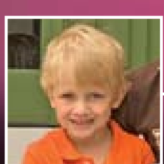
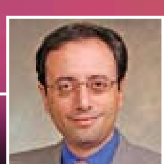
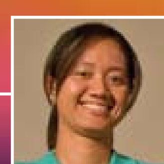
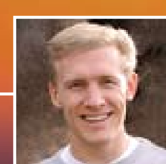
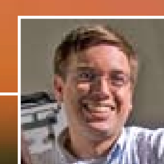
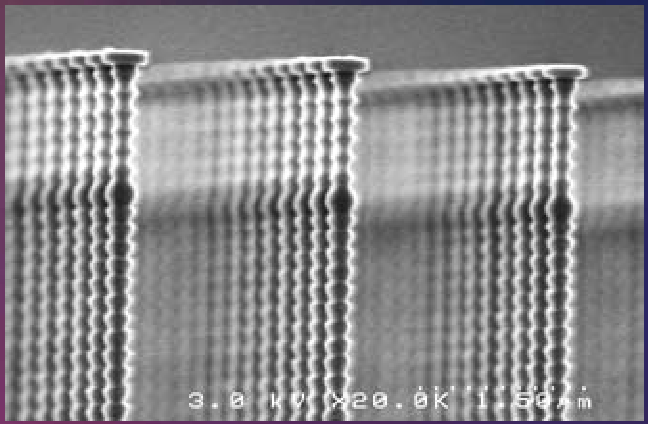
COLLEGE OF **ENGINEERING**
UNIVERSITY OF **WISCONSIN**-MADISON

Annual Report 2008

ON THE COVER: Water droplets sit on the "heads" of "nanonails" developed by Mechanical Engineering Associate Professor Tom Krupenkin. Nanonails are tightly packed nanostructures that create a surface with dynamic wettability. The heads of the tiny nail-like structures can repel liquid until Krupenkin adds electricity, which makes the liquid slip past the nail heads and wet the surface completely.

Nanonails could produce self-cleaning surfaces or be used in "lab-on-a-chip" technology. Nanonails may also be useful in cold climates—the material surface would retard ice formation, which could reduce reliance on toxic deicing fluids and protect helicopter blades from heavy ice.

In addition to the nanonails, Krupenkin's team has developed another unique material at the micro-scale. See page 24 to read more.

www.engr.wisc.edu/news/ar

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Message from Dean Paul S. Peercy

We are doing everything in our power to help every student succeed in engineering. We're not alone. Across the country, educators are rethinking engineering education. The United States simply must do more—not only to attract students to engineering, but also to retain them until they graduate.

For too long, students who stepped up to the challenge of an engineering education faced something akin to boot camp. If they could navigate obstacles and climb the walls of calculus, physics and chemistry, they could proceed to advanced challenges and engineering experiences. Help climbing those walls was available, but those students had to know where to find it. And as a result, many talented students chose a different path. Frustrated and disillusioned, they left the pursuit of an engineering degree for other opportunities.

We as a country—and we as a college—no longer can afford that "sink-or-swim" approach. The days of using such introductory courses as physics as "weed-out" courses are gone. It's not that calculus, physics and chemistry courses are any less demanding. On the contrary, we expect our students to have strong fundamental understanding of these foundation courses.

What's different today is the way in which we're delivering that education.

I send a letter to all freshman pre-engineering students. I welcome them to campus and let them know that we want them to succeed—and that we will provide the help they might need at no additional cost. The students still have to climb the walls of calculus, physics and chemistry—but now they do it in teams, along with an arsenal of tutors who act as their personal trainers.

We remodeled an underused, yet highly traveled, area on the main floor of our Engineering Hall and built an expansive, airy cafe. This very visible area has lots of community and group-study space and a dedicated, flexible room for supplemental instruction. In just a few short years, we changed our student culture from a "needs tutoring" attitude to a "wants to be prepared" mindset.

What's more, students need not wait to try their hands at engineering. They take fundamental courses in math and science along with design-centered and application-oriented offerings such as *Introduction to Society's Engineering Grand Challenges.* We have 53 registered engineering student organizations that offer experiences ranging from international automotive competitions to student chapters of engineering professional societies. In the last year, more than 130 engineering students traveled abroad through our International Engineering Studies and Programs, our internship/co-op program, Engineers Without Borders student organization, the LeaderShape program, and the chemical engineering summer course.

Through these and other opportunities, we are preparing a new generation of engineers to use powerful modern tools to confront global issues in ways we could not imagine just a few short years ago.

While this report provides a snapshot of our college accomplishments throughout the last year, read it with an eye toward the future. We are moving forward—and the best is yet to come.

