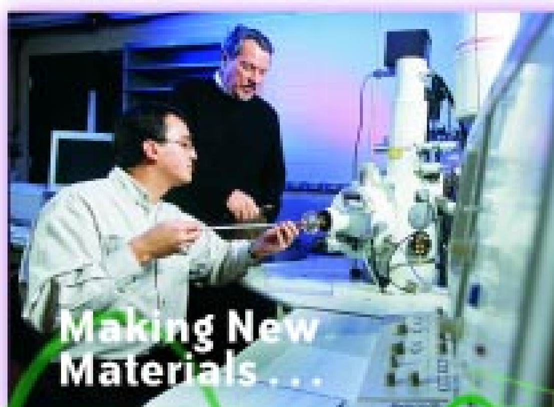
# SIGNATURES

# First-year Engineering Curricula:
## A study in creativity



## Making New Materials . . .
One Reaction at a Time

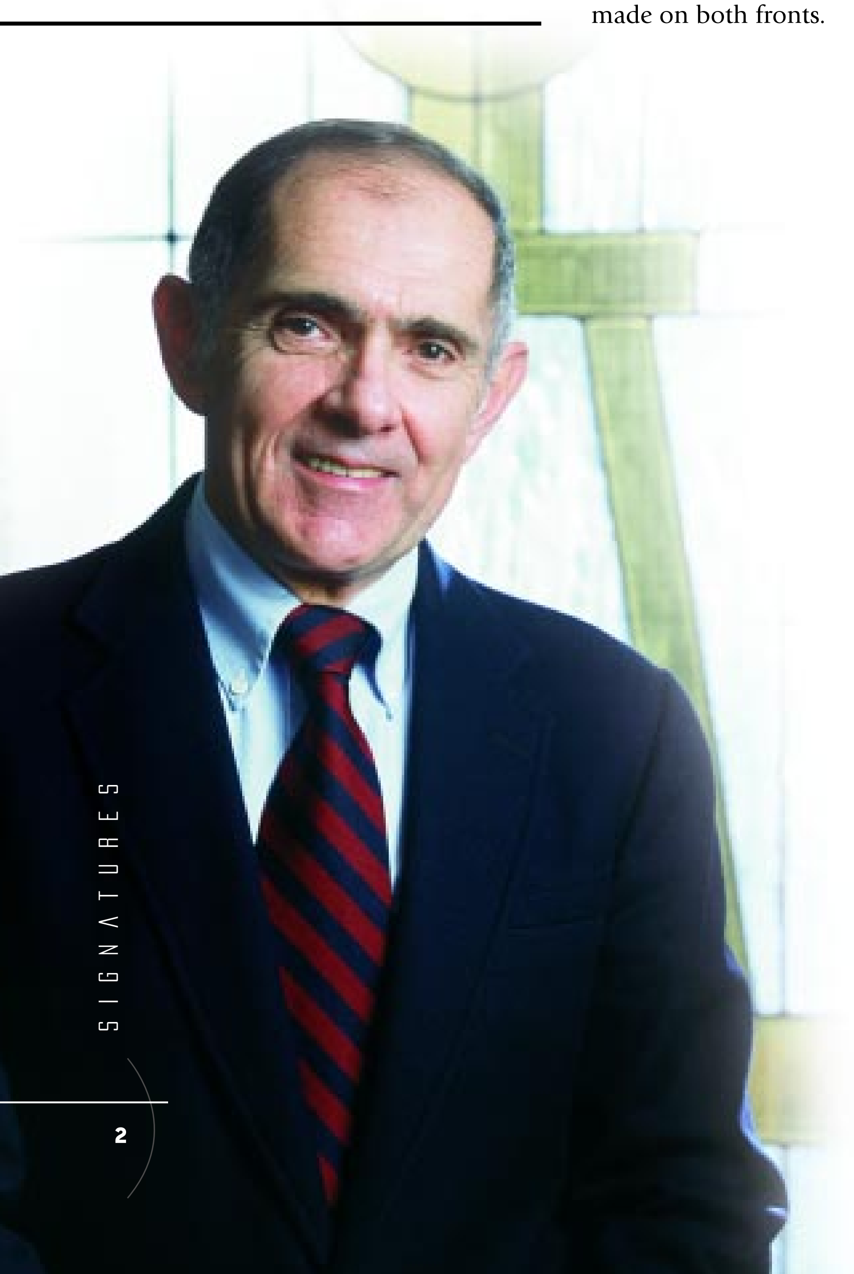
## The Past, Present, and Future of Wireless Communications

Engineering Advances at the University of Notre Dame

Volume 3, Number 1
Spring 2001

# the dean's view

Less than three years ago, an ad-hoc committee was formed to assess the state of undergraduate engineering education at Notre Dame. While the committee found much of value in existing programs, it did call for two major changes, one having to do with the first-year curriculum and the other with transition from a teaching paradigm to a learning paradigm. I'm pleased to report that significant progress has been made on both fronts.



In the 1999-2000 academic year our faculty offered prototype versions of two new courses, EG111 and 112, to a group of 25 first-year students. With subsequent refinement of objectives and content, the courses were offered to a full cohort of approximately 350 first-year students in 2000-01. *(See pages 4-15.)* Like innovative approaches being taken at many universities, the courses involve numerous interactive, collaborative, and experiential learning experiences. But a distinctive feature may be the fact that instruction is provided by faculty from each of the College's five departments, thereby enhancing cross-disciplinary attributes of the courses.

To provide the infrastructure needed to support the interactive learning and team-based project activities of the two new courses, the University moved with near internet speed to provide $1,300,000 for conversion of an antiquated 4,500-sq.-ft. auditorium to a modern Learning Center. *(See page 7.)* Construction was completed in record time, and the Center was ready for use by our first-year students last fall. It is providing an excellent testbed for exploring new approaches to teaching and learning in all of our programs.

inside

SIGNATURES



Concurrently, each of our departments has been assessing its curriculum, and numerous changes are being made to better prepare our students for today's highly competitive environment. Aided by a recent grant from the GE Foundation, attention is also being given to activities that cross departmental boundaries and leverage the special facilities of the Learning Center. *(See page 15.)* With increasing use of these facilities by our first-year and departmental programs, we anticipate a seamless transition to the larger 17,000-sq.-ft. Learning Center planned for the College's proposed multidisciplinary learning and research building.

In research our strategy has been to identify and develop focus areas that meld core competencies of the College's faculty with critical technologies. By their nature, these areas are multidisciplinary and involve collaborations across departments and colleges.

> It is an exciting time for our College, but we are cognizant of a rapidly approaching crossroads ...

In the past two years the College has spearheaded the development of two major university research centers, one in Nanoscience and Technology and the other in Molecularly Engineered Materials, with others presently under consideration. These efforts have enabled us to be more competitive for major government grants, and annual research funding has more than doubled over the past two years. We are also seeing steady and sustainable growth in our research relations with industry, fostered in part by the Indiana 21st Century Research and Technology Fund. However, as we continue to grow our research enterprise, we remain committed to maintaining strong linkages with education, including undergraduate participation in research.

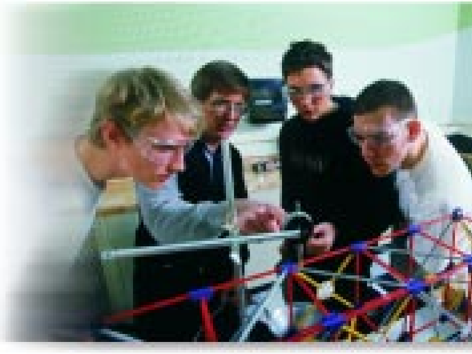
It is an exciting time for our College, but we are cognizant of a rapidly approaching crossroads, one at which continued enrichment of educational and research activities will begin to strain our resources. More than ever, it will be important for us to be judicious in our planning and to effectively manage change.

Frank P. Incropera

**Frank P. Incropera**
McCloskey Dean of Engineering
Brosey Professor of Mechanical Engineering


EG 111/112:

*First-year engineering intents experience a variety of teaching and learning activities as they begin to function as engineers.*



# the creative curriculum

When people think of an engineer, they might envision someone who learns extremely technical information by rote, a spectacled figure in a lab coat who can converse only on a Mensa level, or an individual with a pocket protector. Based in truth, these are antiquated stereotypes of engineering and not reflective of what being an engineer is all about.

Yes, an engineer must understand a myriad of facts and figures. It's part of the job. Sometimes an engineer wears a lab coat, and often he or she wears safety glasses. A pocket protector? These days it's more likely a Palm Pilot. But being an engineer involves so much more.

Engineering is the practice of adapting natural phenomena to fulfill basic human needs. The word itself derives from the Latin *ingenium* and refers to an individual's native genius and ability to create things. There's the rub. How does one teach creativity? And, can it be part of an engineering curriculum?

Educational institutions have traditionally relied upon a teacher-centered approach. Faculty give lectures. Students take notes. Tests determine how much the student has learned. It's a simple formula and one that's used in most high schools and universities across the country.

This method has worked well for Notre Dame's College of Engineering, largely due to the technical content of its programs. But engineering is a constantly evolving field. "Engineering problems and technologies have become extremely complex and multi-faceted," said Frank P. Incropera, McCloskey Dean of Engineering and Brosey Professor of Mechanical Engineering. "Today's engineers must be able to work across traditional disciplines, as well as with professionals from fields such as business and law."

The question then posed to a committee charged with assessing the undergraduate curriculum was "What can the College of Engineering do to better prepare its students

***Prototype EG111/112 courses*** *were offered during the 1999-2000 academic year to 25 first-year engineering intents. Seven of those students are now peer mentors in this year's EG111/112 course sections.*

for the ever increasing multidisciplinary nature of engineering?" One answer was to shift from a teaching focus to a learning focus, one that would enhance leadership, teamwork, experiential learning, the use of information technology, and independent, creative thinking.

One of the first suggestions made by the committee was to replace the first-year programming class, EG120, with a course that would more accurately reflect the nature of engineering and allow students to experience the different disciplines within engineering. The goal of EG120 was to teach C programming language and a little bit of MatLab. It was not developed to excite students about engineering or to help them understand anything more about the field than how to write a computer program.

This often meant that first-year students took the core courses required by the University's First Year of Studies Program and decided on their major and area of emphasis — which engineering department they would enter as sophomores — without ever having taken an "engineering" course. They probably didn't understand why they had to take calculus, chemistry, or physics, merely that these were required components for their degrees. They didn't have the big picture.

The challenge was to create curricula that would provide a comprehensive view of engineering so students could make informed choices. "We're not the only university to have realized there's a problem with first-year engineering curricula," said Thomas E. Fuja, professor of electrical engineering and co-director of EG111/112. "There's a consensus emerging in engineering education that the freshman year represents an opportunity to introduce students to the engineering perspective. Where Notre Dame really stands out is in the commitment it made — a full-year sequence with all the faculty, equipment, and support staffing necessary to provide a first-rate experience for first-year engineering intents."

The challenge was to create curricula that would provide a comprehensive view of engineering so students could make informed choices.

"The faculty were very excited about the prospect of a year-long sequence for freshmen," said Jay B. Brockman, associate professor of computer science and engineering and co-director of EG111/112. "There is a lot of research that indicates that a learning-centered approach where students are active in managing certain aspects of what they learn is a more effective way to teach."


# experiential learning
## in a multidisciplinary setting

**Experience is often one of the best teachers.** It's certainly a vital element of the undergraduate program in the College of Engineering, particularly in the new Engineering Learning Center. Developed as a result of the Undergraduate Curriculum Enhancement Study performed during the 1998-99 academic year, the Learning Center provides an important resource for innovative, interactive learning. The purpose of the Center is to: foster multidisciplinary activities within the College, encourage an understanding of how engineering principles can be used to benefit mankind, promote the opportunities available in engineering, and develop innovative teaching and learning methods.

While a handful of the nation's prominent engineering schools have opened facilities like the Learning Center, Notre Dame's is the first to be used by all first-year engineering intents. In fact, the Center was created with the understanding that EG111/112 students would be the primary users of the facility during its first year of operation. True to its purpose, however, the Center will be used by students at all levels of study and across all engineering disciplines within the College. Working individually and in teams on discipline-specific and multidisciplinary projects, students will analyze, design, build, test, and communicate their findings just as they would in a professional setting.

Departments using the Center will be actively involved in creating courses and – working with Center manager Natalie Gedde – projects that promote hands-on, collaborative learning. "It is very important for engineers to learn how to combine their skills with those of others," said Frank P. Incropera, McCloskey Dean of Engineering and Brosey Professor of Mechanical Engineering. "The Learning Center fosters the development of a multidisciplinary approach to solving problems."

The prototype of a much larger facility planned for a new engineering building, the Learning Center allows for the development of a broad spectrum of activities. For more information on the Learning Center, visit **http://www.nd.edu/~englearn.**

***Natalie Gedde,*** *a professional engineer with degrees in electrical and mechanical engineering, serves as the Learning Center manager. Her responsibilities include scheduling student and faculty use of the Center; recruiting, training, managing, and evaluating student aides for the Center; establishing and enforcing safety and equipment maintenance policies; and assisting faculty in the design of learning modules and other demonstrations for courses held within the Center.*

***A cross between a computer cluster,*** *a library, and a laboratory, the Engineering Learning Center promotes experiential learning for students in all disciplines within the College of Engineering. In addition to traditional academic space, the Center is equipped with fabrication and measurement capabilities for a variety of activities. State-of-the-art audio/visual capabilities are also key elements of the Center.*

# peer mentors contribute much

## EG111/112 students can ask questions with confidence.

In addition to the faculty members who work with these students, each EG111/112 section is assigned a peer mentor. These mentors work with students individually and in groups, offering their expertise in different fields and on a variety of subjects. Their principal role is to assist the faculty and help with student projects.

The mentors are supervised by Gabriel Torres, a graduate teaching assistant pursuing his doctorate in aerospace and mechanical engineering. He meets with them once a week, trains them, administers their schedules, and helps course faculty with upkeep of the EG111/112 web site. “The course is great,” said Torres, who did not have access to this type of program when he was an undergraduate. “What is even more more exciting is the incredible contributions these peer mentors have made to the course. They have been able to do things many people thought undergraduates couldn’t handle. Their involvement has been very positive.”

**John Buckreis**, senior
Electrical engineering

**Jack Connor**, senior
Aerospace and mechanical engineering

**Jim Jenista**, sophomore
Computer science and engineering

**Joe Lammersfeld**, sophomore
Computer science and engineering

**Kathryn Malpass**, sophomore
Electrical engineering

**Loren Masterson**, senior
Chemical engineering

**Jon Reither**, junior
Electrical engineering

**Stacy Rousseau**, sophomore
Electrical engineering

**Corey Shalanski**, senior
Aerospace and mechanical engineering

**Julie Sherwin**, senior
Civil engineering and geological sciences

**Kylie Smith**, junior
Computer science and engineering

**Maria Snyder**, sophomore
Computer science and engineering

**Erich Stuntebeck**, sophomore
Computer science and engineering

**Mark Trandel**, sophomore
Electrical engineering

**Scott Turner**, sophomore
Electrical engineering

**Max Wingert**, senior
Chemical engineering

But being able to execute something that’s good in theory is another matter.

A trial run was scheduled for the 1999-2000 academic year. Brockman and Fuja developed the structure of the course and worked with 25 first-year students. According to Stephen M. Batill, associate dean for educational programs and professor of aerospace and mechanical engineering, the trial ran effectively. “Two skilled faculty worked in close coordination with a small group of students and facilities over which they had complete control,” he said. “They could be very flexible, change things as needed, try different concepts, and experiment with the best way to present material or conduct a project.”

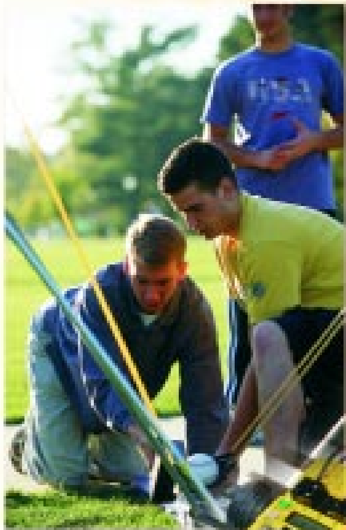
Another benefit to the small class size was the ability to communicate quickly and easily with one another and with the 25 students. The small group also developed its own culture. Students and faculty worked well together in this focused effort.

Was the pilot successful? Yes. Students in the initial EG111/112 sequence responded positively. Many of them serve as peer mentors to students in the first “full-size” version of the course sequence, working in the Learning Center and in recitation sessions with the first-year intents.

This year’s EG111/112 is organized in a similar manner, though a number of important changes were required. The most noticeable difference is the size of the course sequence compared to its prototype. A total of 385 students enrolled in EG111 during the fall semester. To keep the course manageable and promote teamwork, students were divided into 14 groups of 25 to 30 students. The spring semester course, EG112, has approximately 300 students, who are divided into 12 groups.

***EG111/112 faculty*** *are, seated left to right, Jay B. Brockman, Thomas E. Fuja, and Mark J. McCready. Standing, left to right, in the second row are Edward J. Maginn, Wolfgang Porod, and Patrick J. Fay. Shown in the third row, left to right, are Flint O. Thomas, Patrick F. Dunn, and Stephen E. Silliman. Teaching faculty not shown are Stephen M. Batill, associate dean, and Jeffrey C. Kantor, vice president and associate provost.*

# A hands-on ENGINEERING EDUCATION



The objectives of EG111/112 are to help students begin to understand the nature of engineering, to develop and apply fundamental engineering skills, and to gain practical design experience. EG111/112 is divided into four half-semester modules which focus on multidisciplinary systems, their behavior, and their interdependent parts. Students are assigned four projects with recurring emphasis on the central roles of energy, materials, and information technology. Projects undertaken for the 2000-01 academic year by EG111/112 students were:

**Launching a projectile**

Students were required to launch a projectile and hit a target. This introduced the students to propulsion systems and the energy conversion process.

