to put you on a committee." So you see, John is less subtle in these matters than I am, but the message is the same.

A core mission of NAE is to look after the technological welfare of the United States. As Craig Barrett said (pp.41–42) earlier, engineering is critical to meeting the fundamental challenges facing us—challenges to our economy, environment, health, security, indeed, our way of life. Although industries are well aware of the centrality of engineering to the production of competitive products and the delivery of services in the world marketplace, governments at both the federal and state levels are struggling to understand and incorporate science and technology into public policies, some of which are literally matters of life and death.

As NAE members, participants in the world's most formidable think tank, an independent organization of more than 2,000 of the nation's most accomplished engineers, we can play, and must play, an important role in securing the nation's future. In my view, this is a form of engineering leadership.

Engineering Leadership

Interest in engineering leadership is growing around the country—in universities, in industry, and certainly here at NAE, through mechanisms such as the coveted Gordon Prize for Innovation in Engineering and Technology Education. But probably each of us means something different by the term "engineering leadership." So it is worthwhile to ponder its meaning and the qualities and actions we should seek in engineering leaders.

When I think of leadership, I focus on the definition of a leader I learned from our colleague **Bob Galvin**, the legendary former chairman of Motorola and an active NAE member. "A leader is one who takes us elsewhere." That definition not only sums things up but also reinforces my own belief that leadership can be exercised in many different ways and in many different domains of human activity, including those that involve engineering and technology. Leadership has many modes in addition to the usual command-and-control model. It seems to me that there is leadership *in* engineering, leadership *through* engineering, and leadership *informed by* engineering.

Leadership in engineering may have many different forms. The classic, and extremely important, mode of engineering leadership is through project management and product development. A number of engineering schools are developing innovative programs in these areas, usually in collaboration with industry and management schools, and many of you in this room are outstanding project managers.

But if we accept Bob Galvin's definition of a leader as one who takes us elsewhere, leadership in engineering can also take the form of outstanding execution, of discovery, of invention, or of refinement of products, services, and processes. Leadership can be exercised through excellent teaching and through innovation.

Leadership through or informed by engineering includes engineers as business leaders, as entrepreneurs, as politicians, and simply as concerned, active citizens. We are increasingly faced with political and societal decisions that cannot be made without serious engineering input. One need look no farther than the development of biofuels, which all of us, I suspect, agree is a good thing. But we must also be aware of the combination of the politics of corn and farm subsidies, the absence of life-cycle analysis, and the lack of global perspective that are pushing us to develop biofuels in ways that make little technological or economic sense. This is an example of an issue in which government decisions should be informed to a great extent by serious engineering analysis and experience.

In my view, the source of leadership, particularly in professional settings, is respect for people and ideas. Without an understanding of others, their values, their aspirations, and their capabilities, it is very difficult to lead. If one accepts this view, then the source of engineering leadership should be respect for people, ideas, and "things," which may be physical objects that we design, produce, or modify, but may also be constructs like systems, projects, or networks. With respect for things, we can produce pleasing forms, efficiency, effectiveness, precision; use resources appropriately; and make wise choices among design options.

Leadership in the classical sense requires that we establish sound personal values. Developing and imparting such values are important goals of education, of culture, of family, of religion, and indeed of many other influences on young lives. Our values, whether or not we can clearly articulate them, guide our decision making and come into play, especially when, as leaders, we face difficult or stressful decisions.

But engineering leaders must have not only sound personal values but also technical expertise. Preparing our students or employees for leadership should not be thought of as something apart from fundamental engineering training and education. It is not an add-on. Leadership begins with sound engineering fundamentals and can be honed through group work, projects, and so forth.

Why have I sketched out these simple ideas? For one thing, leadership is a topic of increasing interest to engineering schools across the country. A more basic reason is that I believe these times call urgently for engineering leadership in all of its dimensions. NAE as an organization has a mission to exercise leadership informed by engineering.

Competing in the World Marketplace

As we enter the twenty-first century, the United States must attempt both to compete in the global knowledge-based economy and to maintain its prosperity and quality of life. To compete in world markets in this so-called knowledge age, we cannot depend on geography, natural resources, or military might. We will only thrive on brainpower, organization, and innovation. And we must do this through our loosely structured partnership among government, industry, and academia.

Frankly, I think we are about to be hit between the eyes by the full force of global competition and by the realization that many twenty-first century jobs will follow knowledge, innovation, and expertise wherever they exist in the world. Never forget that people everywhere are smart and capable, and, if given opportunities and education, they can achieve great things.

The only acceptable response in this situation is for us to lead. But leading will mean upping the national commitment to education and training at all levels and increasing investments by both government and industry in research, development, and innovation. Leading will require, above all else, inspiring and preparing a new generation of young people to explore and expand the frontiers of science and technology and to devote their energy and intelligence to solving the real problems we face, such as energy, environment, food, efficient delivery of health care, the shift toward a global service economy, and world security.

In fact, our stark options at this moment are either to let fear of globalization—and of terrorism for that matter—become our national ethos or to revitalize our can-do attitude, our openness to the world, and our work ethic in order to lead in this challenging new century. Needless to say, I prefer the latter. Our country is slowly awakening to these realities and challenges, but we are nowhere near having a sense of urgency about them. In fact, the enemy I fear most is complacency.

But there is some good news. We can celebrate that we are living, working, and learning at the most exciting time in science and technology in human history, a time when scientific discovery and engineering innovation are essential to advancing the human condition and creating a sustainable future. This is also a time of great change and the redistribution of intellectual and economic resources—a new century.

The New Century

In the last half of the twentieth century, when most of our careers played out, physics, electronics, high-speed communication, and transportation tended to dominate the agenda. In the early decades of the new century, it appears that biology and information will dominate, but priority must also be given to energy, water, and sustainability.

The new century has new distributions across the world of investments in research and development. North America, Asia, and Europe each contribute roughly one-third of the global investment in R&D. U.S. R&D, by almost every measure, is still on top, but it is losing share in every measurable category. This is understandable and good insofar as it represents a rise and improvement in the rest of the world. But U.S.

declines could reach a tipping point, and that would be tragic.

The new century has new players. India leads in the number of young professionals in finance and accounting. By young professionals I mean college graduates who have up to seven years of experience in the workplace. China leads in the number of young professionals in engineering. The United States leads in the number of young professionals in the life sciences. But graduation rates indicate that China will soon dominate more dramatically in the sheer numbers of engineers.

The new century moves at a new speed. Look back for a moment and ask yourselves how long it took in the past for major innovative products or services to reach 25 percent of American households. The answer is interesting. It took about 55 years for the automobile to reach 25 percent of U.S. households after it was introduced as a consumer product. Fifty-five years in those days was almost a lifetime. It took 23 years for the radio to appear in 25 percent of U.S. households. That was almost a working career. It took only 8 years for 25 percent of U.S. households to have access to the World Wide Web. Many devices and processes, ranging from computing power and digital memory to the sequencing of genes and genomes, seem to be following some form of Moore's law. There is a steady acceleration to everything we do.

The new century features new jobs. More than 70 percent of American employment today is in the services sector, especially in information-based services. The fraction of employment in services has become essentially a measure of how well developed a nation is. Nonetheless, we all know how important it is for a country to also develop and produce things—physical devices and systems.

The new century has new connections. Tom Friedman has famously told us that the world is flat, that location no longer matters, and that many jobs are just a mouse-click away from any location on the face of the Earth. But the new century also has stimulated new debates. There are those who argue strenuously that location does matter—because of the power of regional clusters of innovation, because of the importance of proximity of small companies and corporate laboratories to universities, and because many of our best venture capital networks have something of a local or regional focus.

The new century has new models of innovation. The term "open innovation," coined by Henry Chesbrough, has become very popular, and appropriately so. It means, very simply, that companies today must integrate the best ideas no matter where they originate and that new dynamic business models must be developed for this new, open, connected world. More work will be done in what many of you know as Pasteur's Quadrant, that is, research that not only advances fundamental knowledge but also addresses important technological problems. A well known example is the research that led to the development of the transistor at Bell Labs.

The new century has new enterprise models. The CEO of IBM, Sam Palmisano, has written of what he calls "the globally integrated enterprise," which supersedes the multinational corporation. No longer will companies be clearly headquartered in a particular location with core activities, including research and development, conducted there, and manufacturing and marketing conducted in other places in the world. Instead, new organizations will be driven by globally shared technologies and standards. They will develop borderless strategies, borderless management, and borderless operations for integrated production and value delivery.