2007-2008 Highlights

Research Funding

- UW-Madison engineers are collaborating with researchers at the University of Illinois at Urbana-Champaign and the University of Texas-Arlington on a Multidisciplinary University Research Initiative grant of nearly $5.9 million from the Air Force Office of Scientific Research. Led by Bascom Professor of Surface Science and Erwin W. Mueller Professor of Materials Science and Engineering **Max Lagally**, the team is studying photonic and electronic applications for silicon nanomembranes, flexible single-crystal sheets of silicon. The team also includes Lynn H. Matthias Professor in Electrical and Computer Engineering **Robert Blick**, Materials Science and Engineering and Physics Associate Professor **Mark Eriksson**, Electrical and Computer Engineering Assistant Professor **Zhenqiang (Jack) Ma** and Mechanical Engineering Assistant Professor **Kevin T. Turner**.
- In a $14 million project funded by the U.S. Department of Energy, UW-Madison engineers are collaborating with industrial and government partners to implement a microgrid power backup system at the nation's fifth-largest incarceration facility—the Santa Rita Jail. Grainger Professor of Power Electronics and Electrical Machines **Thomas Jahns** and Electrical and Computer Engineering Professor Emeritus **Robert Lasseter** are providing technical input for implementing Lasseter's microgrid concept at the jail.
- A multidisciplinary team led by Mechanical Engineering and Biomedical Engineering Associate Professor **Darryl Thelen** and Mechanical & Aerospace Engineering Assistant Professor Silvia Blemker of the University of Virginia received a four-year, $1.2 million grant from the National Institute of Arthritis and Musculoskeletal and Skin Diseases. Combining dynamic magnetic resonance imaging, finite element modeling and motion analysis techniques, the researchers are investigating the influence of muscle injury on *in vivo* muscle mechanics and function. Biomedical Engineering and Orthopedics and Rehabilitation Assistant Professor **Bryan Heiderscheit** and Biomedical Engineering and Radiology Assistant Professor **Scott Reeder** are among the UW-Madison collaborators.

Invention Disclosures

During the 2007 fiscal year, College of Engineering faculty, staff and students made 150 invention disclosures through the Wisconsin Alumni Research Foundation, with 88 U.S. patent applications filed and 31 patents issued. For the eighth consecutive year, the college has reported more than 100 patent disclosures.

With $1.5 million from the National Science Foundation, Civil and Environmental Engineering Associate Professor **Katherine McMahon** is among a multidisciplinary group of UW-Madison and University of Illinois Urbana-Champaign researchers that is studying the composition of bacterial communities in humic lakes and how these microorganisms respond to changes in their environment. This fundamental "systems" knowledge may help researchers develop more accurate ecosystem-level models, which enable them to predict carbon or nutrient flow through the system. It also may give high carbon-dioxide-emitting humic lakes greater weight in climate-change models.

- Civil and Environmental Engineering Associate Professor **Katherine McMahon** and Soil Sciences and Civil and Environmental Engineering Associate Professor **Joel Pedersen** are among a group of UW-Madison researchers who received nearly $1 million from the National Science Foundation to prepare a more diverse population of students to obtain graduate education in emerging, interdisciplinary areas of biological sciences research. The group is building a multiyear graduate-prep program that matches students with trained faculty mentors and prepares them to perform interdisciplinary research in the biological sciences.

RESEARCH ADVANCES

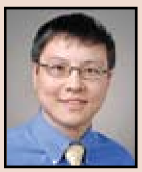
- Writing in the April 7, 2008, issue of *Chemistry and Sustainability, Energy & Materials*, Steenbock Professor of Chemical and Biological Engineering **James Dumesic** and his students detailed an integrated process for creating chemical components of jet fuel from sustainable biomass sources like switchgrass and poplar trees. Whereas in previous research the team demonstrated it could produce jet-fuel components by combining separate catalytic steps, the researchers now show they can integrate the steps and run them sequentially, without complex separation and purification processes between reactors.
- Combining lithography techniques with novel self-assembling materials, Smith-Bascom Professor of Chemical and Biological Engineering **Paul Nealey**, Howard Curler Distinguished Professor of Chemical and Biological Engineering **Juan de Pablo**, colleagues at the UW-Madison Nanoscale Science & Engineering Center, and researchers from Hitachi Global Storage Technologies have demonstrated a patterning technology that could overcome the technological limitations currently facing the microelectronics and data-storage industries and pave the way to smaller electronic devices and higher-capacity hard drives. The researchers described their technology in the August 15, 2008, issue of the journal *Science.*
- For modeling strain in both inanimate and human structures, the "Scan-and-Solve" approach is simpler, faster and more accurate than previous methods. Developed by Bernard A. and Frances M. Weideman Professor of Mechanical Engineering **Vadim Shapiro** and colleagues at Florida International University, the technique takes 3-D sampled or scanned data of an object and calculates where points of weakness occur and how those points will be affected by forces such as gravity, in the case of a centuries-old statue, or activity, in the case of a human bone.

In a four-year, $18 million project with the U.S. Department of Defense and Madison company Resilient Technologies, Kuo K. and Cindy F. Wang Professor of Mechanical Engineering **Tim Osswald** and graduate students Nick Newman and Eric Foltz are helping to develop a non-pneumatic tire for heavy-grade military vehicles. The group studied airless tire designs and ran tests and simulations that helped Resilient confirm the quality of its unique design concept. The project could be a lifesaver for the military: In many situations in Iraq, for example, tires have proven to be weak links in Humvees that enemies target with improvised explosive devices.