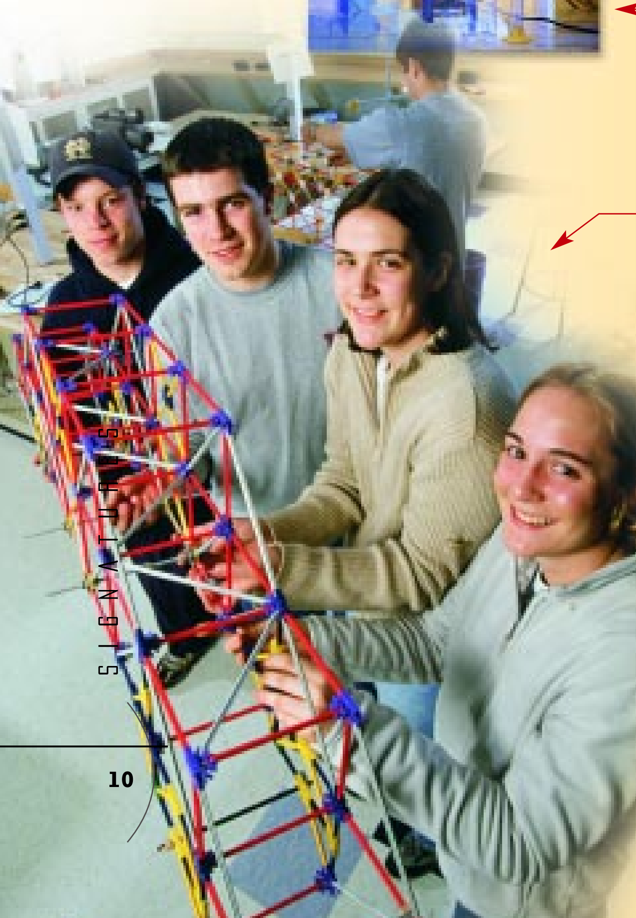
**Scanning and decoding data**

The assignment was to design and build a data scanner that could read a sequence of bar codes/stripes and then convert the “scanned” information into a text message. This project involved three technological domains: electromechanical – how the light sensor traverses the paper, data representation – the techniques used to represent text as a sequence of stripes, and real-time software design – actuator control and data acquisition and analysis.

**Creating a control system for neutralizing an acidic waste stream**

Students designed and built a control system for neutralizing an acidic waste stream. They then compared actual system performance with the computer simulations they developed.

**Designing and building a lightweight truss structure**



Working in teams, students designed and built trusses to support a given load with a specified maximum deflection. They were required to model truss performance with Matlab, a software program used in many engineering applications to solve systems of equations. Students were also asked to incorporate an instrument in their design that would measure and record the forces applied to the structure.

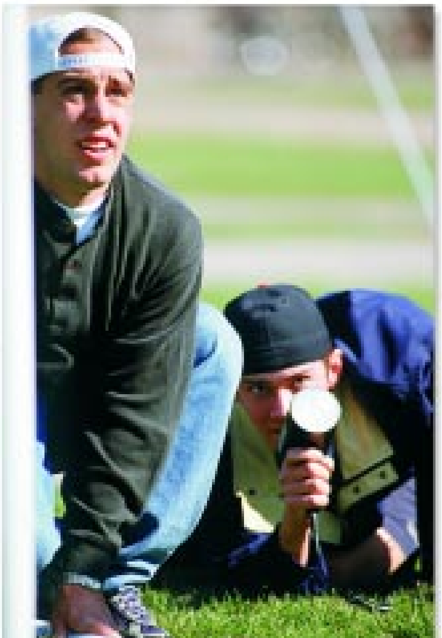
The four EG111/112 modules share a common structure. They outline each project’s requirements and demonstrate how a particular engineering system/artifact can be decomposed. They introduce techniques for modeling the system’s behavior. They teach students how to use engineering models to make design decisions and document their rationale. They require that students build, test, and demonstrate their design, while documenting the results and making recommendations for future improvements. They support learning about the engineering design process, and they allow students to function as engineers.

***EG111/112 students** explore all disciplines within the College — aerospace and mechanical engineering, chemical engineering, civil engineering and geological sciences, computer science and engineering, and electrical engineering.*

Another difference is the number of instructors involved. The prototype was taught by two faculty. This year seven faculty from all departments of the College participate each semester, representing a significant investment of resources by the College.

However, the most important aspect of EG111/112, its objectives, remains the same: to provide students with an appreciation for the nature of engineering, to help them develop and apply fundamental engineering skills, to give them practical design experience, and to offer them useful information for making rational career decisions. Through EG111/112 and in the Engineering Learning Center, students have the opportunity to explore engineering as an educational option and to select the specific field that best fits their interests and talents.

The goal of the course sequence is not necessarily to increase the number of students who choose engineering. That number will be influenced by the interests of students who enroll and other factors beyond the College's control. When asked to identify the principal goal of EG111/112, Batill, Brockman, and Fuja responded almost identically. Their answer? The purpose of EG111/112 is to give students more information about engineering and to help them become independent and critical thinkers.



That can sometimes be a painful task, particularly when it involves first-year students. They come from high school with high-school experiences and expectations. One of those expectations is that there is one right answer for every question. "An important thing we're trying to get across," said Brockman, "is that engineers — who are creative people — constantly work on projects where the answers are not known in advance." There is seldom a single accepted best solution to a particular problem.

"What we're trying to teach them," he continued, "is a process, not just a specific list of facts. When given a problem, how do you approach it?" He, Fuja, and the five other faculty who teach sessions in EG111/112 help students break a problem into hierarchical levels. They call it "top-down design and bottom-up implementation." Starting this process from the top, they ask students, "What's the big picture?" They proceed down through the problem by asking, "How can this problem be partitioned, that is, split into bite-sized chunks?" The students then implement their solutions starting with these bite-sized chunks and work up to an answer for these complex problems.

***Each project** in EG111/112 requires students to design and construct an artifact, mirroring the steps taken in actual product or process development.*

Students are asked to consider the outcome of each project as an artifact — something created by man as opposed to forming naturally. An artifact can be described in three ways: by the form it takes, its function, and through the environment in which it operates — natural, social, and political.

Using the concepts of artifacts and top-down design/bottom-up implementation, students in EG111/112 have successfully developed a model-based methodology for launching a projectile and hitting a target. They have created a compact bar-code scheme and scanning mechanism that reads and decodes the message embedded in the bar code. They have designed and implemented a truss that will support a given load with a specified maximum deflection, measuring and digitally recording deflections and comparing their results with computer model predictions. Based on principles of environmentally-conscious engineering, they have also controlled a dynamic chemical process.

"...engineers — who are creative people — constantly work on projects where the answers are not known in advance."

Each project involved decomposition of the system into its principal constituents and the development of models to predict system behavior. Each required the construction and testing of the design, documentation of results, and recommendations for improvements. In short, each of the projects required that students think and act as engineers. And that's the point.

The traditional way of teaching engineering assumes that freshmen cannot understand or accomplish certain objectives because they don't have the technical background. EG111/112 argues against that premise. It introduces first-year students to engineering. As important, it makes them better students and more informed

One component of EG111/112 is the traditional lecture, most often by a faculty member discussing background information for an upcoming project. However, two times each semester EG111/112 students get the "scoop about engineering" from professionals who have achieved at the highest levels of their fields. The **Distinguished Engineering Lecture Series** is a new addition to the College. It was developed to expose students to successful engineers and to give them an overview of technological trends. The series features four speakers each academic year. According to McCloskey Dean of Engineering Frank P. Incropera, "Each lecture provides students with a better understanding of the role of engineering in society and the impact that they, as aspiring engineers, can have in the world."

Open to the general public as well as the entire University, the lectures are presented during EG111/112 class sessions. Presenters and topics offer a unique overview to students exploring the many fields of engineering. The inaugural speaker was **Larry Augustin**, president, chief executive officer, and director of VA Linux Systems, a leading provider of Linux-based computer operating systems. He addressed a variety of issues facing companies who use the Internet for commerce.

**Kenneth Stinson** delivered the second Distinguished Engineering lecture. Stinson leads the nation's eighth-largest construction firm, Peter Kiewit Sons', Inc. His talk covered many aspects of construction engineering projects from development to completion. In it he shared the excitement of being an engineer with students and faculty as he talked about mega-projects like Kiewit's $1.35-billion contract to rebuild I-15 through Salt Lake City.

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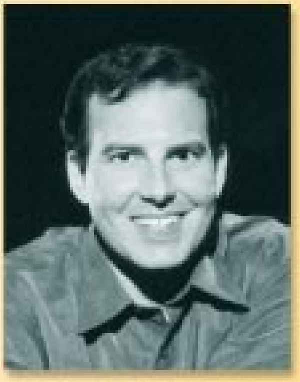
# Giving First-year Students a Glimpse of the Real World of Engineering

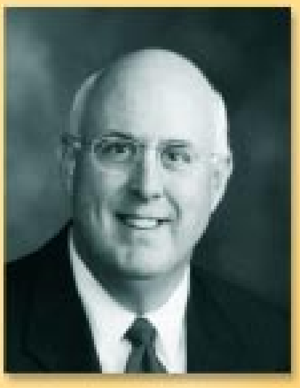
**Kevin Connors** discussed his role as an engineer and venture capitalist in the healthcare field. He revealed exciting breakthroughs in medical technology and how his company puts engineers and innovators together with investors and marketers to address unmet medical needs.

The final lecture in the 2000-01 series featured **Anthony F. Earley Jr.,** chairman and chief executive officer of DTE Energy and its largest subsidiary, Detroit Edison. During his lecture he discussed the dramatic changes taking place in the electric industry as it moves from a highly regulated environment to a more competitive market. He also shared some of the challenges facing electric providers, including environmental pressures and the emergence of advanced technologies.

Earley and Stinson are members of the College of Engineering Advisory Council.



*Larry Augustin, president, chief executive officer, and director of VA Linux Systems, presented "The Future of Software Development and the Internet." He is a 1984 graduate of the electrical engineering department.*



*In 1964 Kenneth Stinson graduated from the University with a degree in civil engineering. Today he is chairman and chief executive officer of Peter Kiewit Sons', Inc. His topic was "Building our Infrastructure: The Role and the Romance."*

*General partner of Spray Venture Partners, Kevin Connors discussed "Healthcare Technology and Venture Capital: Engineering to Improve the Quality of Life." Connors is a 1983 graduate of the electrical engineering department.*

*Anthony F. Earley Jr., chairman and chief executive officer of DTE Energy, discussed "Electricity: Powering our Economy, Protecting our Environment, Linking our World." A 1971 graduate, Earley also received a M.S. in Engineering Science and a J.D. from Notre Dame in 1979.*


***Students in EG111/112*** *learn through discovery, documenting their results and making recommendations for future changes.*

educational consumers regarding their future academic focus.

Has EG111/112 been successful? Has it achieved each of its goals? It's too soon to tell. Many students and faculty are pleased with the current course structure. Others have made suggestions — based on course logistics and experiences in labs, lectures, and recitation sessions — that will be implemented next year. Some students have even decided that engineering is not for them. The College does not view this as a negative.

"Never in all of the discussions has anybody said, 'We're doing this simply to retain engineering students.' What we are doing," said Batill, "is giving these students an opportunity to make informed decisions. If a student decides on engineering, he or she can go almost anywhere … do many things after graduation … including be an engineer. That's not the case if a student does not take engineering. To make that important choice a student must be well informed."

Faculty, and eventually employers and coworkers, will judge the success of the EG111/112 course sequence and the College's undergraduate engineering program based on student attributes. Are they critical, independent thinkers? Can they creatively solve technical problems? Will they, through their engineering contributions, make the world a better place in which to live?

The purpose of EG111/112 is to give students more information about engineering and to help them become **independent, critical thinkers.**

# GE FUND'S LEARNING EXCELLENCE INITIATIVE TO FUND LEARNING CENTER MODULES

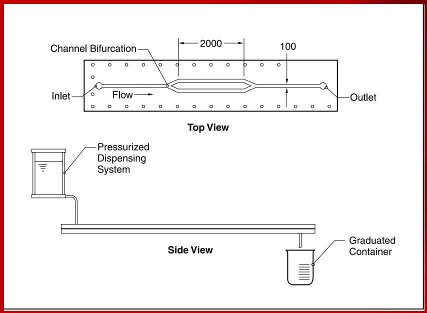
***Embedded microcontrollers** are used across many engineering disciplines. The learning module being developed by Drs. Lemmon and Goodwine will give students hands-on experience in micro-controller technologies. Topics to be covered include analog interfacing and interrupt synchronization.*

**The General Electric Fund** has awarded a $300,000, two-year grant to the University in support of the development of innovative, interdisciplinary curricula and teaching modules within the Engineering Learning Center. This is the maximum grant allowed by the program. "We are especially pleased to receive this gift because it endorses our aspirations for reinventing the curriculum in the engineering disciplines," said Notre Dame's President **Rev. Edward A. Malloy, C.S.C.**

Three undergraduate learning modules will be developed for the 2001-02 academic year. The first focuses on microcontroller interfacing and will be led by **Michael D. Lemmon,** associate professor of electrical engineering, and **J. William Goodwine Jr.,** assistant professor of aerospace and mechanical engineering. **Mohamed Gad-el-Hak,** professor of aerospace and mechanical engineering, **Gary H. Bernstein,** professor of electrical engineering, and **Gregory L. Snider,** associate professor of electrical engineering, are developing a module based on microelectromechanical systems. The third multidisciplinary module, focusing on the degradation of organic contaminants in groundwater flows, is being developed by **Mark J. McCready,** professor and chair of the department of chemical engineering, **Stephen E. Silliman,** professor of civil engineering and geological sciences, and **Jeremy B. Fein,** associate professor of civil engineering and geological sciences.

As part of the grant, a second set of projects will be developed and funded for the 2002-03 academic year. These and future modules developed for undergraduate curricula will 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.

***Water follows** circuitous paths, responding to variations in subsurface geology. In this module students will use probabilistic and numerical models of groundwater and chemical transport to study the degradation of organic contaminants in groundwater.*




***The microelectromechanical system** (MEMS) learning module being developed by Drs. Gad-el-Hak, Bernstein, and Snider will be used as part of three courses: Fluid Mechanics, Frontiers of Microelectronic Systems, and Senior Design. In each of these three courses, students will conduct experiments using an actual MEMS device.*


# The Center for Molecularly Engineered Materials

Mud, stone, wood, and bone ... these were the materials people used thousands of years ago to create the goods their societies needed. Often these “building blocks” were found naturally on the surface of the earth and didn’t require sophisticated forming techniques. Weapons, homes, and even roads were fashioned from these and other available substances. As time passed entire eras – the Stone Age, the Bronze Age, and the Iron Age – were named for the materials that were discovered or processes developed during those times which advanced civilization. Nations flourished as a result of the materials they were able to use to increase commerce, develop a military presence, and raise the quality of life.

Materials are just as vital to the quality of life today, in the United States and around the world, as they were to the Sumerians of Mesopotamia. Clothes, homes, automobiles, computers, medical technologies, even plastic food containers are the results of developments in materials science.

## Creating New Materials


A truly interdisciplinary field, materials science is the study of materials and how they can be adapted or fabricated to meet the needs of civilization. It interfaces between engineering and science to advance society, impacting key industries such as aerospace, automotive, biomaterials, chemical, electronics, energy, metals, and telecommunications. As important as the development of materials has been to today's technology, there is a shift in how researchers are viewing materials and their creation.

Traditionally, engineers processed raw materials and measured the properties before trying to find an application that fit the particular performance benefits of a material. Today, researchers — like those in Notre Dame's newly established Center for Molecularly Engineered Materials — first think of an application, then work toward designing a material that will meet that need.

Created in October 2000 the Center builds upon a long history of faculty research and educational developments in materials science at the University. Its purpose is to actively explore multidisciplinary fundamental concepts in materials science. Emanating from the College of Engineering, Center activities encompass a mix of faculty, visiting scholar, and graduate student research from the Departments of Chemical Engineering, Aerospace and Mechanical Engineering, Chemistry and Biochemistry, Physics, and the University's Radiation Laboratory.

for the New Millennium

***Combustion synthesis*** *is a novel technique used to produce a variety of advanced materials. The concept of combustion synthesis was described in an article written by Arthur J. Schmitt Professor of Chemical Engineering, Arvind Varma, the Center's director, and published in the August 2000 issue of* Scientific American. *Publication of the article is reflective of the international recognition the Notre Dame program has received. Shown here, Laurent Thiers, a doctoral candidate in chemical engineering, studies the progress of a combustion synthesis wave using unique high-speed video microscopy equipment, to the right of the video monitor. This equipment was developed at Notre Dame in Varma's laboratory.*

The main function of the Center is twofold: to develop materials and systems whose structure and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processing, and to train students in emerging materials technologies with an emphasis on fundamentals that prepare them for careers in either the academic or commercial sector.

Why did Notre Dame feel the need to create the Center? Aren't individual corporations also studying advanced materials? According to Center Director Arvind Varma, Arthur J. Schmitt Professor of Chemical Engineering, materials research is not an either-or proposition. In order to create new materials, basic and applied research is vital — research which is beyond the scope of what industry is sometimes able to execute due to market constraints and the challenges of daily operations. "Working with industrial partners and also individually as an academic research center, Notre Dame can gain from the relationships formed while also creating unique educational opportunities for students," he said. "The fact that we're focusing on materials and changing them at the molecular level to obtain desired properties and performance is what makes this Center unique."

As director of the Center, Varma has overall responsibility for its management. A member of the chemical engineering department since 1975, his research interests are in chemical and catalytic reaction engineering and the synthesis of advanced materials. Paul J. McGinn, a materials scientist and professor of chemical engineering, serves as associate director of the Center, assisting Varma in day-to-day operations. Both Varma and McGinn have extensive experience in managing large, multidisciplinary research programs, such as those in the Center.

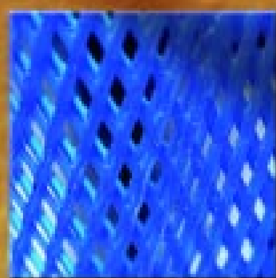
They believe that the creation of the Center adds to the stature of the Notre Dame materials program. "The University has had and continues to have a number of internationally recognized faculty in the field of materials," said Varma. "The creation of the Center for Molecularly Engineered Materials as an organized entity gives those engineers, chemists, and physicists the ability to focus even more specifically on materials research. It provides better opportunities for graduate student education and research, and it encourages the development of additional

... focusing on materials and changing them at the molecular level to obtain desired properties and performance is what makes this Center unique ...

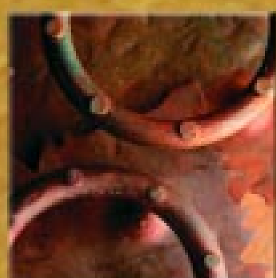
# THE AGE OF MATERIALS

**Stone Age** is the term used to designate the prehistoric stage of human culture during which stone rather than metal tools were used. Early humans made stone artifacts by either smashing rocks into usable pieces or by flaking, a process in which stone chips were fractured away from a larger rock by hammering it with another stone. Later civilization developed other techniques for producing tools, such as grinding, sawing, and boring.

In the Bronze Age before the introduction of iron, most tools and weapons were made of raw copper or bronze. Originally decorative, the use of bronze increased from the sporadic to the common. Forming techniques also increased; the most common processes during this time were hammering and casting, where molten metal was poured into a mold and allowed to cool. As time passed the techniques of engraving, inlaying, enameling, and gilding were also perfected.



The development of a metallurgical society – tools, art, and weapons – coincided with the rise of urbanization. Mining and casting operations became more organized. And, the search for new or greater supplies of raw materials stimulated the exploration and eventual colonization of new territories. The world was expanding.