I believe we will begin to move away from the laissez-faire model implicit in Vannevar Bush's famous report, *Science, the Endless Frontier*, which describes how science and technology in this country move from research into the marketplace. For more than 60 years, we have been largely guided by a model in which the role of each partner in the loosely orchestrated network of our innovation system is reasonably clear. Young people study, learn, and then go off to the world of work. Researchers, whether in universities or industry, discover new facts about nature and invent new technologies. Legislators provide the funds to educate the young and support much of the research. And companies build on the talents and knowledge of graduates and their research results to produce products and services.

We now recognize that, as neat as that package is, each component of this innovation system has different expectations. Young people are drawn to science and engineering by curiosity, by awe of nature, by the excitement of discovery, and by fascination with the unknown. I hope this will always be the case. Researchers, as we all know, are driven by a fire in the belly and obsessive concentration on discovery and solving very complicated and difficult problems. Legislators believe that tax dollars should produce jobs, and companies want increasingly rapid innovation to drive up profits.

Whether we teach in universities or lead industrial organizations or are involved in making policy, we must understand these perspectives, expectations, and motivations and somehow meld them into a workable system to face the challenges of the acceleration and globalization of just about everything.

Frontiers of Engineering

These matters, I believe, are critical for our nation. As the National Academies report *Rising Above the Gathering Storm* concluded, our innovation must be fed in large part by strong investment in research and development at the frontiers of engineering, which is, for the most part, the land of the young. Indeed, those frontiers are being wonderfully explored by the participants in NAE's Frontiers of Engineering programs.

There are two obvious engineering frontiers. One is the so-called bio-nano-info frontier, the domain of things that are becoming smaller and smaller, faster and faster, and more and more complex, things that are based on or done by biological entities. On this frontier, science and engineering are not just interdependent; they have become largely one and the same.

The other frontier is the macro-systems frontier, the domain of things that are becoming larger and larger and more and more complex. This is where advances in energy, environment, manufacturing, logistics, and communications are conceived and realized. The macro-systems frontier has obvious societal importance. To prepare for or work in this domain, engineers and applied scientists must interact with people in the social sciences, management, law, humanities, and medicine. NAE has great potential to encourage these interactions and help build these interfaces.

I suspect that thinkers and doers in industry and academia will soon build strong bridges between the two frontiers, as nanoscale science, synthetic biology, biomimetics, and so forth are applied to the needs of real people on a grand scale. Obvious examples include new ways of designing and manufacturing materials that leave much smaller environmental footprints, the development of personalized and predictive health care, and the creation of means of generating substantial amounts of energy through economically sensible biobased fuels. Small-scale science and engineering will drive our approaches to our largest and most important systems.

Conclusion

I again congratulate each of you on your election to NAE. I hope that you recognize your membership as an opportunity to serve your nation and the world by helping provide well informed, objective, independent advice on crucial matters to our nation that involve technology.

Developing and transmitting such advice is an important way of exercising engineering leadership. You come to this task at a moment in history when there is an urgent need to sustain and enhance the technological welfare of the nation, so that we can both compete in the global knowledge-based economy and maintain our prosperity. You also come to this task at a time when the frontiers of engineering, at both the small and large scale, are not only enormously exciting but also critically important to meeting the great challenges of energy, environment, productivity, health care, food, water, and security.

Acceptance Remarks by Stanford Sol Penner, Recipient of the 2007 Founders Award

Stanford Sol Penner

The 2007 NAE Founders Award was presented to Stanford Sol Penner, Distinguished Professor Emeritus of Engineering Physics, Department of Mechanical and Aerospace Engineering, University of California San Diego, "for pivotal studies on thermal radiation, propulsion, combustion, and energy systems, directing government studies, founding a university department and energy center, and training future leaders." These remarks were delivered on September 30, 2007, during the NAE Annual Meeting.

I am deeply grateful to my colleagues who nominated me for the NAE Founders Award and to the NAE committee that selected me to receive it. In addition, I must acknowledge, first and foremost, the love and selfless, devoted support of Beverly, my late spouse of more than 60 years. A major part of the credit for my being here today belongs to her. Her guidance and efforts were also crucial in making certain that both of our children became professors at major universities, Lynn in psychology and Robert in mathematics and physics.

The importance of studying was inculcated in me from early childhood by both of my parents. I obtained my early education at a German Realgymnasium in a small Westphalian town. When I emigrated to the United States at the age of 15, with good competence in English, I was enrolled for the junior year at Saratoga Springs High School, in Saratoga Springs, New York.

I was fortunate in receiving special instruction over the years from extraordinary scholars. While I was still in high school, O. Baudisch, the balneologist, took me to his laboratory at the Saratoga Springs Spa Authority and taught me the importance of trace elements in biological systems while reciting from Goethe's *Faust*, both parts of which he had committed to memory. As an undergraduate at Union College in Schenectady, New York, from 1938 to 1942, V. Rojansky, the author of an early text on quantum mechanics, gave me many hours of private instruction in theoretical physics. C.B. Hurd introduced me to the methods of thermodynamics made famous by G.N. Lewis at the University of California Berkeley.

F. Daniels, my graduate thesis advisor at Wisconsin, which I attended from 1942 to mid-1944, and again for a few weeks in 1946 to get my Ph.D., conveyed to his students his special brand of humanity and insight related to chemical kinetics before our graduate program became a casualty of World War II. He joined the Manhattan Project and invented the "Daniels pile," which, in modified form, may well become a key feature of the next generation of passively safe, proliferation-resistant nuclear reactors.

Although I arrived at Wisconsin with a Coffin Fellowship from the General Electric Company, my research in graduate school was promptly shifted from studies of nitrogen fixation using pebble-bed cooling (a process invented by Daniels and referred to as the Wisconsin process for nitrogen fixation) to combustion research on double-base rocket propellants. We published the first, rather elementary, paper on this after the war.

I spent most of 1944 and all of 1945 at the U.S. Army Allegany Ballistics Laboratory (ABL) in Cumberland, Maryland, working mostly on problems associated with radiative-energy transfer when using transparent double-base propellants in rocket engines. This work led to a series of postwar publications in the *Journal of Applied Physics*. At various times at ABL, I was a test engineer for newly built rockets but was privileged also to cooperate with S. Sherman, a mathematician from Cornell, in writing a paper on heat transfer through composite cylindrical shells, which was published after the war in the *Journal of Chemical Physics* (and reproduced in its entirety in the classic text on heat transfer by Carslaw and Jaeger).

I received the Ph.D. in physical chemistry from Wisconsin in January 1946 after a few weeks of postwar residence and allowance for wartime research. Although labeled a chemist, my wartime research had actually made me a rocket engineer. Late in 1945, Vannevar Bush, the first recipient of the NAE Founders Award, came to Cumberland and handed out certificates for exceptional achievement to the scientists and engineers at ABL. I could then not have dreamed that I would be here, 62 years after shaking hands with this illustrious pioneer, to receive the same honor accorded him in 1966.

In 1946, following about a year of work on petroleum recovery and lubrication at the Esso Research Laboratory in Linden, New Jersey, I moved to Pasadena with my new family to work on rocket propulsion at the Jet Propulsion Laboratory from 1946 to 1949. This was an especially productive period for me; I worked on combustion, propulsion, and radiative-energy transfer.

Next, I became a faculty member at Caltech (1950–1964) in the Guggenheim Jet Propulsion Center. I was privileged to work there with H.S. Tsien on a theoretical study in radiant-heat transfer. I then established an experimental program to measure fundamental physical properties of the molecules necessary for quantitative assessments of radiant-heat transfer. While at Caltech, I also had ample opportunity to remain involved in rocket development as a consultant to aerospace companies (Aerojet, Rocketdyne, Lockheed, etc.). But my years there were most memorable because of my many outstanding graduate students.

I recall with special thanks the contract monitors who funded my research, among whom I number John Fenn, director of the Navy's Project Squid and a recent Nobel Laureate in chemistry, and Frank Isaacson of the Office of Naval Research, who phoned me once a year and told me what my level of financial support would be if I sent a proposal no longer than one short paragraph.

Around 1951, Theodore von Kármán invited me to be one of the first two U.S. panel members to join the U.S. Air Force program on combustion and propulsion on the NATO Advisory Group for Aeronautical Research and Development. I was involved in these activities for about 18 years as panel chair and member, working periodically with von Kármán and my Caltech graduate students (12 at the peak, about 50 altogether), with research support from various funding agencies.

Among my joint papers with von Kármán was a contribution to the Max Born 60th birthday memorial on laminar flame propagation. Working with von Kármán was a special challenge for me because he liked to have a good meal with wine beginning around 10 p.m. and often lasting until midnight, after which he wanted to develop combustion-related theories. This was doubly challenging for me, because I had to remain alert at that time of night, even though my working day always began by 7 a.m.

