SIGNATURES

precise
high-performance computing

novel
networked embedded systems

integrated
engineering business curriculum

based on **tradition**
bound for **tomorrow**

Engineering Advances at the University of Notre Dame

Volume 5, Number 1
Summer 2003

Ubiquitous, pervasive, embedded. In today's vernacular, these words are often used to describe computers and computing. It is, in fact, hard to imagine a world without computers, and in this issue of *Signatures*, we are pleased to present some of the research being conducted at Notre Dame to enhance their role in our lives.

The article on *Thinking Inside the Box* focuses on high-performance computing and the complex problems being solved for systems as small as molecules or as large as oceans. It also describes work on developing the next generation of high-productivity computing systems, whether through the use of *Processing-in-Memory (PIM)* architectures to achieve peta-scale speeds in a three-year, multimillion dollar collaboration with Cray Inc., Stanford, and CalTech, or architectures based on quantum devices.

But the impact of computers goes well beyond high-performance computing, and the second article on *The Winds of Change* provides a fascinating account of how networked embedded systems will permeate virtually every aspect of our natural and man-made worlds. Application by application, *a global nervous system* is emerging in which embedded processors will optimally monitor and control many important aspects of daily life.

A third article entitled *Engineering and the Bottom Line* describes a unique two-course sequence on integrated engineering and business fundamentals. Its goal is to prepare our students for the broad range of issues they will encounter in the corporate environment, and it has become the most popular elective option ever offered by the College.

We hope you will find the foregoing articles of interest, along with the additional material provided on College and department activities.

The past year has been marked by many noteworthy events. Recent multi-investigator research initiatives are flourishing, particularly in areas such as wireless communications, nanotechnologies, and environmental science and technology. Newer initiatives involving bioengineering and fuel cells are also experiencing considerable success. Research grants reached a new high of approximately $23 million, as did the number of Ph.D. degrees (39) awarded by the College. There were also many examples of enhancements to the undergraduate curriculum in each of our departments, as well as at the College level.

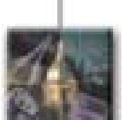
Despite the prevailing uncertainty in economic and political conditions, we look to the future with optimism. The faculty remains committed to the values of the institution and to further advancement in education, research, and service. We will continue to move forward.

the dean's view

Frank P. Incropera

Frank P. Incropera
Matthew H. McCloskey Dean of Engineering
H.C. and E.A. Brosey Professor of Mechanical Engineering

S I G N A T U R E S



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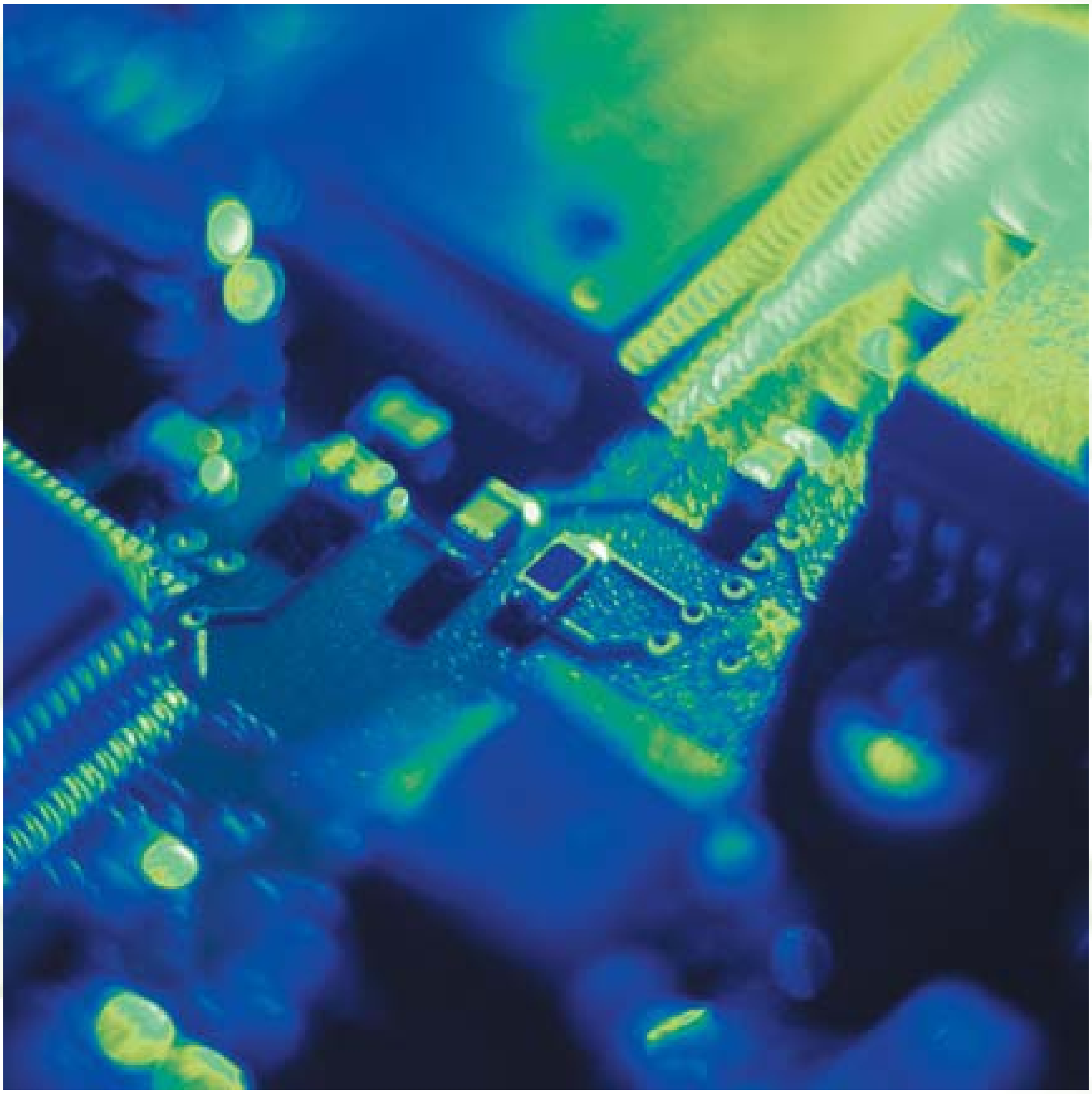
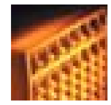
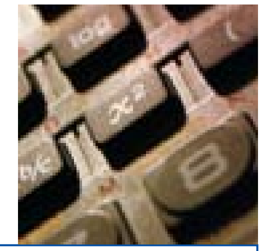
thinking inside



the box





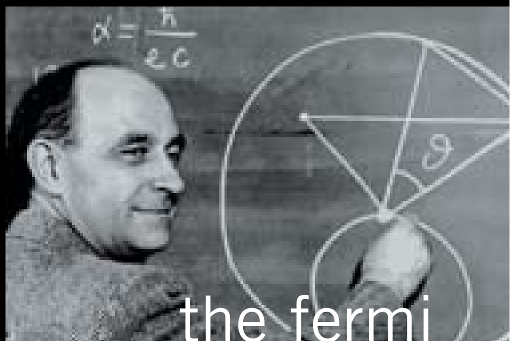
In today's world it is hard to imagine not using computers to analyze phenomena that are too small or too complex to experimentally study. But as few as 50 years ago engineers and scientists could not quickly or accurately model nonlinear systems, where the whole was not equal to the sum of the parts nor the effects directly proportional to the causes. The reason was simple enough. Researchers, who are bound to follow the rules of the physical world, were thinking in a linear fashion. They broke the problem up into parts, but when the sum of the parts didn't equal the whole, the process was slow, painstaking, and often paralyzing.

Much of the progress during the 20th century was made because of man's ability to harness the computer for the processing, storing, and distribution of information. The modern computer age began in the 1940s with the completion of the Atanasoff-Berry Computer in 1942 and the Electronic Numerical Integrator Analyzer and Computer (ENIAC) in 1945, two of the world's first electronic digital computers. Housed at the University of Pennsylvania's Moore School of Electrical Engineering, ENIAC's function was to have been the development of firing tables for World War II artillery, so that gunners could quickly determine which settings to use for a particular weapon given an identified target. Solutions to the governing equations took the Ballistics Research Laboratory, normally responsible for providing the data, days to solve. ENIAC was going to shorten that time dramatically. The machine was commissioned in 1943, but by the time it was completed, the war had been over for three months.

Since the dawn of time man has continued to develop methods and machines to help solve complex physical problems. From the first abacus to the most recent generation of computers, these tools and the people who created them have inspired other researchers to explore possibilities beyond the limits of conventional technology, where intricate computer simulations and detailed modeling are the norm and millions of mathematical equations can be solved in a matter of seconds.

Although ENIAC didn't help the gunners, it did prove to be almost a thousand times faster than its predecessors. It could solve more than 5,000 equations per second. And, in spite of its drawbacks — such as requiring two days and massive rewiring to reprogram the machine because of its punch cards and plug boards — ENIAC was a shining example of what could be accomplished.

ENIAC was the first step. The second came in 1953 at Los Alamos National Laboratory in New Mexico, when Enrico Fermi, John Pasta, and Stanislaw Ulam introduced the concept of a "computer experiment" and changed the course and function of computers in research forever. Computational science, as it's known today, uses high-performance or "super" computers and advanced software algorithms to solve real physical problems that defy pencil-and-paper calculations, the processing power of many computers, and traditional algorithms.



the fermi **factor**

Enrico Fermi, son of an Italian railroad official, was born in Rome in 1901. Displaying an aptitude for mathematics and physics in grammar school, he won a fellowship to the University of Pisa in 1918. After receiving his doctorate in physics, he was awarded a scholarship from the Italian government in 1923 and received a Rockefeller Fellowship in 1924. By 1933 he had developed the theory of beta decay. In 1938 he received the Nobel Prize "for his discovery of new radioactive elements produced by neutron irradiation and for the discovery of nuclear reactions brought about by slow neutrons." He designed the first man-made nuclear reactor, introduced a theory on the origin of cosmic rays, and co-developed the Thomas-Fermi model of the atom and Fermi-Dirac particle statistics.

In 1944 Fermi became an American citizen. Later that year he began working full-time on the Manhattan Project in the Los Alamos National Laboratory in New Mexico. His contributions to the development of the atomic bomb and the subsequent Trinity test — the actual ignition of the device which took place on July 15, 1945 — were vital, as he solved a multitude of physical problems from hydrodynamics to nuclear chemistry. His tireless efforts helped the United States produce the atomic bomb, altering the length and possibly the course of World War II. Considered by many to be one of the great scientists of the 20th century and often called the father of modern physics, Fermi died of stomach cancer in 1954; he was only 53.

In his short life Fermi harnessed the atom, but, more important, he opened a door. When asked by one reporter how he wanted to be remembered, Fermi replied, "I want them to remember all the peaceful uses for nuclear energy that are being developed because of my work." Today, nuclear energy provides much of the world's electric power, and radioactive materials are used in a variety of industries — from agriculture to medicine. Of all of his accomplishments, the one that is perhaps the least recognized is his part in the introduction of computational experiments as a research tool. Fermi, John Pasta, and Stanislaw Ulam suggested the concept of using a computer to conduct experiments in order to detail complex mathematics and processes, like the interaction of subatomic particles. Using Maniac, the most powerful computer of its time, these researchers created a virtual world in which they could simulate atoms and how they react to one another. Fifty years later, the insights they gained into nonlinear systems are developing into new and exciting technologies.

When Fermi and his associates proposed this new avenue for research, they literally opened a whole new world. Problems previously "unsolvable" became less daunting as researchers, such as Fermi, John Von Neumann, and Edward Lorenz, began to combine computational science with theoretical and experimental science. For example, in the last 50 years researchers employing techniques, such as computational fluid dynamics or finite-element methods and molecular dynamic methods, have gained sufficient knowledge of nonlinear systems to enable remarkably precise characterization of those systems — from the flow over a wing to the strength of a DNA molecule.

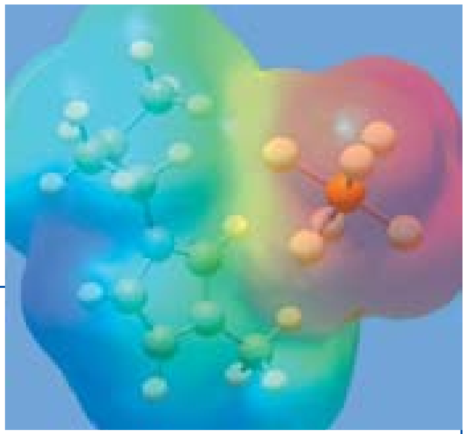
Researchers in the College of Engineering at the University of Notre Dame are also employing high-end computational techniques to address a variety of problems. "High-performance computing," says **Joseph M. Powers,** associate professor of aerospace and mechanical engineering, "is a tool that gives researchers the ability to reliably solve multiscale problems. That knowledge can then be applied to a wide range of applications."

"When you're trying to solve a problem computationally, you use a variety, and sometimes a combination, of tools," says **Samuel Paolucci,** professor of aerospace and mechanical engineering. It may be as simple as processing a standard model and method on one very powerful computer or a large cluster of computers able to handle the number and intensity of calculations required to solve the problem.

one very **powerful** computer or a large cluster of computers

The University offers two supercomputing centers: the Bunch-o-Boxes (B.O.B.) Laboratory and the High-performance Computing Cluster (HPCC). Located in Stepan Chemistry Hall, B.O.B. is one of the 500 fastest computers in the world. It was designed and built by the colleges of engineering and science to enhance high-end computing capabilities at Notre Dame. Researchers from throughout the University use B.O.B.

Edward J. Maginn, associate professor of chemical and biomolecular engineering, estimates that approximately 90 percent of his research in molecular dynamics is carried out within the B.O.B. cluster. Maginn and his students focus on statistical mechanics and the structure-property relationships of molecules in order to better



This is an example of the electron density of an ionic liquid molecule, shown here via quantum mechanical simulation. Associate Professor Edward J. Maginn, Professor Mark A. Stadtherr, and Joan F. Brennecke, the Keating-Crawford Professor of Chemical and Biomolecular Engineering, are studying ionic liquids to determine their viability as replacements for traditional, more toxic solvents. Ionic liquids, which have only been known for the last decade, do not evaporate, so they cannot contribute to air pollution.

understand the nature of specific materials and how molecules within a material interact with one another.