By definition the Iron Age was the period of history that began with the general use of iron. Although the transition from the Bronze Age to the Iron Age was not as radical as from the Stone Age to the Bronze Age, it had more impact upon society. The superiority of iron gave mankind greater dexterity, more power, and better defenses.

Iron, lead, and steel – these materials and their uses – gave way to other eras, such as the making of machines to make machines. Known as the Industrial Revolution, this period of innovation and use of materials includes the eventual development of the steam locomotive, the steamboat, the skyscraper, the electric telegraph, electric lighting, the internal combustion engine, aircraft, radio, television, radar, computers, and nuclear power. Once again, mankind proved its ability to adapt, fabricating materials and processes to meet the needs of technology and civilization.

Obviously today's materials encompass more than metal, wood, and stone, and they can be divided into several categories:

**METALS** are still extremely versatile and valuable materials. They are strong, durable, and useful in a wide range of applications. Revolutionary techniques are allowing researchers to create new metallic compounds, manipulate their structure on the molecular level, and yield enhanced properties, i.e., active and selective catalysts, and corrosion-resistant surfaces.

**CERAMICS,** which traditionally include bricks, glass, and concrete, are also being used in high-tech applications such as medical implants, integrated electronics, and aerospace applications, such as heat-resistant tiles for the space shuttle.

**ELECTRONIC AND PHOTONIC MATERIALS** span a full range of chemical and structural compositions. Organic and inorganic, they include metals, ceramics, glasses, and plastics. Many of these materials are designed atom-by-atom with thin films of the materials stacked on top of one another to perform a specific function.

**POLYMERIC MATERIALS** are simply large molecules (macromolecules) made up of smaller molecules (monomers) that can be linked together in various ways. Natural polymers are cotton, wool, and silk. Plastics and resins are today's polymeric materials. In fact, plastics processing is the fourth largest manufacturing industry in the United States and one of the fastest growing. Why? Try to think of something that doesn't include a plastic, isn't packaged, or isn't synthetic. Plastics are ubiquitous in today's society.

To engineers and other researchers, however, the most compelling aspect of any material, new or old ... natural or man-made, remains the interrelationship between a material's structure and its properties. Because of this, it is probable that the next "Industrial Revolution" will not revolve around machinery or processes but materials. How does a material perform? Can its structure be changed to redefine its performance? Can its performance be enhanced, thereby advancing society? And, can all this be accomplished in a reliable and cost-effective manner?

interdisciplinary and collaborative activities between departments and Colleges."

During its early stages of operation, the Center will support four interdisciplinary research groups (IRGs). The number of groups and their focus will evolve as the Center matures so that it will remain flexible to developing technology and relevant applications.

Each IRG is led by a faculty member who is an acknowledged expert in his or her respective research area. To ensure seamless interaction among the groups, each group leader actively participates in at least one of the other groups. IRG activities are then coordinated through the director, associate director, and the group leaders. This provides a coherent approach to evolving concepts while also establishing a framework for the addition of industrial and governmental partners. These federal and corporate relationships will be developed and managed through an industrial coordinator, who is yet to be named.

***In creating catalysts*** *it is important to understand how the surface of a catalyst can affect a reaction. The scanning electron microscope shown here creates magnified images using electrons instead of light waves, revealing minute, three-dimensional levels of detail and complexity in the surface structure. Francisco Gracia, a graduate student in chemical engineering, seated, and Eduardo Wolf, professor of chemical engineering, prepare a sample for study.*

The IRGs which the Center has identified for immediate exploration are in the areas of catalysis and reaction processes, electrochemical interfaces and processes, nanostructured materials, and advanced processing techniques. They involve faculty, staff, and graduate student researchers in several departments across the University.

## Catalysis and Reaction Processes

**Eduardo E. Wolf,** professor of chemical engineering, leads the interdisciplinary IRG on catalysis and reaction processes. Joining Wolf are: the Center's director and associate director, Varma and McGinn; Joan F. Brennecke, professor of chemical engineering; Seth N. Brown, assistant professor of chemistry and biochemistry; Hsueh-Chia Chang, Bayer Corporation Professor of Chemical Engineering; Thomas P. Fehlner, Grace-Rupley Professor of Chemistry and Biochemistry; David T. Leighton Jr., professor of chemical engineering; Mark J. McCready, professor and chair of chemical engineering; Slavi C. Sevov, associate professor of chemistry and biochemistry; and William C. Strieder, professor of chemical engineering.

This group focuses on steady-state and dynamic aspects of adsorption and reaction processes. Studying the synthesis and characterization of new materials with potential for applications in heterogeneous catalysis, these researchers collaborate to discover new catalysts that will be more active and selective. The customer base for these types of catalytic applications includes the chemical, petroleum, energy, and manufacturing industries.

Catalysis is the acceleration of the rate of a chemical reaction induced by a material, a catalyst, that is not consumed by the reaction. "More than 90 percent of all chemical processes employed by industry today use some form of catalyst to accelerate chemical reactions," said Wolf. "The goal is to produce more useable product and less waste or byproducts." One of the most widely known examples of catalysis in industry may be the automotive catalytic converter, which helps reduce emissions from automobile exhaust, such as carbon monoxide, unburnt hydrocarbons, and nitrogen oxides.

Selectivity — producing a desired chemical compound — is a key function of a catalytic material. A more selective catalyst reduces the extent of separation needed after the reaction has occurred, when either the desired product or the remnant must be extracted from other constituents so the undesired portion can be disposed of properly. The ability to control both how much the reaction is accelerated by a catalyst, its activity, and its selectivity is critical in the design of catalysts.

To balance these functions it is necessary to understand how the surface of a catalyst affects the reaction. Often if a catalyst is too active, it is less selective. For example, gasoline is produced from oil by cracking large hydrocarbon molecules into smaller ones that meet the requirements of a combustion engine, like the octane number. If a catalyst is too active, it cracks the feed but also the desired products, as well as producing paraffins with low octane numbers. When the catalyst is not active enough, there is not enough cracking and more of the crude oil goes toward the production of heating oil instead of gasoline products.

The Catalysis and Reaction Processes IRG has initiated several projects aimed at designing new catalysts in which activity and selectivity are maximized. These include interdisciplinary collaborations in the use of nanoshells to encapsulate homogeneous catalysts and the synthesis of special materials called molecular sieves. Researchers involved in the molecular sieve project are studying their activity for oxidation reactions in the manufacture of new chemicals.

***Filled with pure, ultra-dry nitrogen gas,*** *the glove box shown here is used to process compounds that are air or moisture-sensitive. Graduate student Svilen Bobev and Slavi C. Sevov, associate professor of chemistry and biochemistry, prepare the reactants for the synthesis of intermetallic compounds. These compounds have excellent thermoelectric properties, actually lowering their temperature upon contact with electric current. Similar materials are already used in some spacecraft and other specialty equipment where low temperatures are required. Bobev recently received the 2001 Rohm & Haas Award For Excellence in Graduate Student Research.*

## Electrochemical Interfaces and Processes

**Led by Albert E. Miller,** professor of chemical engineering, the Electrochemical Interfaces and Processes IRG studies reactions in which electrons are exchanged from one entity to another — how those reactions occur and how they can be controlled — as well as non-electron exchange reactions, such as molecular adsorption, that occur at electrodes. Applications for their research

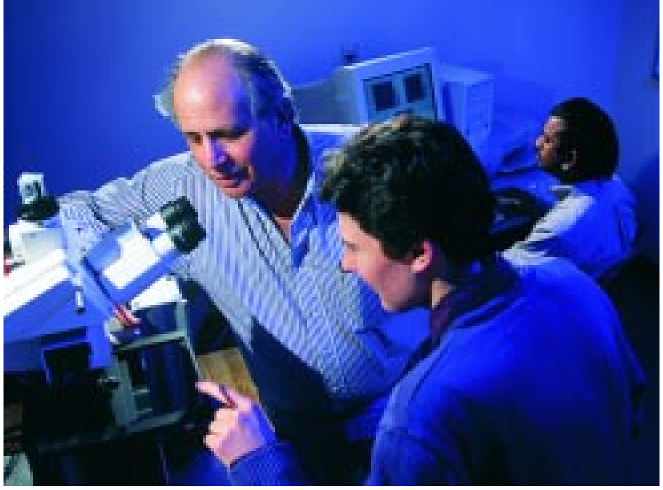
More than 90 percent of all chemical processes employed by industry today use some form of catalyst to accelerate chemical reactions ...

include the design of passive layers that resist corrosion by pitting; environmentally benign general corrosion inhibitor design; electrolyte and electrode design for the production of nanoscale patterning for electronic, magnetic, optical, and membrane use; semiconductor interfaces for solar energy conversion; the spatial manipulation of objects on the nanometer scale; surface patterning via microcontact printing; and scanning probe lithography.

Much of the group's work involves placing the material they wish to investigate in an electrolyte. Since electrolytes contain mixtures of organics and water-based systems, by passing an electric current through the solution, the water and organic compete for adsorption on the surface of the material to form a nanoscale pattern. This is a new twist on an existing process called electropolishing. At this stage group researchers anodize the surface of the material to produce an oxide skin or film, which develops a regular pore structure templated by the pattern that was on the electropolished material. These pores are highly regular and highly uniform. This process was discovered at Notre Dame, and the University holds the patent on it.

Depending upon the end use of the material, researchers then selectively deposit different elements or compounds into the pores of the film. The possibilities are as extensive as the user base — all metal producers and users, as well as chemical, petroleum, medical, and electronics industries. For instance, enzymes reactive to certain types of bacteria could be placed in the pores or allowed to bind to deposits formed in the pores. Semiconductor material can be placed

***Albert E. Miller,*** *professor of chemical engineering, standing, and Michael M. Crouse, a graduate student in chemical engineering, prepare to work with an electrochemical processing system which was built entirely at Notre Dame. All the variables in an electrochemical reaction process are monitored by the computer, which allows for high-speed data acquisition during each step of the reaction. One unique feature of this system is that it produces pulsed voltages which can be controlled. Using this system, Miller and colleagues can capture 50 separate electrochemical measurements during a single surface reaction.*



***Dan Meisel,** professor of chemistry and biochemistry and director of the Notre Dame Radiation Laboratory, works with Dr. Catherine Whitby, a research associate in the lab, on the nearfield scanning optical microscope. This dual microscope, optical and atomic force, allows for direct observation of single molecules. Meisel and others in the Radiation Lab, such as T. Dhanasekaran, an associate professional specialist, seated, add immeasurably to the multidisciplinary nature of the research being conducted in both the Electrochemical Interfaces and Processes and Nanostructured Materials IRGs.*

in the pores. Even corrosion-resistant materials can be deposited into the film.

One of the most exciting examples of this process is a corrosion-inhibitor experiment Miller, Charles Arvin, a chemical engineering graduate student, and Dr. Gautam Banerjee, a research associate in chemical engineering, submitted for testing to the Navy one year ago. While the samples from other laboratories lasted a mere 30 days before showing signs of corrosion, Notre Dame's samples withstood a year of stringent testing. "They look the same as the day we sent them out," said Miller, "which, of course, is the point. If we can successfully engineer this thin film, we can either prevent things from getting to the surface or help them get to it more readily."

Depending upon the end use of the material, researchers then selectively deposit different elements or compounds into the pores of the film.

Faculty collaborating with Miller in the Electrochemical Interfaces and Processes IRG are: Chang; Prashant V. Kamat, professional specialist in the Radiation Laboratory; Marya Lieberman, assistant professor of chemistry and biochemistry; Dan Meisel, director of the Radiation Laboratory and professor of chemistry and biochemistry; and Strieder.

## Nanostructured Materials

**Nanostructured materials** are the focus of the third IRG. "Activities in this group complement the research that is taking place in the University's Center for Nano Science and Technology" said Edward J. Maginn, associate professor of chemical engineering. "What the Nano Center does is focus more on the electronic applications of nanoscale materials," he continued. "Because it encompasses chemical engineering, chemistry and biochemistry, and the Radiation Laboratory, there is more of a chemical viewpoint in our IRG."

***Marya Lieberman,** assistant professor of chemistry and biochemistry, also works with two of the Center's IRGs.*

Members of the nanostructured materials IRG focus on tailoring the properties of materials through changing the structure or the chemical nature of the materials at the nanolength scale. The concept is that with all the "action" taking place on the molecular level, researchers can discriminate against unwanted molecules. This ranges from redesigning existing materials to creating new ones.

In fact, there is a whole new class of materials being studied now called "templated silicas." Imagine dumping several large round rocks into wet plaster, placing another layer of plaster on top of that, and then being able to remove the rocks so all that is left are the cavities inside the block of plaster. This type


***Edward J. Maginn,*** *associate professor of chemical engineering, and Jennifer Anthony, a graduate student in chemical engineering, measure an adsorption isotherm using a Hiden Analytical Flow Gravimetric Balance. In addition to this balance, the Center for Molecularly Engineered Materials has several other instruments, as well as access to a wide range of materials characterization equipment throughout the University.*

of template is a called a sacrificial template, and the Nanostructured Materials IRG is working on creating similar types of templates, minus the plaster, and then placing select molecules inside the pores.

The group can also grow a silica shell around an element or compound, eventually removing that element to form a nanobubble. Biological molecules can then be inserted into the shell, which will protect it from being consumed or denatured. However, because of the porous nature of silica, other selected molecules can move into and out of the shell to accomplish their biochemistry. In essence, the shells function like mini bioreactors. Still in the experimental stage, these shells could conceivably provide a means of delivering cancer drugs and other medical therapies. They could also function as biosensors to determine the contamination level of food or detect disease-producing agents in food and water supplies.

The nanostructured materials that are being synthesized and studied by this IRG also include self-assembled layers, main-group clusters, and metal and semiconductor nanoparticles with areas of application that encompass adsorption, separations, fuel cells, encapsulation, non-linear optics, nanomagnetics, and environmental remediation. Each of these technologies are critical to a variety of industries from chemical processing, pharmaceutical, and automotive to energy storage/conversion and petroleum.

Members of the Nanostructured Materials IRG include Kamat; Lieberman; Meisel; Miller; Agnes E. Ostafin, assistant professor of chemical engineering; Sevov; Varma; and Wolf.

# Management and Leadership of the Center for Molecularly Engineered Materials

**Director**

Arvind Varma, Arthur J. Schmitt Professor of Chemical Engineering

**Associate Director**

Paul J. McGinn, professor of chemical engineering

**Advisory Council**

Hsueh-Chia Chang, Bayer Corporation Professor of Chemical Engineering
Thomas P. Fehlner, Grace-Rupley Professor of Chemistry and Biochemistry
Edward J. Maginn, associate professor of chemical engineering
Paul J. McGinn, professor of chemical engineering
Dan Meisel, professor of chemistry and biochemistry and director of the University's Radiation Laboratory
Albert E. Miller, professor of chemical engineering
Slavi C. Sevov, associate professor of chemistry and biochemistry
Eduardo E. Wolf, professor of chemical engineering

**IRG Leaders**

**Catalysis and Reaction Processes**

Eduardo E. Wolf, professor of chemical engineering

**Electrochemical Interfaces and Processes**

Albert E. Miller, professor of chemical engineering

**Nanostructured Materials**

Edward J. Maginn, associate professor of chemical engineering

**Advanced Processing Techniques**

Paul J. McGinn, professor of chemical engineering

**Educational Coordinator**

Mark J. McCready, professor and chair of chemical engineering

## Advanced Processing Techniques

**The fourth IRG** is concerned with various advanced processing techniques for materials, including combustion synthesis, ceramics processing, crystal growth, microfluidics, powder metallurgy, tribology, and polymer rheology. The group also addresses manufacturing issues related to solidification and casting.

According to McGinn, who leads this IRG, the mantra of materials science is that processing affects structure which affects properties. "The common theme with all the researchers in our group," said McGinn, "is that depending on how you process a material, you can control its structure, and then you can control the property. We've seen this in the development of materials science."

Consider that the field of materials descended from the development of iron and steel. Most of the "truths" known about materials were discovered when people were trying to make better iron and steel ... and then aluminum ... and then plastics. For this reason, most materials courses begin with an overview of the development of iron and steel. And, many of today's breakthroughs,

***College of Engineering faculty lead*** *the Center for Molecularly Engineered Materials. Shown here are, front row, left to right, Eduardo E. Wolf, Arvind Varma, and Paul J. McGinn. In the back row, left to right, are Edward J. Maginn and Mark J. McCready. Not pictured is Albert E. Miller.*

Honeywell / Notre Dame

# Research Alliance Announced

**IN APRIL 2001** the University of Notre Dame began a five-year research alliance with the South Bend, Ind.-based Honeywell Aircraft Landing Systems, a leading supplier of aircraft landing systems, wheel and brake support, and repair and overhaul services. The agreement provides for a $1,280,000 grant from the corporation for doctoral fellowships, research, and a visiting professorship in the University's Center for Molecularly Engineered Materials. "We are excited to enter this alliance with a market leader like Honeywell Aircraft Landing Systems," said James L. Merz, Notre Dame's vice president for graduate studies and research.

Led jointly by Arthur J. Schmitt Professor of Chemical Engineering Arvind Varma, director of the Center, and Honeywell's Daniel Hayes, a visiting research professor and aerospace fellow in high-temperature materials, the collaboration and accompanying grant will fund five doctoral fellowships and establish a research initiation fund. Hayes serves as the technical liaison from Honeywell within the Center.

"The Center's expertise provides Honeywell access to fundamental and novel thinking," said Adriane M. Brown, vice president and general manager of Honeywell Aircraft Landing Systems. "We look forward to the innovation and discovery in technology and processes that will surely result."

Although this specific alliance is new, Notre Dame and Honeywell enjoy a long history of collaboration and cooperation. The company has regularly recruited and hired Notre Dame students for long-term career opportunities as well as summer internship programs. Additionally, Honeywell and the University have partnered on a number of projects, ranging from program and scholarship activities within the University to research and specific curriculum development programs, even community service initiatives. College of Engineering faculty and Honeywell engineers and scientists have teamed up to present seminars; they have also collaborated on proposals to government and private funding sources, such as Indiana's 21st Century Research and Technology Fund.

Honeywell Aircraft employs more than 1,400 people worldwide. Its parent company, Honeywell International, is a diversified technology and manufacturing leader with more than 120,000 employees in 95 countries. Why then, would this corporation consider a research agreement, even with a University sharing the same geographic community and housing a research center with similar technical interests?

***Honeywell's Daniel Hayes*** *joined the University in April 2001. He currently serves as the company's technical liaison within the Center for Molecularly Engineered Materials.*

It is vital that the company continues its own research and development activities to create new opportunities for products and processes. However, Honeywell Aircraft must also balance its investment of resources with the demands of the market and daily operations. Notre Dame's Center for Molecularly Engineered Materials provides an exceptional source of engineering and scientific talent. The partnership allows Honeywell to continue its efforts without compromising day-to-day operations. It enables Notre Dame to further investigate advanced materials on the molecular level with an industry partner who can provide graduate students with a unique perspective on the commercial sector. In short, it creates exciting business and academic value for both Honeywell and the University.