From 1962 to 1964, I took a leave of absence from Caltech to become director of the Research and Engineering Support Division of the Institute for Defense Analyses (IDA) in Washington, D.C., where I had an excellent opportunity to learn about complex-systems problems and work with outstanding scientists and engineers in many disciplines. At IDA, I founded a classified publication, *Journal of Missile Defense Research*, which I edited for five years. The initial roster of associate editors included four physicists who received Nobel Prizes within a few years of joining the editorial board and engineers who played pivotal roles in the creation of NAE (including **Court Perkins**, **William Pickering**, **Clark B. Millikan**, **Nicholas Hoff**, and **Guy Stever**). The journal still exists, in modified form, and is still managed at IDA.

Years earlier, I had become acquainted with K.A. Brueckner, the theoretical physicist who was vice president for research at IDA. He invited me to join both IDA and, later, the newly founded University of California San Diego (UCSD), where he was dean and creator of most of the initial departments, for which he recruited the initial chairs. He invited me to be the first chair of a department dealing with engineering and applied science, and the appointment became official in late 1963 after a visit and interviews with the first chancellor, H. York, and the inspiring creator of UCSD, Roger Revelle.

Since 1964, I have served in many capacities at UCSD. I was founding chair of the Department of Aeronautical and Mechanical Engineering Sciences (AMES), which has since been divided into the Department of Mechanical and Aerospace Engineering, Department of Structural Engineering, Department of Bioengineering, and Department of Nanoscience Engineering. I also founded the UCSD Energy Center, was director of the Institute for Pure and Applied Physical Sciences, was vice chancellor for academic affairs, and so on. But this brief summary would be incomplete if I did not emphasize the joy and stimulation of collaborating with successive generations of illustrious graduate students at Caltech and UCSD, many of whom have become world-class leaders in various fields.

For about 20 years, from 1950 to 1970, the foci of my research and training of graduate students at Caltech and at UCSD were quantitative spectroscopy and radiant-heat transfer, coupled with theoretical and experimental studies on combustion phenomena. I founded the *Journal of Quantitative Spectroscopy and Radiative Transfer* in 1960 and was editor until 1992, when I was succeeded by my former Ph.D. student P. Varanasi. Three experts in allied fields now share the editorial responsibilities.

As a Guggenheim Fellow in 1972–1973, I took an around-the-world sabbatical during which I visited England, Germany, Italy, Israel, Iran, India, Hong Kong, Australia, and New Zealand. When I returned to UCSD, I was convinced that the resolution of energy issues was crucial for the future. With administrative support from the university and funding from the local electric utility and DOE, we developed research and instructional programs, I founded *Energy—The International Journal* (which I edited from 1975 to 1998), published a three-volume series of texts on energy issues, and developed complementary graduate initiatives. I was privileged to lead many basic energy studies for DOE as chair of the DOE Fossil Energy Research Working Group, participate in studies for the Electric Power Research Institute, collaborate with nuclear energy experts from General Atomics, and serve as chair of an early (1979) coal-science exchange visit to China. I am indebted to the qualified experts associated with industry, government laboratories, and universities who contributed to these activities. Their inputs were invaluable. I am also indebted to many others, many more than I can mention here.

The Founders Award for 2007 is an especially gratifying recognition of the modest contributions I have been able to make, thanks to the many outstanding people who have helped me in all my professional activities.

Acceptance Remarks by Jordan Baruch, Recipient of the 2007 Bueche Award

Jordan J. Baruch

The 2007 Arthur M. Bueche Award was presented to Jordan J. Baruch, president, Jordan Baruch Associates, "for the promotion of innovation and management of science and technology nationally and internationally, thereby enhancing the economy of the U.S. and developing nations." These remarks were delivered on September 30, 2007, at the NAE Annual Meeting.

Let me start by thanking the National Academy of Engineering for bestowing on me the prestigious Bueche Award. The citation recognizes the role of innovation in addressing society's problems. To a lesser extent, it recognizes my role in some of those innovations. For me, being involved in innovative efforts has been like taking an exciting ride on an often bumpy road.

I am deeply grateful to two disparate groups for making that ride possible. The first is my wonderful family who are here with me: Rhoda and my three children, Bobi, Marjory, and Larry, who, with the aid of their wonderful spouses, have produced nine grandchildren, some of whom are also here. All of them, and many good friends collectively and individually, held my world together during many absences when I had to travel and my mental absences when I withdrew to search for a solution to a problem. Their wit and familiarity eased me down from the highs that often followed successes, and their unconditional love pulled me back from the brink of despair when something I tried failed. Indeed, Rhoda eventually convinced me that my frequent failures, far from meaning I was a failure, were a natural consequence of the challenges I chose to tackle. To this group I owe my very survival.

The second group is composed of a lifelong series of wonderful mentors, colleagues, and friends who have played critical roles in shaping my multidisciplinary course:

- Sam Brownstein, a teacher at James Madison High School in Brooklyn, led me into hands-on biology and encouraged me to build a kymograph like one I had seen, my first instrument.
- Jack Sharefkin at Brooklyn College got me committed to organic chemistry.

- An unsung hero canceled the chemistry option of the Army Specialized Training Program and offered us the choice of joining the paratroops or switching to electrical engineering.
- Bill Timbie at MIT made me glad I'd made the switch to electrical engineering.
- Leo Beranek took over when I returned from the army. As my undergraduate professor at MIT, he got me committed to acoustics and persuaded me to pursue an interdepartmental doctorate. He has been my partner at BBN and my guardian angel for 40 years.
- Jack Mazur at NIH cleared my path for years of innovation in medical instrumentation and informatics.
- Scores of others also influenced the shape of my trajectory. I wish I had time to pay them the homage they deserve.

So, I've been lucky, but, as my father always said, "Given the choice between smart and lucky, take lucky!"

So much for the past. Now, what's next?

Let me share with you my concern about a major worldwide problem and my sense of the opportunities it presents. Right now, today, the planet faces a crisis of both ability and will. The people of this planet must start now to manage the trajectory of energy development and use into the distant future. Three drivers and their associated world decisions will shape that trajectory:

- An estimated demand for 8.6 TW of power to maintain the per-capita demand—if the population grows to my predicted 11 billion by 2107, a century from now.
- The need for an additional 16 TW of power if no carbon-capture and sequestration program is developed and adopted.
- The need, in the distant future, for a total of 254 TW of power, so a steady-state population of 11 billion will have the same per-capita energy availability as developed nations now enjoy.

These goals represent an enormous quantitative challenge, and if we meet them wisely, the world will have a future of plenty—if we can avoid exceeding the accepted threshold of 560 ppm of CO_2 in the atmosphere. If we exceed that threshold, the future world will be one of widespread misery. It will be up to engineering leaders to develop the *ability* to meet these goals. It will be up to the economists, business leaders, politicians, bankers, and many others in the innovative community to provide the *will* to use that ability wisely.

So much for the problem; now for my possible trajectory:

- We will have to accelerate the number of thermal nuclear plants to be built and brought online around the world in the next 50 years, because no other source of energy can readily meet those targets. It will fall to the leaders of the developed nations, the World Bank, the United Nations, and others to join together to bring that about.
- The engineering community, with requisite funding and encouragement, will develop fast neutron reactors—25 MW to 500 MW nuclear batteries totaling 22,000 TWY by 2107 and continuing at that rate into the far future. I predict nuclear batteries will:
  - operate for at least 25 years on a single charge
  - be fueled by reprocessed waste and tailings
  - recover 48 times as much energy from each ton of ore as thermal nuclear reactors
  - be returned to the factory and replaced as needed for repair or recharging
  - have a sufficient negative coefficient of reactivity to make on-site control unnecessary except at start-up and shutdown
  - be sealed and remotely monitored for problems that require outside service and for attempts to break into them
- Finally, the combined engineering and innovative communities, with whatever outside support they need, will create a new manufacturing industry to produce, market, distribute, and maintain nuclear batteries worldwide.

Once all of this happens, we can visualize one nuclear battery, as small as 50 MWe, supplying 25 MW of electrical power to homes, schools, and clinics in dozens of isolated communities, and 80 million gallons a day of freshly purified or desalinated water for domestic and agricultural use.

Who will be the leaders that make this happen? And what will it cost? I hope you, and those you can influence, will bring this about. I really don't know what it will cost to create such a world of plenty, global equity, and peace. But I'm betting it will be far less than the cost of not doing it.

NAE Anniversary Classes

Members of the NAE anniversary classes, many of whom attended the 2007 Annual Meeting, have given 25, 30, 35, and 40 years of service to the National Academy of Engineering. Their accomplishments include instrumental contributions in the early stages of the space program, the development of computer technology, and contributions in the fields of electronics, heat transfer, advanced materials, and numerous others.