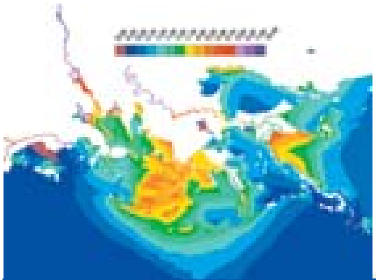
Cluster computing is perhaps better known as parallel computing. **Mark A. Stadtherr,** professor of chemical and biomolecular engineering and chair of the University's technical computing committee, uses parallel computing strategies in the B.O.B. cluster and the University's HPCC to solve global optimization problems and model the phase behavior of complex molecules.

"We can solve complex problems faster and more reliably using high-performance computing," says Stadtherr. "But it's not simply a matter of taking the computation and moving it from a single processor to a parallel cluster. You have to think about how you're going to take advantage of the parallel computing environment." One method Stadtherr and colleagues have used is the Message Passing Interface (MPI), where individual processors communicate with each other by passing messages back and forth. "What this has allowed us to do," he says, "is solve problems that we could not even imagine solving years ago."

For some problems using traditional hardware alone — whether one or several computers — is not sufficient. This is why many researchers write their own very efficient software. For example, **Joannes J. Westerink,** associate professor of civil engineering and geological sciences, and students in the Computational Hydraulics Laboratory design, test, and implement new algorithms and MPI based parallel processing code in order to solve flow patterns and transport in the coastal ocean. The models they produce provide a detailed array of information — from the flood heights of storm surges for the design of levees to intricate maps of salt water intrusion into estuaries. Organizations using these computational models include the United States Army and Navy, the National Ocean Service, and the states of Texas and Louisiana, as well as universities and consultants worldwide.

According to Westerink, many computer models and algorithms that worked well 10 years ago don't work today because the resolution has increased so much. "It's a constantly evolving process," he says, "which means

Edward J. Maginn, associate professor of chemical and biomolecular engineering, seated center, discusses a zeolite crystal structure simulation with graduate student James Larentzos. In addition to this cluster, located in Fitzpatrick Hall, Maginn's team also uses the University's Bunch-o-Boxes Laboratory and the High-performance Computing Cluster to conduct simulations.



that algorithms and software must be constantly improved. In order to design accurate and efficient coastal hydrodynamic software, you must consider the mathematical properties of algorithms, the architecture of computers, the physics of the coastal ocean flows, and the ultimate goal, which is to obtain a very useful design tool."

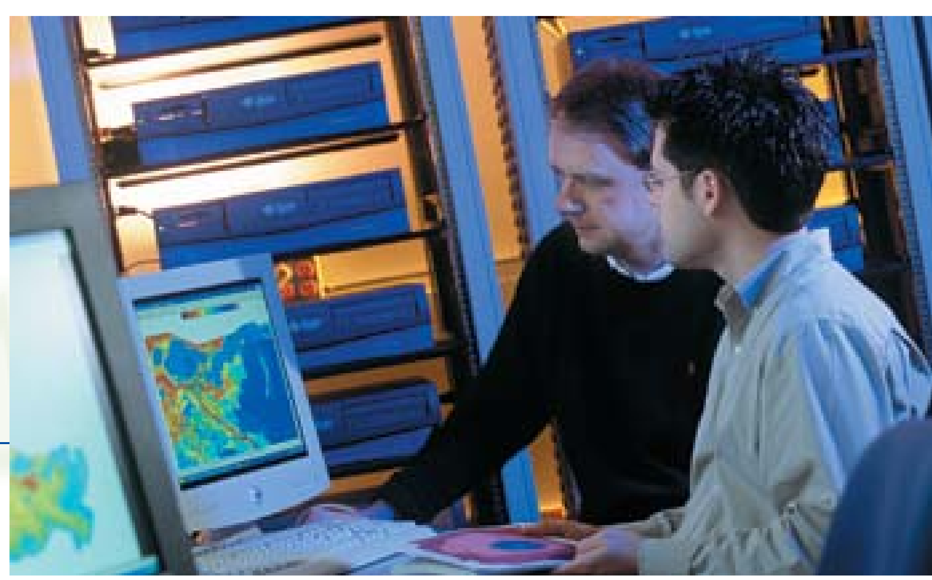
very **efficient** software

Another researcher using a very specific and efficient software program is **Jesus A. Izaguirre,** assistant professor of computer science and engineering. "The computer software we use as we study biological processes [CompuCell: Software for Morphogenesis] allows us to simulate the individual mechanisms of cells as they grow as well as their elaborate interactions."

The first step, according to Izaguirre, is to analyze the problem and develop a parallel or high-performance algorithm. The next is to develop and implement the software. "It is more complicated to produce software that is reliable when it is executing concurrently. But because of the combination we use — clever algorithms and fast parallel implementations, we have enabled some simulations that other researchers have not yet been able to duplicate."

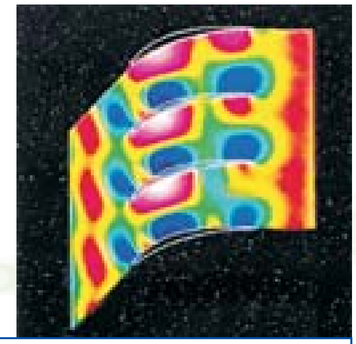
Izaguirre and colleagues use departmental resources as well as the high-performance clusters in the University's HPCC and the B.O.B. lab. But they also employ supercomputing centers throughout the country.

Preprocessing, applying high-performance algorithms before beginning a computational cycle, is a method Notre Dame researchers use to efficiently solve multiscale problems. For example, in conjunction with Los Alamos National Laboratory, Powers and Paolucci have been focusing their efforts on the combustion of gases — such as hydrogen-oxygen mixtures — and energetic solids, such as those used in the space shuttle booster rockets and high explosives. "The combustion of these materials," says Powers, "involves a



Joannes J. Westerink, associate professor of civil engineering and geological sciences, left, and students in the Computational Hydraulics Laboratory are currently working with the New Orleans district of the U.S. Army Corps of Engineers and the state of Louisiana to develop a model of hydrodynamic circulation and storm surge heights in southern Louisiana. Using massively parallel processing, Westerink and students run some of their simulations on the 32 Sun Blade 100s in their laboratory. Other simulations for this project are performed using up to 256 processors on a Cray T3E, located at the U.S. Army Engineer Research and Development Center in Vicksburg, Miss. Westerink and his team have run literally hundreds of simulations in order to develop the most accurate storm surge prediction capability. The software they are writing as a result of their research will be used to redesign levees in southern Louisiana.

Focusing on jet aircraft and marine propellers, Hafiz M. Atassi, the Voila D. Hank Professor of Aerospace and Mechanical Engineering, studies the generation and propagation of sound. The computer simulation shown here represents the noise field generated by a fan jet engine. The alternating colors, with red representing the peak and blue the trough, indicate the wavelike nature of propagating sound.



large range of temporal and spatial scales, making the solution of mathematical equations modeling these processes computationally challenging. We've been developing and refining techniques that help us to better understand the combustion process and to resolve the actual chemistry and material motion occurring during combustion with a great deal of detail, speed, and accuracy."

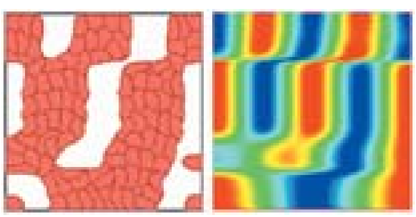
Key to their research are the wavelet and low-dimensional manifold methods. According to Paolucci, the wavelet method uses the computer as both a mathematical microscope, capturing the length scales of the combustion process below the micron level, and a macroscope, viewing the entire process on the scale of centimeters. The low-dimensional manifold method applies sophisticated multidimensional techniques to identify low-dimensional surfaces that capture the essence of how important chemical reactions occur in nature.

high-performance algorithms

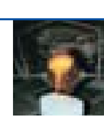
Additionally, Paolucci and Powers are developing a suite of high-performance algorithms for problems in computational mechanics. In fact, Paolucci recently completed a project that models the fluid mechanics and heat transfer associated with the solidification of a liquid metal alloy used in the manufacture of pistons. Funded by Federal Mogul, his task was to develop better methods to more quickly manufacture a casting while maintaining proper strength characteristics.

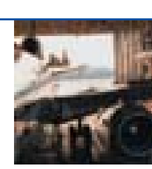
Powers has also employed an ultra-accurate discretization algorithm to model the flow behind the bow shock experienced by vehicles such as the space shuttle during the re-entry process. With this algorithm he has developed a technique to optimize the vehicle shape so as to minimize the drag during re-entry.

Hafiz M. Atassi, the Viola D. Hank Professor of Aerospace and Mechanical Engineering, creates specific algorithms for parallel computing platforms. He uses these algorithms to simulate the noise produced in aircraft engines and marine propellers. Working with the Office of Naval Research and the Ohio Aerospace Institute Consortium, Atassi, postdoctoral research associates Basman Elhadidi and Romeo Susan-Resiga, and students in the Hessert Laboratory for Aerospace Research develop



Researchers in the Interdisciplinary Center for the Study of Biocomplexity seek to understand and predict the complex patterns and cellular organization exhibited by living organisms ... to understand how cellular decisions are made at the molecular level. Once they understand how cells sense and respond to their environments, they may be able to develop techniques and tools to address significant biological problems, such as cancer, diabetes, or birth defects. Directed by Mark S. Alber, professor of mathematics, center research focuses on four areas — biological networks, cellular dynamics, organogenesis and tissue development, and population dynamics and ecological systems. Shown above are models of avian limb development, a multiscale study led by Alber, Jesus A. Izaguirre, assistant professor of computer science and engineering, and Stuart A. Newman, professor of cell biology and anatomy at New York Medical College.





Associate Professor Joseph M. Powers, far left, and Professor Samuel Paolucci, far right, discuss the use of wavelet adaptive multilevel representations with doctoral candidates Yevgenii Rastigejev and Sandeep Singh, standing. With this method, these researchers can model a broader range of spatial and temporal scales — from the smallest microscopic length scale to the largest physical scale and from nanoseconds to slow time scales. Their work, which is currently supported by Los Alamos National Laboratory, has also received funding from the National Science Foundation and the Air Force Office of Scientific Research.

models that solve approximately one to five million equations in a matter of hours.

"Using mathematics to develop highly accurate algorithms, we can simulate noise generation and propagation from aircraft engines and marine propellers. We have also developed algorithms for what we call the 'Inverse Problem,' so we can identify the source of a noise by examining the level and signature of the sound," explains Atassi. "When we pinpoint the source of the sound using this method, we then have a better understanding of what creates the noise (generation) and how the sound wave travels (propagation)."

The government has placed a high priority on noise reduction, particularly the noise produced by jet engines. Federal regulations now require reductions totaling 20 decibels over the next 20 years. "With our algorithms — which are designed to reduce computational time and memory requirements — and by using parallel processing, we can identify and control the parameters affecting noise generation," says Atassi.

Although he does use some of the computer facilities on campus, Atassi has developed close relationships with Argonne National Laboratory, the National Aeronautics and Space Administration (NASA), and the Navy, which he uses for large computational models. "But," he says, "if the algorithms are not precise, it doesn't matter how much processing power or how many computers you apply to the problem, you will not get an accurate representation of the sound."

a better computer

The final way to ensure the fastest and most reliable processing of computationally intensive problems is to build a better computer. Computer architects at Notre Dame are investigating three new architecture structures: morphable architectures for better energy use; Processing-in-Memory (PIM) architectures for faster access and processing of items stored in memory; and molecular architectures, the development of an architecture based on Quantum-dot Cellular Automata (QCA) where the "chips" are the size of strands of DNA and the "transistors" are molecules.

The impetus for each of these initiatives stems from today's electronic applications — multimedia, network servers and appliances, real-time embedded systems, and other computationally demanding systems or services — together with an increasing push from emerging technologies. On a daily basis engineers and computer scientists are realizing that the computers of the future need to be radically different from those conceived and built even a decade ago.

Morph project researchers — **Peter M. Kogge,** the Ted H. McCourtney Professor of Computer Science and Engineering; **Jay B. Brockman,** associate professor of computer science and engineering; Kanad Ghose, chair and associate professor of the Department of Computer Science at the State University of New York at Binghamton; and Nikzad B. Toomarian of the Center for Integrated Space Microsystems at NASA's Jet Propulsion Laboratory — are working to develop a computer architecture whose energy and performance characteristics will adapt to

The Bunch-o-Boxes cluster is one of 24 of the top 500 supercomputing clusters which are "self-made," designed and assembled by the end users. It ranks approximately 42nd out of all supercomputing systems at U.S. academic institutions.

one of the world's fastest computers

The Bunch-o-Boxes (B.O.B.) Laboratory is a 106 dual-processor Beowulf cluster located in the Stepan Chemistry Hall and administered by the Science Computing Facility. According to a list of the top supercomputing sites which was published in June 2003, the B.O.B. lab is one of the top 500 clusters in the world. Designed and built by the colleges of engineering and science in order to provide high-end computing on campus for data- and time-intensive projects, the cluster was funded through a grant from the National Science Foundation's Major Research Initiative program.

Research simulation and modeling activities in B.O.B. span a broad range of disciplines and departments throughout the University. Experiments currently under way include projects in nanomaterials and complex fluids, directed by Edward J. Maginn, associate professor of chemical and biomolecular engineering, as well as projects in global optimization, interval analysis, and environmentally conscious process design, which are led by Mark A. Stadtherr, professor of chemical and biomolecular engineering. Albert-László Barabási, the Emil T. Hofman Professor of Physics, directs studies in networks and granular media. J. Daniel Gezelter, assistant professor of chemistry and biochemistry, focuses on diffusion through biological membranes, glass formation in metallic alloys, theories of diffusion in liquids, and the development of methods for molecular dynamics in biomembranes. Projects in theoretical astrophysics, relativistic hydrodynamics, and stellar evolution are being directed by Grant J. Matthews, professor of physics. Olaf G. Wiest's efforts in B.O.B. include the development of mechanisms and models of DNA photolyase, studying the structure and reactivity of hydrocarbon radical ions, and defining molecular implementations of Quantum Cellular Automata, a transistorless nanoscale approach to computing developed at Notre Dame. Wiest is an associate professor of chemistry and biochemistry.