- America Online (AOL) has added a real-time text function to its instant messenger beta version 6.8, allowing users to see each other's text live as it is typed. The option was the result of a collaboration among AOL, the UW-Madison Trace Center and Industrial and Systems Engineering and Biomedical Engineering Professor **Gregg Vanderheiden**, and the Gallaudet University Technology Access Program. The feature is particularly useful for people—such as those who are deaf or hard of hearing—who rely on text messaging as a primary means of communication.
- Building on the observation that microorganisms swim either as "pushers" or "pullers," Harvey D. Spangler Professor of Chemical and Biological Engineering **Michael Graham** and fellow researchers Patrick Underhill and Juan Hernandez-Ortiz created a computer model that analyzes how populations of up to 100,000 model bacteria swim. Their results, published in the June 20, 2008, issue of *Physical Review Letters*, indicate that the particular style of swimming leads to different large-scale fluid motions and mixing. Studies of how microorganisms move through and diffuse liquid could enable scientists to develop artificial swimmers, enhance fluid flow in microfluidic devices, or better understand how microorganisms sample their environment.
- Led by Lynn H. Matthias Professor of Electrical and Computer Engineering **Robert Blick**, a team of UW-Madison engineers has blended modern semiconductor technology and nanomachines. Reported in the September 26, 2007, issue of the journal *Physica Status Solidi*, the research marks the advent of a new class of nanomechanical devices, with implications ranging from improved solar energy cells and light-emitting diodes to highly sensitive probes capable of measuring single biological molecules.

Faculty Honors


Grainger Professor of Power Electronics and Electrical Machines **Thomas Lipo** *(left)* and Industrial and Systems Engineering Professor Emeritus **Stephen Robinson** are among 65 engineers elected to the National Academy of Engineering in 2008. Director of the Wisconsin Power Electronics Research Center, Lipo has made significant contributions to the design and development of variable-speed drives and motor controls, while Robinson has made fundamental contributions to the theory of nonlinear optimization and to military planning.




Four College of Engineering faculty received prestigious National Science Foundation CAREER awards in 2008:

Electrical and Computer Engineering Assistant Professor **Hongrui Jiang** is developing a tunable compound "eye,"

Biomedical Engineering Assistant Professor **William Murphy** is studying stem cell differentiation in protein gradients,

Mechanical Engineering Assistant Professor **Krishnan Suresh** is perfecting a method for modeling geometrically complex manufactured components, and

Materials Science and Engineering Assistant Professor **Izabela Szlufarska** is developing biosensors that can identify specific individual molecules.

College faculty are among the most productive researchers in the nation, according to the 2007 *Chronicle of Higher Education* Research University Faculty Scholarly Productivity Index, which compiles overall institutional rankings for 164,843 faculty at 375 PhD-granting universities. Faculty can be judged on as many as five factors: books published, journal publications, citations of journal articles, federal-grant dollars awarded, and honors and awards. Eight college programs received top-10 rankings:

- Second—geological & mining engineering, industrial engineering, materials engineering, nuclear engineering
- Third—chemical engineering
- Fifth—civil engineering, engineering mechanics
- Ninth—environmental engineering



A national fraternity that promotes chemistry and chemical engineering, Alpha Chi Sigma inducted Chemical and Biological Engineering Professors Emeritus **R. Byron Bird** *(top)*, **Edwin Lightfoot** *(center)* and **Warren Stewart**, posthumously *(bottom)*, into its Hall of Fame. The honor recognizes their efforts in promoting chemistry and their contributions to the success of generations of chemical engineers. While the organization has more than 60,000 members, fewer than 40 have been inducted into the Hall of Fame since that honor began in 1982.

Idaho National Laboratory selected Engineering Physics Assistant Professor **Todd Allen**, a nuclear fuels and materials expert, to lead its newly created Advanced Test Reactor (ATR) National Scientific User Facility. A pressurized light-water reactor, the ATR is owned by the U.S. Department of Energy (DOE) and has operated continuously at the laboratory since 1967.

Until recently, the U.S. Navy used the reactor for testing nuclear fuels and materials. In April 2007, the DOE designated it a national scientific user facility to support university, industry and national laboratory research of nuclear fuels and materials.

Allen divides his time between the laboratory and his faculty position at UW-Madison and conducts research at both institutions.

For his groundbreaking work on processes for transforming biomass-derived sugar into liquid transportation fuel, Steenbock Professor of Chemical and Biological Engineering **James Dumesic** was named one of the 2007 *Scientific American* 50.

Dumesic and graduate students Yuriy Román-Leshkov, Christopher J. Barrett and Zhen Y. Liu developed a two-stage process for turning biomass-derived sugar into 2,5-dimethylfuran (DMF), a liquid transportation fuel with 40 percent greater energy density than ethanol.

The team received additional recognition when the manuscript editors of *Nature* selected the team's paper on DMF as one of their "favourites" from the papers *Nature* published in 2007.

Student Innovation

Designed by *(from left)* Jon Sass, Ben Schoepke, Dave Schurter, Marty Grasse and Arin Ellingson, a catheterized system to sense bladder pressure and control urine flow to prevent incontinence won the $10,000 top prize in the **Schoofs Prize for Creativity** during the 2008 Innovation Days competitions. Kyle Hanson *(far right)* won first place and $2,500 in the **Tong Prototype Prize** for his invention, the Portable Refrigerated Beverage Dispenser, a lightweight, self-contained unit for transporting, cooling and dispensing a keg. Open to all UW-Madison undergraduates, the contests award prizes to participants whose ideas are most creative, novel, innovative and likely to succeed in the marketplace.