40 Years of Service

Gene M. Amdahl
Harold Brown
Karl P. Cohen
Don U. Deere
Alexander H. Flax
Jay W. Forrester
Donald N. Frey
Charles H. Kaman
George E. Mueller
Mark K. Smith
Lombard Squires

35 Years of Service

Albert L. Babb
James R. Johnson
T. William Lambe
Cedomir M. Sliepcevich
Morris Tanenbaum

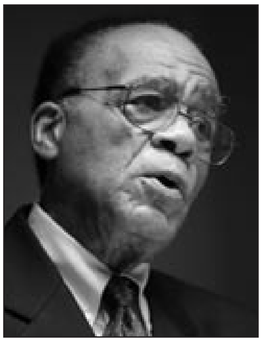
30 Years of Service

Andreas Acrivos
Nathaniel Arbiter
C. Gordon Bell
Elwyn R. Berlekamp
William B. Bridges
Stephen H. Crandall
Elio D'Appolonia
Robert C. Dean Jr.
Charles A. Desoer
Leo Esaki
Ronald L. Geer
Wolf Hafele
Robert N. Hall
Grant L. Hansen
Stephen E. Harris
William J. Harris Jr.
Julius J. Harwood
Robert W. Hellwarth
Philip G. Hodge
C. Lester Hogan
D. Brainerd Holmes
Paul C. Jennings
Jan Kaczmarek
Eneas D. Kane
Arthur Kantrowitz
William M. Kays
Clyde E. Kesler
Thomas R. Kuesel
Christian J. Lambertsen
Frederick F. Ling
Frank W. Luerssen
Artur Mager
Perry L. McCarty
Ross E. McKinney
Johannes Moe
Kenneth H. Olsen
Carlos S. Ospina
Walter S. Owen
Stanford Sol Penner
Joseph Penzien
Jacques Peters
William N. Poundstone
Ronald F. Probstein
Jean E. Sammet
Thorndike Saville Jr.
Mete A. Sozen
Arthur M. Squires
Morris A. Steinberg
Stanley D. Stookey
Lawrence E. Swabb Jr.
Paul B. Weisz
Robert H. Wertheim
Robert H. Widmer
Maurice V. Wilkes
Edward Woll

25 Years of Service

Jan D. Achenbach
Mihran S. Agbabian
Floyd Dunn
Peter S. Eagleson
Gunnar Fant
Kent F. Hansen
Kenneth E. Haughton
R. Richard Heppe
Donald R. Herriott
Irwin M. Jacobs
Trevor O. Jones
James N. Krebs
George Leitmann
Hudson Matlock
Douglas C. Moorhouse
William R. Opie
M. Kenneth Oshman
Walter L. Robb
Stanley T. Rolfe
James F. Roth
Donald G. Russell
William R. Schowalter
Willard F. Searle Jr.
John H. Seinfeld
John B. Slaughter
Gareth Thomas
Theodore Y. Wu
Dante C. Youla

NAE Member John Brooks Slaughter Addresses Engineers Week Coalition Diversity Council



John Brooks Slaughter
Photo courtesy of SAE International.

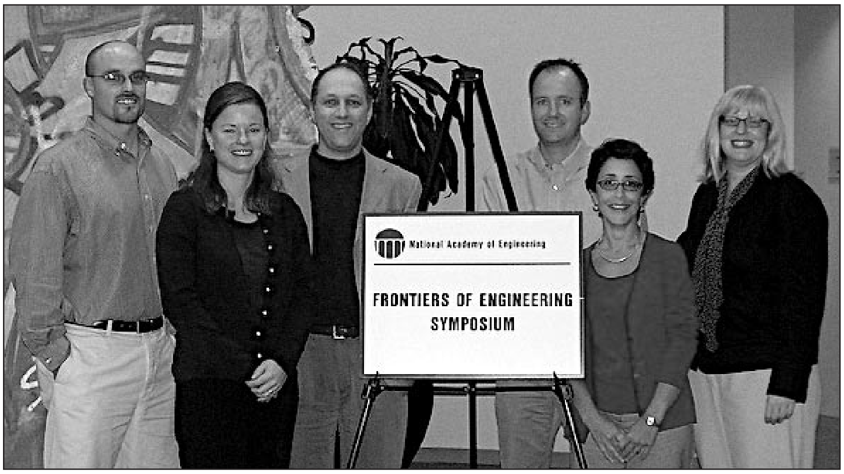
The Engineers Week Coalition Diversity Council held its inaugural event, "The Business of Engineering Diversity," on October 17, 2007, in Washington, D.C. The goal of the council is to promote collaboration and partnerships among corporations and engineering associations to encourage diversity in the engineering and technical workforce. Participants from corporations and engineering organizations who participated in the event included representatives of IBM, SAE International, Verizon, National Society of Black Engineers (NSBE), Society of Women Engineers (SWE), and American Indian Science and Engineering Society (AISES). The goal of the project is to develop a national coordinated strategy of diversity outreach.

NAE Council member **John Brooks Slaughter**, CEO, National Action Council for Minorities in Engineering (NACME), addressed the group on "Diversity in Presidential Politics." He predicted that innovation in America will ultimately fail unless we involve the 50 percent of the population that is not fully engaged. Diversity is not an end but a means to an end, he said, and diversity and equity must both be addressed. If we become fixated on diversity, he warned, we may not achieve equality of opportunity.

Slaughter noted that neither the National Academies' publication *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* nor Thomas L. Friedman's *The World Is Flat: A Brief History of the Twenty-First Century* addresses the people in our society who do not fully participate in science, technology, engineering, and mathematics (STEM) education or the STEM workforce. He encouraged the audience to read Frans Johansson's *The Medici Effect: Breakthrough Insights at the Intersection of Ideas, Concepts, and Cultures*, in which the author argues that a diverse technological workforce that includes people from different cultures and with different experiences is likely to contribute to innovation and new approaches.

Slaughter believes that we need "plurality," rather than diversity. Diversity, he said, is a passive means (e.g., through demographic shifts of population) to create change. He used the mathematical concepts of necessity and sufficiency to illustrate his point. A necessary condition of a statement must be satisfied for the statement to be true. A sufficient condition is one that, if satisfied, assures that a statement is true. In Slaughter's opinion, diversity alone is not a sufficient condition. He called for an unwavering commitment to excellence and for openness to change.

2007 U.S. Frontiers of Engineering Symposium



Organizers and speakers of the "Safe Water Technologies" session pose in front of a section of the Berlin Wall at the Microsoft Conference Center. From left to right: Jess Brown, Carollo Engineers; Amy Childress, University of Nevada, Reno; Karl Linden, University of Colorado-Boulder; Paul Westerhoff, Arizona State University; Carol Rego, CDM; and Vanessa Speight, Malcolm Pirnie.

FOE symposia provide long breaks, mealtimes, and other opportunities for informal exchanges.

On September 24–26, Microsoft Research hosted the 2007 U.S. Frontiers of Engineering (US FOE) Symposium at the Microsoft campus in Redmond, Washington. NAE member **Rick Rashid**, senior vice president of research, offered Microsoft's facilities for the meeting. In 2005, NAE began holding US FOE and NAE-hosted bilateral FOE symposia at corporate research sites to provide participants with a firsthand look at a corporate research facility and to help defray the cost of the meeting.

One hundred six engineers attended the 2007 symposium to hear talks on five topics—computer security, control of protein conformations, biotechnology for fuels and chemicals, modeling and simulating human behavior, and safe water technologies. Presentations at the first session, "Engineering Trustworthy Computer Systems," were focused on cutting-edge research for meeting the security challenges of current computing infrastructure. Speakers described new software engineering tools and technologies to improve computer security and the public-policy issue of whether owners of devices have the right to tinker with them, which might lead to the discovery of system vulnerabilities and, ultimately, to more trustworthy systems.

In the second session, "Control of Protein Conformations," speakers described advances in imaging technologies and techniques using optical, magnetic, and mechanical forces to manipulate proteins directly in order to control protein function. Research in this area is advancing our understanding of cell signaling and protein-to-protein interactions, which is essential to understanding the properties of biological systems. Presentations on various techniques described their applications in drug discovery, vaccine development, and new tunable biosensors and bioassays.

The overarching theme of the third session, "Biotechnology for Fuels and Chemicals," was the development and commercial deployment of renewable, sustainable, cost-effective technologies to meet challenges in transportation fuels and chemical feedstocks. The three speakers in this session addressed the current and potential uses of corn-based products in the polymer and pharmaceutical industries, cosmetics, and drug delivery; biochemical processes, operations, and trends in the conversion of biomass to ethanol; and sustainable biorefineries.