Of specific interest to Honeywell is the research that will be conducted at the Center on high-temperature composites. The five Honeywell Graduate Fellows will explore thermal management and heat transfer mechanisms during composite use at high temperatures; novel manufacturing processes as a way to reduce cycle times and manufacturing costs; composite compounding and engineering to allow for a more stable performance and oxidation protection; and friction and wear to improve the life and reliability of high-temperature composites used for friction applications. These five fellows will be named during the first semester of the 2001-02 academic year. However, their projects have already been selected. They include the "Tribological Investigation of the Carbon-carbon Composite Brake Systems," "CVI/CVD of Pyrocarbon in Porous Carbon," "Thermal Characterization of Carbon Brake Materials," "Processing of Mesocarbon Microbeads to High-toughness Materials for Friction Applications," and "Blocking and Catalytic Mechanisms for Oxidation of Carbon-carbon Composite Friction Materials." These projects create several new collaborative teams which will bring increased interdisciplinary input to important fundamental research problems.

particularly in silicon, are based on the principles learned while developing steel.

Examples of the research occurring within the advanced processing group include the collaboration of Samuel Paolucci, professor of aerospace and mechanical engineering, with a local company that makes piston assemblies for the automotive industry. The company would like to better control heat flow during the casting process.

McGinn and Howard A. Blackstead, professor of physics, search for novel materials through a process called combinatorial synthesis. Using this relatively new materials discovery technique, they develop an array of permutations of three or more elements and then screen the resulting compounds for desired properties. Because of its rapid automated production of compounds, combinatorial synthesis is an appealing technique to generate libraries of compositions for discovery of advanced materials such as phosphors, dielectrics, heterogeneous catalysts, or magnetoresistive materials.

Faculty members participating in this IRG include Bruce A. Bunker, professor and chair of the physics department; Chang; Davide A. Hill, associate professor of chemical engineering; Leighton; Maginn; Miller; Timothy C. Ovaert, professor of aerospace and mechanical engineering; Paolucci; Sevov; Mark A. Stadtherr, professor of chemical engineering; and Varma.

It is important to point out that each IRG description is cursory at best. The interdisciplinary nature and interdependence of each of these groups upon the other, and the number of projects they have undertaken, is exemplary. Like the Center for Nano Science and Technology, the Center for Molecularly Engineered Materials is dedicated to

*__Howard A. Blackstead,__ professor of physics, standing, and Paul J. McGinn, professor of chemical engineering, are members of the Advanced Processing Techniques IRG. The mirror furnace-based crystal grower, shown here, can produce temperatures in excess of 2000° C. With it Blackstead and McGinn grow a variety of oxide materials for advanced applications. One of the advantages of this system is that it allows for growth without contact with a crucible, eliminating one of the leading sources of contamination in crystals. In understanding the mechanism of crystal growth and the fundamental properties of materials, it is desirable to have as pure crystal as possible.*

partnering experts from many fields and viewpoints. It involves engineers, physicists, and chemists in a unique multidisciplinary setting as it explores the concepts in materials science and engineering. In other words, this is just the beginning.

## Educational Initiatives in the Center

**In addition to its research objectives,** the Center will serve as a resource for Notre Dame students as well as professional materials science technologists. The Center's educational coordinator Mark J. McCready, professor and chair of the chemical engineering department, has identified three goals for the educational component of the Center. First is the creation of a graduate program in materials science. Students would be admitted to any of a number of departments in engineering or science, but they would undertake coursework and thesis research in materials science. Faculty members in the Center are working to create the curriculum for this degree that will include some new courses as well as some existing ones. Because of the growing interdisciplinary nature of materials research, students may have advisors from more than one department or college.

The Center will also sponsor outreach programs for practicing engineers. For example, faculty might host a two-day program on the latest trends and topics in materials science research. Presented in a continuing education format, the outreach program would help expose practicing engineers to new developments.

McCready indicated that the third component of the Center's educational program would be the development of educational modules. These will most likely consist of web-based textual and video information that is used in conjunction with laboratory experiments. Students would be able to access these materials modules, the experiment requirements, and assignments through the Engineering Learning Center, presently located in Cushing Hall. Center faculty would supervise and develop these modules, which would be offered as College courses, allowing students to obtain a certificate program in materials science. Operating like an independent study course, students would work closely with the faculty member who developed the module, collaborating with him or her on the required experiment and other assigned projects.

Why the emphasis on developing additional programs for students in materials science? Why support a multidisciplinary materials effort, like the collaborations occurring within the Center for Molecularly Engineered Materials? Look at the world. More and more products are based on materials. New ceramics, new combinations of old ceramics, plastics, and biomaterials are everywhere.

Advanced materials are becoming more and more pervasive. Society is demanding new and better materials to meet its needs. These new materials must be stronger, more flexible, lighter, more corrosion-resistant, and less expensive than the old ones. They must meet the requirements of new and emerging technologies. These new materials — like the wood and stone of years ago — are the building blocks of tomorrow. And, the Center for Molecularly Engineered Materials is poised to play a leading role in their development.

*For more information on the Center for Molecularly Engineered Materials, visit http://www.nd.edu/~cmem/.*

**The Center will also sponsor outreach programs for practicing engineers.**

***Using an atomic force microscope,** Kishori Deshpande, a chemical engineering graduate student, explores the microstructure of nanoscale-grained Palladium-composite membranes. The membranes were developed at Notre Dame using a novel technique, also developed at the University, that combines two fundamental phenomena — electroless plating and osmosis. As a result, the structures exhibit the highest hydrogen flux values currently reported and can be used in a variety of applications, including fuel cells and petroleum refining processes.*

# The Market Value of Thin

When the Department of Electrical Engineering purchased a piece of the frequency spectrum for its new wireless communications testbed, it added to the significant history of communication research at Notre Dame. From the successful completion of the first wireless transmission in North America to being one of the handful of academic institutions to own a piece of the spectrum, College of Engineering researchers have been making waves.

Wireless communication is big business. In the United States alone, wireless carriers employ more than 150,000 people and generate more than $44 billion in annual revenue. Telecommunications and the Internet are among the most important sectors of the national economy.

While it's unusual for a university to own a wireless license, Notre Dame is not the only organization purchasing these licenses. In January 2001 Telecom New Zealand, an incumbent fixed-line carrier, paid NZ$37.6 million (US$16.94 million) for a wireless license they expect to use to roll out second and third-generation (2G and 3G) wireless services to their customers. The entire auction, which was sponsored by New Zealand's government, raised NZ$133 million (US$59.89 million). European spectrum auctions have also proven lucrative ... and very competitive. Recent auctions in Germany and the United Kingdom raised $46 and $35 billion respectively.

Other communication corporations are also getting into the act. In April 2001 Nokia, the world's largest cell phone manufacturer, entered into three-year contracts with mobile phone networks in Britain, France, and Germany. Under the agreement, Nokia will provide mobile core and radio networks, including a full range of professional services and operations support systems, to Britain's Orange, France's Itineris, and Germany's MobilCom. Nokia's fee for this service? A cool $1.3 billion.

Why are communication companies vying so intensely for bandwidth? And, why are researchers, like the faculty and staff of Notre Dame's Wireless Communications Testbed, investigating ways to increase the efficiency and robustness of wireless signals? According to a 1998 National Science

## an **overview** of wireless communications

# Air

Foundation Workshop Report, *Tetherless T3 and Beyond*, "the extreme popularity of cellular telephones that has developed in the decade and a half since their inception underscores the desire of humankind for communication anywhere and anytime." Immediate access to information is an idea whose time has come.

Before delving into the ramifications and reasonable expectations of the future of wireless communications, one should first explore the definition of wireless communications and how signals are sent.

## ANCIENT **HISTORY**

TELEGRAPHY, DISTANCE WRITING IN GREEK, is a communication system that transmits signals which represent coded letters, numbers, and signs. It has its roots in ancient times and can be divided into three categories: acoustic, optical, and electrical.

Diodorus Cronus, a Greek historian, recorded that King Darius I of Persia often sent important news from his capitol to the provinces of the Empire by means of a line of shouting men positioned at the tops of hills and mountains. Although not the "wireless" technology known today, this type of acoustical telegraphic communication was 30 times faster than a normal courier.

Optical telegraphy, as described by Aeschylus in the classic *Agamemnon*, detailed how people wishing to communicate with each other would use fire at night and smoke or mirrors during the day. This was a crude form of the coding used today to send signals around the world.

## 19TH AND 20TH-CENTURY **ACHIEVEMENTS**

A REVOLUTION IN TELEGRAPHY followed the discovery of electric current and the invention of the battery. For example, the first modern telegraphic systems featured one wire with a ground return. In 1832 Samuel Morse developed the concept of a telegraph based on electromagnetism. From that he built the first electric telegraph, receiving a patent for his invention in 1838. But the device still required wires.

Heinrich Hertz demonstrated the existence of electromagnetic waves in the late 1800s, but it was Guglielmo Marconi who is considered most responsible for taking the theories of radio waves out of the laboratory and applying them to practical devices. His "wireless" telegraph demonstrated its potential for worldwide communication in 1901, when he sent a Morse code symbol — the letter "s" — a distance of 2,000 miles across the Atlantic Ocean.

Marconi's system was soon adopted by the Italian and British navies. By 1907 it had been improved enough for commercial use. Even with the success of Marconi's Atlantic transmission, there were aspects to wireless communication that still needed to be explored. These included transmitting and receiving coded messages and developing a device that could convert high-frequency oscillating signals into an electric current capable of registering as sound.

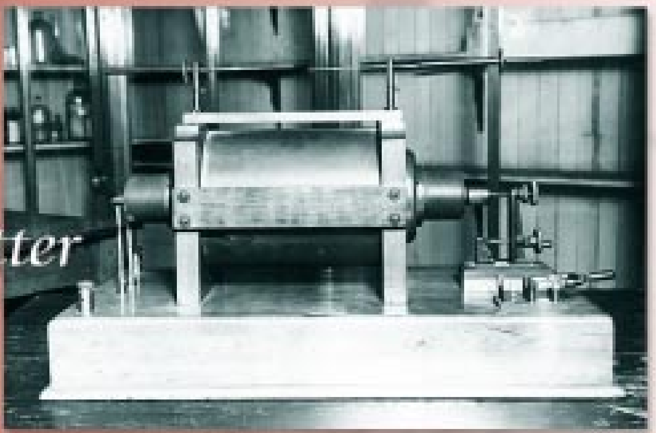

Guglielmo Marconi

The first significant breakthrough was the "Edison effect," the discovery that — if it had a positive charge — the carbon filament used in electric light bulbs of the time could also radiate a stream of electrons to a nearby test electrode. In 1904 Britain's Sir John Ambrose

# First Wireless Transmission in North America Sent from **Notre Dame**

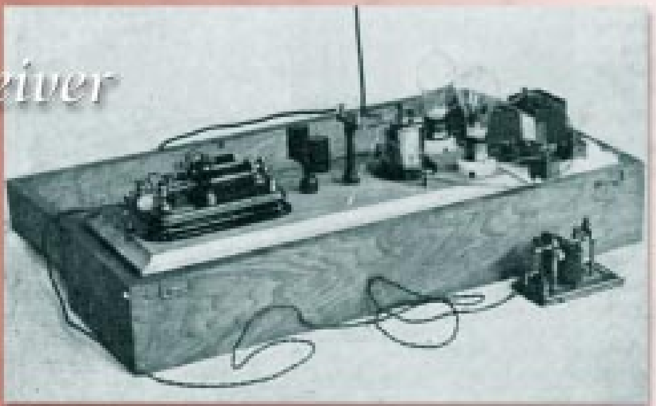
**In April 1899 Jerome Green, professor of electrical engineering, sent the first North American wireless transmission from the University of Notre Dame to the Saint Mary's College campus. Using equipment built on campus, Green wired a transmitter to a University flagpole and also hung wires to his receiver from a clock tower on the Saint Mary's campus. His message was simple ... just three Morse code dots.**

transmitter



*__This transmitter__ (above) and the receiver (below) were built by Professor Jerome Green on the Notre Dame campus. With them, he sent the first wireless transmission in North America. On September 5, 1998, the University celebrated the 100th anniversary of that feat. Alumni George Scheuer and John Pine, members of the Notre Dame Amateur Radio Club, duplicated Green's message. They were also on campus and demonstrated American amateur radio to Guglielmo Marconi when he visited the University in 1933.*

receiver



J E R O M E G R E E N

Fleming developed the diode. This allowed electric current to be detected by a telephone receiver. Two years later an American, Lee DeForest, developed the triode, introducing a third electrode between the filament and the plate. The triode amplified the signal enough to make live voice broadcasting a reality; this was added to Marconi's wireless telegraph to produce the radio.

Further radio development was hampered by the restrictions placed on airwaves during World War I. Technical limitations were also problematic. Few people had receivers. Transmission distances were short, and transistors hadn't been invented yet.

But by the mid-1930s almost every American household owned a radio. It would soon become the symbol of family togetherness and the main way the country received its news. In spite of these developments or perhaps because of them, radio — wireless communication — was in a state of transition, expanding into new frontiers.

Television and radar were logical spin-offs of radio communication. Televisions quickly began to appear in households after World War II. More than a million sets were sold before the end of the decade, with an average set costing $500. This was at a time when the average salary was less than $3,000 a year. When engineers perfected the rectangular cathode-ray tube, prices dropped, and within 10 years another 45 million sets were sold.

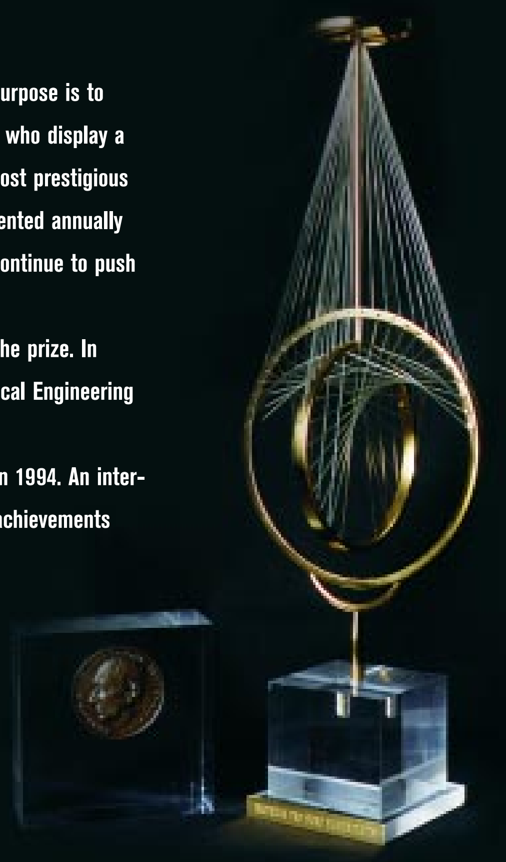
The transition of telegraphy from smoke signals with limited range to devices that could impact an entire country in a matter of seconds was nothing short of remarkable. Today, radio — wireless communication — is still in transition.

## NOTRE DAME RESEARCHERS RECEIVE THE MARCONI PRIZE

**The Marconi Foundation was created by Gioia Marconi Braga, the daughter of Guglielmo Marconi. Its purpose is to commemorate the spirit of Marconi and his contributions by honoring the achievements of researchers who display a similar dedication to the use of science for the betterment of the human condition. Regarded as the most prestigious prize in the field of telecommunications and information technology, the Marconi Award has been presented annually since 1974. It is given to engineers and scientists in the field of communications who, like Marconi, "continue to push forward the frontiers of knowledge."**

**In 1999 Dr. James Massey, a 1956 graduate of the Department of Electrical Engineering received the prize. In addition to graduating from Notre Dame, Massey also served as Frank M. Freimann Professor of Electrical Engineering from 1962-1977.**

**Oliver M. Collins, professor of electrical engineering, received the Marconi Young Scientist Award in 1994. An international prize, the Marconi Young Scientist Award is presented to a young researcher for outstanding achievements in communications science and technology. Specializing in deep-space communications, satellite communications, and coding theory, Collins joined the Notre Dame faculty in 1995.**



# WIRELESS RESEARCH AT **NOTRE DAME**

WITH ALL THE CELL PHONES, personal digital assistants (PDAs), satellites, and remote-controlled devices available today, it may seem as if wireless communication is a mature technology. To a certain extent this is true. Engineers and communications technologists have made great strides in using radio waves to help people around the world communicate with one another. Current wireless communications services include wideband cellular phone systems, personal communication services (PCS), broadband wireless systems, wireless local loops, wireless local area networks (LAN), satellite communications, and wireless multimedia.

The demand for these types of services has skyrocketed in recent years, triggering an evolution of operating standards. For instance, in the mobile cellular industry, communication standards have evolved from Advanced Mobile Phone Service (AMPS), which is an analog technology designed to simply carry voice signals, to interim digital standards, to Groupe Speciale Mobile (GSM) and IS-95, which allow limited data as well as voice transmission.

Future generations of digital wireless communication systems, such as 3G, will most definitely accommodate substantial data transmission capabilities and highly integrated multimedia services. "Think of the Internet 10 years ago," said Thomas E. Fuja, professor of electrical engineering. "That's where wireless is now. Ideally, the goal is to provide the same kind of access on a Palm Pilot that is available on a T1 line."

So what's the problem? Multipath fading, receiver noise power, and transmitter signal power all play roles in how efficiently and effectively a signal travels from Point A to Point B. However, one of the major factors that limits the service capacity of wireless communications systems today is interference, especially multiple access interference (MAI), the interference from other users.

When multiple users try to gain access to the base station, one user's signal may interfere with another. This can seriously hamper the communication, particularly when the desired user is farther away from the base station than the other users.

Intersymbol interference (ISI) is also a type of interference; it is caused by frequency-selective multipath fading. Both MAI and ISI can be mitigated by employing statistical signal processing techniques. Research in this area is led by Yih-Fang Huang, professor and chair of the electrical engineering department.

Another challenge to wireless communications is something called spectral or bandwidth efficiency, the number of bits per second per hertz (Hz) or unit of bandwidth at which a signal can be reliably transmitted. Typically, wireless communication systems operate at around one bit per second per Hz. In contrast, the most sophisticated telephone line modems, wired communications, operate in excess of 10 bits per second per Hz. This is the reason individuals can access streaming video on their computers and not on their cell phones or other wireless devices. Researchers in the electrical engineering department are interested in developing the capability of producing more spectrally efficient communications for wireless applications.

> The University has a strong history in error-control coding and reliable **communications.**

The University has a strong history in error-control coding and reliable

# THE FEDERAL COMMUNICATIONS COMMISSION **AND THE BATTLE FOR AIRWAVES**

An independent agency of the U.S. government, the Federal Communications Commission (FCC) was created in 1934. The function of the FCC is to regulate interstate and foreign radio, television, wire, and cable communications; to provide for the development and operation of orderly broadcasting services; to provide rapid, efficient telegraph service – across the nation and around the world; to promote the safety of life and property through the use of wire and radio communications; and to employ communications facilities for strengthening national defenses. The agency has jurisdiction over communications in the 50 states, Guam, Puerto Rico, and the Virgin Islands.