TONG Biomedical Engineering DESIGN AWARDS University of Wisconsin

Every semester of their education, nearly 150 UW-Madison biomedical engineering undergraduate students work in teams to design meaningful solutions to real-world clinical problems posed by clients in medicine, academia and industry. In less than a decade, the Wisconsin Alumni Research Foundation—the UW-Madison patenting and licensing arm—has received 41 disclosures based on these inventions.

Electrical engineering alumnus Peter Tong (MS '65) and the Tong Family Foundation sponsor the **Tong Biomedical Engineering Design Awards** each May to honor the best sophomore, junior and senior design. A panel of judges also selects projects for additional support.

In 2008, the committee chose senior Tim Pearce's project, "A soluble factor gradient generator," and senior Matt Kudek's project, "A leg positioner/pannus retractor," for funding that supports further development of the designs and intellectual property in collaboration with a biomedical engineering faculty member.

A company formed by mechanical engineering students Chris Meyer and Gene Shiau, PerBlu earned second place and $7,000 in the 2008 **G. Steven Burrill Business Plan Competition**. The students' product, Parallel Kingdom, is a massive multiplayer online role-playing game for Global Positioning System-enabled mobile phones. The company has the competitive advantage of being first to market with a mobile multiplayer role-playing game that uses a GPS to allow the player to physically interact with the surrounding virtual world. The game first will be available on the Google Android mobile phone, but any type of phone with GPS is a potential platform. The students hope to raise venture capital to further develop the game and capture market share.

Student Honors and Educational Advances

- In January, 30 UW-Madison engineering students traveled for three weeks to Cape Town, South Africa, to participate with 22 University of Cape Town students in the first-ever LeaderShape Institute held in Africa. The intense, six-day program not only helped the students form lifelong bonds, but also enabled them to develop their leadership skills and personal vision. Students from both countries also participated in community service projects. While UW-Madison has hosted LeaderShape for more than a decade, the trip to Africa also marked the first time American students have traveled overseas to participate.

- In spring 2008, Electrical and Computer Engineering Professor Susan Hagness and several colleagues debuted the course, *Introduction to Society's Engineering Grand Challenges*, which enables first-year engineering students to investigate the humanitarian applications of engineering. Based on challenges outlined by the National Academy of Engineering, the class aims to inspire students to become engineers to improve the quality of life around the world. With challenges that range from individual-level issues such as privacy, biometrics and assistive technologies to engineering for the megacity or for life in space, the course structure offers students a taste of different engineering disciplines while enabling them to examine broad engineering issues. Hagness conceived of the course as a means to engage first-year students and to help them better understand what engineers do for society.

- In 2008, members of the UW-Madison chapter of Engineers Without Borders (EWB) began projects throughout the world, and in their own back yard. They traveled to El Salvador to begin construction on a wastewater system that will stretch more than four miles and provide sewer access to nearly 2,350 El Salvadorans. In Orongo, Kenya, EWB members met with community members to plan projects in crop irrigation and water transport, small-business development, tree farming, and water purification. A team of four students visited Bayonnais, Haiti, to survey land, take measurements, and talk with community leaders and residents about projects that include an addition to a school, a new clinic and a hydroelectric generation facility to power the clinic. At the Red Cliff reservation, which wraps around 14 miles of the northernmost peninsula of mainland Wisconsin, they laid the groundwork for three projects related to flooding and stormwater infrastructure on the reservation.

The UW-Madison Clean Snowmobile Team blew the competition out of the snow at the Society of Automotive Engineers (SAE) Clean Snowmobile Challenge in Houghton, Michigan, March 10-15, 2008.

During the six-day zero-emissions competition, the UW-Madison team unveiled its new all-electric snowmobile, Bucky EV, which captured top honors. During the endurance portion of the competition, the Bucky EV held a 20 mph pace for 17.2 miles—nearly 10 miles past the second-place finisher—before the team voluntarily stopped to ensure efficient recharging. The sled also outshone the competition in acceleration and sound (at 50 feet, the sled produces a quiet 55 decibels).

For two months in summer 2008, the National Science Foundation tested the Bucky EV at one of its arctic study camps in Greenland.

- With its through-the-road parallel hybrid-electric Chevrolet Equinox Crossover SUV, the UW-Madison Hybrid Vehicle Team took second place in the final year of the Challenge X competition, while the UW-Madison Formula SAE Team was the top U.S. finisher at its world championship event in May. The team placed fourth out of nearly 120 teams from 20 countries.

- For their capstone design class, civil and environmental engineering students Dan Zignego, Jake Varnes, Bill Schmitz and Nick Bobinski worked with state of Wisconsin REACT Center Director Michael Kunesh to create a structure that simulates the wreckage created by an apartment building collapse onto a parking garage. Operated via the Wisconsin Office of Justice Assistance, the center provides specialized disaster- and complex-rescue training to approximately 480 state firefighters.