B.O.B. processes at a rate of 280 gigaflops — 280 billion floating operations — per second. The Earth Simulator, located in the Earth Simulator Center in Yokohama, Japan, is the world's fastest "processor." Performing at 35.61 teraflops — more than 35 trillion floating operations per second, its function is to analyze global environmental problems such as tectonic activities, global warming, and unusual atmospheric phenomena.

University researchers using the Bunch-o-Boxes Laboratory include, front center, J. Daniel Gezelter; second row, from left, J.C. Ducom, the lab manager, and Olaf G. Wiest; and last row from left, Mark A. Stadtherr and Edward J. Maginn.

The first supercomputer, the Cray-1® system, was installed at Los Alamos National Laboratory in 1976. Functioning at a record speed of 160 million floating-point operations per second, it cost approximately $8 million. Cray Inc., a leading provider of supercomputing solutions for engineering and scientific computing, is currently working with faculty in the Department of Computer Science and Engineering to develop a trans-petaflops computer which will be able to process a million billion operations per second.

it started with cray-1

Photo: Cray Inc.

available energy profiles. Their innovative approaches include developing memory hierarchies and adaptive algorithms for placing data within the hierarchies and adapting run-time operations and data structures to be more energy aware.

PIM is another focus of College of Engineering faculty. Current technology dictates that logic and memory exist on two separate silicon chips. PIM says that instead of two chips, one for memory and one for logic, a single chip can be used for both functions. Computer processing time would be drastically reduced because there would be no need to go from the processor to the memory (to access information) and back again. PIM would also greatly reduce power levels needed to operate a computer. "It's radically different from the way we execute computing now," says Kogge, "and, that's very exciting."

Researchers in the Department of Computer Science and Engineering, led by Kogge — who was part of the IBM team that built a prototype PIM chip in February 1993 — are developing new computer architectures that utilize PIM for a variety of applications. For example, the PIM team, working with collaborators at several institutions and led by the California Institute of Technology, is creating a hybrid technology multithreaded (HTMT) machine. This new type of supercomputer, which would feature PIM memory, would be capable of executing a petaflop — 10^{15} flowing point operations per second, which is about one million times faster than what a decent personal computer can accomplish today.

In another PIM project computer science and engineering faculty in collaboration with Cray Inc., the company that built and installed the first supercomputer at Los Alamos National Laboratory in 1976, are developing the memory functions for computers 10 times faster than the HTMT machine. The goal of this project, a three-year $43 million effort funded by the Defense Advanced Research Projects Agency as part of its High Productivity Computing Systems Program, is to build the first "trans-petaflops systems-computers able to

FOR MORE INFORMATION ON HIGH-PERFORMANCE COMPUTING AT NOTRE DAME, VISIT:

B.O.B. LABORATORY
http://bob.nd.edu/

COMPUTATIONAL HYDRAULICS LABORATORY
http://www.nd.edu/~coast/

COMPUTER ARCHITECTURE PROJECTS AT NOTRE DAME
http://www.nd.edu/~cse_proj

HESSERT LABORATORY FOR AEROSPACE RESEARCH
http://www.nd.edu/~ame/facilities/Hessert.html

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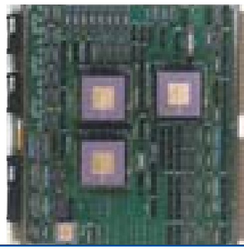
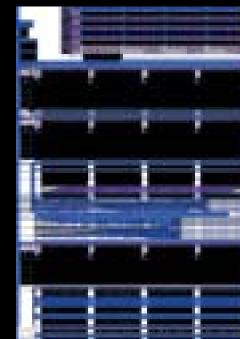


perform more than a million billion calculations per second" and have a product available by 2010 for the national security and industrial user communities.

PIM and some of the other methods being studied by Notre Dame researchers revolve around the use of conventional silicon and a transistor paradigm. Another avenue they are exploring focuses on nanotechnology, specifically using QCA to create circuit architectures. QCA was developed at Notre Dame. It "computes" not on the basis of electron flow but on Coulombic interactions. So when a signal from a control cell changes the state of one electron, it affects the next electron, which repels its neighbor and so on down a row of cells. How an array of quantum-dots is assembled determines how it functions — memory, processing, or a unique molecular combination of both.

To date Notre Dame faculty have developed a new CAD system for QCAs, created a layout and timing model that matches QCA characteristics, and designed a simple microprocessor. "It turns out that QCA is the natural next step from PIM. If we can build molecules that can 'compute,' and that's still a long way off," says Kogge, "then we can reduce the size of computers by a factor of 100. The power requirements and processing time would also go down incredibly. You could even conceive of putting 'computers' in something like paint or fabric."

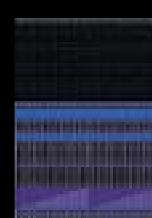
Whether located in laboratories, woven into clothing, or scattered throughout paint, it's apparent that the computers of tomorrow will be as different from the computers used today as the space shuttle is from the Kitty Hawk flyer. Molecules may process and store information inside the "box," providing split-second solutions to large, complicated multi-scale problems. There may not even be a "box." But it will still be engineers and computer scientists overseeing the process, developing the algorithms and software needed for the next generation of computers, and finding ways to solve some of the most crucial problems on the planet.



Detail 1

a new processing-in-memory **chip**

Jay B. Brockman, associate professor of computer science and engineering, and graduate student Shyamkumar Thoziyoor are finalizing the design of a Processing-in-Memory (PIM) chip for use in a new generation of computers. Members of the Notre Dame PIM team, Brockman and Thoziyoor are collaborating with researchers from the California Institute of Technology and NASA's Jet Propulsion Laboratory to develop massively parallel computer systems using PIM technology for applications including finite-element analysis, molecular dynamics, astrophysics, and data mining.



Detail 2

The chip will be fabricated by the Metal Oxide Semiconductor Implementation System (MOSIS) in August 2003 using 0.18 micron technology. The fine lines and densities which can be achieved using this state-of-the-art silicon lithography process is necessary to support high-performance processing and high-capacity data storage.

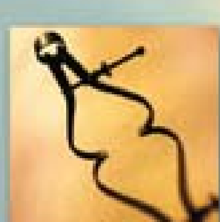
Founded by the Defense Advanced Research Projects Agency in 1981, MOSIS is a low-cost, small-volume prototyping production service for VLSI circuit development. It has fabricated more than 50,000 circuit designs for academic institutions, governmental agencies, and commercial firms since its inception.

Detail 3

The key feature of the PIM design is that it places a custom microprocessor and main memory on the same chip, eliminating one of the major bottlenecks in conventional computer systems. The chip will hold four independent PIM units, similar to Detail 1. The dense area at the top of Detail 2 is the "memory," and the processors, in blue, are segmented in columns to align with the memory. Each horizontal band is a step in the processing pattern. Detail 3 highlights the permutation network located in the triangular sections shown on Detail 2. The permutation network rearranges the order of data as it is accessed from memory. Although the chip will run at clock speeds slower than today's fastest commodity microprocessors, it will be capable of performing many operations in parallel, leading to higher performance for many scientific and engineering applications.

Society expects **engineers** to contribute to the greater good through technology — creating new products and processes. **Industry,** on the other hand, is looking for engineers who, while they are technically astute, employ the concepts, practices, and skills needed to succeed in today's **business** environment.

engineering



To successful corporations and successful professionals the "big picture" and "the bottom line" are more than catch phrases. Understanding how to be effective in a corporation is what sets employees apart from their peers. Some companies call this level of comprehension a "soft skill." But in today's work environment it's a corporate necessity — one that an increasing number of companies are demanding of their current engineers and their new hires.

Most engineers learn about business in the workplace. They spend years in various departments and at numerous levels of management developing a keen understanding of the marriage between business and technology. According to the American Society for Engineering Education, the field of engineering — with more than 1.2 million engineers — is the second-largest profession in the United States. The National Engineers Week Headquarters in Alexandria, Va., indicates that more chief executive officers of the top 1,000 publicly held U.S. companies majored in engineering than any other discipline.

& the bottom line

A few engineers learn about business while still in school, with some completing dual engineering and business degrees. Others pursue graduate degrees in business. But, there is a growing need for engineers to learn the fundamentals of business during their undergraduate studies.

Product development, marketing, and life cycle management are among the topics covered in the innovation processes segment of the course.

While a handful of universities — particularly those with business schools — offer business management training for engineering undergraduates, the Integrated Engineering and Business Practices Program at the University of Notre Dame is one of the few programs actually integrated into engineering curricula. And, it is taught by an engineer.

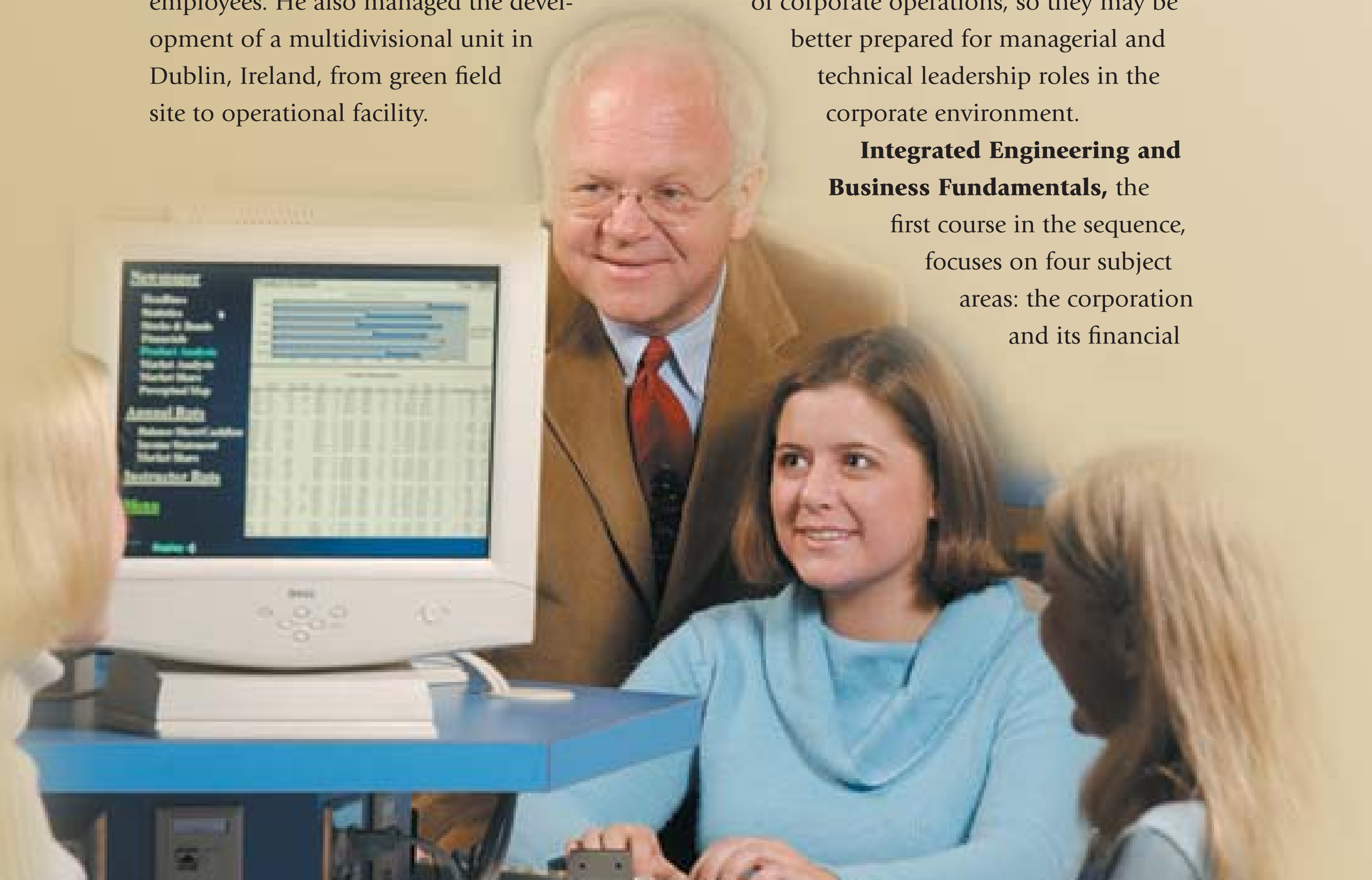
When Program Director **Robert M. Dunn,** joined the University in 2001, the former vice president of Corporate Manufacturing at IBM brought with him 33 years of experience. During his tenure at IBM, Dunn's responsibilities progressed from those of a design engineer to the manager of major product development programs for midrange processors to the vice president and site manager of the corporation's Poughkeepsie, N.Y., complex, a facility composed of 15 major divisions and 6,000 employees. He also managed the development of a multidivisional unit in Dublin, Ireland, from green field site to operational facility.

Dunn graduated from Notre Dame with a bachelor's degree in engineering science in 1965. He earned a master's degree in engineering mechanics from Pennsylvania State University in 1967 and a doctorate in aeronautical engineering from the University of Illinois at Urbana-Champaign in 1972.

Over the years his career has involved the management of complex business relations in North America, South America, Asia, and Europe. His expertise in product development, technology development, human resources, manufacturing, and management has proven to be a valuable resource for the engineering undergraduates in his classes.

The College of Engineering's business practices program is a two-course sequence designed to help engineering students develop an understanding of the dynamics of corporate operations, so they may be better prepared for managerial and technical leadership roles in the corporate environment.

Integrated Engineering and Business Fundamentals, the first course in the sequence, focuses on four subject areas: the corporation and its financial



processes; human resources and management; innovation processes, including project management; and supply chain processes and quality. Students learn how to read a financial report, and they study business planning cycles as they review corporations and their financial processes. They examine managerial styles and organizational climates and discuss hiring trends in human resources.