The FCC regulates amplitude modulation (AM) and frequency modulation (FM) broadcasting as well as other kinds of radio services. It issues construction permits and licenses for all nongovernmental radio stations, assigning frequencies, operating power, and call signs. It also inspects transmitting equipment and regulates the use of the equipment.

Television broadcasting is regulated by the FCC in much the same way as radio. Cable television is regulated by the FCC only in regards to use and quality of service.

Common-carrier operations, such as telephone, telegraph, radio, and satellite communications, are supervised by the FCC. The agency is responsible for domestic administration of the telecommunications provisions of treaties and international agreements. It licenses radio and cable circuits from the U.S. to foreign points.

Additionally, the FCC supervises the Emergency Broadcast System. The System alerts and instructs the public in severe weather, local emergencies, and in the event of enemy attack.

What has raised the eyebrows of many wireless providers is the FCC's approach to broadband communications. The FCC has traditionally controlled how much bandwidth any communications company can own in a specific community. This "spectrum cap" has meant that larger carriers, who had the financial means to purchase more spectrum or pay a larger amount for a piece of the spectrum during an FCC auction, were limited as to how much they could "win" at any given auction.

Why has this been a problem? Because everybody wants more bandwidth. The pressure on federal regulators – and the airwaves that carry wireless signals – is intense. An October 2000 report by the Council of Economic Advisers studying the economic impact of third-generation (3G) wireless technology indicated that the number of wireless subscribers around the world is rising at an incredible pace. For example, 19 percent of the population in Finland subscribed to wireless services (mobile phones) in 1995. By 1999 65 percent of the Finnish population were subscribers. In the U.S. 11 percent of the population owned mobile phones in 1995. By 2000 that figure exceeded 35 percent. That's a lot of traffic for networks that are already clogged. And, the demand keeps growing – both in sheer numbers of subscribers and in the types of services they want.

Providers are gearing up to meet the needs, but with the cap in place, those who are at or near capacity are out of luck. They may not be able to launch next-generation services without additional spectrum. But they cannot purchase additional spectrum because of the cap.

Acknowledging that third-generation services might be hampered by the cap, the FCC has said it may take up the spectrum requirements of 3G services in a future ruling. Until that time wireless providers may apply for a waiver of the cap, assuming they can demonstrate that they could not otherwise develop and provide the new services.

The purpose of the facility is to provide a realistic test **environment ...**

communications. They are also designing coded modulation schemes — methods of representing bits with waveforms — that incorporate redundancy into the bits in a bandwidth efficient manner. This year Notre Dame took another step in addressing the issue of spectral efficiency by creating a unique wireless communications testbed.

The process began in 1999 when Dr. Oliver Collins, associate professor, suggested that the Department of Electrical Engineering purchase a piece of the frequency spectrum for research. What started as Collins' brainstorm became reality as the department, in partnership with the University, purchased its own spectral allocation, 200 kilohertz in the 220 MHz band, from a Federal Communications Commission 220 MHz Phase II auction.

The University's frequency band has a four-county range in South Bend and the surrounding area. "The bandwidth purchased for Notre Dame is ideal for the research being conducted," said Daniel J. Costello Jr., Leonard C. Bettex Professor of Electrical Engineering. "Although we're actually working on what would be considered narrowband communication — 5kHz and 50kHz slots — the research can also be applied to wideband systems."

It is important to note the difference between narrowband capabilities, which offer a small transmission capacity useful for carrying voice and limited data messages, and wideband capabilities. Also called broadband, wideband systems allow for the higher transmission capability necessary for video and image communication.

As the department was purchasing its piece of the spectrum, it was also receiving a major research instrumentation grant from the National Science Foundation for the development of an experimental radio facility. With these funds electrical engineering faculty members Costello; Collins; Patrick J. Fay, an assistant professor; Fuja; and Huang created the Wireless Communications Laboratory.

As unusual as it is for a university to have its own spectral allocation, it is even more uncommon for an institution to have a testbed the scope of Notre Dame's. In essence, the testbed will provide narrowband digital radio communications between a base station in Fitzpatrick Hall and mobile transceivers in the greater South Bend area.

The purpose of the facility is to provide a realistic environment for the development of advanced modulation, coding, and interference mitigation techniques as well as high-speed analog-to-digital converters.

According to Collins, in the last few years wireless communications technology has come a long way, and it is close enough to its ultimate limits that the existing mathematical models used to describe wireless channels are no longer sufficient. The flaws are beginning to show.

Consider this: In the past researchers could accurately predict the performance of a communication link using mathematical models and simulation. As the codes become more sophisticated, this becomes less and less true. Today it is

# MEET THE **FACULTY**…

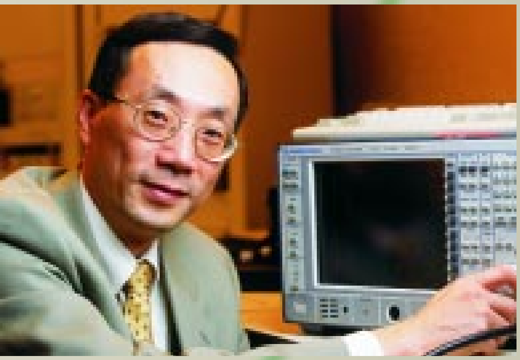
involved in the Wireless Communications Laboratory. From the writing of grant proposals to the development of hardware and software, several faculty and staff members from the Department of Electrical Engineering have been key. They are:

*Professor **Oliver M. Collins** specializes in coding for communication channels, tapes and semi-conductor memories; high-performance packet and circuit switch architectures; information theory; cryptography; miniature satellites; and radio frequency hardware and modem design. Collins joined the Notre Dame faculty in 1995. He is part of the Coding Theory Research Group at Notre Dame, a team of engineers working on several projects, including the development of turbo and low-density parity check coding for reliable communication, interactive decoding and hybrid sequential decoding methods, bandwidth-efficient error-control strategies for wireless networks, and joint source and channel coding for the transmission of voice, images, and video over noisy channels.*

*Also part of the University's Coding Theory Research Group, **Daniel J. Costello Jr.,** Leonard C. Bettex Professor of Electrical Engineering, specializes in information theory, error-control coding, digital communications, multiple-user communications, and communication networks. Support for his research comes from NASA, the National Science Foundation, Lockheed Martin Corporation, Motorola, and Raytheon. Costello was principal investigator on the 1999 proposal to the NSF's Major Research Instrumentation Program. Funds awarded as a result of this grant, a total of $547,566, have purchased the equipment currently being used in the Wireless Communications Laboratory.*

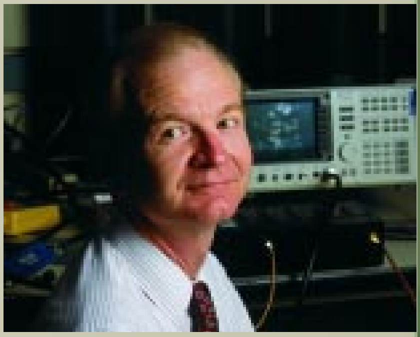
***Patrick J. Fay,** assistant professor, joined the electrical engineering faculty in 1997. His research interests include microwave device characterization; monolithic microwave integrated circuit and optoelectronic integrated circuit design, fabrication, and characterization; and device technologies for ultra-high-speed digital circuits.*

*In 1998* ***Thomas E. Fuja*** *joined the Department of Electrical Engineering as an associate professor; he had spent 11 years on the faculty of the University of Maryland prior to coming to Notre Dame. He is also a member of the Coding Theory Research Group. Fuja's research addresses the problem of reliably transmitting information over unreliable and constrained communication channels. Most of his projects focus on coding for wireless applications and on the interface between source coding (compression) and channel coding (error control).*



*Professor and chair of the Department of Electrical Engineering* ***Yih-Fang Huang*** *specializes in statistical signal processing and communications. His research includes detection and estimation, adaptive signal processing, and set-membership filtering and applications to modern communication systems. Dr. Huang has been a member of the Notre Dame faculty since 1982.*

***John L. Ott,*** *assistant professional specialist, has been a member of the Department of Electrical Engineering since 1984. His experience in design, maintenance, and supervision of the non-solid state undergraduate laboratories within the department enhance his current position as wireless communications engineer. Ott has been pivotal in the development of the Wireless Communications Laboratory working with Collins to acquire, set-up, and calibrate equipment and software programs needed for the lab to function properly.*



# WIRELESS TERMS
## and what they mean

### BANDWIDTH
The term "bandwidth" describes the transmission capacity of a channel in terms of the range of frequencies it can convey. A greater bandwidth indicates the ability to transmit a larger amount of data, more bits, over a given period of time.

### BROADBAND (ALSO KNOWN AS WIDEBAND)
A communications channel of high bandwidth, broadband describes a communications channel capable of transmitting a relatively large amount of data over a channel in a specific period of time.

### DIGITAL
Most newer wireless phones, devices, and networks use digital technology, which encodes information using a binary code of ones and zeroes.

### MULTIPOINT MULTICHANNEL DISTRIBUTION SERVICE (MMDS)
Often called "wireless cable" MMDS is a communications system that distributes cable television and other broadband signals to multiple users via a single transmitter.

### PERSONAL COMMUNICATION SERVICES (PCS)
Recently authorized by the FCC, PCS systems are one of the newer classes of wireless communications services available today. They use a different radio frequency, the 1.9GHz band, than cellular phones and digital technology for transmission and reception.

### PERSONAL DIGITAL ASSISTANT (PDA)
This handheld device combines organization, computing, telephone, fax, and networking features. While most PDAs began as pen-based devices, which means that many PDAs include handwriting recognition, some devices can react to voice input. Most of today's devices are available in either a stylus or keyboard version.

### NARROWBAND
A communications channel of low bandwidth, it is usually restricted for a single user or a single purpose, such as voice transmission only.

### RADIO FREQUENCY (RF)
Electromagnetic waves propagate through the air at radio frequencies from as low as tens of kilohertz to as high as hundreds of gigahertz.

### RADIO FREQUENCY INTERFERENCE AND NOISE
RF interference is an undesired signal that conflicts with the desired signal, causing extraneous noise during transmission and disrupting the signal as well as its effective and accurate reception.

### SPECTRUM
The spectrum is the entire range of electromagnetic frequencies.

### THIRD-GENERATION WIRELESS (3G)
This is the next generation of wireless communications being developed. It enables much higher transmission rates to devices and will allow for a larger array of services to consumers.

more often that the designed code works well in computer simulations but does not perform as it should across a real channel. "This is the essence of the Wireless Lab," says Collins. "We want to be able to test communications systems in the real world as easily as we have through computer simulations in the past."

Collins and his colleagues are seeking to make the most efficient use of a channel ... meaning for a given bandwidth and power allocation, sending more bits over the same channel in the same amount of time. This is important because, in telecommunications, spectrum is the most important resource. It's also finite and can be expensive. Being able to transmit more bits per second for every Hz of bandwidth enables more rich information to pass through the channel. It's the difference between poor voice transmission and real-time video ... an option not currently available in personal wireless communications devices.

Another approach to improving spectral efficiency is the use of multiple antennas. Currently, Huang and his students are working on adaptive beamforming, using multiple antennas to exploit spatial diversity and increase spectral efficiency.

Spectral efficiency is important, but so is

## ELECTROMAGNETIC WAVES AND HOW THEY FUNCTION

**Radio, wireless technology, is a system of communication that employs electromagnetic waves propagated through space. These waves have distinct characteristics and are used for a variety of purposes. For example, radio waves are used not only in radio broadcasting but in wireless telegraphy, telephone transmission, television, radar, navigational systems, and space communications.**

**The shortest waves have the highest frequency, number of cycles per second, and the longest waves have the lowest frequency. The unit of frequency – hertz – was named for German radio pioneer Heinrich Hertz. Radio waves typically range from a few kilohertz, 1,000 cycles per second, to several gigahertz, billions of cycles per second.**

**How these waves travel depends upon many things, including their frequency and the atmosphere they must pass through. For instance, electromagnetic waves in a uniform atmosphere travel in straight lines, but the earth's surface is not straight. Therefore, long-distance transmissions can only be achieved in a direct line, such as between the earth and a communications satellite. The signal may then be relayed from the satellite to any other point on the earth. Physical characteristics of the air can also cause slight variations in velocity, which are often sources of errors in communications systems.**

... wireless communications remains an industry in **transition.**

power efficiency. According to Collins and Fuja, any message can be transmitted simply by cranking up the power. "Someone could take the entire book *Gone with the Wind*, encode it into one long number, string of bits, and transmit it instantly over an infinitesimally small section of bandwidth," said Fuja. "But it would require an incredible amount of power." Power is expensive, and the requirement of such a large amount could be cost-prohibitive. In addition, such powerful signals would interfere with other transmissions.

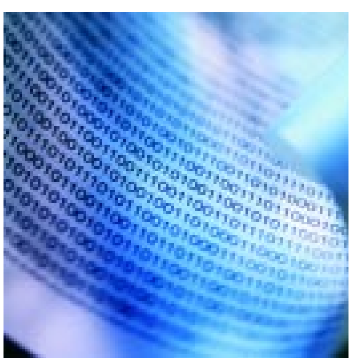
This is a challenge, especially when dealing with cellular communications. People want devices to be smaller, but they also want them to be powerful. The signal-to-noise ratio — how much power it takes to transmit over how much noise is present — is a concern. People don't want to carry a power pack the size of a car battery for a cell phone.

The testbed and the fact that it can operate over a broad geographic area gives the Notre Dame faculty and staff the unique ability to experiment along less traditional avenues. For example, the group is investigating the interaction between signal design and radio frequency hardware, the equipment that generates and ultimately receives a signal.

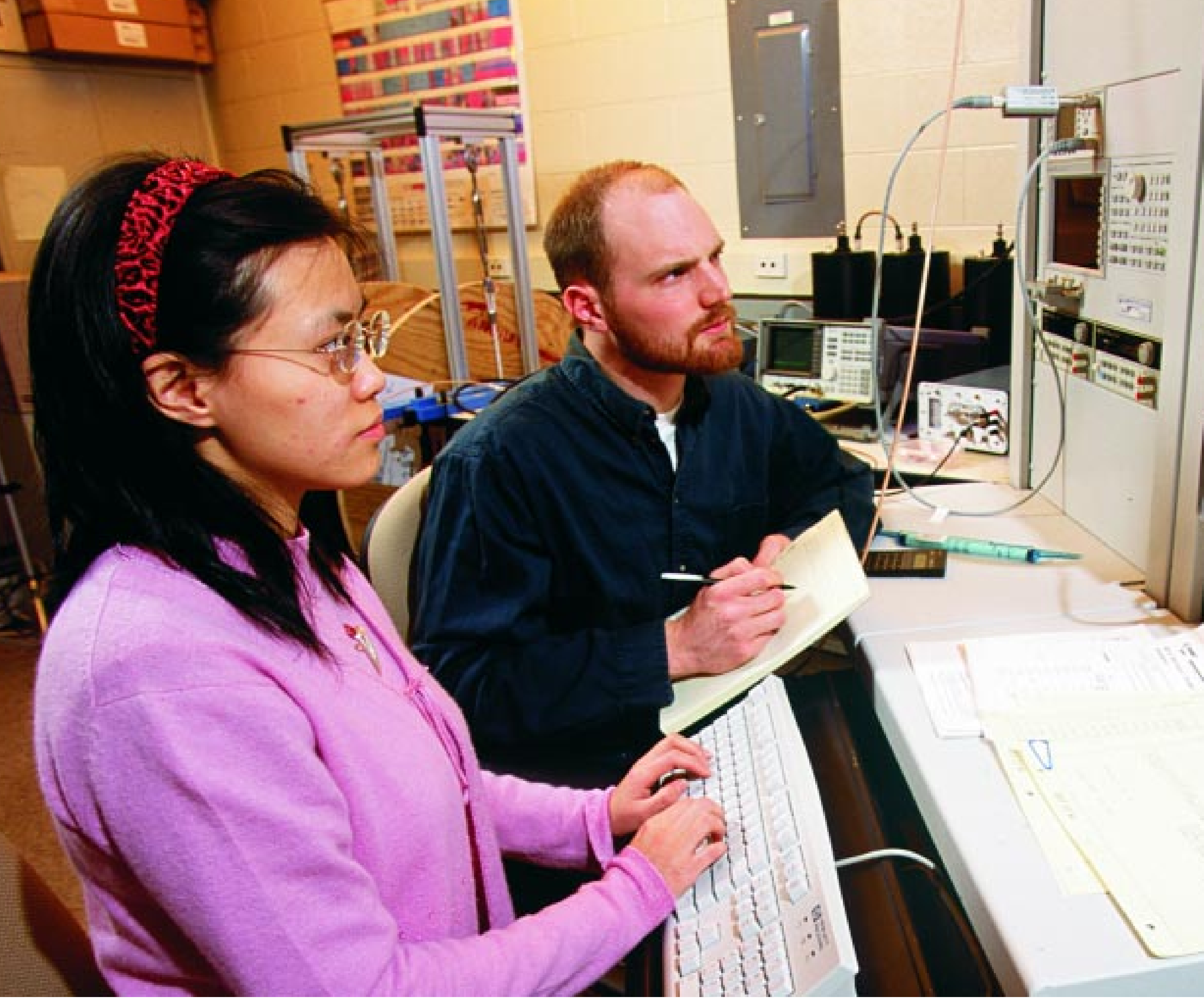
They are also exploring the use of direct conversion receivers. Many researchers have attempted to develop this unusual architecture, but have failed because of flicker noise — also called 1/f noise — in the mixers. Collins and colleagues have created a mixer with a much lower flicker noise, allowing them to receive a signal in an efficient and relatively error-free manner.

The group is also developing coding schemes, designing the signal in such a way that damage to the signal or medium would not corrupt the message. One of the best known examples of applied coding theory is Reed-Solomon codes, which work by adding redundant information to a bit stream, like repeating a statement three or four times so another party can understand it. The genius of R-S codes is that they maintain accuracy at the receiving end while adding as few redundant bits as possible. They are also very versatile and, in addition to wireless communications, can be used in a variety of applications.

For example, the use of R-S codes can be found in the compact disc market. Every CD player contains a highly efficient R-S decoder, which processes two million bits of information per second. R-S codes are also used in digital video devices, high-definition television, and in the deployment of 500-channel cable TV. They allow a device, such as a CD player, to recreate data that was damaged. Thus, defects like minor scratches have no effect on the recovery of the message, i.e., playing the CD.