Among its key facilities is Wing 1 of the Rubble Pile, a jumbled mass of steel, concrete, wrecked vehicles and mannequin victims that enables trainees to simulate an eight-hour-long structural-collapse rescue. Designed by the UW-Madison students, Wing 2 opened in June 2008. While it includes elements similar to the original wing, the students' design makes the structural-collapse rescue more realistic, more intense—and easier to clean up and "reset" after the exercise.

Enrollment and Degrees Granted*

	Fall 2008 Enrollment[3]			Degrees Granted[4]		
	BS	MS	PhD	BS	MS	PhD
Biomedical Engineering	160	33	52	43	19	9
Chemical and Biological Engineering	237	5	111	65	7	23
Civil and Environmental Engineering	308	71	64	69	27	14
Electrical and Computer Engineering	334	138	167	106	70	33
Engineering Physics	195	37	47	57	25	11
Engineering Professional Development[1]	–	129	–	–	46	–
Environmental Chemistry and Technology	–	1	15	–	–	1
Geological Engineering	13	6	2	7	5	–
Industrial and Systems Engineering	163	82	58	45	40	12
Limnology and Marine Science	–	3	10	–	2	2
Manufacturing Systems Engineering	–	16	–	–	17	–
Materials Science Program	–	28	94	–	20	12
Materials Science and Engineering	52	–	–	12	–	–
Mechanical Engineering	511	95	81	169	34	17
Polymer Engineering and Science	–	10	–	–	–	–
Pre-Engineering[2]	1,481	–	–	–	–	–
TOTALS	**3,454**	**654**	**701**	**573**	**312**	**134**

1 Department does not grant BS or PhD degrees.
Master of Engineering in Professional Practice enrollment 62, degrees granted 27;
Master of Engineering in Technical Japanese enrollment 13, degrees granted 5;
Master of Engineering in Engine Systems enrollment 54, degrees granted 14.

2 Undergraduates not yet admitted to degree-granting departments.
3 According to university records.
4 According to university records; August and December '07; May '08
* As of Sept. 16, 2008.

At Madison East High School, the area's first National Society of Black Engineers (NSBE) Jr. chapter exists because of a UW-Madison industrial and systems engineering student and her dedication to reaching out to younger students. UW-Madison NSBE members and members of the Wisconsin Black Engineering Student Society have tutored and given presentations at East for the past five years, and in October 2007, UW-Madison's Mitchelle Lyle contacted East High to jump-start the chapter. She says the junior chapter enables UW-Madison NSBE members to give back in a way that recognizes the people and programs that positively affected their college choices. Likewise, time with positive college role models is what sets NSBE Jr. apart from other math and science clubs at East.

Body of knowledge: Culturing stem cells for tissue engineering

Assistant Professor **William Murphy** derives inspiration for his work as a tissue engineer from studying the complex processes through which human cells develop into tissue, limbs, organs and the like. "As these organs and limbs develop, cells on one end of the tissue have to differentiate into a different cell type than cells on the other end of the tissue," he says.

That's where protein concentration gradients do their work. For his National Science Foundation CAREER Award research, Murphy hopes to generate materials that deliver such gradients to stem cells—in this case, adult human stem cells isolated from bone marrow—in a controlled way.

He has developed an array-based approach that enables him to study, simultaneously, the effects of hundreds or thousands of different gradients on stem cells in three-dimensional culture. The approach increases the likelihood that Murphy will identify a gradient that significantly affects cell behavior.

Eventually, Murphy, who also maintains affiliations with the Departments of Materials Science and Engineering, Pharmacology, and Orthopedics and Rehabilitation, hopes to mimic protein concentration gradients in his efforts to engineer tissue.

For now, he is attempting to create biomaterials in which the stem cells throughout initially are homogeneous, but are exposed to heterogeneous signaling environments. "If we can spatially control whether they're alive, first, in different parts of the material, and then second, whether they then differentiate into a particular mature cell type, then we have a pretty powerful approach for trying to engineer tissues," he says.

Eight new translational research partnerships funded

The W.H. Coulter Translational Research Partnership in Biomedical Engineering oversight committee has selected its third-annual round of collaborative research projects for funding:

- Professor **David Beebe** and Pediatrics Associate Professor Carol Diamond: "Non-electronic, disposable drug delivery platform for hemophilia."
- Associate Professor **Walter Block** and Radiology Associate Professor Fred Kelcz: "Increased specificity for MR screening of high-risk women for breast cancer."
- Assistant Professor **Darin Furgeson** *(also pharmacy)* and Radiology Assistant Scientist Chris Brace: "Microwave thermal ablation and tumor margin directed chemotherapy for cancer eradication."
- Professor **W. John Kao** *(also pharmacy)* and Pediatrics Professor Paul Sondel: "Multifunctional drug delivery matrix for immunotherapy."
- Assistant Professor **Kristyn Masters** and Surgery Research Associate David Stacey: "Advanced bioactive materials for the treatment of chronic wounds."
- Assistant Professor **William Murphy** and Orthopedics and Rehabilitation Associate Professor Ben Graf: "Controlled protein delivery technology for treatment of ischemic disease."
- Assistant Professor **Brenda Ogle** and Transplantation Surgery Assistant Professor Luis Fernandez: "Multichannel two-photon flow cytometry to guide cellular transplantation."
- Assistant Professor **Justin Williams** and Neurosurgery Assistant Professor Karl Sillay: "Thin-film micro-electrode arrays for minimally invasive neurological monitoring."