In the fourth session, "Modeling and Simulating Human Behavior," the presentations covered advances in functional brain-imaging techniques, computational cognitive architectures, and artificial intelligence that have led to a better understanding of brain organization and human performance. With the convergence of disciplines in this field, researchers are contributing to the building of an empirical and computational framework for understanding, modeling, and simulating human behavior. Speakers described the current state and future outlook for research in this area and applications for military training and serious games.

The final session, "Safe Water Technologies," included four presentations. Three of the talks featured the latest advances in three technologies for producing high-quality water—UV irradiation, membrane processes, and biological water treatment. In the fourth talk, the speaker described distribution systems, the final frontier in providing safe water to consumers.

On the first afternoon of the meeting, participants gathered in small groups to discuss public-policy topics, such as the meaning of sustainability for the engineering community, improving the preparation of Ph.D. engineers for careers in the competitive global marketplace, balancing career and family, the role of the social sciences in engineering, how engineers can fulfill their responsibilities as members of society, and balancing rigor and creativity in information technology, science, engineering, and design. Summaries of those discussions will be included in the annual symposium proceedings published in February 2008.

On the second afternoon, Microsoft set up displays and demos about some of the company's research on surface computing, web security, tablet PCs, and the visualization of data in graphs and charts. Participants circulated among the displays and asked questions of Microsoft researchers about the various technologies.

On the first evening, the traditional dinner speech was given by Dr. Henrique (Rico) Malvar, managing director of Microsoft Research. In his talk he emphasized the goals, open academic model, and long-term focus of Microsoft Research.

Julia M. Phillips, director of the Physical, Chemical, and Nano Sciences Center at Sandia National Laboratories, chaired the organizing committee and the symposium. She will continue in this role for the 2008 U.S. Frontiers Symposium, which will be hosted by Sandia on September 18–20, 2008, and held at the University of New Mexico.

Funding for the 2007 U.S. Frontiers of Engineering Symposium was provided by Microsoft Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, U.S. Department of Defense (Defense Research and Engineering), National Science Foundation, and Cummins Inc.

The annual U.S. FOE Symposium provides opportunities for outstanding engineers (ages 30 to 45) from industry, academia, and government to learn about advances in techniques and new approaches in a variety of fields. These interdisciplinary gatherings also facilitate contacts and collaborations among the next generation of engineering leaders.

For more information about the U.S. symposium series, or international bilateral symposia with Germany, Japan, and India, or to nominate an outstanding engineer to participate in a future symposium, contact Janet Hunziker at the NAE Program Office at (202) 334-1571 or by e-mail at *jhunziker@nae.edu*.

Ethics Case Discussions Webforum

The Ethics Case Discussion (ECD) Webforum (formerly the Ethics Help-Line) is up and running on the NAE Online Ethics Center website (*www.ethicscasediscussions.org*). The objective of the ECD Webforum is to provide users with an opportunity to discuss and think through ethically significant problems that may arise in engineering research and practice. Everyone is invited to open a free account (using your own name or a pseudonym) and to submit cases and/or comments, which will then be available to everyone. Many former Help-Line team members will also post comments.

Program Office Welcomes New Mirzayan Science and Technology Policy Fellows


Mark Fleury


John McMurdy


Antwuan Wallace

Mark Fleury recently completed his Ph.D. in biomedical engineering at the École Polytechnique Fédérale de Lausanne in Switzerland, where he studied the role of small convective flows in promoting cancer metastases and forming new blood vessels. He received an M.S. from Northwestern University in chemical engineering and a B.S. in the same field from Kansas State University. Mark is also a licensed professional engineer who has worked for Cargill Incorporated as a process engineer in the corn-sweetener industry and has experience in designing wastewater treatment systems. Mark plans to continue his research career with a post-doc on the misregulation of cellular signaling pathways in cancer. During his Mirzayan Fellowship, he is working in the Center for the Advancement of Scholarship on Engineering Education (CASEE) on two projects: (1) reviewing the literature comparing asserted and actual faculty instructional behavior; and (2) developing a brochure that succinctly summarizes the value of research on engineering education.

John McMurdy, currently working toward his Ph.D. in biomedical engineering at Brown University, has conducted research on biomedical optics for use as a noninvasive method of characterizing tissues and biofluids and the implementation of ultra-compact optical sensors fabricated using liquid crystalline materials. John is also chief technology officer for Corum Medical, a start-up company developing a noninvasive anemia-screening device for use in hospital triage and blood banks. He earned a B.S. and M.S. in optics from the University of Rochester, where he studied biomedical diagnostics using Raman spectroscopic characterization of biofluids. During his Mirzayan Fellowship, John is working with CASEE to identify research in psychology and behavioral sciences relevant to engineering education and to distill these results into research briefs that will be quickly and easily accessible to engineering faculty.

Antwuan Wallace is completing a Ph.D. in policy analysis at Milano, The New School for Management and Urban Policy. His research on the digital divide will examine negotiations of telecommunication policies by postindustrial U.S. cities to deploy municipal wireless broadband connectivity as a means of remaining relevant and competitive in the global economy. A researcher by training and an informed advocate for policy innovations predicated on social justice, Antwuan earned a B.A. from Hampton University and an M.P.A. in policy analysis from Indiana University-Bloomington before completing an M.S. in survey methodology from the University of Michigan-Ann Arbor. During his fellowship at NAE, he worked with the Engineering Ethics Center to develop a national conference series on engineering ethics and leadership. The conference will focus on engineering, humanitarian action, social justice, and sustainable community development. He also wrote case studies for the Online Ethics Center, a pedagogical resource used by college engineering programs around the world.

In Memoriam

OLIVER C. BOILEAU, 80, retired president and COO, Northrop Grumman Corporation, died on July 27, 2007. Mr. Boileau was elected to NAE in 1979 "for contributions to the technical and cost management of major aerospace programs and to national defense."

MELVIN W. CARTER, 80, consultant on international radiation protection and Neely Professor Emeritus, Georgia Institute of Technology, died on August 15, 2007. Dr. Carter was elected to NAE in 1999 "for leadership and teaching in radiation protection, health physics, and public health standards and practices."

HSIEN K. CHENG, 84, Professor Emeritus, Department of Aerospace and Mechanical Engineering, University of Southern California, died on July 11, 2007. Dr. Cheng was elected to NAE in 1988 "for original contributions to hypersonic flow theory and to the aerodynamics of three-dimensional wings in subsonic and transonic flows."

MICHAEL FIELD, 93, retired chairman and CEO, Metcut Research Associates Inc., died on May 26, 2007. Dr. Field was elected to NAE in 1976 "for discoveries and developments in the fields of machine tool engineering, machining, and surface integrity."

RUSSELL R. O'NEILL, 91, Dean and Professor of Engineering, Emeritus, Henry Samueli School of Engineering and Applied Science, University of California Los Angeles, died on October 11, 2007. Dr. O'Neill was elected to NAE in 1975 "for contributions and leadership in the fields of engineering education, maritime cargo handling systems, and marine transportation engineering."

ALLEN F. RHODES, 82, adjunct professor of mechanical engineering, University of Houston, died on August 18, 2007. Mr. Rhodes was elected to NAE in 1985 "for contributions to petroleum production technology and to the growth of the engineering profession."

WOLFGANG SCHMIDT, 65, independent consultant, died on November 2, 2007. Dr. Schmidt was elected a foreign associate to NAE in 2001 "for outstanding contributions to computational aerodynamics and air vehicle design and engineering, and for promoting international leadership and cooperation."

ALEXANDER C. SCORDELIS, 83, Byron L. and Elvira E. Nishkian Professor Emeritus of Structural Engineering, University of California Berkeley, died on August 27, 2007. Professor Scordelis was elected to NAE in 1978 "for pioneering the development and application of advanced structural analysis to the design of record-breaking and unique structural systems."

L.E. SCRIVEN, 75, Regents Professor, Department of Chemical Engineering and Materials Science, University of Minnesota, died on August 3, 2007. Dr. Scriven was elected to NAE in 1978 "for the application of fluid mechanics to fundamental problems of absorption, interface stability coating flows, surface wetting, and oil recovery."

TADAHIRO SEKIMOTO, 80, chair, Institute for International Socio-Economic Studies, Tokyo, died on November 11, 2007. Dr. Sekimoto was elected a foreign associate of NAE in 1991 "for advancing satellite and digital communications and for leadership in promoting the core technologies for computing, communications, and components."

WILLIAM D. STEVENS, 89, retired chair, Foster Wheeler Corporation, died on November 5, 2007. Dr. Stevens was elected to NAE in 1983 "for major contributions in fossil and nuclear power and innovations in managerial and financial techniques for large engineering projects and organizations."