Product development, marketing, and life cycle management are among the topics covered in the innovation processes segment of the course. The supply chain section covers topics from manufacturing and procurement to distribution, flow of materials, and quality concepts — such as ISO 9000 and Six-Sigma. In addition to classroom instruction, the course features guest speakers who are professional engineers

A Company **of Their Own**

Capacity versus production, market share, fixed assets, depreciation, and gross margins — these are the subjects of many of the discussions that students in the Advanced Topics in Integrated Engineering and Business course have throughout the semester. The discussions are driven by the **Capstone® Business Simulation software (CAPSIM),** a program used by more than 200 universities and corporations for executive education and management training.

More than a sophisticated computer game, CAPSIM offers student teams the opportunity to learn about a company's inner workings — how individual functions integrate into the whole corporation — and how to develop effective business strategies. Students using the CAPSIM program become familiar with the forces of market demand, the fickle nature of customer confidence and buying criteria, and the pressure that can be applied to a company's bottom line by competitive products.

"The beauty of CAPSIM," says Robert M. Dunn, director of the Integrated Engineering and Business Practices Program, "is that students can see the impact of their decisions on their company's position in the market in a matter of seconds. It has been a real eye-opener for many of them."

Through the simulation students experience "real-life" corporate situations such as running out of cash or having the wrong product for the market. They also learn to work in teams with each student filling a different corporate position. For example, one student might function as the product manager, while another would be responsible for research and development.

During the eight-week simulation, where each week is equivalent to a year's worth of business, students learn to assess a variety of situations and come to respect the animated discussions that ultimately lead to more informed decisions.

"This is our second year with the CAPSIM program," says Dunn, "and the students have done very well. The most successful team grew its 'company' from a $100 million to a $350 million operation. That's not bad ... even in a simulated market."

The Importance of a Business Program for **Engineering Majors**

Nikolas Larsen

Shana Blair

Engineering students at Notre Dame are lining up to participate in the two courses offered through the Integrated Engineering and Business Practices Program. As electives, Integrated Engineering and Business Fundamentals and Advanced Topics in Integrated Engineering and Business are giving students what they term "a competitive advantage."

Whether learning how to write a more effective resume or developing better public speaking and presentation skills, students in these courses have been very vocal and very excited about their experiences. "I took the first course in the first semester of my junior year," says Nikolas Larsen, a senior in chemical engineering, "and I am currently enrolled in the second one." By December 2003, more than half of the University's engineering graduates — Classes of 2002, 2003, and 2004 — will have taken the fundamentals course. And, many of the students who take the first course enroll in the second.

Why? According to Larsen and Shana Blair, a senior in the Department of Computer Science and Engineering, the courses provide management concepts, knowledge, and skills not typically introduced in undergraduate engineering curricula. "I have always believed that an engineer wishing to end up in a management position should have some kind of background in business," says Blair. "These courses helped me become more confident in myself and in my understanding of business practices so that I can offer extremely competitive technical and business skills to a company. ... I can be a more valuable asset to my company."

and managers, teleconferences with industry executives, and required student presentations.

The second course, **Advanced Topics in Integrated Engineering and Business,** is comprised of three main sections — lecture, case studies and special projects, and the Capstone® Business Simulation software (CAPSIM). Guest speakers and a corporate field trip are also part of the advanced topics course.

During lectures students learn about globalization, outsourcing, and the creation of business plans. Case studies and special projects offer them opportunities to study the successes and failures of others. But the simulation portion of the class is what they seem to enjoy the most.

CAPSIM teams students together in roles that mimic executives in the corporate world. One student becomes the product manager.

Throughout both courses students also study the characteristics of modern industrial leaders. They begin to develop the interpersonal and decision-making skills that will be required of them as managers and leaders.

Another is the competitive intelligence officer. A third might be the marketing manager or human resources professional.

CAPSIM simulations are run every week for a total of eight weeks, and each week's efforts correspond to a year's worth of business. The point is that the simulation provides students with opportunities to practice what they have been learning in class.

"CAPSIM takes our students to a level where they can really experience the dynamic interactions of a company's operations," says Dunn. They learn to assess a multitude of situations, and, because teamwork is encouraged, they come to respect the animated team discussions as precursors to more informed, productive, and beneficial decisions.

Throughout both courses students also study the characteristics of modern industrial leaders. They begin to develop the interpersonal and decision-making skills that will be required of them as managers and leaders.

The fact is that an engineering degree, particularly when paired with a keen understanding of business processes, is very marketable and can be applied in a variety of careers. For example, three presidents and several governors and senators have had engineering backgrounds. Engineers are also represented in the financial community, as well as in manufacturing and academia. Edmund T. Pratt Jr., former chief executive officer of Pfizer; Roberto C. Goizueta, former chairman and chief executive officer of Coca-Cola®; and Arthur Nielsen, developer of the Nielsen rating system, were all engineers.

Notre Dame alumni Larry Augustin, Kevin Connors, and Celeste Volz Ford have also succeeded in the corporate world. Augustin, a 1984 graduate of the electrical engineering department, is chairman of the board of VA Software, a leading provider of collaborative development tools and software. A 1983 graduate of the Department of Electrical Engineering, Connors is a general partner in Spray Venture Partners, a firm that provides capital as well as technical and business expertise to emerging health-care companies. Volz Ford is the founder and chief executive officer of Stellar Solutions, Inc. Since founding the company in 1995, this 1978 aerospace and mechanical engineering graduate has also established the Stellar Solutions Foundation, a venture investing and incubating organization focused on early-stage technology development and market applications.

The bottom line is that engineers can bring technical and problem-solving skills to a wide range of industries. "The challenge," says Dunn, "is learning how to best apply those skills."

Although not a new concept, network embedded systems are being used in novel ways in a variety of research initiatives. From civil structures and defense systems to environmental and health monitoring, networked embedded systems represent the next generation in computing, communications, and technologies, where individual sensors react to, communicate with, organize, and maintain themselves in relationship to each other, to the entire system, and to the environment in which the system is placed.

the winds of change

The American poet James Russell Lowell once said, “There is no good arguing with the inevitable. The only argument available with an east wind is to put on your overcoat.” Change is inevitable, but it can also be exciting. One of the most exciting changes occurring today is the proliferation of embedded systems and the development of large-scale distributed systems which include real-time routing, independent data collection, and autonomous behavior.

“There are two very important notions about embedded systems,” says **Panos J. Antsaklis,** the H.C. and E.A. Brosey Professor of Electrical Engineering. “Most obvious is the fact that they are embedded. You cannot access an embedded system and change its programming as easily as you could that of a computer. As important is that the mission of these little computers – because that’s what a microprocessor is, and embedded systems are made up of microprocessors – is not to ‘compute.’ It is to improve the function of the device in which it is embedded.”

Perhaps the most widely publicized embedded system in consumer products today is the OnStar® service, which is available in a variety of new cars, trucks, and recreational vehicles. OnStar tracks vehicles and assists drivers as needed in real time, providing services such as air bag deployment notification, roadside assistance, stolen vehicle tracking, remote door unlock, and remote diagnostics. But it is just one example of an embedded system.

Embedded systems are prevalent in households around the world. Washing machines, dryers, microwaves, and cell phones all feature embedded systems. They were developed by engineers who embraced the change that has been steadily progressing since Jack Kilby and Robert Noyce first introduced the microchip in the early 1960s. In essence OnStar and other embedded systems take a microprocessor, originally used to analyze data or interact with a desktop user according to a series of commands, and instead program it to interact with the real world. The benefits of using embedded systems in consumer products are obvious; they raise the quality of life by making products more functional and more efficient.

Equally as positive are the benefits derived when embedded systems technology is applied to a variety of research projects, such as the work being accomplished at the University of Notre Dame. Following Lowell’s analogy, faculty in the College of Engineering are not “putting on their overcoats” in an effort to shield themselves from the change but to embrace it. Donning their boots and hats and running headlong into the “east wind,” they are leading the way in developing network embedded systems for research in disciplines not previously employing this type of sophisticated technology.

Tracy Kijewski-Correa, the Rooney Family Assistant Professor of Civil Engineering and Geological Sciences, monitors the static and dynamic performance of several tall buildings in downtown Chicago from Notre Dame's NatHaz Modeling Laboratory. Using the Leica MC500 Global Positioning System (GPS) with Real Time Kinematic potential, Kijewski-Correa and Ahsan Kareem, the Robert Moran Professor of Civil Engineering and Geological Sciences — in collaboration with researchers from Skidmore, Owings & Merrill LLP, and the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario — are able to track the movement of these structures down to five millimeters with data acquired at one-tenth of a second, instead of one minute, intervals. In addition to monitoring the tall buildings, Kijewski-Correa and Kareem utilize a low-rise base station in Chicago to enhance the accuracy of the GPS. The project is funded by the National Science Foundation.

For example, as part of a National Science Foundation study, **Ahsan Kareem,** the Robert Moran Professor of Civil Engineering and Geological Sciences, and Rooney Family Assistant Professor **Tracy Kijewski-Correa** are using networked embedded devices to monitor the structural performance of several tall buildings in Chicago. They are working with Skidmore, Owings & Merrill LLP (SOM), one of the world's premier architecture and engineering firms and the company responsible for the design of structures such as the Sears Tower, the Lever House in New York City, and the Bank of America World Headquarters in San Francisco. Another partner in the study is the Boundary Layer Wind Tunnel Laboratory of the University of Western Ontario, a world leader in commercial wind tunnel testing.

"We've been interested in how wind affects the performance of tall buildings for several years," says Kareem. "This particular study focuses on some of the signature structures in the world, which were designed and built at a time when scale-model testing and computer modeling were not as advanced as they are today. We want to determine if the structures are behaving in the manner for which they were designed."

Questions Kareem and the research team, known as Team Chicago, are asking include: Were the procedures used at the time of the structures' design representative of realistic loadings and response? Are the structures performing as expected? And, if they are not, how does that impact design criteria for the next generation of urban structures?

Hour by hour the sun and the rain, the air and the rust, and the press of time running into centuries, play on the building inside and out and use it.

— Carl Sandburg, Skyscraper

Modeling technologies have changed over the years, but cityscapes have also changed. The urban landscape of Chicago, for instance, is much more developed than it was a few decades ago, when buildings like the Sears Tower and the Aon (Amoco) Building were designed. Thus, the wind travels through cities and buffets buildings in a much different manner than it did in the early 1970s.

Kareem and Kijewski-Correa are using traditional monitoring devices, such as anemometers and accelerometers, in conjunction with cutting-edge technology such as the Leica MC500 Global Positioning System (GPS) with Real Time Kinematic potential. Four accelerometers have been mounted in pairs in opposite corners on the highest floor of each building in the study. This positioning enables detection of a building's motion along its two lateral perpendicular axes, as well as twisting movements.

"We use high-precision servo-force balance accelerometers," says Kijewski-Correa, "because these buildings move at very low amplitudes and with long periods. It's not like measuring a seismic event, where you see much larger levels of motion."

According to Kareem, stand-alone implementation of this technology does not provide sufficient accuracy to monitor building displacements as indicators of performance. In order to make corrections for atmospheric conditions that affect the GPS signal, he and Kijewski-Correa use a low-rise structure in the city as a base station. This differential monitoring reduces errors to as little as five millimeters. Using this measurement protocol, the Notre Dame team can monitor a building's movements every one-tenth of a second. (A real-time feed of the data can also be used by owners in the daily management of the buildings in the study, including the operation of elevator systems and skydecks.)

"What's important to remember is that even before

High-precision Columbia sensors are placed in pairs in opposite corners of the top floor of each building in the study. This allows researchers to detect the motions of the structures along lateral perpendicular axes, as well as twisting motions. An ultrasonic anemometer and Global Positioning System antenna, shown above, are also utilized in the study. Before installing any hardware, however, the Notre Dame team spent two years calibrating the sensors to the urban environment in order to assure reliable measurements.

Embedded: It's a way of life.

When Jack Kilby and Robert Noyce first introduced the microchip in the early 1960s, they drastically changed the course of the computer industry by transforming room-sized machines into an array of mainframes, mini, and personal computers. Their chip was used to make computers. But it touched many other industries as well: education, transportation, manufacturing, and entertainment. In fact, the impact of the microprocessor on the life of the average person has been likened to the changes wrought by the Industrial Revolution.

Today, microprocessors are literally everywhere. And the number of chips being manufactured to meet an ever-growing consumer demand is enormous. More than a quarter of a billion microprocessors are built and sold every month.

But they are not manufactured for traditional computer applications. Instead, these chips are embedded in products such as washing machines, dryers, dishwashers, refrigerators, televisions, stereos, automatic garage door openers, microwaves, and cell phones. In fact, it's difficult to name an electronic or electro-mechanical device in a home today that does not feature one or more embedded microprocessors.

There are approximately 50 microprocessors in an average middle-class American household today. Add a personal computer and that number jumps to 60. Add a car, depending on the model, and the number of microprocessors in a typical household doubles. In fact, on any given day, an individual might interact with as many as 70 microprocessors before lunch.

While microprocessors are found in household products, they are also present in children's games, toys, and a variety of other devices. The recently introduced Segway, a self-balancing people mover, contains 10 microprocessors. The Mercedes C-Class sedan features 153 microprocessors and offers an optional satellite-based communication system, stock updates, and emergency assistance.

The most exciting thing about microprocessors is that there is no such thing as a "typical" embedded system. But they all have one thing in common: Embedded processors are being used by a variety of industries and researchers in a number of different ways to help improve the way people live.

The Adaptive-optic Challenge

Aero-optics is the study of the interaction of light with a turbulent flow. The light could emanate from distant space objects or celestial bodies, or it could be a laser beam. In general, the interaction of these optical signals with turbulent air has a degrading effect, which is why stars appear to twinkle. This effect is particularly devastating to the quality of a laser beam projected from an aircraft, where the thin layer of turbulent air surrounding an aircraft can reduce the focus of a laser on a distant target to less than 1 percent of its intensity.