The Coulter Translational Research Partnership in Biomedical Engineering fosters early-stage collaborations between UW-Madison biomedical engineering researchers and practicing physicians. These collaborations will enable researchers to deliver advances more quickly to patients. The Biomedical Engineering Center for Translational Research promotes and facilitates these collaborative efforts.

The center actively develops partnerships, cultivates new translational research projects based on clinical practice needs, identifies and supports promising biomedical engineering collaborative research projects, and rapidly translates solutions into the clinic by fully using UW-Madison campus resources for technology transfer and commercialization.

A palm-sized, pain-free drug-delivery platform

With funding from the W.H. Coulter Translational Research Partnership in Biomedical Engineering, which encourages faculty-clinician research that leads to a commercial product, Professor **David Beebe** and colleagues have developed a palm-sized device that could deliver measured, timed doses of drugs ranging from aspirin to insulin.

Easy and inexpensive to make, the disposable device is slightly larger than a poker chip and contains no electronic parts. Inside are three layers: a stimulus-responsive material called a hydrogel, the stimulus, and the drug. "When you press the button, it connects the stimulus to the hydrogel," says Beebe. "The stimulus makes the hydrogel swell, which is the pumping action, and it simultaneously connects the drug packet to the skin. So, there's just one simple motion required to operate the device."

Initially, Beebe, biomedical engineering alum Ben Moga and Pediatrics Associate Professor Carol Diamond developed this platform technology to deliver a vital blood-clotting factor to children with hemophilia. Since then, they have conducted animal studies using liquid aspirin and a vaccine.

The Wisconsin Alumni Research Foundation has patented the technology, which Beebe and Moga are continuing to research and develop. Currently, they are perfecting a microneedle array, which replaces the current single needle, for virtually pain-free drug delivery. In addition, Beebe and UW-Madison biomedical engineering and business alum Tony Escarcega formed Ratio, a spin-off company that is commercializing the device.

Among their closest competitors is a simple microneedle array coated with dry-formulated drugs. Beebe's device bypasses the need for drug reformulation—making it an attractive technology for a pharmaceutical company to license. "In theory, ours has a lot of fundamental advantages in that we could take almost any drug off the shelf and deliver it immediately, which can provide a significant value-add proposition for pharmaceutical companies," says Beebe.

Initially developed for young children with hemophilia, this palm-sized device could administer many drugs.

Strength in numbers: Manipulating cells for bio applications

Combining both experimental and computational approaches, Assistant Professor **Jennifer Reed** models biological systems, such as metabolism and regulation, to better understand and predict cell behavior. Her research may enable scientists to design microbes with desired characteristics that include enhanced production yields of desired products, such as ethanol.

"My group is interested in building, analyzing and using metabolic and regulatory models of organisms involved in bioremediation, biofuels production or biotechnology applications," says Reed.

Central to Reed's research in this field of systems biology are computational approaches that enable her and her students to analyze and integrate various types of high-throughput data, including genomic, proteomic and transcriptomic data. From their computational models, Reed and her students generate hypotheses about cellular responses to genetic or environmental perturbations or biological network structure. They then can test these model-generated hypotheses experimentally in their lab.

They also are developing computational methods to help them identify and develop new strains or cell lines with desired phenotypes. "For example, we can determine computationally what enzyme encoding genes we should introduce or remove from an organism in order to improve ethanol production," says Reed.

She and her students also hope to use their models to identify novel gene functions or new regulatory interactions, further clarifying the roles gene products play within the cell. "By developing new computational methods, we will increase the utility of models in biological research, as well as improve the capabilities of organisms for a variety of applications," she says.

Sustainability through synthetic biology

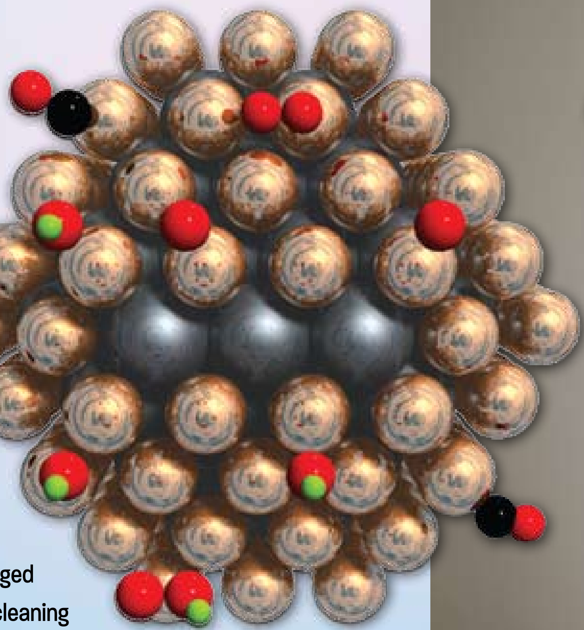
The most abundant energy source on the planet, sunlight could free society from relying on fossil fuels. Yet, converting solar energy into a usable form remains a formidable challenge.