JOHN E. SWEARINGEN, 89, retired chairman of the board, Standard Oil Company, Indiana, died on September 14, 2007. Mr. Swearingen was elected to NAE in 1969 "for his early recognition of and contributions to the technology of expanders and compressors, cryogenic systems, and development in the design of shaft seals for high-speed machinery."

ROY F. WESTON, 96, chairman emeritus, Weston Solutions Inc., died on August 18, 2007. Mr. Weston was elected to NAE in 1976 "for leadership in the multidisciplinary approach to solving difficult waste problems involving municipal waters, industrial wastes, and solid wastes."

Calendar of Meetings and Events

2008

January 1–31	Election of 2008 Class of NAE Members and Foreign Associates
January 2	NAE Awards Call for Nominations
January 15	Deadline for submission of petition candidates for Officers and Councillors
January 15	Governing Board Executive Committee Meeting
January 29	Finance and Budget Committee Conference Call
February 1	Membership Policy Committee Meeting Irvine, California
February 4–5	Governing Board Meeting Irvine, California
February 6–7	NAE Council Meeting Irvine, California
February 7	NAE National Meeting Irvine, California
February 8	Announcement of NAE Class of 2008
February 13	Governing Board Executive Committee Meeting
February 17–23	National Engineers Week
February 19	NAE Awards Forum and Awards Dinner
February 28–March 1	Indo-American Frontiers of Engineering Symposium Irvine, California
March 1–31	Election of NAE Officers and Councillors
March 3–17	Call for nominations for Section Officers
March 4	NAE Regional Meeting Princeton, New Jersey
March 12	Governing Board Executive Committee Meeting

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

Publications of Interest

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

Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. Natural and human-induced changes in Earth's interior, land surface, biosphere, atmosphere, and oceans affect all aspects of life, and understanding these effects will require a wide range of observations from land-, sea-, air-, and space-based platforms. To assist the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and U.S. Geological Survey to develop these tools, the National Research Council was asked (1) to provide a decadal strategy for Earth and environmental observations for 2005 to 2015 and beyond based on key questions developed from a survey of Earth science and applications from space and (2) to develop a prioritized list of space programs, missions, and supporting activities to address the key questions. This report includes an overall vision for the Earth science program; an analysis of the existing Earth Observing System and recommendations for restoring its capabilities; an assessment of and recommendations for new observations and missions for the next decade; recommendations for applications of those observations; and an analysis of ways to sustain the system.

NAE member **Warren M. Washington**, senior scientist and section head, Climate Change Research Section, National Center for Atmospheric Research, was a member of the study committee. Paper, $46.00.

The Future of Disability in America. The future of disabled Americans will depend on how well this country prepares for and manages demographic, fiscal, and technological developments in the next two to three decades. Building upon two prior studies from the Institute of Medicine (*Disability in America* [1991] and *Enabling America* [1997]), this report reviews progress and investigates concerns about barriers that continue to limit the independence, productivity, and participation in community life of people with disabilities. This comprehensive assessment of the principles and scientific evidence for disability policies and services covers a wide range of issues, including the prevalence of disabilities in people of all ages; the role of assistive technologies; barriers posed by inaccessible buildings, equipment, and information formats; the needs of young people moving from pediatric to adult health care and of adults experiencing premature aging and secondary health problems; selected issues in health care financing (e.g., risk-adjusted payments to health plans, coverage of assistive technologies, etc.); and the organization and financing of disability-related research. The recommendations address how barriers can be eliminated and how the evidence base for future public and private measures can be improved to limit the impact of disabilities on individuals, families, and society as a whole.

NAE member **P. Hunter Peckham**, professor of biomedical engineering, Case Western Reserve University, was a member of the study committee. Hardcover, $59.95.

2005–2006 Assessment of the Army Research Laboratory. The U.S. Army Research Laboratory (ARL) is the Army's "corporate" laboratory for basic and applied research. For the last 12 years, at the request of the Army, the National Research Council has provided biennial assessments of the scientific and technical quality of ARL research programs. These assessments focus on the work of ARL directorates and on technical, rather than programmatic, issues. This report provides a review of accomplishments and opportunities for future research, an assessment of ongoing research, and an examination of crosscutting issues facing the six ARL directorates: computational and information science; human research and engineering; sensors and electron devices; survivability and lethality analysis; vehicle technology; and weapons and materials research.

NAE members on the study committee were **Robert W. Brodersen** (chair), professor, Department of Electrical Engineering and Computer Science, University of California Berkeley, and **Dwight C. Streit**, vice president, Northrop Grumman Space Technology. Free PDF.

Assessment of Wingtip Modifications to Increase the Fuel Efficiency of Air Force Aircraft. The high cost of aviation fuel has focused the attention of Congress and the U.S. Air Force on improving the fuel efficiency of military aircraft. One possibility is to modify wingtips by installing winglets to reduce drag, as is commonly done on commercial aircraft. To encourage the Air Force to consider modifying its planes in this way, Congress, in H. Rept. 109-452, directed the Air Force to investigate the feasibility of modifying its aircraft with winglets. To comply with this directive, the Air Force asked the National Research Council to evaluate its aircraft inventory and identify aircraft that might be good candidates for wingtip modification. This report provides reviews of winglets and other kinds of wingtip modifications, reviews of previous analyses and experiences with such modifications, and assessments of wingtip modifications and potential investment strategies for various Air Force aircraft.

NAE members on the study committee were **Natalie W. Crawford** (vice chair), senior fellow, RAND Corporation; **Ilan Kroo**, professor, Department of Aeronautics and Astronautics, Stanford University; and **Eli Reshotko**, Kent H. Smith Professor Emeritus of Engineering, Case Western Reserve University. Paper, $26.75.

Elevation Data for Floodplain Mapping. Floodplain maps are used by the National Flood Insurance Program (run by the Federal Emergency Management Agency [FEMA]) to determine whether homes or buildings require flood insurance. Approximately $650 billion in insured assets are now covered under the program. Congress has mandated that FEMA modernize its floodplain maps, but concerns have been raised about the quality of the "base map" information available to support modernization. This report, initiated by the National Research Council to advise Congress and the nation on this issue, concludes that two-dimensional "base map imagery" available from digital orthophotos (aerial and satellite photographs similar to those available on Google Earth) are sufficient to meet FEMA's needs. However, the three-dimensional "base elevation data" necessary for determining if a building needs flood insurance are not adequate. The study committee concludes that FEMA needs land-surface elevation data about ten times as accurate as current data for most of the nation and recommends that high-accuracy, digital elevation data be collected nationwide using laser measurements from aircraft (lidar technology). The new data should be input into the National Elevation Dataset maintained by the U.S. Geological Survey to support FEMA's modernization of floodplain maps.

NAE member **Elvin R. Heiberg III**, retired chief of engineers, U.S. Army, was a member of the study committee. Paper, $37.00.

Assessment of the Performance of Engineered Waste Containment Barriers. The Resource Conservation and Recovery Act, enacted in 1976, required that waste be managed in ways that protect the public from harm. The law required that modern waste-containment systems use "engineered" barriers to isolate hazardous and toxic wastes and prevent them from seeping into the environment. The effectiveness of these containment systems, which are now used at thousands of waste sites around the United States, must be continually monitored. At the request of the Environmental Protection Agency, U.S. Department of Energy, National Science Foundation, and U.S. Nuclear Regulatory Commission, this National Research Council report was conducted to assess the performance of waste-containment barriers based on data collected to date. The report concludes that existing data suggest that waste-containment systems with liners and covers, when constructed and maintained in accordance with current regulations, have performed well thus far. However, they have not been used long enough to assess their long-term (post-closure) performance, which may extend for hundreds of years. The report recommends that data collection and reporting be increased, that models be improved, and that new monitoring techniques be developed to improve future assessments and increase confidence in predictions of the long-term performance of barrier systems.

NAE member **James K. Mitchell**, University Distinguished Professor Emeritus, Virginia Polytechnic Institute and State University, chaired the study committee. Paper, $45.00.

Mining Safety and Health Research at NIOSH. The U.S. mining sector has the highest fatality rate of any industrial sector in the country, even though advances in the past three decades in mining technology, equipment, processes, procedures, and workforce education and training have significantly improved mining safety and health. The National Institute for Occupational Safety and Health (NIOSH) Mining Safety and Health Research Program (Mining Program) has been instrumental in these improvements. This assessment of the relevance and impact of research by the NIOSH Mining Program concludes that the program has made essential contributions to improvements in health and safety in the mining industry. To increase its effectiveness, however, the study committee recommends that the Mining Program proactively identify workplace hazards and establish more challenging and innovative goals for reducing hazards. The committee recognizes that improvements will depend on the amount of funding available.

NAE member **Raja V. Ramani**, independent consultant and Emeritus George H. Jr. and Anne B. Deike Chair in Mining Engineering, Pennsylvania State University, chaired the study committee. Paper, $57.00.

Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory. Since the 1940s, the Los Alamos National Laboratory (LANL) in New Mexico—part of the nation's nuclear weapons complex under the direction of the U.S. Department of Energy—has disposed of its radioactive and other hazardous wastes on site, and contaminants have been detected in groundwater beneath the site. This report assesses LANL's groundwater-protection program, which was mandated nine years ago by New Mexico state law and has now reached its halfway point. The report finds that, despite recent progress, LANL must still address substantial technical challenges before it can accurately characterize and quantify its inventories of hazardous wastes and understand how contaminants can migrate to groundwater beneath the 40-square-mile site.

NAE member **Larry W. Lake**, W.A. (Monty) Moncrief Centennial Endowed Chair, Petroleum and Geosystems Engineering, University of Texas, Austin, chaired the study committee. Paper, $25.00.

Assessment of the NASA Applied Sciences Program. Remote-sensing data and models from the National Aeronautics and Space Administration (NASA) are essential to a wide range of scientific research and many public and private services. The NASA Applied Sciences Program (ASP) and its precursors are responsible for ensuring that NASA Earth observation data and associated research are transferred to practical applications through external partnerships. Approximately five years have elapsed under the current ASP structure, and government-wide emphasis on societal benefits from Earth observing programs is growing. NASA and the ASP leadership asked the National Research Council to assess ASP's approach to extending NASA research results to practical, societal applications. The report recommends that ASP partnerships not only focus on federal agencies but also find ways to directly engage the broader community of users. The report also recommends that ASP improve its communication and feedback mechanisms with its partners, the end users and beneficiaries of NASA data and research, and the NASA organization.

NAE member **B. John Garrick**, independent consultant, Laguna Beach, California, was a member of the study committee. Paper, $34.75.

A Review of the Ocean Research Priorities Plan and Implementation Strategy. Ocean research provides countless benefits, from improving fisheries management to discovering new drugs to enabling early detection of tsunamis and hurricanes. At the request of the Joint Subcommittee on Ocean Science and Technology (JSOST), the National Research Council convened a committee to review the draft and final versions of the Ocean Research Priorities Plan and Implementation Strategy described in *Charting the Course for Ocean Science in the United States: Research Priorities for the Next Decade*, the first coordinated national ocean-research plan involving all federal agencies that support ocean science. The plan presents an ambitious vision for ocean research that will be of great benefit to the ocean-sciences community and the nation. This report recommends that JSOST undertake a variety of outreach activities to continue to engage nonfederal partners in ocean-research planning activities, such as establishing external committees to provide scientific and technical advice and to review progress on implementation of the research plan.

NAE members **Gerald E. Galloway Jr.**, Glenn L. Martin Institute Professor of Engineering, University of Maryland, College Park, and **William A. Kuperman**, director, Marine Physical Laboratory, Scripps

Institution of Oceanography, were members of the study committee. Paper, $32.75.

Conventional Prompt Global Strike Capability: Letter Report. The FY2007 budget request of the U.S. Department of Defense included funding for the development of a capability to strike any point in the world with conventional weapons within a few hours. This prompt, global strike capability would be implemented by replacing the nuclear warheads on selected Trident missiles with conventional explosive warheads. To address congressional concerns, in the 2007 Defense Appropriations Act, the National Research Council was asked to analyze a wide range of technical and policy aspects of this proposal and to explore other options. This letter report, the first response to that request, summarizes the requirements and supporting enablers for a prompt global strike capability and recommends near-term options for providing such capability. A report scheduled for release in early 2008 will provide a more comprehensive assessment.

NAE members on the study committee were **John S. Foster Jr.**, Northrop Grumman Space Technology; **Richard L. Garwin**, IMB Fellow Emeritus, IBM Thomas J. Watson Research Center; **L. David Montague**, president, L. David Montague Associates, and retired president, Missile Systems Division, Lockheed Martin Missiles & Space; **John P. Stenbit**, retired executive vice president, TRW Inc.; and **Robert H. Wertheim**, consultant, San Diego, California. Free PDF.

Decadal Science Strategy Surveys: Report of a Workshop. The National Research Council (NRC) has often used decadal surveys to review the status of and outlook for selected fields of research and to recommend scientific and programmatic priorities for federal funding. Although these surveys have generally been successful, fiscal, technical, or policy factors have sometimes made implementation of the recommendations difficult. To determine whether future surveys could be modified or improved to take those factors into account, NRC held a workshop for representatives of the research community and relevant federal agencies. This summary provides a review of recent decadal surveys; a discussion of effective ways to assess program costs and technical risks; an analysis of lessons learned from past surveys; and descriptions of approaches to ensuring that future surveys are realistic and useful.

NAE members on the workshop planning committee were **Warren M. Washington**, senior scientist and section head, Climate Change Research Section, National Center for Atmospheric Research, and **A. Thomas Young**, retired executive vice president, Lockheed Martin Corporation. Paper, $18.00.

Proceedings of the Materials Forum 2007: Corrosion Education for the 21st Century. Much of the nation's infrastructure is vulnerable to degradation by corrosion, which can seriously compromise its lifetime, reliability, and functionality. The direct costs of corrosion have been estimated at about 3.2 percent of the U.S. GDP. Improving corrosion control and management will require better engineering education in this area. In 2007, the National Materials Advisory Board sponsored the 2007 Materials Forum to assess current corrosion-engineering education. This volume includes abstracts of the forum proceedings, which address motivations for improving corrosion-engineering education; assessments of current practices in the teaching of corrosion problems in engineering schools and undergraduate education; and identification of other issues relevant to the development of a comprehensive corrosion curriculum in undergraduate engineering.

NAE member **Ronald M. Latanision**, principal and director, Mechanics and Materials, Exponent Inc., was a member of the workshop organizing panel. Paper, $12.00.

Review of Chemical Agent Secondary Waste Disposal and Regulatory Requirements. As mandated by Congress, the United States is in the process of destroying its chemical weapons stockpile under the direction of the U.S. Army Chemical Materials Agency (CMA). In the process, large quantities of secondary waste are being generated, and managing these wastes safely and effectively is a critical part of CMA's weapons-disposal program. CMA asked the National Research Council to examine the environmental and regulatory requirements relevant to the treatment of secondary waste and identify best practices in industries with similar facilities subject to these requirements. This report provides an overview of secondary wastes from chemical agent disposal facilities (CDFs), a comparison of CDF and industry experience, site-specific analyses of major secondary-waste issues, and a discussion of the disposal of closure wastes. The report provides findings and offers recommendations to help CMA make critical decisions about the disposal of secondary waste from CDFs.

NAE member **Walter J. Weber Jr.**, Gordon M. Fair and Earnest Boyce Distinguished University Professor, University of Michigan, was a member of the study committee. Paper, $18.00.

Social Security Administration Electronic Service Provision: A Strategic Assessment. The use of the Internet by individuals to conduct business with a wide range of private and public organizations is now very common. One of the largest of these, the Social Security Administration (SSA), has been developing online (e-government) services for more than a decade. SSA asked the National Research Council to examine its proposed e-government strategy and compare it with those of comparable public- and private-sector institutions. This report provides an overview of the organizational, technological, and societal contexts in which e-services are being developed; a review of lessons learned from electronic services for global financial institutions; an assessment of existing and expected technologies; and an analysis of the organizational transformation necessary for effective e-government services.

NAE members **Michael J. Carey**, senior engineering director, BEA Systems Inc., and **David J. DeWitt**, John P. Morgridge Professor, Computer Sciences Department, University of Wisconsin, Madison, were members of the study committee. Paper, $36.75.

Strategy for an Army Center for Network Science, Technology, and Experimentation. Since the U.S. military committed itself to a strategy of network-centric warfare, the Army has become increasingly interested in network science, stimulated largely by an earlier National Research Council (NRC) report, *Network Science*. The Army asked the NRC to conduct a new study to define advanced operating models and architectures for future Army laboratories and centers focused on network science, technologies, and experimentation (NTSE). The study also includes an analysis of how challenges from base realignment and closure relocations of Army research, development, and engineering resources have affected NTSE programs. This report includes a discussion of the NTSE necessary for the Army; a review of NTSE currently being done by the Army; an assessment of necessary infrastructure resources for Army NTSE; and an analysis of goals, models, and alternatives for an Army NTSE center.

NAE member **Larry Lynn**, retired director, Defense Advanced Research Projects Agency, chaired the study committee, and **W. David Sincoskie**, vice president, Network Systems Research, Telcordia Technologies Inc., was a committee member. Paper, $18.00.