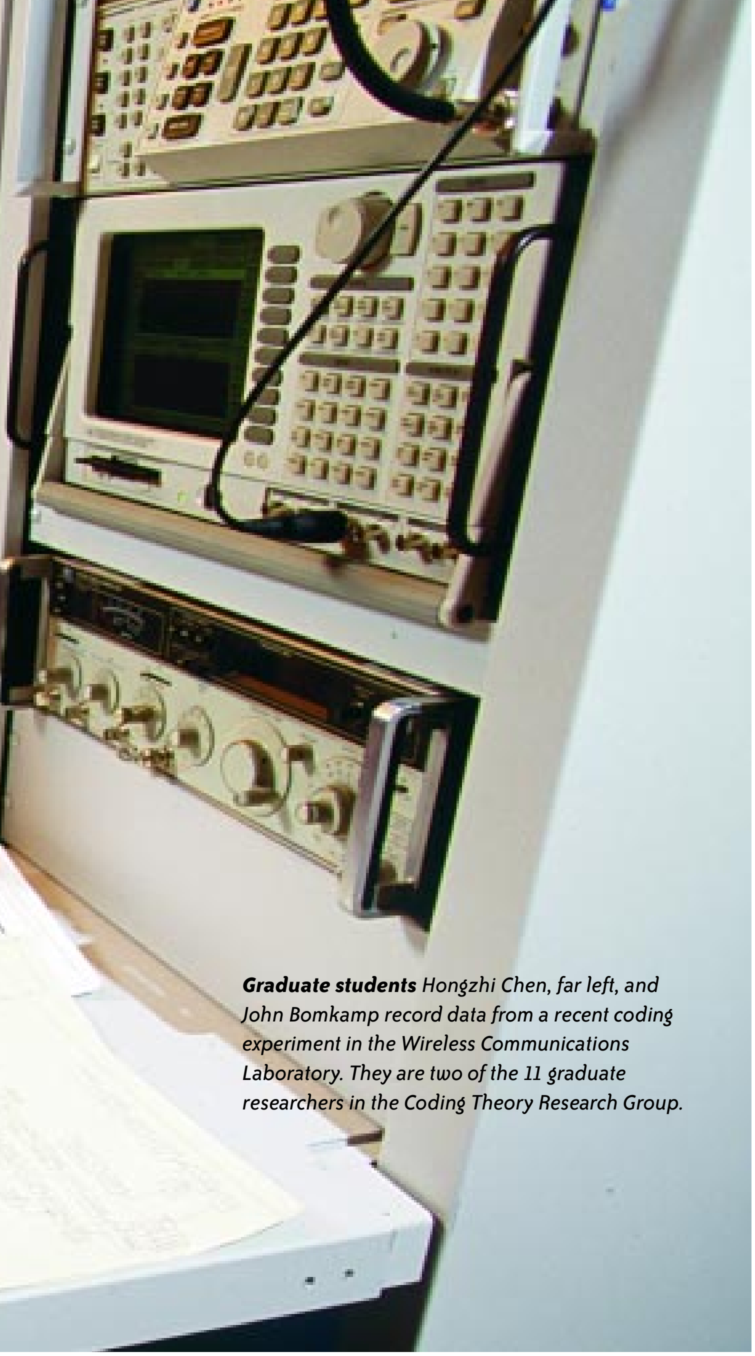


Another coding scheme the Coding Theory Research Group — Costello; Fuja; Collins; Joachim Rosenthal, professor of mathematics; and Peter C. Massey, a research assistant professor in electrical engineering —



is investigating is parallel concatenated convolutional codes, also know as turbo codes. A newer form of error-control coding, turbo codes were developed in France in 1993. Original computer simulations indicated bit error rates on the order of $10^{-5}$ were achievable with an incredibly low signal-to-noise ratio, which is desirable for transmitting and receiving data, particularly images or video. In fact, current 3G standards use turbo codes for transmitting data over wireless channels. The Notre Dame research team did some of the early work on turbo codes, and Costello and Fuja are now working on turbo coded modulation, a more bandwidth efficient turbo coded scheme.

Lab faculty, staff, and students are also working on a software radio design. Necessary because of the rapid transition from analog to digital communications, a software radio is an electronic device whose modulation and signal processing functions are contained in its software. An information bearing signal — a stream of bits — is converted from digital to analog via a wideband digital-to-analog converter and then "upconverted" to form a radio wave. The software radio receiver uses a wideband analog-to-



***Graduate students*** *Hongzhi Chen, far left, and John Bomkamp record data from a recent coding experiment in the Wireless Communications Laboratory. They are two of the 11 graduate researchers in the Coding Theory Research Group.*

digital converter to capture the waveform, then extracts, down converts, and demodulates the signal, using software processing techniques.

Employing a combination of techniques that include multiband receiving antennas and RF converters, software radios extend the evolution of programmable hardware and increase digital radio flexibility. The concept of software radio identifies some of the trade-offs that must be made in radio architectures while attempting to balance changing standards, an evolving technology, and the economics of a highly competitive market.

Current support for these and other projects in the lab comes from NSF, NASA, Lockheed Martin, Motorola, and Raytheon.

The bottom line? Although wireless communications remains an industry in transition, it is here to stay. "Wireless communications will play an indispensable role in the establishment of a ubiquitous communication system which allows for the immediate accessing and transmitting of information anytime, anywhere," said Huang. It is the wave of the future.

As long as the world's population continues to demand faster and more reliable communication services, wireless technology will continue to develop. "It took 30 to 40 years before telephone line modems reached their natural capacity," said Fuja. "Increasing the efficiency and robustness of wireless communication systems is a long-term project."

Much has already been accomplished. With the improvements in data transmission, costs have fallen and capabilities have expanded. Wireless telephone and pager markets have grown dramatically. Wireless devices will soon offer 3G capabilities; consumer demands will require it.

However, more spectrum cannot be created; it's a finite resource. To develop it sufficiently for 3G and future services, it must be re-allocated from existing licenses. It, therefore, becomes even more imperative that research and development efforts — like those being undertaken in the Wireless Communications Laboratory — continue to find ways to increase the bandwidth and power efficiencies of wireless systems.

*For more information on the Wireless Communications Laboratory, visit http://www.nd.edu/~ee/research/researchindex.html.*

# Research and Technology Fund Supports High-tech Efforts

***William Strieder,** professor of chemical engineering, is working with Honeywell International on carbon-carbon composites. Shown here is a close-up of a carbon brake rotor. The lugs must be structurally strong for optimized wear.*

INDIANA HAS TRADITIONALLY BEEN KNOWN as a maker and grower state, not a major source of technological innovation and new business development. But in 1999, the Indiana General Assembly created the 21st Century Research and Technology Fund for the purpose of expanding the high-technology sector of the state's economy. A total of $50 million was allocated to the program for a period of two years.

Similar to development programs in other states, the Legislature's goals were to encourage academic-commercial partnerships, create intellectual and physical infrastructures, transfer technology into products and thus to the economy, and increase the state's capacity to compete for research and development funds, both federal and private.

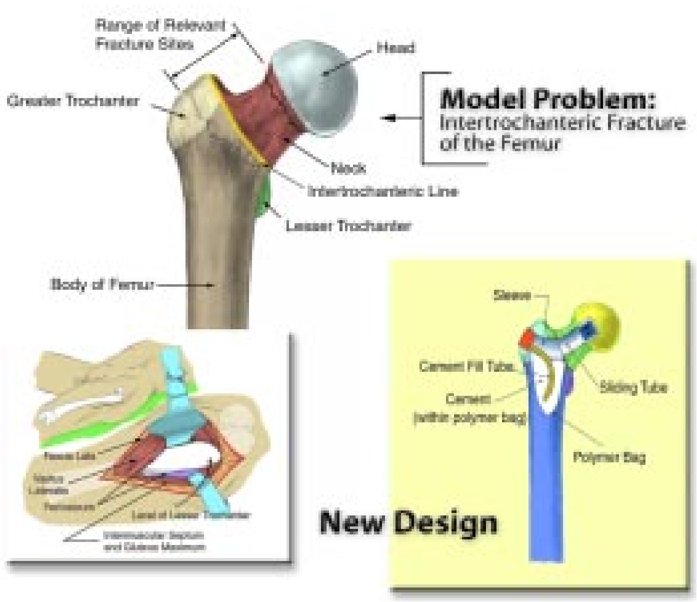
In the planning stages of the Fund, the General Assembly recognized that many organizations operate under a 19th-century model of engineering, science, and technology — a clearly discipline-specific method. In contrast they noted that the technological advances of the last three decades have come from interdisciplinary approaches in both the academic and corporate arenas.

The Legislature then identified industries and/or technologies with significant potential for growth. These included: genetics, proteomics, advanced materials, telecommunications, and photonics.

Genetics is a focal point for economic growth, providing the basis for innovation in medical diagnostics, disease prevention, and therapeutic treatments. It could transform agriculture, as well as change the ways in which diseases are diagnosed and treated. Proteomics offers advances in biological systems and cell biology. The development of advanced materials, particularly relating to micro and nanotechnologies, could create new approaches and capabilities for manufacturers. Telecommunications and photonics offer breakthroughs for traditionally "wired" industries.

The first 21st Century Fund awards were made in early 2000, and the final round of awards were announced in January 2001. All awards, totaling $49.2 million, were made using guidelines developed by the Fund's board. A review panel comprised of researchers and

***Minimally Invasive Orthopedic Implant Development***



economic experts from across the country examined the quality of the proposals, determined the merit of the scientific or technological objectives, and weighed the intent and feasibility for commercialization of each project. Proposals were also evaluated on the basis of collaborative efforts between academic institutions and corporations.

Why? Because because state officials believe that the number and nature of interactions between academic and commercial sector partners, particularly in the identified frontier areas, will determine the success of this program and the future of the state's economy.

Over the course of the program, Notre Dame received $8,900,392. The University has joined other academic institutions and corporations in efforts to convince the Legislature to continue the 21st Century Research and Technology Fund for an additional two years.

## AN OVERVIEW:
### 21ST CENTURY RESEARCH AND TECHNOLOGY FUNDING FOR NOTRE DAME PROJECTS

| Principal Investigator(s) | Department | Title of Project | Amount |
|---|---|---|---|
| **Gary Bernstein** | **Electrical Engineering** | **Development of a Microfluidics-based Blood Monitoring System**<br>**Collaborators: Bayer Corporation and South Bend Controls** | **$ 1,670,536** |
| **Joan Brennecke** | **Chemical Engineering** | **Environmentally Benign Solvents for Pharmaceutical Processing**<br>**Collaborator: Eli Lilly and Company** | **$ 226,483** |
| Frank Collins | Biological Sciences | Indiana Center for Insect Genomics<br>Collaborator: Purdue University | $ 1,503,007 |
| Jacek Furdyna | Physics | Semiconductor Spintronics<br>Collaborator: Indiana University | $ 304,000 |
| **James Mason and Steve Schmid** | **Aerospace and Mechanical Engineering** | **Advanced Spinal Instrumentation**<br>**Collaborators: Purdue University, Indiana University, and Zimmer Inc.** | **$ 1,998,987** |
| **Paul McGinn** | **Chemical Engineering** | **Combinatorial Synthesis of Microwave Ceramics**<br>**Collaborator: CTS Corporation** | **$ 541,421** |
| **Kenneth Sauer** | **Electrical Engineering** | **Statistical Methods for Tomographic Image Reconstruction and Analysis**<br>**Collaborator: Indiana University** | **$ 31,248** |
| **Steve Schmid and James Mason** | **Aerospace and Mechanical Engineering** | **Minimally Invasive Orthopedic Implant Development**<br>**Collaborators: Purdue University, Indiana University, and Zimmer Inc.** | **$ 1,967,958** |
| **Robert Stevenson** | **Electrical Engineering** | **Video over the Internet**<br>**Collaborator: Purdue University** | **$ 114,594** |
| **William Strieder** | **Chemical Engineering** | **Carbon-carbon Composites**<br>**Collaborators: Purdue University and Honeywell International Inc.** | **$ 236,040** |
| **Arvind Varma** | **Chemical Engineering** | **Combustion Synthesis of Orthopedic Implant Materials**<br>**Collaborator: Zimmer Inc.** | **$ 188,672** |
| **Eduardo Wolf** | **Chemical Engineering** | **21st-century Infrared Sensing**<br>**Collaborator: Purdue University** | **$ 117,446** |

# College Introduces **Integrated Engineering and Business Program**

In EG111/112 and other courses throughout the College, the administration and faculty stress the importance of collaboration and multidisciplinary teams. Just as practicing engineers need to work with engineers from other disciplines, they also need to understand how to function in the business world. For this reason, the College is developing a new integrated engineering and business practice curriculum for undergraduates. As the first step in this process, a director has been hired and prototype elective courses are being planned for the 2001-02 academic year.

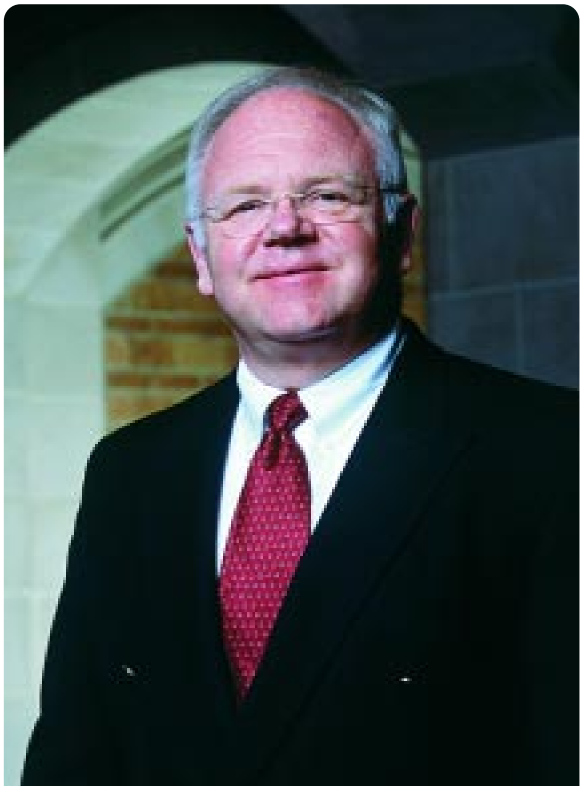
Joining the College in April 2001, Robert Dunn serves as director of the integrated engineering and business practice curriculum. "We would be hard pressed to find someone with better credentials," said Frank P. Incropera, McCloskey Dean of Engineering. "He has had an extremely successful career as an engineer and a business leader."

Dunn graduated from Notre Dame with a bachelor's degree in engineering science. He continued his education, earning a master's degree in engineering mechanics from Pennsylvania State University and a doctorate in aeronautical engineering from the University of Illinois at Urbana. He comes to Notre Dame with 30 years' experience at the IBM Corporation, where his career involved the management of complex organizations and business relations around the world.

For example, during his tenure at IBM, Dunn's responsibilities progressed from those of a design engineer to technical assistant to the president of the Systems Technology division. He served as manager of the Packaging, Development, and Production Quality Assurance division and then as director of the Systems Technology Laboratory. He also managed the start-up of an IBM facility in Dublin, Ireland, and subsequently served as vice president and manager of the corporation's Poughkeepsie site, a facility comprised of 15 major divisions and 6,000 employees.

Two courses will be offered during the 2001-02 academic year. The first, open to

***Robert Dunn** was named director for the integrated engineering and business practice curriculum in April 2001. Beginning in the fall semester, he will teach two pilot courses, "Integrated Engineering and Business Fundamentals" and "Advanced Topics in Integrated Engineering and Business Practice." The new curriculum is a result of the efforts of a joint committee of faculty from the College of Engineering and the Mendoza College of Business with input provided by the College of Engineering Advisory Council.*



Just as **practicing engineers** need to work with engineers from other disciplines, they also need to understand how to function in the **business** world.

seniors and fifth-year engineering students, is titled "Integrated Engineering and Business Fundamentals." It will explore how the actions of engineers and managers relate to income statements, balance sheets, and cash flow. The roles and responsibilities of diverse corporate functions — such as marketing, sales, research, development, procurement, manufacturing, finance, and human resources — will also be reviewed.

Topics to be covered also include product development, project management, quality, customer satisfaction, teamwork, mentoring, and management styles and roles.

Scheduled for spring 2002 and titled "Advanced Topics in Integrated Engineering and Business Practice," the second course will expand on the foundation laid during the first-semester class. Trends such as e-business, globalization, outsourcing, consulting, and the role of logistics in competitiveness will be studied.

Both of these three-credit courses will examine the characteristics of modern industrial corporate leaders and will feature guest speakers. Although the prototype courses will be offered to a limited number of students, normal sequencing, with unlimited enrollment, is expected to begin in the fall semester of the 2002-03 academic year.

## Center for Nano Science and Technology Names New Director

***A faculty member since 1985,*** *Wolfgang Porod, professor of electrical engineering, focuses on solid state physics and its application to electronics; reliability, degradation and breakdown; quantum devices and architectures for nanoelectronics; and the limits imposed by the laws of physics on computation.*

**Wolfgang Porod,** professor of electrical engineering, has been named the director of the Center for Nano Science and Technology. He has served as the associate director of the Center since its inception. In his new capacity, he will coordinate the Center's research and educational programs while functioning as a focal point for the University's activities in the emerging area of nanoscience and technology.

Led by the College of Engineering's electrical engineering department, the Center is comprised of a multidisciplinary team of researchers from the departments of electrical engineering, computer science and engineering, chemistry and biochemistry, and physics. One of the major research initiatives within the Center is the concept of computing through Quantum-dot Cellular Automata (QCA). Pioneered at Notre Dame, QCA is a new paradigm for transistorless computing — no electron flow or current. The Center is the only research facility in the country addressing nano-computing capabilities in this particular fashion.

Porod replaces former director Gerald Iafrate, professor of electrical engineering, who is leaving Notre Dame to join the faculty at North Carolina State University. Although he will not be on the Notre Dame campus, Iafrate will continue collaborating with colleagues from the College.

For more information on the Center for Nano Science and Technology, visit http://www.nd.edu/~ndnano/.

# Five Engineering Faculty Named to Endowed Chair Positions

University Provost Nathan O. Hatch announced that five faculty members of the College of Engineering were awarded endowed chair positions. The endowed chair designation represents the highest appointment the University can make to recognize a faculty member's achievements. It is awarded based on his or her scholarship and contributions to research as well as the faculty member's commitment to the moral and intellectual growth of Notre Dame students.

The University's 146 endowed professors represent a diverse mix of senior scholars who have distinguished themselves through long careers of accomplishment and younger faculty who have demonstrated exceptional enterprise, scholarly promise, and outstanding teaching ability. Engineering faculty honored in 2000 were Daniel J. Costello Jr., Ahsan Kareem, Billie F. Spencer Jr., Peter C. Burns, and Danny Z. Chen.