Taking their cue from photosynthetic organisms, Assistant Professor **Brian Pfleger** and his students are developing ways to harness the solar energy stored in biomass. They are using tools in the emerging field of synthetic biology to engineer microorganisms to convert photosynthetically captured carbon dioxide into fuels and chemicals.

Synthetic biology combines science and engineering skills to design and construct new biological systems from known biological parts, says Pfleger. For instance, synthetic biology gives engineers the tools to synthesize and regulate new metabolic pathways. These pathways give microorganisms the capability to convert renewable resources into useful products. "By studying the parts needed to convert biomass into chemicals, engineers can assemble new factories to efficiently synthesize a wide array of compounds, including fuels, medicines, solvents, materials and other specialty chemicals," says Pfleger.

Currently, he and his students are studying enzymes to produce hydrocarbon fuels and bioplastics. They are also developing tools to use cellulose and carbon dioxide as metabolic inputs. Eventually, they will integrate these parts into microbial hosts, resulting in new methods of sustainably producing chemicals.

In addition to department faculty, Pfleger's collaborators include faculty, staff and students in the U.S. Department of Energy-funded Great Lakes Bioenergy Center at UW-Madison. These interactions help integrate Pfleger's synthetic biology research with ongoing work in the life sciences, biotechnology, catalysis, materials science, nanotechnology and computational modeling. "These unique resources, available only at UW-Madison, create an ideal environment for students to develop sustainable technologies and bring them into practice," he says.



Surrounding a nanoparticle of ruthenium with a monolayer or two of platinum atoms, Professor **Manos Mavrikakis** and University of Maryland Professor of Chemistry and Biochemistry Bryan Eichhorn created a robust, room-temperature chemical catalyst that could pave the way for more efficient hydrogen fuel cell vehicles.

Currently, most of the world's hydrogen supply is derived from fossil fuels in a process called reforming, which yields a mixture of carbon monoxide and hydrogen.

However, carbon monoxide poisons the fuel cell catalyst. Therefore, hydrogen produced from reforming needs to be purged from carbon monoxide prior to entering the fuel cell. For that cleaning process, industry has been using expensive all-platinum catalysts.

New nanoparticle catalyst brings fuel-cell cars closer to the showroom

The researchers' new catalyst dramatically improves this hydrogen purification reaction and leaves more hydrogen available to make energy in the fuel cell.

A conventional ruthenium and platinum catalyst must reach 158 degrees Fahrenheit to purge the carbon monoxide. Combined as core-and-shell nanoparticles, however, the ruthenium-platinum catalyst can operate at room temperature. The lower the temperature at which the catalyst activates the reactants, the more energy is saved.

Both the core-and-shell nanostructure and a novel reaction mechanism—hydrogen-assisted carbon-monoxide oxidation—are key to making the catalyst work, says Mavrikakis.

While the breakthrough is important to the development of fuel-cell technology, the researchers say it's even more significant to catalysis research as a whole. Not only did the researchers, including graduate students Anand Nilekar of UW-Madison and Selim Alayoglu of Maryland, use a theoretical approach to identify the catalyst materials, but their nanoscale approach to fabricating the catalyst resulted in a nano-architecture different from when ruthenium and platinum are combined in bulk. Pairing these approaches could bridge the gap between surface science and catalysis, opening new paths to novel and more energy-efficient materials discovery for a variety of industrially important chemical processes.

Freeing underground oil, with water

Although world demand for oil is increasing, some estimates indicate that crude oil output has hit a plateau at 85 million barrels a day and, within a few years, will begin to decline. "We are reaching a capacity as to how much oil we can get out of the ground," says Assistant Professor **Dante Fratta**. "But when we pump, we leave about 50 percent of the oil in there."

Like the greasy post-dinner buildup on a kitchen stove, much of that remaining oil coats the rocks and minerals in an oil field. "In some formations, the oil gets attached to the surface, and it's difficult to remove," says Fratta.

With Geology & Geophysics Professor Herbert Wang and Universidad Nacional de Cōrdoba (Argentina) Assistant Professor Franco Francisca, Fratta is developing an enhanced oil recovery method that uses salt water as a wedge to "scrape" oil away from the porous, uneven underground surfaces. Their method exploits the power of a technique called electrowetting.

Using their technique, the researchers would inject a detergent-saltwater mixture into the oil reservoir, then apply a low voltage to sensors placed throughout the oil field. Both the voltage and detergent reduce the surface tension of the water droplets, essentially flattening them and turning them into wedges that can release the oil. "So you have an oil drop, and you force the water to go in between," says Fratta.

While the researchers have shown that the technique works in the laboratory, their next challenge is figuring out how to implement it in the field.

Returning to our roots: Watershed study solidifies science behind ecosystem restoration projects

Working with The Nature Conservancy in Wisconsin and the state Department of Natural Resources, a pair of hydroecologists is evaluating the efficacy of an ecosystem restoration project along a stretch of the Pecatonica River in southwest Wisconsin. Results of their research could apply to similar watershed restoration initiatives around the country.

In southwest Wisconsin—undulating, unglaciated terrain known as the Driftless Area—170 years of farming and grazing in the region has flattened former prairies and oak savannahs and eroded hill slopes, resulting in sediment runoff into streams.