An Assessment of the NIST Chemical Science and Technology Laboratory: Fiscal Year 2007. The National Research Council conducts biennial assessments of the measurement and standards laboratories at the National Institute of Standards and Technology (NIST). The assessments focus on the technical quality, merit, effectiveness, and the adequacy of resources for each laboratory. They also include assessments of the relevance of NIST programs and the adequacy of the laboratory's facilities, equipment, and personnel. This overview of the Chemical Science and Technology Laboratory (CSTL) includes assessments of each of the laboratory's five divisions, including (when appropriate) how well each division addresses national priorities, the impact and level of innovation, technical merit, and infrastructure. The study committee concludes that CSTL is meeting its obligations and has established appropriate goals that are aligned with national priorities.

NAE members on the study committee were **John L. Anderson** (chair), president, Illinois Institute of Technology; **Jerome J. Cuomo**, Distinguished University Research Professor, Department of Materials Science and Engineering, North Carolina State University; **Frederick J. Krambeck**, president, ReacTech Inc.; and **Jan D. Miller**, chair and Ivor Thomas Professor of Metallurgy, University of Utah. Paper, $12.00.

An Assessment of the NIST Electronics and Electrical Engineering Laboratory: Fiscal Year 2007. This assessment by the National Research Council is one of a series of biennial assessments of the measurement and standards laboratories at the National Institute of Standards and Technology (NIST). The assessments focus on technical quality and merit, effectiveness, adequacy of resources, and the relevance of NIST programs. The Electronics and Electrical Engineering Laboratory (EEEL) has four divisions, which are assessed separately based on four criteria: alignment with national priorities, motivation of programs, technical merit, and technical quality. The assessment also touches on staffing and funding, international issues, and planning processes.

NAE members on the study committee were **David K. Barton**, independent consultant, Hanover, New Hampshire; **David E. Borth**, corporate vice president, Advanced Technology and Standards, Networks and Enterprise, Motorola Corporation; **Young-Kai Chen**, director, High Speed Electronics and Optoelectronics Research, Bell Laboratories, Alcatel-Lucent; **Joel S. Engel**, president, JSE Consulting; **Jennie S. Hwang**, president, H-Technologies Group Inc., and CEO, Asahi America Inc.; **Tatsuo Itoh**, Northrop Grumman Professor of Electrical Engineering, University of California Los Angeles; **Herwig Kogelnik**, Adjunct Photonics Research Vice President, Alcatel-Lucent; **Richard S. Muller**, professor of EECS and director, Berkeley Sensor & Actuator Center, University of California Berkeley; **Kurt E. Petersen**, CEO, SiTime; **Arun G. Phadke**, research professor and University Distinguished Professor Emeritus, Virginia Polytechnic Institute and State University; and **Jesse E. Russell**, president and CEO, incNetworks Inc. Paper, $12.00.

An Assessment of the NIST Information Technology Laboratory: Fiscal Year 2007. This assessment of the National Institute of Standards and Technology (NIST) Information Technology Laboratory (ITL) is one of the regular biennial assessments of the NIST measurement and standards laboratories provided by the National Research Council. This volume includes a general assessment of ITL and individual assessments of the six ITL divisions. The assessments address research strategies, opportunities, planning for growth, the research culture, and the computing infrastructure. The assessment committee concludes that the work done by ITL generally ranks at or near the top of work being done by peer institutions.

NAE members on the study committee were **Jeffrey D. Ullman** (chair), Stanford W. Ascherman Professor of Engineering Emeritus, Stanford University, and **Alfred Z. Spector**, independent consultant, Pelham Manor, New York. Paper, $12.00.

Sediment Dredging at Superfund Megasites: Assessing the Effectiveness. Contaminated sediments in estuaries, lakes, and other bodies of water can adversely affect fish and wildlife and may find their way into the human food chain. Dredging, one of the few options available for cleaning up contaminated sediments, can remove sediment but also uncover and re-suspend buried contaminants creating additional harmful exposures for wildlife and people. At the request of Congress, the Environmental Protection Agency (EPA) asked the National Research Council (NRC) to evaluate the effectiveness of dredging for cleaning up contaminated sediments. Based on a review of available evidence, the NRC study committee finds that the effectiveness of dredging is still an open question. Analyses of sediments before and after dredging at about 20 sites revealed some increases, some decreases, and some intermediate changes in concentrations of contaminants in surface sediments. Determining the potential long-term benefits of dredging will require that EPA step up monitoring before, during, and after cleanups to determine how well dredging works, either alone or in combination with other techniques.

NAE member **Charles R. O'Melia**, Abel Wolman Professor of Environmental Engineering, Johns Hopkins University, chaired the study committee. Other NAE members on the study committee were **Dominic M. Di Toro**, Edward C. Davis Professor of Civil and Environmental Engineering, University of Delaware; **Richard G. Luthy**, Silas H. Palmer Professor of Civil and Environmental Engineering, Stanford University; **Perry L. McCarty**, Silas H. Palmer Professor Emeritus, Department of Civil and Environmental Engineering, Stanford University; and **Danny D. Reible**, Bettie Margaret Smith Chair of Environmental Health Engineering, University of Texas, Austin. Paper, $46.00.

The National Science Foundation's Materials Research Science and Engineering Centers Program: Looking Back, Moving Forward. In response to an informal request from the National Science Foundation (NSF), a committee of experts was formed to assess the NSF program for establishing and funding materials research science and engineering centers (MRSECs). The committee developed a general methodology for assessing MRSECs and, after extensive research and analysis, came to the following conclusions. First, MRSEC awards continue to be in great demand, which indicates that they are perceived as very valuable. Second, the quality of MRSEC programs is generally as high as the quality of other multi-investigator and individual-investigator programs. Finally, MRSECs generally undertake projects that might not have been undertaken without NSF support. Despite these pluses, the committee also observed that the program is not as effective as it once was and recommends that it be restructured to ensure that resources are used and leveraged more efficiently. The committee recommends that the restructured program fully invest in MRSECs, as well as in stand-alone teams of researchers, to ensure that the focus remains on key aspects of the program.

NAE member **Matthew V. Tirrell**, dean of engineering, University of California, Santa Barbara, chaired the study committee. Other NAE members on the committee were **Edith M. Flanigen**, consultant and retired fellow, UOP LLC; **Venkatesh Narayanamurti**, dean, School of Engineering and Applied Sciences, Harvard University; **Julia M. Phillips**, director, Physical, Chemical, and Nano Sciences Center, Sandia National Laboratories; **Lyle H. Schwartz**, retired director, Air Force Office of Scientific Research; and **Eli Yablonovitch**, professor of electrical engineering and computer sciences, University of California Berkeley. Paper, $51.50.

Coal: Research and Development to Support National Energy Policy. Coal provides nearly a quarter of U.S. energy supplies and generates more than half of the nation's electricity. Although the future use of coal may be impacted by the regulation of carbon dioxide emissions, the demand for coal is expected to increase over the next 10 to 15 years. At the request of Congress, the National Research Council conducted a study to examine the need for funding of R&D to support "upstream" aspects of coal mining, such as worker safety, environmental protection and reclamation, coal-reserve assessments, and mining productivity. The report concludes that increased investment in R&D is needed in these areas and recommends that an additional $144 million be allocated. The report also recommends that federal agencies, state agencies, and industry enter into partnerships to coordinate their R&D activities.

NAE member **Corale L. Brierley**, principal, Brierley Consultancy LLC, chaired the study committee. Other NAE members on the committee were **Raja V. Ramani**, independent consultant and Emeritus George H. Jr. and Anne B. Deike Chair in Mining Engineering, Pennsylvania State University, and **Jean-Michel M. Rendu**, mining consultant, Englewood, Colorado. Paper, $36.00.

Toward a Safer and More Secure Cyberspace. Because much of the nation's critical infrastructure depends on information technology (IT), the United States is vulnerable to adversaries who might exploit weaknesses in critical information systems. However, we do not have a clear understanding of what makes IT systems vulnerable, the best ways to reduce these vulnerabilities, or how to implement cybersecurity techniques. At the request of Congress, the National Research Council undertook a study to develop a strategy for cybersecurity research to address vulnerability issues. This report provides an assessment by a committee of experts of the nature of the cybersecurity threat; an analysis of why previous research efforts have not been completely effective; an analysis of the human resources required to advance cybersecurity research; descriptions of illustrative research areas; and recommendations for action.

NAE members on the study committee were **Steven M. Bellovin**, professor, Department of Computer Science, Columbia University; **Joel S. Birnbaum**, independent consultant and retired senior vice president of research and development, Hewlett-Packard Company (who chaired the committee until August 2006); **Anjan Bose**, Regents Professor/Distinguished Professor of Electric Power Engineering, Washington State University; and **Alfred Z. Spector**, independent consultant, Pelham Manor, New York. Paper, $57.00.

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