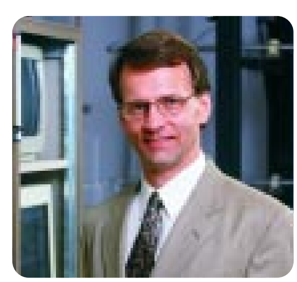
*Daniel J. Costello Jr.*

**Daniel J. Costello Jr.** was named the Leonard C. Bettex Professor of Electrical Engineering. A member of the College faculty since 1985, Costello's research is in the area of digital communications with emphasis on coding and information theory, communication networks, and error-control coding. He helped design the communication system for NASA's Tracing and Data Relay Satellite System and has contributed to the design of the codes used by NASA for its Pioneer space series. In 2000 he also received the Millennium Medal from the Institute of Electrical and Electronic Engineering and was awarded the Alexander von Humboldt Foundation Research Prize, Germany's highest research honor for senior American engineers and scientists.

*Ahsan Kareem*

A leading researcher in probabilistic structural dynamics, fluid-structure interactions, structural safety, and the mitigation of natural hazards, **Ahsan Kareem** was appointed the Robert M. Moran Professor of Civil Engineering. He also serves as chair of the Department of Civil Engineering and Geological Sciences. Kareem's work focuses on probabilistic structural dynamics, risk assessment, and the mitigation of natural hazards such as earthquakes, tidal waves, and heavy winds. His research has led to the revision of the ASCE7-95 Standard for Minimum Design of Loads on Buildings and Other Structures, which has helped to create safer and more wind-resistant infrastructure in the United States and the Caribbean. It also serves as a model for building codes around the world. In addition to his many honors, Kareem recently received the Munro Prize for the best paper from *Engineering Structures: The Journal of Earthquake, Wind, and Ocean Engineering*.

The Leo E. and Patti Ruth Linbeck Professor of Civil Engineering is **Billie F. Spencer Jr.** A faculty member since 1985, Spencer

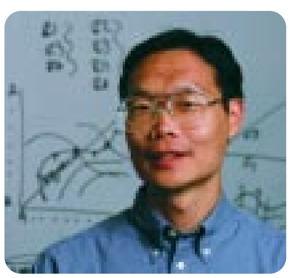


*Billie F. Spencer Jr.*

specializes in earthquake engineering, structural dynamics, and fatigue/fracture reliability. He and Michael K. Sain, Freimann Professor of Electrical Engineering, have developed a system that counteracts the damaging structural responses due to earthquakes, strong winds, and other natural disasters. The recipient of many honors and awards, he was most recently appointed by the White House Office of Science and Technology Policy to serve on an advisory committee to assess U.S.-Japan science and technology relations.

*Peter C. Burns*

Other faculty honored with endowed collegiate chairs in 2000 are **Peter C. Burns,** Henry Massman Associate Professor in Civil Engineering and Geological Sciences, and **Danny Z. Chen,** Rooney Family Professor of Engineering. Burns specializes in environmental mineralogy and crystallography, crystal chemistry, mineral structural energetics, and nuclear waste disposal. Chen, an associate professor in the Department of Computer Science and Engineering, focuses on algorithm design, analysis, and implementation; computational geometry; parallel and distributed computing; computational medicine; data mining; and computer graphics.



*Danny Z. Chen*

## A LIST OF THE ENDOWED CHAIRS IN THE COLLEGE OF ENGINEERING INCLUDES:

### UNIVERSITY CHAIRS

**Hafiz M. Atassi**
*Viola D. Hank Chair in Aerospace and Mechanical Engineering*

**Hsueh-Chia Chang**
*Bayer Corporation Chair in Engineering*

**Thomas C. Corke**
*Clark Equipment Chair in Engineering*

**Daniel Costello Jr.**
*Leonard C. Bettex Chair in Electrical Engineering*

**William G. Gray**
*Henry Massman Chair in Civil Engineering*

**Frank P. Incropera**
*Matthew H. McCloskey Dean of the College of Engineering and H. Clifford and Evelyn A. Brosey Chair in Engineering*

**Ahsan Kareem**
*Robert M. Moran Chair in Engineering*

**Peter M. Kogge**
*Ted H. McCourtney Chair in Computer Science and Engineering*

**Ruey-Wen Liu**
*Frank M. Freimann Chair in Electrical and Computer Engineering*

**James L. Merz**
*Frank M. Freimann Chair in Engineering*

**Anthony N. Michel**
*Frank M. Freimann Chair in Engineering*

**Thomas J. Mueller**
*Roth-Gibson Chair in Aerospace and Mechanical Engineering*

**Michael K. Sain**
*Frank M. Freimann Chair in Electrical Engineering*

**Roger A. Schmitz**
*Keating-Crawford Chair in Chemical Engineering*

**Billie F. Spencer Jr.**
*Leo E. and Patti Ruth Linbeck Chair in Engineering*

**Arvind Varma**
*Arthur J. Schmitt Chair in Chemical Engineering*

### COLLEGIATE CHAIRS

**Peter C. Burns**
*Henry Massman Chair in Civil Engineering and Geological Sciences*

**Danny Z. Chen**
*Rooney Family Chair in Engineering*

# 5 Years & Counting

## The Ameritech Pre-college Minority Engineering Program Celebrates Another Year ... and a New Director

***For the last five years** the Ameritech Minority Engineering Program has had the opportunity to introduce more than 200 minority students to engineering. Using distance-learning technology, students in each of the program sites can interact with one another as they learn.*

AN AFTERSCHOOL INSTRUCTIONAL INITIATIVE designed to pique interest in engineering among minority middle school youth, the Ameritech Pre-college Minority Engineering Program (APMEP) celebrated its fifth year of operation with the addition of a school in the Indianapolis Public School Corporation.

During the first four years of the APMEP, participants from middle schools in the South Bend/Mishawaka community gathered twice a month from October through May, at four different sites. Two-way interactive video conferencing delivered the program, enabling each site to participate in real time with instructors and other students in the program. In the 1999-2000 academic year APMEP expanded to include Harshman Middle School, in Indianapolis. Students there, and in the South Bend area, examined the different facets and opportunities available in engineering. They spoke with practicing engineers, performed experiments, and took virtual field trips, exploring corporations like Lockheed Martin and talking with their engineers.

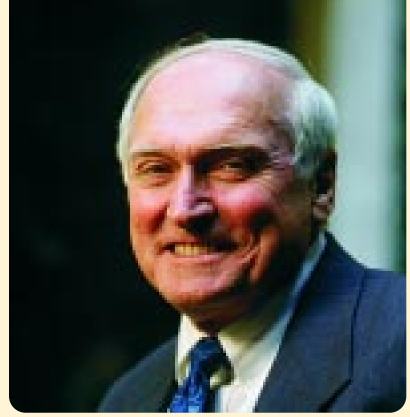
Thirty-one minority middle school students, their parents and families, and the staff and volunteers of the APMEP celebrated the end of another successful year — its fifth — in a closing awards ceremony. Typical of the program's operation, the awards ceremony was also conducted using distance-learning technology.

In addition to celebrating its five-year anniversary, APMEP and the Minority Engineering Program are welcoming a new director, Erica Cain-Ward, who joined the College in February 2001. A 1993 graduate of the University, she most recently served as manager of recruitment and retention for the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc., a not-for-profit organization headquartered at Notre Dame. As director she will oversee the program's Academic Excellence Workshops, Mastering Techniques for Excellence in Engineering courses, the annual General Motors Scholars' Competition, the Graduate School Connections program, the Five-year Scholars Initiative, the MEP Alumni Network, and the APMEP.

***Erica Cain-Ward** was named director of the Minority Engineering Program in February 2001.*

### VANN-HAMILTON APPOINTED ASSISTANT PROVOST

The former director of the Minority Engineering Program, **Joy Vann-Hamilton**, has been appointed assistant provost of the University. In this new position she oversees Notre Dame's Upward Bound, Educational Talent Search, and Ronald McNair Post-baccalaureate Programs. Each of these federally funded projects is designed to enhance postsecondary educational opportunities for economically disadvantaged youth. She assists in approving appointments and hires of new tenure-track faculty and is developing a tracking system for undergraduates who pursue graduate education for future faculty positions. She is chair of commencement ceremonies and also serves as liaison to the University's Early Childhood Development Center. Vann-Hamilton served as MEP director for nine years.



# Merz Returning to Teaching

**James L. Merz,** vice president for graduate studies and research, will return to teaching and research in June as Frank M. Freimann Professor of Electrical Engineering. According to Nathan O. Hatch, University provost, Notre Dame's graduate studies program and research profile have risen substantially under the leadership of Merz. During his five-year term as vice president, he has been responsible for the development and state of all postbaccalaureate work at the University, as well as the administration of all research conducted at Notre Dame. His accomplishments as vice president have included: creating interdisciplinary research centers such as the Center for Nano Science and Technology, the Walther Center for Cancer Research, the Keck Center for Transgene Research, the Center for Tropical Disease Research and Teaching, and the Center for Molecularly Engineered Materials; establishing partnerships with other universities on major research projects; and increasing fellowships and stipends to graduate students.

A 1959 graduate of Notre Dame, Merz returned to the University in 1994 from his post as director of the Center for Quantized Electronic Structures at the University of California at Santa Barbara — a National Science Foundation Science and Technology center — to direct a team of researchers investigating the field of nanoscience, specifically Quantum Cellular Automata, an emerging technology that could produce a new generation of digital devices and circuits. The College welcomes his return to teaching and the vision he offers students as an internationally recognized scholar in the field of optoelectronic materials and devices.

## CARBERRY SUCCUMBS

On August 27, 2000, after a long illness, **James J. Carberry** died; he was 74. A professor of chemical engineering, Carberry was affectionately regarded by fellow faculty and students. He was also internationally recognized for his research in the fields of reaction chemistry and catalysis. He developed the Carberry reactor, which facilitated the study of the kinetics of catalytic reactions and the design of various industrial and automotive reactors. A member of the National Academy of Engineering, Carberry received numerous awards throughout his life, including the Yale Engineering Association Award for Advancement of Pure and Applied Science, the American Chemical Society's E.V. Murphree Award in Industrial Engineering Chemistry, and the American Institute of Chemical Engineers' R.H. Wilhelm, William H. Walker, and Thiele Awards. He was twice named a Sir Winston Churchill Fellow at Churchill College, Cambridge University, and he was a Life Fellow of Cambridge's Clare Hall. Carberry received both his bachelor's and master's degrees from Notre Dame. He received his doctorate in fluid dynamics from Yale University before returning to the University as an assistant professor in 1961.

## NEW ENGINEERING ADVISORY COUNCIL MEMBERS NAMED

**John A. Martell,** vice president, Trans Tech Electric, Inc., South Bend, Ind.; **Myron C. Noble,** chief executive officer and chairman of the board, PiRod, Inc., Plymouth, Ind., and **Thomas M. Rohrs,** group vice president for global operations, Applied Materials, Inc., Santa Clara, Calif., have been named to the College of Engineering Advisory Council. Their appointment was announced in November 2000 by Rev. Edward A. Malloy, C.S.C., the University's president. Martell is a 1977 electrical engineering graduate. Rohrs graduated from Notre Dame in 1973 with a bachelor's degree in mechanical engineering.

AEROSPACE AND MECHANICAL ENGINEERING

## NOTRE DAME CO-HOSTS ICTAM 2000

The University co-hosted the 20th International Congress of Theoretical and Applied Mechanics in Chicago in August 2000. Mohamed Gad-el-Hak, professor of aerospace and mechanical engineering, served as University liaison for the conference, organizing and chairing the general session on flow control.

Held every four years, researchers from around the world gathered to examine topics such as turbulent mixing of fluids, electromagnetic processing of materials, flow of granular materials, vehicle dynamics, the mechanics of foams and cellular materials, and the damage and failure of composite materials.

Faculty and staff who presented papers included: Igor Veretennikov, research associate in physics; Alexandra Indeikina and Pavlo Takhistov, research associates in chemical engineering; Bayer Corporation Professor of Chemical Engineering Hsueh-Chia Chang; Stanislav Gordeyev, research associate in aerospace and mechanical engineering; Viola D. Hank Professor of Aerospace and Mechanical Engineering Hafiz Atassi; Flint Thomas and Samuel Paolucci, professors of aerospace and mechanical engineering, and James Mason, associate professor of aerospace and mechanical engineering.

## CAD/CAM Course Uses Reverse Engineering

DIRECTED BY JOHN E. RENAUD, associate professor of aerospace and mechanical engineering, and engineers from the Bayer Corporation, students in the the fall 2000 CAD/CAM course worked on a reverse engineering project of the Glucometer DEX Diabetes Care System. Bayer engineers redesigned the product, and Notre Dame students conducted a product evaluation study, comparing the operation of the previous DEX System with the re-designed model.

According to Renaud, "At first glance, the DEX System looks like a fairly simple device, but in reverse engineering the students are required to re-create part geometries for which there are no blueprints." In CAD/CAM most projects involve creating geometry which is fully prescribed as part of the assignment; in reverse engineering that is not the case. Students were required to explore and learn new features of the Pro/Engineer software they had not previously been exposed to. They learned that even "simple" parts can contain numerous geometric features which can be difficult to re-create. And, since most of the parts were made by plastic injection molding, they also gained an appreciation for the versatility of injection molding.

Working in teams of five, the students measured and inspected each of the mechanical components of the DEX. They then re-created each part's geometry, with some parts requiring more than one detail drawing to document its different features. Team members also completed an assembly of the DEX and submitted a portfolio of assembly drawings.

At the end of the course, Renaud and students visited the Bayer DEX facility, a fully automated plant that manufactures more than 2,500 glucometers per eight-hour shift.


***The Glucometer DEX Diabetes Care System,*** *manufactured by Bayer Corporation of Elkhart, Ind., is one of the most advanced handheld blood glucose monitoring systems in the world.*

# Two Grads Selected for NASA Candidate Class

*Kevin A. Ford*

*Michael T. Good*

ALUMNI KEVIN A. FORD AND MICHAEL T. GOOD have been named by the National Aeronautics and Space Administration to the astronaut candidate class of 2000. Consisting of seven pilot and 10 mission specialist trainees, the candidate class will undergo numerous scientific and technical briefings, intensive instruction in Shuttle and International Space Station systems, physiological training, water and wilderness survival techniques, and ground school preparation. Upon completing their training, the candidates will serve in technical capacities at the Johnson Space Center before being assigned to a space flight.

Each candidate is selected through a highly competitive process and evaluated for his or her education, training, experience, and qualifications. Ford is a 1982 graduate of the aerospace engineering program. Entering the class as a pilot trainee, he is a lieutenant colonel in the Air Force. He had been director of plans and programs at the Test Pilot School at Edwards Air Force Base before joining the candidate class. He is a resident of Lancaster, Calif.

Good, a resident of Niceville, Fla., enters the class as a mission specialist. He received a bachelor's degree in aerospace engineering from Notre Dame in 1984 and a master's degree in 1986. He currently holds the rank of major in the U.S. Air Force and, prior to his selection as a candidate, was Operations/F-15 Test Officer at Eglin Air Force Base.

They are the second and third Notre Dame alumni to be named astronaut candidates. A 1974 graduate, James Wetherbee was selected for the program in 1984. He has since served as both a pilot and mission commander on five shuttle flights. His most recent command began March 8, 2001, when the Space Shuttle *Discovery* made its way to the International Space Station, the second such expedition to the orbiting science outpost.

*Steven R. Schmid*

## National Academy of Engineering Honors Schmid

**Steven R. Schmid,** associate professor of aerospace and mechanical engineering, was invited to participate in the Frontiers of Engineering Symposium. Each year the National Academy of Engineering invites select engineers from industry, academia, and government to discuss pioneering technical work and leading-edge research in various engineering fields and industry sectors. Invitees are typically between 30 and 45 years of age who have demonstrated accomplishment in engineering research and technical work with recognizable contributions to advancing the field of engineering.

## GAD-EL-HAK ELECTED APS FELLOW

Mohamed Gad-el-Hak, professor of aerospace and mechanical engineering, was elected a Fellow of the American Physical Society. He was cited for "his original contributions to reactive control of turbulent flows, pioneering work in developing laser-induced fluorescence techniques, and definitive experiments detailing fluid-compliant surface interactions."

*Mohamed Gad-el-Hak*

## YANG RECEIVES INTERNATIONAL AWARD

*Kwang-tzu Yang*

Kwang-tzu Yang, Viola D. Hank Professor Emeritus of Aerospace and Mechanical Engineering, received the Thermal Engineering Award for International Activity. The award, presented by the Thermal Engineering Division of the Japan Society of Mechanical Engineers, cites his outstanding achievements and contributions to the field. Official presentation was made at the Annual Meeting of the JSME in Nagoya, Japan.

# CHEMICAL ENGINEERING

## Brennecke Recognized by American Chemical Society

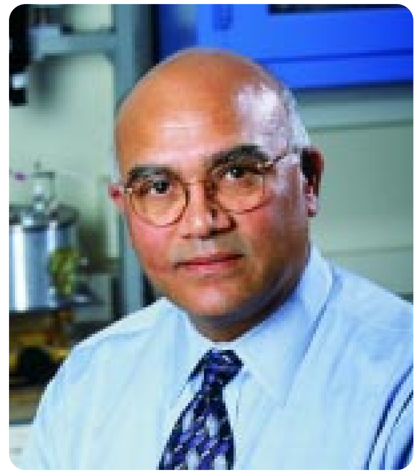
JOAN F. BRENNECKE, professor of chemical engineering, has been named the Ipatieff Prize winner by the American Chemical Society. Issued every three years, the Ipatieff Prize honors researchers under the age of 40 for their outstanding experimental work in the field of catalysis or high-pressure chemistry. Formal presentation of the Prize took place in April 2001 at the 221st ACS national meeting in San Diego, Calif., where Brennecke was scheduled to deliver a lecture at the symposium organized in her honor.

In addition to receiving the Ipatieff award, she was invited to submit an article for inclusion in "New Voices in Chemistry," a section in *Chemical & Engineering News*, the primary publication of the ACS, that celebrated the Society's 125th anniversary. "New Voices," highlighting the thoughts and aspirations of 171 top young chemical engineers, chemists, and business leaders for the future of the chemical industry, appeared in the March 26, 2001, issue of the magazine.

*Joan F. Brennecke*

## Varma Published in *Scientific American*

ARTHUR J. SCHMITT PROFESSOR of Chemical Engineering Arvind Varma described the findings from his research on combustion synthesis of advanced materials in the August 2000 issue of *Scientific American.* The article, titled "Form from Fire," examined the emerging field of combustion synthesis as a materials production technology and the strides taken in recent years toward monitoring and understanding ultraquick chemical reactions.

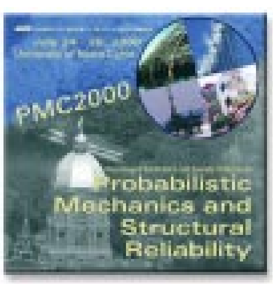


*Arvind Varma*

# CIVIL ENGINEERING AND GEOLOGICAL SCIENCES

## PMC 2000 Conference Held at Notre Dame

MORE THAN 300 ENGINEERS and engineering students from government, industry, and academia attended the Eighth ASCE Joint Conference on Probabilistic Mechanics and Structural Reliability (PMC 2000) held at Notre Dame July 24-26, 2000. Co-sponsored by the Engineering Mechanics and Aerospace Divisions of the American Society of Civil Engineers and the ASCE Structural Engineering and Geotechnical Institutes, the conference featured nearly 70 technical sessions and addressed topics related to risk and reliability in all aspects of engineering analysis and design.