Airborne imaging faces a similar challenge; for example, an airborne camera might be able to image a vehicle from 60,000 ft. with sufficient resolution to identify it as a car, but it may not be able to read the license plate. Using high-speed wavefront sensors developed at Notre Dame; multiple dedicated, embedded processors; deformable mirror technology; and the Notre Dame Shear-Layer Facility, a team of researchers led by **Eric J. Jumper,** professor of aerospace and mechanical engineering, is preparing to measure the distortion of the laser beam, develop the conjugate of the distortion, adjust a deformable mirror – which will be part of the embedded system, and restore the laser beam's quality by bending the mirror up to 15,000 times per second. In short, the team is developing the technology that will allow an aircraft flying at high Mach numbers to project correctly configured laser beams, a feat thought impossible only a few years ago. "This is a very dynamic process," says Jumper, "so a traditional approach to an adaptive-optic correction was not feasible. We have incorporated flow control, high-frequency non-real-time wavefront sensing, and a new approach to controlling adaptive optics into making this correction. We could not have achieved our successes to date without embedded, dedicated processors. There are too many calculations that need to be made in order to determine the mirror's configuration and compensate for the wavefront aberration efficiently and effectively."

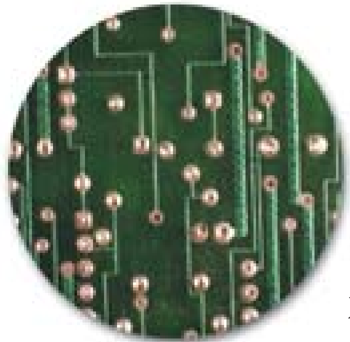
The above circuit board, developed at Notre Dame by Professor Eric J. Jumper and designed by Joel Preston, an electronic specialist in the Department of Aerospace and Mechanical Engineering, features 64 amplifiers, supporting a 4 x 4 sensor array. Four of these arrays will be ganged to form an 8 x 8 array. UDT Corporation is making the sensors, which will line up with the actuators on a deformable mirror, built by Xenetics Corporation. Jumper's research is funded through a contract with Oceanit, a Hawaii-based engineering, science, and research company under the sponsorship of the Air Force Office of Scientific Research. He is also working with the Air Force Research Laboratory, Boeing, and Northrop Grumman.

we installed the hardware and began collecting data, we spent two years calibrating the equipment in relation to the GPS system," says Kareem. "Because of this, we are very confident in our data."

Information from the sensors is transmitted to a communications hub in the SOM building in Chicago and then relayed, via the Ethernet, to Notre Dame, where it is archived in a web-assisted database and analyzed. Scale models of the structures and the surrounding built environment are then developed in the Boundary Layer Wind Tunnel to compare the predicted response to full-scale data.

"In essence we're tracking the vital signs of individual structures in order to give us a better indication of in-situ building performance," says Kijewski-Correa. "By using conventional and advanced sensors, Notre Dame is taking the lead in the integrated monitoring of tall structures. We are not designing the sensors themselves, but we have adapted and prototyped a networked configuration of these devices for capturing signals peculiar to long-period civil structures. Our findings could directly impact the architectural and structural communities for years to come."

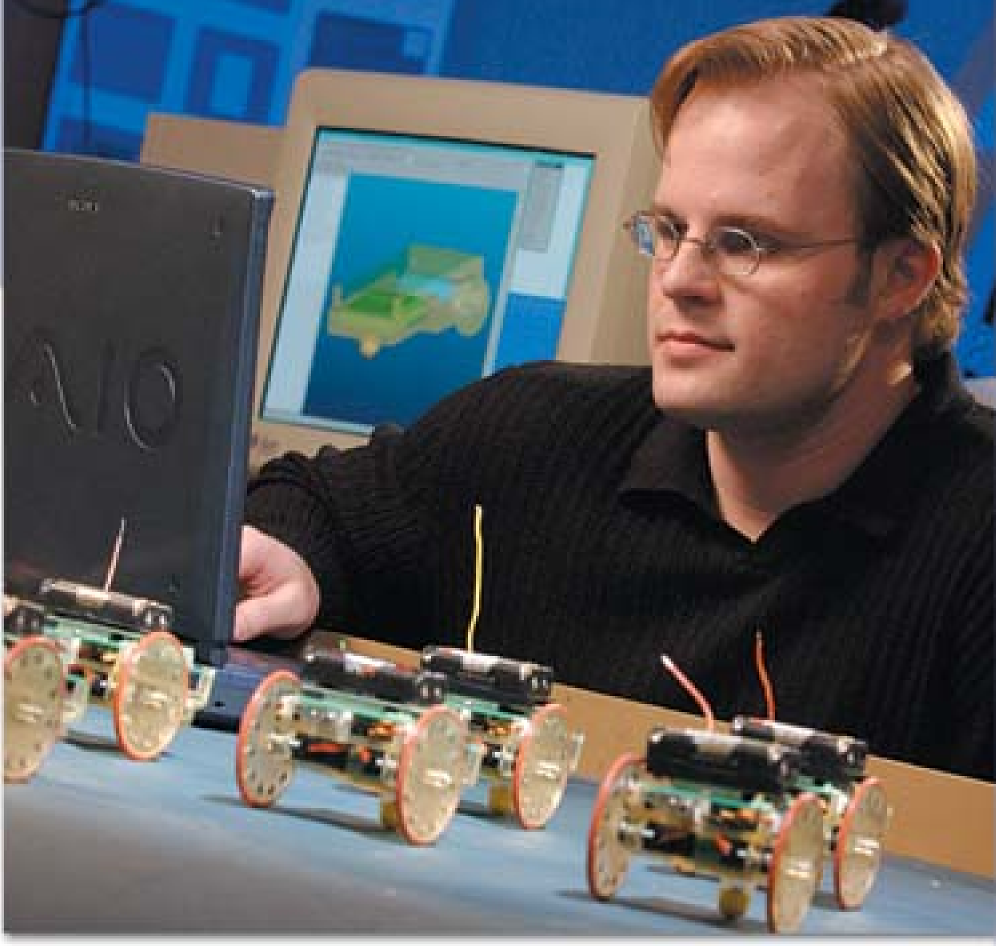
According to **Martin Haenggi,** assistant professor of electrical engineering, networked embedded systems can also be placed in natural environments, enabling researchers to observe any kind of habitat at the scale and in the amount of detail that has never before been possible. Haenggi and a team of researchers from throughout the College of Engineering are developing an embedded sensor network for monitoring the hydrology and ecology of freshwater lakes and streams, the Naiades project.



Named for the nymphs of rivers, lakes, and streams of Greek mythology, Naiades represents what will be a five-year collaborative effort between researchers in the Department of Electrical Engineering and the University's Center for Environmental Science and Technology (CEST), including team leaders **Patricia A. Maurice,** professor of civil engineering and geological sciences and director of CEST, and **Michael D. Lemmon,** associate professor of electrical engineering. Other faculty currently involved in the project are Antsaklis; Haenggi; **Sharon Hu,** associate professor of computer science and engineering; **J. Nicholas Laneman,** assistant professor of electrical engineering, **Agnes E. Ostafin,** assistant professor of chemical and biomolecular engineering; **Jeffrey W. Talley,** assistant professor of civil engineering and geological sciences; and George Hornberger, the Ernest H. Ern Professor of Environmental Sciences at the University of Virginia.

"The Naiades project," says Maurice, "has the potential of greatly enhancing our knowledge of the hydrologic cycle, water quality, pollution, the potential effects of microorganisms, and even biological warfare. It's an innovative solution to building better environmental models so we can better understand our world and what impacts it."

According to J. Nicholas Laneman, assistant professor of electrical engineering, one of the unique aspects of the University's research in networked embedded systems is the test bed located in the Department of Electrical Engineering. The test bed — developed by H.C. and E.A. Brosey Professor Panos J. Antsaklis, Associate Professor Michael D. Lemmon, and Assistant Professor Martin Haenggi as part of the Network Embedded Software Technology project and funded by the Defense Advanced Research Projects Agency — is one of a handful of such facilities in the country. It allows researchers and students, like doctoral candidate Qiang Ling, shown here, to build and validate their networks in order to help determine the best ways to develop hardware and software, as well as ways to improve network communication and node performance while operating on limited power. The new protocols developed as a result of this type of research may eventually be used for the long-term autonomous monitoring of a variety of systems, from large-scale manufacturing applications and social networks to monitoring the habitats of endangered species.



Brett McMickell, above, a graduate student in the Department of Aerospace and Mechanical Engineering, and Assistant Professor J. William Goodwine have designed and built prototypes of mobile robots (motes), using the same University of California-Berkeley microprocessor employed by the Naiades team, and an experimental hardware platform that focuses on maintaining a robust and reliable ad hoc network. Each of the motes McMickell and Goodwine have built communicates through radio frequencies to identify where its neighbors are and to maintain a specific formation when mobile. Goodwine's work in control theory is funded by the National Science Foundation.

Current technology dictates that a researcher seeking to understand the physicochemical reactions that occur in a lake or stream has to either collect samples — physically go to the lake or stream, gather water, and take it back to a lab for testing — or set up a commercial sensor in the water to record variables in things like pH or conductivity. The trouble has been that the real world involves a variety of spatial and temporal scales not addressed by these testing methods. Although researchers gather samples under a variety of conditions, they do not normally collect data during sub-zero temperatures or thunderstorms. In addition, even the most accurate commercial sensors have been limited in the number of samples or amount of information they could record or process.

Naiades will differ from current technologies in two very important ways. First, the system will be an internet of control area networks connected through wireless gateways that link simple sensors — measuring things like temperature, conductivity, turbidity, flow, and ambient light — to bacterial sensors and bulk water samplers, which will measure major cations, anions, metals, and pesticides. Secondly, the system will feature underwater nodes and surface base stations, each with an embedded computer. The wireless ad hoc network formed by the base stations, the Naiades subnet, will be able to automatically reconfigure routing pathways based upon the local analysis performed by the sensors, individually and collectively.

A lake is the landscape's most beautiful and expressive feature. It is the earth's eye; looking into which the beholder measures the depth of his own nature.

— Henry David Thoreau, *Walden*

Information gathered by the system could be used for immediate needs, such as issuing alerts to the appropriate agencies of increased E. coli levels in beach areas or for long-term research projects. Field tests, scheduled to begin

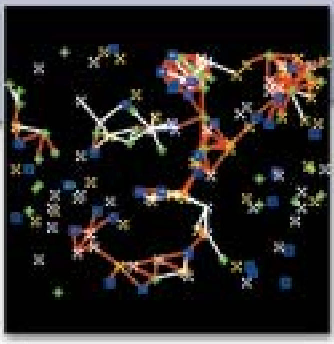
The Multidisciplinary Microprocessor

Thomas R. Szarek, a graduate student in the Department of Aerospace and Mechanical Engineering, loads a student designed microcontroller-based system featuring two sensors into a model rocket. Using the microcontroller, undergraduates in the department can measure the acceleration and velocity of the rocket as it is launched and determine its final height. Szarek, working with Professor Patrick F. Dunn and Thomas C. Corke, the Clark Equipment Professor of Aerospace and Mechanical Engineering, has developed the rocket project in order to focus on the use of embedded systems for data acquisition. Undergraduates build on this project and the concept of using microcontroller-based systems throughout their studies with an effort culminating in AME 441: Senior Design, when they design and build an airplane and program it to fly autonomously.

Throughout the course of their studies, undergraduates in the Department of Aerospace and Mechanical Engineering learn how to design aircraft. As important, they learn how to design and build a series of microcontrollers – tiny embedded systems operated by rechargeable batteries – that features a global positioning system, accelerometers, pressure transducers, thermocouples, an analog-to-digital converter, and a transmitter. The purpose of designing these microprocessors is two-fold: to introduce undergraduates to the interdisciplinary nature of engineering today via the building block of all mechatronic systems and to address real-world applications. This is particularly important, says graduate student Thomas R. Szarek, "because digital processors are finding their way into more and more, and smaller and smaller, technologies."

According to **Thomas C. Corke,** the Clark Equipment Professor of Aerospace and Mechanical Engineering, there is an increasing need for remote controlled aircraft, particularly for data collection. "The obvious need is a military one for reconnaissance and tracking, such as the drone planes that flew over Iraq. By using remote piloted aircraft for these types of missions, human lives were not put at risk," says Corke.

"But there's also a lot of interest in using these autonomous aircraft as environmental monitors," he says. In fact, one of Corke's students is conversing with the forestry service in Florida about the possibility of using a remote piloted plane to follow migratory animals. The embedded system in such a vehicle could trace the paths of animals tagged with radar transmitters, but it could also track them visually via an embedded pattern recognition program. In addition, these aircraft could be used to measure air and water quality. And, using infrared sensors, they could monitor thermal pollution. "The idea," says Corke, "is that all the information is gathered by the embedded system and then transmitted to a receiver on the ground. It's less expensive than sending up manned flights, and, because of that, it would be possible to operate more aircraft, cover larger areas, and collect more data."



Graduate student Bren Mochocki is working with Gregory R. Madey, associate professor of computer science and engineering, to develop an agent-based simulation of an ad hoc sensor network. The goal of this project is to help identify the types of routing protocols useful in a network while also tracking how messages flow through a network. The graphic shown above was captured from one of the simulations run using Mochocki's research.

in year three of the project, will focus on detecting, forecasting, and monitoring storm events and diel (day/night) fluctuations.

The Naiades project also includes several educational objectives. A learning module will be developed for the University's first-year engineering course sequence. Information from the project will also be incorporated into the curriculum of CE 498/598: Introduction to Environmental Engineering and Science and a graduate course on water-rock interactions. Graduate students involved in the project will participate in a one-credit-hour interdisciplinary special topics course to be taught by project faculty. And, an interdisciplinary workshop on environmental sensors will be held on campus during the final year of the project.

Perhaps one of the most attractive elements of this interdisciplinary effort is that researchers will not have to travel far to find a natural laboratory in which to test the system they are creating. The Naiades system will first be tested in the two lakes on campus, St. Mary's and St. Joseph's, in order to develop accurate predictive models of algal blooms, an important environmental question that would benefit from the high-resolution, real-time data collection offered via the Naiades system.

Unfortunately, the solution — using embedded systems to better monitor the real world — is not as straightforward as it seems. "Embedded processors and their proliferate use, such as the development of the Naiades project," says Antsaklis, "is driven by the fact that we are able to cheaply manufacture these devices. But, you cannot simply set out a group of processors and expect them to act together in a coherent fashion in relationship to the real world. It simply will not happen without a tremendous amount of planning and a detailed understanding of hybrid dynamical systems."

According to Antsaklis, when a system is distributed, so is the information. No single node contains all the information, and no single node acts as the command center. "The traditional notions of communications are challenged," he says. "One of the first considerations in a network is to establish a path along which the nodes communicate. In addition, there is a lot of protocol software that needs to be written or refined to ensure that the processors are synchronized with one another and with the real world. And, finally, because they are out in the real world ... some of them miles away from a power source ... they need to be able to operate on small batteries or solar power." These are some of the issues being addressed by the Naiades team.

Under the supervision of Professor Panos J. Antsaklis and graduate student Luis Montestruque, seniors Kevin McGirr, shown here, and Travis Cuprak use wireless embedded controllers to coordinate the movements of two model helicopters.

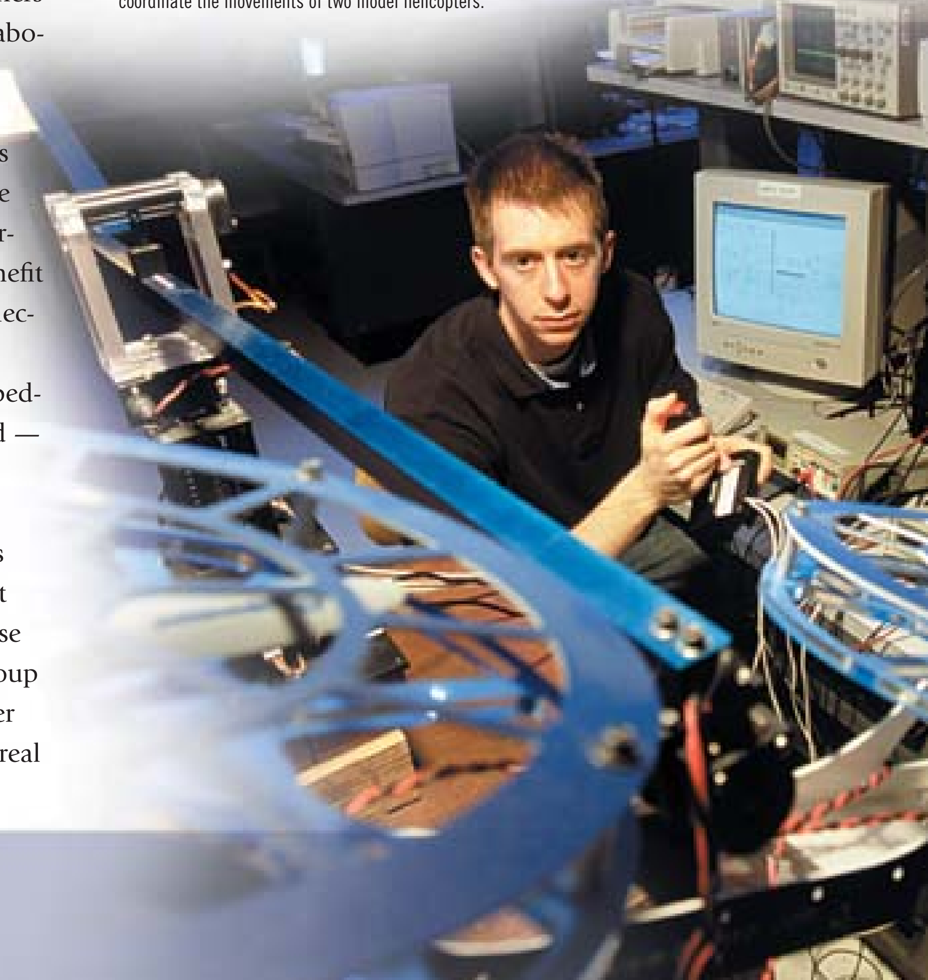


Photo: Heather Gollatz

In Greek mythology the Naiades — nymphs of rivers, lakes, streams, brooks, and marshes — were often imbued with supernatural powers and worshiped in conjunction with the gods of healing, fertility, and growth. At Notre Dame Naiades is the title of an embedded sensor network project designed to monitor the hydrology and ecology of freshwater lakes and streams. The project, focused on developing predictive models of algal blooms, will study St. Mary's and St. Joseph's lakes on campus. Using a networked array of sensors, faculty and students — such as Professor Patricia A. Maurice, left, and Leilani Arthurs, a graduate student in the Department of Civil Engineering and Geological Sciences — will monitor temperature, conductivity, algae biomarkers and by-products, and light in order to determine the trigger mechanisms for algal blooms and to develop and verify high-resolution spatio-temporal models of algal blooms and decays.

When they are successful in developing these intelligent sensors and flexible embedded systems, they will have made a quantum leap in environmental monitoring. This knowledge can then be applied to defense systems, to health monitoring, to the coordination of satellites or traffic systems ... the list is endless. But, the change is inevitable. The novel ways University researchers are employing networked embedded systems to collect data will usher in improvements to the way skyscrapers are designed, aircraft are built, and the environment is monitored. These changes may not inspire a 21st-century Sandburg or Thoreau to wax eloquent about the nodes, motes, or actuators, but the changes which will be implemented from the information gained will help build a better world.

FOR MORE INFORMATION ON NETWORKED EMBEDDED SYSTEMS TECHNOLOGY AND RESEARCH IN THE COLLEGE OF ENGINEERING, VISIT:

CENTER FOR ENVIRONMENTAL SCIENCE AND TECHNOLOGY
http://www.nd.edu/~cest/

DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING
http://www.nd.edu/~ame/

DEPARTMENT OF ELECTRICAL ENGINEERING
http://www.nd.edu/~ee/

NATHAZ MODELING LABORATORY
http://www.nd.edu/~nathaz/
http://windycity.ce.nd.edu/

University Establishes Environmental Molecular Science Institute

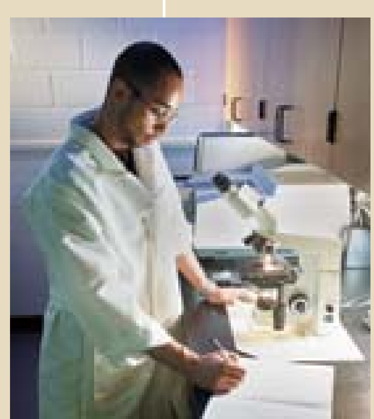
In addition to research activities — which focus on the process of bacteria binding heavy metals or actinides, as well as natural organic matter and mineral aggregates and their roles in the environment — the Environmental Molecular Science Institute (EMSI) has partnered with the National Consortium for Graduate Degrees for Minorities in Engineering and Science to provide a master's program in environmental molecular science. EMSI also offers a number of innovative educational opportunities for students studying environmental molecular science.

Created in July 2002 and funded by the National Science Foundation and the Department of Energy, the Environmental Molecular Science Institute (EMSI) at Notre Dame is one of six such facilities in the country. The goal of EMSI is to bring engineers and scientists together in order to better understand, model, and predict the interaction between microparticles and heavy metals in the environment.

"Although invisible to the human eye, we know there are nano- and microparticles in the ground," says **Jeremy B. Fein,** professor of civil engineering and geological sciences and director of the newly created institute. "What we've found is that these microparticles interact both with the minerals that make up the geologic matrix and with dissolved contaminants. In fact, they strongly influence how metals, organic solvents, and other contaminants are distributed in soil and groundwater aquifers."

While groundwater is generally considered a safe source of drinking water, pollutants from a variety of sources, including landfills, chemical storage tanks, agricultural operations, hazardous waste sites, and mining operations, threaten to contaminate water supplies. The interaction between microparticles and other substances in the environment — such as the process of bacteria binding heavy metals or actinides — is one of three focal points of EMSI. The institute is also studying natural organic matter and mineral aggregates and their roles in the environment.

"Perhaps the most important task we have," says Fein, "is to accurately model the transport and fate of contaminants in the environment. It is obvious from the poor record in cleaning up Super Fund sites that no one fully understands the molecular-scale chemistry occurring at contaminated sites. EMSI researchers are working to develop models that can be used to make groundwater cleanup efforts more efficient and to design more effective containment treatment strategies."



All activities in the institute, whether focusing on organic or inorganic systems, integrate traditional macroscopic and microscopic techniques with state-of-the-art molecular-scale approaches, such as X-ray adsorption spectroscopy, atomic force microscopy, and molecular dynamics modeling. Researchers, centered at the University, are working closely with their counterparts at Argonne, Oak Ridge, and Sandia National laboratories and DuPont Engineering Technology. These collaborative efforts pool expertise from a wide range of environmental sciences, including aqueous and organic chemistry, actinide chemistry, environmental engineering, hydrology, microbiology and geomicrobiology, mineralogy, molecular dynamics modeling, physics, and surface chemistry.

"According to our initial investigations, there appears to be a common structure in the bacterial cell wall that will make predicting interactions much easier," says Fein. "We anticipate that the insights we have already gained and the information we have yet to uncover will continue to provide clues to responsible and economic ways to protect the environment and preserve it for future generations."

Silliman Named Associate Dean

Stephen E. Silliman, professor of civil engineering and geological sciences, has been named associate dean of educational programs. In addition to his teaching and research duties, Silliman is responsible for the development and coordination of cross-disciplinary curricula within the college, as well as soliciting federal and industrial funds to support innovative educational opportunities for engineering students.

Author of numerous articles pertaining to hydrology, Silliman has successfully combined his professional expertise with a commitment to service that characterizes the University. For several years he has led a joint student venture between the Department of Civil Engineering and Geological Sciences and the Center for Social Concerns. He and teams of students annually spend a week in Haiti repairing hand-pump wells, which are the primary water supply in rural regions of the country. They train villagers in the maintenance and repair of these pumps, and they teach them to manufacture inexpensive parts equivalents.

Silliman, fellow faculty, students, and colleagues at the Universite Nationale du Benin have launched similar efforts in the Republic of Benin in western Africa. For his efforts Silliman was awarded the 2002 Grenville Clark Award, presented annually to a faculty member, administrator, or student "whose voluntary activities serve to advance the causes of peace and human rights." Most recently, he received the 2003 Outstanding Teacher of the Year Award from the College of Engineering.

His research interests include groundwater hydrology flow and transport in heterogeneous media, stochastic hydrology, groundwater-surface interaction, microbial transport, water source protection, and Third World water supplies. He has a been a member of the faculty since 1986.

Photo: Wes Evard

University efforts relating to the environment and environmental issues were the topic of the inaugural Symposium on Notre Dame Environmental Education and Research. Joan F. Brennecke, the Keating-Crawford Professor of Chemical and Biomolecular Engineering; Patricia A. Maurice, professor of civil engineering and geological sciences and director of the Center for Environmental Science and Technology; and Jennifer A. Tank, the Ludmilla F., Stephen J., and Robert T. Galla Assistant Professor of Biological Sciences, planned the event, which featured speakers from the Department of Economics as well as the newly created Environmental Molecular Science Institute.

Symposium on Environmental Education and Research Inaugurated

More than 120 faculty and students attended the first Symposium on Notre Dame Environmental Education and Research (NDEER) in November 2002. Sponsored by the colleges of engineering and science and the Center for Environmental Science and Technology (CEST), the symposium featured several faculty presentations, a student poster session, and a keynote address by Diane McKnight, professor of civil, environmental, and architectural engineering at the University of Colorado.

"The purpose of the symposium," said **Patricia A. Maurice,** professor of civil engineering and geological sciences and director of CEST, "was to highlight the depth and diversity of environmental research occuring throughout the University. As the symposium progressed, it became apparent that University efforts relating to environmental issues touch more than engineering or science faculty, and we were able to develop closer ties among a multidisciplinary group of faculty focused on a single issue."

For more information on environmental research efforts at Notre Dame, visit **http://www.nd.edu/~cegeos.**

Notre Dame Team Receives EPA Star Grant

A multidisciplinary University team of researchers from the colleges of engineering and science, in conjunction with researchers from the University of Minnesota-Duluth and the University of Oregon, was one of four groups to receive a grant from the Environmental Protection Agency's (EPA) Science to Achieve Results (STAR) program.

The team will be studying the effects of global climate changes on aquatic ecosystems. According to team member **Patricia A. Maurice,** professor of civil engineering and geological sciences and director of the Center for Environmental Science and Technology at Notre Dame, "By better understanding how climate changes affect these systems, we hope to be able to develop strategies to reduce or avoid damage in the future."

While team members will be focusing on the Ontonagon River in northern Michigan, they will also conduct a variety of tests at the University of Notre Dame Environmental Research Center in Wisconsin. Team members include: Maurice; Scott D. Bridgham, associate professor of biology at the University of Oregon; Carol A. Johnston, senior research associate, Natural Resources Research Institute, University of Minnesota-Duluth; Gary A. Lamberti, professor of biological sciences; David M. Lodge, professor of biological sciences; and Boris A. Shmagin, research associate, Department of Geological Sciences, University of Minnesota-Duluth.

College Establishes Women's Engineering Program to Recruit and Retain Students

Universities typically expect some attrition during the first year of studies, particularly in regard to a technologically demanding major, such as engineering. One area many institutions have been addressing is the higher attrition rate of women than men from engineering programs. Notre Dame is no exception. For example, for the Class of 2005, 25 percent of the men and 52 percent of the women enrolled in the engineering program opted out between the beginning of their freshman and start of their sophomore years. Although losing 52 percent of the women in a class sounds alarming, the overall number of undergraduate women in the Notre Dame engineering program is 21 percent; the national average is 19 percent.

According to **Cathy Pieronek,** director of the Women's Engineering Program (WEP), "Part of the attrition we're seeing is expected during the first year a student is at the University." Each engineering intent, male or female, is required to take EG111/112, the first-year course sequence designed to introduce freshmen to engineering. The sequence allows students to explore each engineering discipline offered in the college while also examining the career options available for engineers. "It's not unusual to experience a 25 percent drop after the first year," says Pieronek. "The sequence is successful when it helps students decide very early in their careers if engineering is an appropriate choice for them. The problem is that women who would make excellent engineers are also leaving."