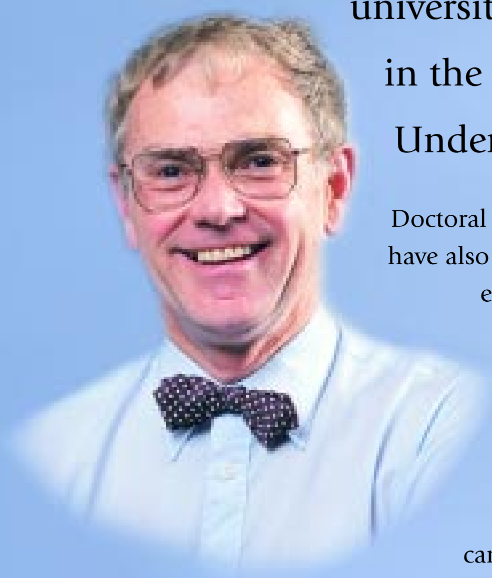

***Conference proceedings,*** *technical sessions, schedules, and websites relating to PMC 2000 were made available on an interactive conference CD.*

***Engineers, researchers, and students*** *gathered for PMC 2000, the premier meeting of national and international experts in stochastic mechanics, random vibration, stochastic processes, structural reliability, stochastic control, and related topics. It was the largest College of Engineering conference ever held, with attendance listed at 310.*

Conference co-chair Ahsan Kareem, Robert M. Moran Professor and Chair of Civil Engineering and Geological Sciences, and local organization chair B. F. Spencer Jr., Leo E. and Patti Ruth Linbeck Professor of Civil Engineering, attribute the large attendance, as well as the quantity and scope of the technical sessions, to the growing importance of probabilistic mechanics and reliability analysis as tools in dealing with the uncertainties of structural and mechanical systems, particularly those related to damage from natural hazards such as hurricanes and earthquakes.

# Civil Engineering Students Contribute to Community's EPA Award

Since 1998 undergraduates from Notre Dame and universities around the country have participated in the University's Research Experiences for Undergraduates (REU), a summer research program.



*Lloyd H. Ketchum Jr.*

Doctoral students from the civil engineering and geological sciences department have also worked with officials from the city of Elkhart, Ind., on a variety of environmental projects, which have resulted in the city receiving a U.S. EPA Region 5 Award for superior operation and maintenance of their wastewater treatment plant and being nominated for the National EPA Award.

According to Lloyd H. Ketchum Jr., associate professor of civil engineering and geological sciences and departmental adviser for the REU program, one of the benefits of the Elkhart program is that students can interact with practicing professionals in a real-world setting. Some of the students' projects have included a sewer overflow control plan, a comparison between rubberized asphalt and conventional asphalt pavements, superfund reclamation, the feasibility of various abatement technologies, treatability of a specific industrial waste stream, and the development of a sequencing batch reactor (SBR) to model the Elkhart Wastewater Treatment Plant during wet weather operations.

***The 10-liter sequencing batch reactor** shown here was developed by Notre Dame students to model the activated sludge process at the Elkhart Wastewater Treatment Plant during wet weather conditions. It was a significant contribution and assisted in the community's efforts to achieve superior treatment at reduced costs.*

It was this last project that proved perhaps the most beneficial to the city. Working with plant supervisors to monitor the SBR and the activated sludge process of the plant, students were able to prove that reduced aeration of the sludge in one part of the wastewater treatment process could concurrently achieve superior treatment, saving the city up to $125,000 a year in energy usage.

Ketchum is quick to point out that Elkhart's efforts began long before this particular program. However, he also strongly believes that REU students and the department's graduate students have contributed to the city's success and this most recent award, an acknowledgement of their environmental efforts.

## Kareem Receives Munro Prize

ROBERT M. MORAN PROFESSOR and Chair of the Department of Civil Engineering and Geological Sciences Ahsan Kareem received the Munro Prize for his paper "Applications of Wavelet Transforms in Earthquake, Wind, and Ocean Engineering." Coauthored with Kurtis Gurley, formerly a Notre Dame doctoral student and currently an assistant professor at the University of Florida, the paper discussed the use of wavelet transforms for time-frequency analysis. Although it is not a new technique, its use in civil engineering applications — particularly in studying the random processes involving wind, ocean, and earthquake engineering — is novel and often more informative than the traditional Fourier transform, which cannot precisely capture the time evolution of a signal's frequency content. This ability to combine time and frequency domains affords engineers and researchers new analysis perspectives.


***The Munro Prize*** *was presented to Ahsan Kareem, left, at the 2000 ASCE Structures Congress for his paper on wavelet transforms and their use in civil engineering applications.*

## KIRKNER RECEIVES FULBRIGHT SCHOLAR GRANT

David J. Kirkner, associate professor of civil engineering and geological sciences, was awarded a Fulbright scholar grant for the 2000-01 academic year by the U.S. Department of State and the Council for the International Exchange of Scholars. He is one of the approximately 800 U.S. faculty and professionals who received Fulbright grants to lecture or conduct research outside of the U.S.

*David J. Kirkner*

In accordance with requirements of the grant, Kirkner plans to use the Fulbright funds to conduct research at the Polish Academy of Sciences in Warsaw, Poland. His topic is "Random Field Model of Fictitious Cracks in Asphalt Concrete Pavement Structures for Prediction of Thermal Cracking."

## TAYLOR RECEIVES DISTINGUISHED SERVICE AWARD

James I. Taylor, professor of civil engineering and geological sciences, has received the Distinguished Service to Safety Award from the National Safety Council. Bestowed on individuals based on their dedication and commitment to public welfare, this award is given in recognition of an individual's outstanding service to the Council's Highway Traffic Safety Division, the recipient's employer, other organizations, and the individual's local community. It is presented annually to fewer than two dozen individuals from across the nation. Taylor was one of the 19 safety professionals honored for 2000. He received the award at the Annual Congress and Expo of the National Safety Council in October 2000.

*James I. Taylor*

## Geological Society of America Honors Winkler

IN NOVEMBER 2000 the Engineering Geology Division of the Geological Society of America presented Erhard M. Winkler, professor emeritus of civil engineering and geological sciences, the Meritorious Service Award. Nominated by his peers in recognition of outstanding service throughout his career, Winkler received the award at a special ceremony during Summit 2000, the annual meeting and exposition of the GSA.

*Erhard M. Winkler*

# Indiana Institutions Team up at SC2000

THE DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING at the University of Notre Dame, along with counterparts at Indiana University and Purdue University, collaborated to present a high-tech display demonstrating Indiana's growing stature in the field of information technology, at SuperComputing 2000. SC2000 is the top annual international event highlighting supercomputing and advanced networking technology. More than 6,000 researchers, faculty members, information technology support staff members, vendors, and entrepreneurs gathered at the conference, which was held Nov. 4-10, 2000, at the Dallas Convention Center.

The 1,600-sq.-ft. Indiana booth — one of the largest research exhibits at the conference — featured two ImmersaDesks, virtual reality systems, and other high-performance computing and communications applications in engineering, science, medicine, the arts, and informatics. A total of 50 faculty members, staff, and graduates from the three universities manned the display.

Notre Dame's contingent included Andrew Lumsdaine, associate professor, Jesús A. Izaguirre, assistant professor, and Ted H. McCourtney Professor Peter Kogge, chair of the computer science and engineering department. Graduate students Ron Garcia, Lie-Quan Lee, Michael McNally, Jeremy Siek, Jeff Squyres, and Jeremiah Willcock also attended the conference, along with undergraduates Brian Barrett, Arun Rodrigues, and George Viamontes. "We were excited about the opportunity to participate in the Research@Indiana display," said Kogge. "SC2000 gave the department the chance to demonstrate, to a large and sophisticated audience, how well the University's computing research meshes with other leading-edge work."

***In the Research@Indiana booth*** *Jesús A. Izaguirre, assistant professor of computer science and engineering, far right, demonstrates the use of a haptic device with a virtual reality display to investigate simulations of molecular dynamics.*

***Financial contributions*** *from the Indiana Technology Partnership, Indiana Pervasive Computing Research Initiative, and the Indiana Information Technology Association helped the three universities fund the display. Compaq Computer, IBM Corporation, Intel Corporation, Storage Technology Corporation, and Sun Microsystems each provided equipment in support of Research@Indiana for the SC2000 display.*

## JOINT INDUSTRY ADVISORY COMMITTEE FORMED

The Departments of Electrical Engineering and Computer Science and Engineering have formed an Industry Advisory Committee. Why? With the field of information technology moving at a breakneck pace, it is vital for engineering students to understand the interactive nature of engineering and to be kept abreast of the technological trends and needs of industry. This joint committee will assist the College in its efforts to enhance engineering education on both the undergraduate and graduate levels.

Consisting of 12 members, the committee is comprised primarily of industry representatives who serve three-year terms. Members are well-versed in the technical aspects of information technologies and have a good vision of future directions for the advancement of such technologies. They also have a keen interest in engineering education at Notre Dame. Committee activities include two meetings during which members review educational programs, covering the effectiveness of current curricula and the development of new courses based on industry forecasts and market trends. The committee also assesses research and instructional infrastructures and facilitates relationships among industry, students, and faculty members within the electrical engineering and computer science and engineering departments, which include internships, industry mentor programs, and research and employment opportunities.

# Irish Racing Team Bound for Boy Scout Jamboree

From July 19 through August 1, 2001, the Irish Racing Team will partner with Brigham Young University to help nearly 3,000 boy scouts — a fraction of the 30,000 who will attend the Jamboree — earn their electricity merit badges at the 2001 National Scout Jamboree. Held every four years, the Jamboree nurtures the skills of scouting, supports its national heritage, emphasizes physical fitness, encourages environmental conservation, and promotes strong values and leaders.

"The prospect of interacting with thousands of young men and teaching them how to safely handle electricity and introduce them to engineering is very exciting," said William B. Berry, professor of electrical engineering and Irish Racing Team adviser. Attending the Jamboree is even more attractive to Berry because of his belief that the Jamboree conservation program and the canons of the Boy Scouts of America mesh with the efforts of Notre Dame and the Irish Racing Team.

Comprised of nine students the goal of the team is to provide its members with hands-on experience while advancing the technology of zero-emission


*__In July__ the Irish Racing Team will travel to Fort A.P. Hill in Virginia to participate in the conservation program of the 2001 National Scout Jamboree.*

transportation. Students integrate the motor, drive systems, and batteries for the vehicle. Berry believes nothing ignites the imagination or invites innovation like firsthand experience.

An official program of the University, the team represents one of the many groups at colleges and universities across the country who fuse higher education with the spirit of competition. But the team's focus remains the development of fast and efficient electric vehicles and propulsion systems. Faculty and students work closely to build the team's car, not just to win races, but to also gain practical experience. This unique educational experience fosters student participation and team communication — from the initial design stage to the final testing and racing of the vehicle. It helps students put to practical and immediate use what they are learning in the classroom.

For more information about the Irish Racing Team, to follow the team's progress throughout the year, or check out vehicle specifications, visit **http://www.nd.edu/~ndracing.**

## 2001 Racing Schedule

| *Date* | Race/Location |
|---|---|
| *May 5-6* | Winchester Track in Winchester, Ind. |
| *June 15-16* | Detroit Grand Prix at Belle Island in Detroit, Mich. |
| *July 19 - August 1* | B.S.A. Jamboree at Fort A.P. Hill, Va. |
| *October 5-7* | Mid-Ohio Track in Lexington, Ohio |

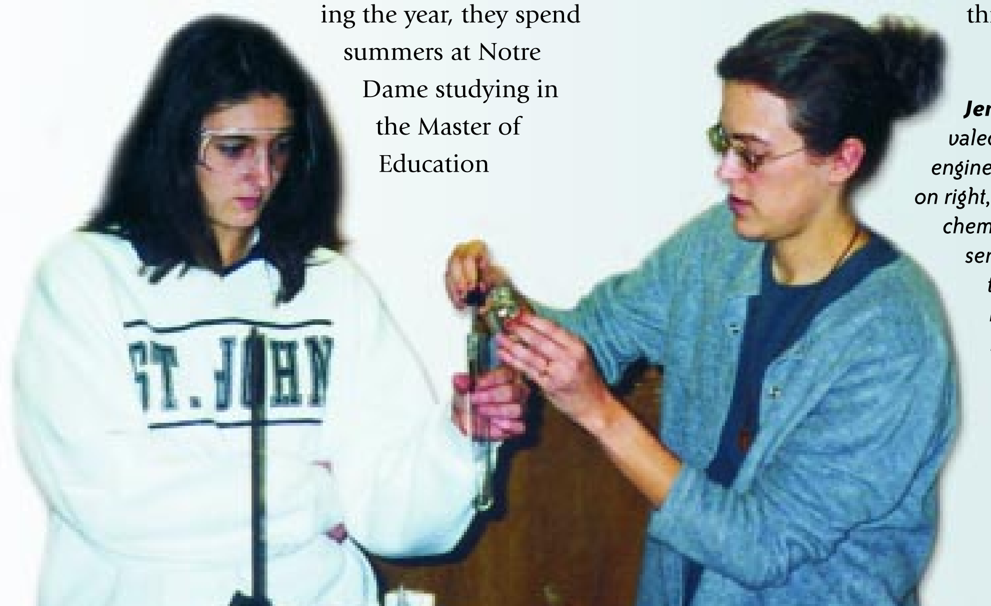
# A Lifetime of Service

AN ENGINEER'S OBLIGATION TO SERVE stems from the Order of the Engineer. It is not a membership organization; the Order represents all engineering graduates who promise to uphold the standards and dignity of the profession and to put the needs of society ahead of their own. This commitment to serve is especially reflective of the mission of Notre Dame and the emphasis the College and the University place on using talent, skill, and knowledge to help people in need.

For example, as the University's 1999 valedictorian, **Jennifer Ehren** could have had her pick of jobs. She had received a bachelor's degree in chemical engineering and was being actively recruited by many corporations. Instead of accepting one of those lucrative offers, she applied to the University's Alliance for Catholic Education program (ACE). A two-year service initiative, ACE gives college graduates the opportunity to work as full-time teachers in underserved Catholic schools throughout the southern United States. Teaching during the year, they spend summers at Notre Dame studying in the Master of Education program. Upon completing two years of service, ACE graduates are awarded a tuition-free degree.

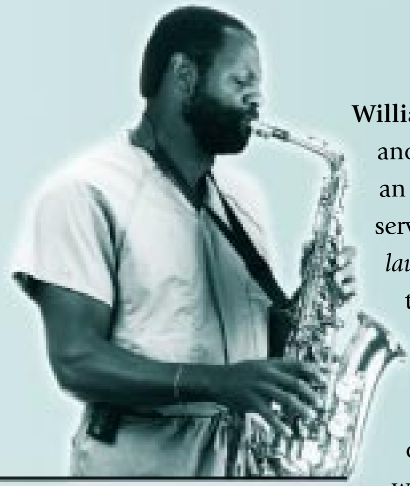
Ehren was assigned to Saint John High School in Gulfport, Miss., where she has taught AP Chemistry, advanced mathematics, physics, calculus, general chemistry, algebra, and physical science. Ehren has found her experience invaluable. "The curriculum and internship experiences I had at Notre Dame helped tremendously," she said. "I have been able to show students where the information they are learning applies while teaching them critical-thinking skills and problem-solving techniques that will benefit them in whatever field they pursue."

This "giving back" was extremely important to Ehren. It was also part of her selection of an employer; she joins Merck Pharmaceutical's Vaccination and Technology Department in Lansdale, Penn., this fall. "I am very excited to work for a company that helps others — in the making of drugs and vaccines as well as on the philanthropic level."




***Jennifer Ehren,*** *1999 valedictorian and chemical engineering graduate, shown on right, assists a student with a chemistry experiment. Ehren serves as a volunteer teacher at Saint John High School in Gulfport, Miss., part of a two-year master's program through the University's Alliance for Catholic Education.*

*Upon graduation an engineer accepts more than a diploma. He or she also accepts the Obligation of the Engineer: to serve humanity by making the best use of his or her talents and the earth's resources.*



**William C. Hurd** is another example of an engineer who serves. A 1969 *cum laude* graduate of the Department of Electrical Engineering, Hurd is an ophthalmologist who specializes in cataract surgery, radial keratomy, and corneal transplants. He was a 1968 U.S. Olympic Trials finalist in both the 100 and 200-meter sprints, the 1968 Notre Dame Athlete of the Year, and a two-time winner of the Saxophone Award at the Notre Dame Collegiate Jazz Festival.

As a physician it could be argued that Hurd serves his fellow man every day. But his commitment extends beyond his practice in Memphis, Tenn. Every year for the past two decades, Hurd has traveled around the world — to places such as Africa, South America, Mexico, and China — offering free medical services to the needy through his airlift eye hospital. During one trip alone, Madagascar in February 2000, Hurd and his associates treated 1,100 patients and performed 38 eye surgeries.

In March 1999 **Stephen E. Silliman,** professor of civil engineering and geological sciences, traveled with seven students, a Lifewater International volunteer, and Father John Herman, C.S.C., to Haiti to train villagers in water pump repair. Part of a one-credit seminar, the trip helped students understand how to place engineering in a social context while giving them the opportunity to expand clean water resources in underdeveloped areas.

A second trip to Haiti took place in October 2000, and a third trip, with eight students, took place in April 2001. These examples may suggest involvement by relatively few students, but the fact is that approximately 80 percent of the Notre Dame student body takes part in local and national service initiatives like the Haiti trip.

Closer to home, many students and faculty are involved in Engineering Projects for Community Service (EPICS). The EPICS program gives students the opportunity to put their problem-solving skills to use for the community through technologically challenging service projects, ranging from the development of a wetlands management program to the design of software used to track a not-for-profit group's maintenance calls.

What do all of these these engineers have in common? They have not asked "How much do I get out of it?" Instead they have asked "How much can I give?" This is the question that should drive engineers to achieve at all levels, professional and personal. It is the response to this question that makes Notre Dame even more proud of its engineering students, alumni, and faculty.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## Based on Tradition

## Bound for Tomorrow

For more than a century, faculty of the **College of Engineering** have nurtured the educational aspirations of thousands of students and, through their research, have contributed much to the generation of new knowledge and technologies.

We are committed to providing an undergraduate education that is rich in technical content, relevant to the needs of the 21st century, and fosters the growth of moral character and a spirit of service among our students. In our research we must have foci which are linked to important needs and opportunities and prepare our students for leadership in the development and application of new technologies.