Notre Dame and other universities are working to understand the reasons women shy away from engineering, which is why recruitment and retention are two of the key areas on which the WEP is focusing. "Because of the many different reasons for the high attrition rate," says Pieronek, "there will not be a single solution. But we believe that one of the main factors is the quality of relationships between women engineering students."

Junior mechanical engineering major Michaele Carney agrees. "Being a female engineer is tougher than many people think and not just because of the classes. So few of your friends in the dorm can relate to you on a technical level. When I want to discuss a current project or an interesting fact, they might be excited for me, but they aren't always as enthusiastic and they don't understand why I'm excited, like another female engineer would."

Meghan Roe, an officer of the Notre Dame section of the Society of Women Engineers, has experienced the difference a mentoring relationship can make — both as a freshman and now as a junior chemical engineering student. "When I was a freshman, the junior chemical engineer down the hall from my dorm room was a huge encouragement to me because she was making it through a tough program and seemed to be having a lot of fun. Now I'm able to help freshmen transition from high school to college and give them some additional support. Hopefully, through my actions, they will be able to see the benefits of staying in engineering."

Roe's sentiments mirror the goals of the WEP, which was established by the College of Engineering in 2002. The program focuses on developing activities that encourage young women in the study of engineering, supporting first-year women engineering students as they enter the college's program, and providing opportunities for all women engineers to develop leadership skills.

"One very valuable thing we can do for the young women in our program," says Pieronek, "is to share success stories with them. Our alumnae have accomplished remarkable things using their engineering degrees. Upper-level and graduate students can also serve as models and mentors for students. Although we're a new program, I believe we are well on the way to meeting our goals."

For more information about the WEP, visit **http://www.nd.edu/~engwomen.**

Established by the College of Engineering in July 2002, the Women's Engineering Program works with students, industry, and alumni to develop activities that encourage young women — particularly first-year students — in the study of engineering. Elements of the program include career information seminars, leadership training, alumnae and special guest lectures, peer group development, a mentoring program, and community-building activities. Shown here are, left to right, Nicole Wykoff, president of the Notre Dame section of the Society of Women Engineers (SWE); Allyson Swanson, SWE representative to the college's Joint Engineering Council; Cathy Pieronek, director of the Women's Engineering Program; Carolyn Lauer, SWE treasurer; Meghan Roe, SWE secretary; and Jenna Spanbauer, SWE vice president.

Society of Women Engineers: More than 50 Years of Service

"Women think that an engineer is a man in hip boots building a dam," said Beatrice A. Hicks, the first president of the Society of Women Engineers (SWE). Originally cited in a 1952 article in *Mademoiselle,* this is just one of the misconceptions that SWE has battled for more than 50 years.

A nationally recognized, nonprofit organization whose membership includes professional, graduate, and undergraduate female and male engineers, the mission of SWE is to increase awareness of the opportunities for women in engineering while also helping them overcome some of the challenges they may encounter during their academic and professional lives. Career guidance, mentoring programs, scholarships, awards, and service projects are some of the tools that both the national and university sections of SWE have used to encourage and support women in engineering.

In March 2003 volunteers from the Notre Dame section of the Society of Women Engineers helped members of Junior Girl Scout Troop 22 from Prairie Vista Elementary School in Granger, Ind., earn their technical merit badges. This was one of the many community service projects that SWE students participated in throughout the year. In addition to proving to be a fun time for all involved, it served to encourage the elementary students to continue their studies in math and science by modeling successful women engineering undergraduates. It was also a great way to introduce engineering as a career option for girls.

For more than 20 years the Notre Dame SWE section has encouraged women in the College of Engineering to reach out to one another and to the community. Students from the current section are active in the South Bend area, whether working with local Girl Scout troops to earn technical merit badges, volunteering for science demonstrations at the Robinson Community Center, or participating in "Expanding Your Horizons in Science and Mathematics," a University sponsored career conference for sixth- to eighth-grade girls.

Notre Dame SWE members also encourage one another through student-to-student mentoring, dorm community activities, monthly meetings, and special speakers. For example, one of the featured speakers this year was Kristen Carey, a 2002 graduate of the civil engineering and geological sciences department. Carey, a field manager for Turner Construction, is currently working on the renovation of Chicago's Soldier Field.

Officers for the 2002-03 academic year were: Nicole Wykoff, president and a junior in electrical engineering; Jenna Spanbauer, vice president and a senior in mechanical engineering; Meghan Roe, secretary and a junior in chemical engineering; Carolyn Lauer, treasurer and electrical engineering senior; and Allyson Swanson, liaison to the Joint Engineering Council and a junior in the Department of Civil Engineering and Geological Sciences.

For more information on the Notre Dame SWE section, visit **http://www.nd.edu/~swe.**

Beatrice A. Hicks, a founder and the first president of the Society of Women Engineers, was also the first woman engineer employed by the Western Electric Company and the first to receive a doctorate in engineering from Rensselaer Polytechnic Institute. A pioneer in the design, development, and manufacture of pressure and gas-density controls for aircraft and missiles, Hicks was inducted into the National Women's Hall of Fame in 2001 for her professional achievements and her tireless efforts to gain recognition for women engineers at a time when less than 1 percent of the employed engineers in the United States were women.

Photo: Society of Women Engineers Collection, Walter P. Reuther Library, Wayne State University

Second Phase of GE Learning Projects Funded

In 2000 the General Electric Fund awarded a $300,000 grant to the University in support of the development of innovative, interdisciplinary curricula and teaching modules for undergraduates. Among the criteria for each module was that it help bridge traditional disciplinary boundaries and provide students with experiences that highlight the interfaces between disciplines, enhancing their education and better preparing them for careers in engineering.

The initial set of modules, which included projects focusing on microcontroller interfacing, microelectromechanical systems, and the degradation of organic contaminants in groundwater flows, were created for the 2001-02 academic year. Three more projects have been developed and are being implemented for the current academic year. The new modules focus on building complete autonomous robots, remote sensing and data acquisition using a microprocessor-based system, and satellite communications.

Using the "building complete autonomous robots" module, students from the departments of aerospace and mechanical engineering and computer science and engineering will be able to experiment with a robot at various stages of its development as a complete system while also exploring the variety of tasks which can be assigned to the mechanism itself. As they create the six-legged robot, the course requirement, they will be able to rely on the functional implementations of the other disciplines — such as vision control, artificial intelligence, and navigation — which are being prepared by faculty and will be stored in the Engineering Learning Center.

Students will also learn how to use microcontrollers for data acquisition in the "remote sensing and data acquisition using a microprocessor-based system" module. Throughout the course of the module, they will explore the data acquisition process and learn how to analyze data and draw meaningful conclusions. Faculty from aerospace and mechanical engineering and electrical engineering developed this module.

The "satellite communications" module creates a bidirectional communication link — satellite-earth, providing hands-on activities for undergraduates in the electrical engineering and aerospace and mechanical engineering departments. Students using this module will learn how to map antenna patterns and take field measurements, but they will also gain practical experience in developing communication link budgets and estimating orbital elements from acquired signal parameters.

department news

AEROSPACE AND MECHANICAL ENGINEERING

Batill Named Department Chair

Professor **Stephen M. Batill**, a faculty member since 1978, has been named chair of the Department of Aerospace and Mechanical Engineering. He replaces Robert C. Nelson, professor of aerospace and mechanical engineering, who had served as department chair since 1996.

Long recognized by fellow faculty and students for his innovative approach to engineering education, Batill most recently served as associate dean of educational programs in the College of Engineering. During his three-year term as associate dean, he was actively involved in the development of EG111/112, the first-year engineering course sequence, and the creation of the Engineering Learning Center, a prototype facility that promotes multidisciplinary, hands-on activities.

Batill received his bachelor's, master's, and doctoral degrees — all in aerospace engineering — from Notre Dame. He began his career as an aeronautical engineer at the Air Force Dynamics Laboratory at Wright-Patterson Air Force Base.

In addition to his duties as department chair, course instructor, and researcher, Batill conducts a National Science Foundation sponsored workshop for faculty from other universities to study his team-based design methodologies.

Corke Publishes Book on Aircraft Design

Thomas C. Corke, the Clark Equipment Professor of Aerospace and Mechanical Engineering and director of the Hessert Laboratory for Aerospace Research and the Center for Flow Physics and Control, has published a textbook on aircraft design. The book, released by Prentice Hall in November 2002, divides the conceptualization and design process into 14 elements, demonstrating how the historical aspects of aircraft systems provide the necessary parameters for the design of a supersonic business jet.

Corke has been a faculty member since 1999. His research interests focus on fluid mechanics, specifically hydrodynamic stability; transition of laminar flow to turbulent flow; computational fluid dynamics; aeroacoustics; turblence; and applications of flow control related to these topics.

Mueller Named RAeS Fellow

Roth-Gibson Professor of Aerospace and Mechanical Engineering **Thomas J. Mueller** has been elected to the grade of fellow in the Royal Aeronautical Society of London (RAeS). Cited for his "outstanding contributions to the aeronautical sciences," Mueller is the first member of the Notre Dame faculty to be elected a fellow in the RAeS.

A leading researcher in the area of the aerodynamics of micro-air-vehicles and the complex flow phenomena present at low Reynolds numbers, Mueller has been a member of the Notre Dame faculty since 1965.

Nelson Receives Fulbright Scholar Award

The U.S. Department of State and the J. William Fulbright Foreign Scholarship Board have awarded **Robert C. Nelson,** professor of aerospace and mechanical engineering, a Fulbright Scholar grant for the 2002-03 academic year. Nelson is one of approximately 800 U.S. faculty and industry professionals who will travel to some 140 countries during the year. He will be conducting research and lecturing on aviation safety in Göttingen, Germany.

A member of the Notre Dame faculty since 1975, Nelson's research interests include aircraft stability and control, fluid mechanics, and aerodynamics.

Schmid Named Kaneb Fellow

Steven R. Schmid, associate professor of aerospace and mechanical engineering, has been named a faculty fellow for the 2002-03 academic year by the University's Kaneb Center for Teaching and Learning. Throughout the year Kaneb faculty fellows, who are selected for their accomplishments in discipline-specific areas, share their teaching expertise and experiences via workshops, discussion groups, research, and individual consultation.

Co-author of three books and various journal and conference papers, Schmid specializes in tribology; manufacturing process simulation and optimization; surface generation, measurement, and modeling; and the tribo-characteristics and wear of tool materials and machinery elements. He joined the University in 1993.

http://www.nd.edu/~ame

Automated Wheelchair Offers New Freedom for Disabled People

Steven B. Skaar, professor of aerospace and mechanical engineering, and Linda Fehr, an electrical engineer in rehabilitation research at the Edward Hines Jr. Veterans Administration Hospital, have developed a prototype wheelchair that follows pre-programmed paths with little physical direction from the user. For example, a chair "rider" could steer the device by blowing through a straw, using a bite switch, or actually speaking the commands.

Funded by the Department of Veterans' Affairs and Rehabilitation Research and Development Service, Skaar and associates are halfway through their two-year plan. But the idea was born in 1990, when a company asked him to develop an automatic floor sweeper. From that original concept he continued to refine the navigational technologies that now automate the "smart" wheelchair.

Although the prototype chair has some limitations — only able to move along pre-programmed paths and unable to function accurately out of doors — Skaar compares the chair's potential to that of the early computer. "It can be an incredible tool, enabling users to travel beyond their immediate physical abilities," he says, "but its users will be the ones to chart its ultimate success. There are other 'automatic' chairs available, but we're offering a different approach to the navigational capabilities of the chair along with command flexibility for the user."

Other automated wheelchair projects are under way throughout the world, but very few of them are based in the United States. Many of those already on the market are called "power wheelchairs" with a base price of $4,000. Veterans' Affairs has applied for a patent on Skaar's smart chair, and their researchers are talking with several manufacturers who have exhibited an interest in producing the smart chair.

For more information on Skaar's smart wheelchair project, visit **http://www.nd.edu/~ame/facultystaff/Skaar,Steven.html.**

Department Adopts New Name

In order to better reflect the growth of molecular biology as one of the fundamentals of its research program and undergraduate curriculum, the Department of Chemical Engineering has changed its name to the Department of Chemical and Biomolecular Engineering. As a result, it joins the ranks of departments at institutions such as the University of Illinois and Cornell University, who have recently made similar name changes.

Mark J. McCready, professor and chair of the department, stresses that the department has not abandoned its commitment to traditional chemical engineering. In fact, he credits the understanding and use of traditional chemical engineering principles with the department's ability to offer fundamental knowledge in biomolecular engineering. "Engineering continually progresses," he says. "This particular 'change' is part of the 'directed evolution' of the field, one that promises exciting developments in the near future."

For more than 100 years chemical engineers have been the people who have designed the processes and created the materials society has needed. Originally working with small inorganic and organic molecules and later with polymers, chemical engineers have developed design and analysis techniques that combine a fundamental understanding of chemicals with sophisticated mathematical tools, enabling researchers to accurately describe matter from molecular and nanoscales up to the macroscopic dimensions necessary for commodity production. They have made major contributions to the fabrication of electronic devices, the creation of selective catalysts through nanoscale synthesis, and the production of chemicals and pharmaceuticals using fermentation processes. Today, because of this unique perspective, chemical engineers are becoming leaders in "bio" fields such as tissue engineering, metabolic engineering, and drug delivery.

"Although we're starting activities in the biomolecular area later than some institutions, we have already made significant strides in our research programs, particularly in the areas of drug delivery, biosensors, and nanotechnologies," says McCready. "We're also one of the first engineering programs to develop undergraduate curricula that offers significant life science content integrated throughout the curriculum."

For information on the biomolecular activities and curricula within the department, visit **http://www.nd.edu/~chegdept/Bioengineering.html** and **http://www.nd.edu/~chegdept/Undergrad_Curricula.html.**

Faculty Article on Ionic Liquids Named One of Most Cited Papers in Engineering

The Institute for Scientific Information (ISI) has named an article by **Joan F. Brennecke,** the Keating-Crawford Professor of Chemical and Biomolecular Engineering, as one of the most cited papers in the field of engineering. Titled "Recovery of Organic Products from Ionic Liquids Using Supercritical Carbon Dioxide" and co-written with Lynnette A. Blanchard, the article was published in the January 2001 issue of *Industrial & Engineering Chemistry Research,* a journal of the American Chemical Society.

Blanchard, who received her bachelor's degree from the University of Massachusetts-Amherst in 1995 and her doctorate in chemical engineering from Notre Dame in 2000, is a senior process engineer at Intel Corporation in Boston. She works on Pentium 4 and Centrino Mobile Technology products.

ISI featured this and other select articles on a special topics Web site during May 2003. All featured articles were reviewed by ISI's Essential Science Indicators database. The institute is also surveying each of the authors to gather more info on the papers and their potential impact on engineering and society. For more information on Brennecke's article, visit http://esi-topics.com under the heading "New Hot Papers."

For more information on Brennecke's work to develop environmentally friendly chemical design processes, visit **http://www.nd.edu/~chegdept/Brennecke.html.**

Catalytic Converters Contaminate Roadsides

A team of University researchers led by **Clive R. Neal,** associate professor of civil engineering and geological sciences, has presented data indicating that automotive catalytic converters distribute platinum-group elements (PGEs) — such as platinum, palladium, and rhodium — as far as 50 meters from the roadsides on which the vehicles travel. They are now in the process of examining whether the PGEs dispersed by the devices could enter groundwater supplies or the food chain.

Although catalytic converters reduce the carbon monoxide and hydrocarbons produced from the combustion of a gasoline engine, they are also distributing platinum group elements (PGEs) — such as platinum, palladium, and rhodium — along roadways. Platinum is an allergen. The effects of exposure to palladium and rhodium are unknown. As part of a two-year project, a University team is investigating whether or not PGEs dispersed along roadways are entering groundwater supplies or the food chain.

The team — Neal; Charles F. Kulpa, professor and chair of the Department of Biological Sciences; and James C. Ely, research associate in the Department of Civil Engineering and Geological Sciences — has received a two-year grant from the American Chemical Society to study the environmental impact of the PGEs. They will be testing food crops for the uptake of the elements to determine the extent of penetration. They will also be assessing the economic benefit of "mining" the PGEs.

For more information on the roadside contamination project, visit **http://www.nd.edu/~cneal/petrol.html.**

REU Program Focuses on Three Themes

Funded in part by the National Science Foundation and sponsored by the Department of Civil Engineering and Geological Sciences, the eight-week Research Experiences for Undergraduates (REU) program focused on three areas for 2002 — the development of water resources in Third World countries such as Benin, Chile, Haiti, and Honduras; structural engineering and analysis; and the development and operation of small community mentoring centers.

At the end of the program students participated in a forum in which they shared their experiences through 15-minute presentations. The keynote speakers were Scott Tyler, director of the Hydrological Sciences Program at the University of Nevada-Reno, and Michael Campana, director of the Water Resources Program at the University of New Mexico. Tyler discussed his work in the mountains of northern Chile, while Campana described his efforts in Honduras.

The REU program provides undergraduates from across the United States the opportunity to work with professional engineers, faculty, and other students on collaborative, multidisciplinary teams. While many of the students come from Notre Dame, a significant number are from other institutions. Among the schools represented in the 2002 program were Princeton University, the University of California-Los Angeles, Michigan Technological University, the University of New Mexico, Taylor University, the University of Virginia, and the University of Nevada-Reno.

For more information on the department's REU program, visit **http://www.nd.edu/~reuwater/** and **http://www.nd.edu/~emsi/app03.htm.**

Every year students from across the country participate in the Research Experiences for Undergraduates (REU) program at Notre Dame. The 2002 program focused on three themes and offered a variety of national and international opportunities.

Faculty Called to Active Duty

Jeffrey W. Talley, an assistant professor in the College of Engineering, was deployed to the Middle East in February 2003. "Although he was unable to give us details while he was gone," says Peter C. Burns, Massman Chair of the Department of Civil Engineering and Geological Sciences, "he checked in with us periodically, so we knew he was okay. And, members of our staff sent care packages to him to show our support of his efforts and concern for his safety."

Talley, who returned home in July, is a lieutenant colonel in the United States Army Corps of Engineers (USACE). He is chief of operations for the 416th Engineer Command, which means he is responsible for all engineering missions within the southwest Asia theater. His job during the Iraqi conflict was to organize and control all of the theater Army engineering missions throughout Kuwait and Iraq.

Typical design-and-build assignments for his troops included roads, airfields, base camps, buildings, bridges, enemy prisoner of war camps, water and wastewater treatment plants, and environmental baseline surveys of areas impacted by the war. In addition, he and his troops were instrumental in supporting humanitarian assistance to the Iraqi citizens by returning water and electrical service to numerous Iraqi cities.

Because he specializes in the treatment of contaminated groundwater, soils, and sediments, Talley was called on to assist in various environmental assessment and remediation efforts of different environmental sites in Kuwait and Iraq. Talley also provided environmental assistance to Task Force Restore Iraqi Oil (RIO) at those oil fields destroyed by the former regime. A faculty member since 2001, he has been been in the Army, serving in active and reserve capacities, for 21 years.

Jeffrey W. Talley, left, and Gary Masapollo, assistant professor of military science and instructor in the University's Army ROTC program, posed for this picture at Camp Arifijan in Kuwait. Talley returned home on July 3, 2003.

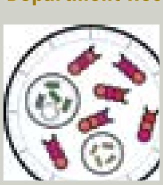
The USACE is made up of approximately 35,000 civilians and 700 military men and women. They are biologists, engineers, geologists, hydrologists, natural resource managers, and scientists. The mission of the corps is to provide "quality, responsive engineering services to the nation including: planning, designing, building, and operating water resources and other civil works projects; designing and managing the construction of military facilities for the Army and Air Force; and providing design and construction management support for other defense and federal agencies."

The corps began in 1775 when the Continental Congress authorized the first chief engineer to build fortifications at Bunker Hill. In 1802 the corps was stationed at West Point and constituted the nation's first military academy. With the founding of West Point in 1866, the corps began a tradition of military and civil works that has continued to the present. Today, the corps is organized into eight national divisions and 41 districts throughout Asia and Europe. It provides a wide variety of services … from disaster relief and electrical power generation and distribution to national water resource planning and ship building management.

http://www.nd.edu/~cegeos

http://www.cse.nd.edu

Department Hosts Swarm Conference



The Department of Computer Science and Engineering and the Swarm Development Group co-sponsored the seventh annual Swarm Users/Researchers Conference (SwarmFest 2003) at Notre Dame in April. During the conference engineers, scientists, modelers, and programmers, who work in a variety of domains, had the opportunity to share their research in multi-agent modeling, including but not limited to the Swarm simulation system.

John Holland, concurrent professor of cognitive psychology and electrical engineering and computer science at the University of Michigan, delivered the keynote address. Holland originated the field of genetic algorithms, a field that may one day allow computers to employ flexible intelligence.

Based in Santa Fe, N.M., the Swarm Development Group is a not-for-profit organization committed to advancing multi-agent based simulation.

Gregory R. Madey, associate professor of computer science and engineering, served as the organizing chair.

Porod Invited to Join Nanoengineering Council

Wolfgang Porod, the Frank M. Freimann Professor of Electrical Engineering and director of the Center for Nano Science and Technology, has been appointed to the NanoEngineering Advisory Council of the International Engineering Consortium (IEC). A newly formed board of leading technologists, scientists, academics, and industry professionals, members of this council will guide and oversee the IEC's development of educational programs as well as the creation of infrastructure required to translate research in nanotechnology into successful commercial applications.

Founded in 1944, the IEC is a nonprofit organization sponsored by universities and engineering societies. It is dedicated to the continuing education of the U.S. electronics industry and encourages close partnerships between academic institutions and industry sponsors.

Haenggi Receives Junior Faculty Award

A faculty member since 2000, Associate Professor of Electrical Engineering **Martin Haenggi** has been selected to receive a Junior Faculty Enhancement Award from Oak Ridge Associated Universities (ORAU). A private, nonprofit corporation consisting of 86 doctoral-granting colleges and universities, ORAU issues these awards annually to faculty members at participating institutions who are in the early stages of their careers.

Haenggi is a member of the Institute of Electrical and Electronics Engineers and co-author of the book *Cellular Neural Networks: Analysis, Design, and Optimization.* His research interests include wireless communications, networks, and nonlinear dynamics.

http://www.nd.edu/~ee

Massey Donates Marconi Prize to Electrical Engineering

James L. Massey, professor emeritus at ETH Zurich in Switzerland and adjunct professor at Lund University in Sweden, presented the Department of Electrical Engineering with the Marconi Award he received in 1999 from the Marconi International Fellowship.

James L. Massey, the University's 1956 valedictorian and the first Frank M. Freimann Professor of Electrical Engineering, left, presented his Marconi Award to Yih-Fang Huang, professor and chair of the Department of Electrical Engineering, during the 2002 Edison Lecture Series.

The Marconi Prize is awarded annually to engineers and scientists in the field of communications who "continue to push forward the frontiers of knowledge."

Massey, the valedictorian of Notre Dame's Class of 1956 , was one of the founders of Codex Corporation — later a division of Motorola — and of Cylink Corporation, Santa Clara, Calif. He also served as Frank M. Freimann Professor of Electrical Engineering from 1962 to 1977, the first endowed professorship at the University.

He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Swiss Academy of Engineering Sciences, a member emeritus of the U.S. National Academy of Engineering, an honorary member of the Hungarian Academy of Science, and a foreign member of the Royal Swedish Academy of Sciences.

Massey's other honors include the 1988 Shannon Award of the IEEE Information Theory Society, the 1992 IEEE Alexander Graham Bell Medal, and the 1987 IEEE W.R.G. Baker Award.

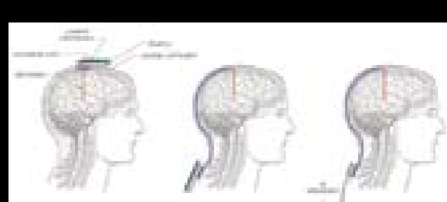
On campus as part of the College of Engineering's Edison Lecture Series, Massey presented a talk entitled "What Can Cryptography Do and What Should It Be Allowed to Do?" during which he addressed the emergence of cryptography as a field for active public research, as well as the opportunities and capabilities it offers.

Controlling Parkinson's with Deep Brain Stimulation

Approximately 1.2 million people in the United States and Canada are affected by Parkinson's disease. A degenerative neurological disorder, Parkinson's attacks a section of the midbrain called the s*ubstantia nigra* and is characterized by rigidity, tremors, slowness or incompleteness of movement, and postural instability — the inability to move or change positions abruptly.

Since there is no known treatment for the disease, health-care givers focus on managing its symptoms. There are four main options: transplantation — replacing the damaged tissue; thalamotomy/pallidotomy — surgical procedures that destroy parts of the brain in order to better control symptoms; drug therapy; and deep brain stimulation (DBS) — the use of a pacemaker-like device to stimulate synaptic activity.

Although many patients opt for DBS over the available surgical procedures, there are drawbacks, which include the size and cost of the "pacemaker." To address these issues, **Gary H. Bernstein,** professor of electrical engineering, and graduate student Jayne Wu are developing an inductively-coupled deep brain stimulator that is much smaller than the current device and can be implanted under a patient's scalp instead of under the skin of the chest.



Deep brain stimulation (DBS) is one of the treatment options available to Parkinson's patients. It often causes less residual damage than other treatments but also has its drawbacks. Gary H. Bernstein, professor of electrical engineering, is working to develop a DBS system that doesn't require major surgery to implant in a patient, can be more easily adjusted to match the severity of tremors, and can conveniently attach to a belt, shirt collar, or hat.

Bernstein, whose other biomedical research activities include collaborative efforts to develop an inductively-powered wireless system for monitoring blood flow, has demonstrated the basic operation of the stimulator. He and colleagues are working to miniaturize the system and the substrate to allow the attachment of the generator to a patient's hat, shirt, or belt.

"Parkinson's was first diagnosed in 1817, and many researchers are working to find a cure, as well as control this disease," says Bernstein. "While we're very excited about the results of this particular project, we still have a lot of work to do."

SIGNATURES

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LED Traffic Light Study Identifies Significant Benefits to Communities Making the Switch from Incandescent Lights

Most people fondly remember childhood games such "Red Rover," "Simon Says," or "Red Light-Green Light," the stoplight game where participants start and stop depending on the command barked out by the leader. Students in the Engineering Projects in Community Service (EPICS) program are looking at traffic commands in a much different light.

In fact, one of the EPICS groups within the College of Engineering is working with city engineers, community leaders, and transportation companies throughout Indiana to implement the replacement of incandescent traffic lights with light-emitting diode (LED) signals.

Shown are, left to right, Tom Silio, Michael Kramer, David Schwartz, Michael Bien, and Douglas Hall, associate professor of electrical engineering.

What the group has found is that, although the LED signals are initially more expensive, they use approximately 90 percent less energy than incandescent bulbs and last up to 10 times longer. Additionally, LED stoplights emit colored light instead of a white light filtered through a colored lens, enhancing the overall visibility of each signal.

Approximately 40 percent of the traffic signals in California have been switched to LED technology, but only 10 percent of the signals nationwide use LEDs. The students are currently performing analyses of the significant energy savings provided by the LED devices and studying methods of financing a community's initial investment in a switchover. They are also developing educational outreach tools for elementary and secondary school students that encompass LED lights and other energy-saving technologies, the role of engineering in society, and the importance of energy conservation to the environment.

Editor's Note: *The EPICS program, founded in 1995 at Purdue University, is designed to partner teams of engineering undergraduates with local service agencies. EPICS students are able to experience the design process from start to finish, develop management and leadership skills, learn to work on an often multidisciplinary team, and assist community organizations in reaching their goals in a timely and economic manner. The Notre Dame program, which has partnered students with local organizations since 1997, is one of six EPICS programs in the country.*