"When you have this different surface—the agriculture on the upland, contributing more water to the valleys—you have more floods, and with those floods, you have a lot more sediment in them," says limnology PhD student Eric Booth, who, with Assistant Professor **Steven Loheide**, is studying the area.

Over time, floods carried sediment over the Pecatonica floodplain, depositing it on the land. The sediment buried former wet prairies and sedge meadows, building up the watershed and triggering ecosystem changes driven by the rising land surface.

"What you're left with now is a floodplain surface that's much further from the water table, and it's drier without the sedge meadow and wet prairie," says Booth. "You also have cropland and grazing on the floodplains."

For the restoration project (funded through state wildlife action grants), crews "scraped" about 12,000 cubic yards of topsoil—years of deposited sediment—from about 20 acres of floodplain. A year later, heavy rains showed that the restored site effectively reduced the velocity of floodwaters through the river and gently spread the excess over the floodplain, lessening erosion and encouraging sediment deposition. Now the restored area also provides increased habitat for wildlife and amphibians.

Currently, Booth is monitoring the site to quantify the hydrologic and vegetative effects of the project. Ultimately, he hopes to translate his field data into a computer model that will enable watershed managers to predict the ecological effects of the changes they make.

Bridge between transportation and health could be in the bike lane

Assistant Professor **Jessica Guo** *(left)* hopes to give city planners the tools to make fiscally responsible, neighborhood-level decisions that reduce vehicular traffic and also improve public health. "Our focus is really more about identifying win-win solutions that would take people out of their cars and have them use more of the walking and biking mode," she says.

In particular, Guo is interested in non-commuter travel, which constitutes up to 70 percent of all daily travel. "The non-commuter trips are contributing a lot to pollution and congestion throughout the day and on the weekends," she says. "Yet, these trips tend to be short—and therefore represent good opportunities for the travelers to improve their fitness if they bike or walk."

With colleagues at the University of Texas at Austin, Guo analyzed San Francisco Bay-area residents' personal travel diaries and related their non-commute travel habits to such neighborhood characteristics as population density, percentages of residential and commercial land use, number of businesses, roadway density, street connectivity, and others. In addition, she also studied how travel decisions and modes varied across different population segments. For example, for most population groups, mixed-land use discouraged driving; however, it increased vehicular trips among single parents and people in households with multiple vehicles.

After analyzing personal travel data from other areas of the country—including Dane County, Wisconsin, with master's student Sasanka Gandavarapu *(right)*—Guo hopes to identify commonalities among each population segment. She will use those patterns to develop general guidelines for city planners and engineers throughout the country. Because most previous studies examined aggregate—rather than personal—travel behavior, Guo says one plan to modify the built environment might not work for everyone.

"We have to make sure that, whatever we do, we are meeting the needs of the residents in that neighborhood while offering environmentally friendly and health-promotive alternatives," she says.

Biometric encryption guards your electronic identity

For Assistant Professor **Stark Draper**, identity theft means much more than a lost credit card number. Draper is developing a novel type of encryption for biometric data—such information as fingerprint and iris scans, DNA profiles and the like. His research may add an extra layer of protection to your identity.

Now, for example, if your credit card information is stolen or the credit card company's database is broken into, the company simply issues a new card with a new number. "But since you've only got ten fingers, if that happens to your fingerprint, you've got a problem," says Draper.

He studies a type of data encryption that prevents burglars from retrieving original biometrics from the data stored in a database or security program, while allowing the legitimate owner of the biometric data to verify his or her identity.

For example, a user could set up a fingerprint-scan lock on his or her computer. Using Draper's "secure biometrics" approach, the computer would be able to verify the user's fingerprint based on stored data. "But if someone broke into your computer and looked at the data stored there, they couldn't replicate your fingerprint," says Draper. "That's different from how current biometric systems work. Right now they just store your biometric in a recognizable form."

The underlying ideas have applications beyond biometrics. The ideas also can be used in wireless ad-hoc networks to derive encryption keys from natural phenomena in an eavesdropper-proof manner, and even form the basis for reliable communication across the backbone of the Internet.

Power struggle: Advocating for energy consumers

Too-high electricity bills can leave consumers wondering if their energy providers are cheating them. According to Associate Professor **Bernard Lesieutre**, they just might be.

Lesieutre and his research group are trying to determine whether electricity suppliers can manipulate the markets to their advantage.

Current guidelines overseeing energy markets are based on financial models and regulations for market share; however, those models don't take into account the physical limitations of the energy grid. Power lines have a limited capacity for how much electricity they can carry before they become congested, and too much power can physically warp the cables. Even an exceptionally hot day could reduce the amount of energy the lines can tolerate.

Because the lines cannot carry any more power, when conditions create congestion, competitors might not be able to supply power to where it's needed. As a result, one power company might become the only provider in an area for a time. "If they know or can guess that, they can raise their prices to make more money," explains Lesieutre. "They know their electricity is no longer substitutable. People can't get their energy from somewhere else because the grid is overloaded."

Based on sensitivity analyses, Lesieutre's group has determined that such inflation is possible. While there are regulations for substantial manipulation, current measures only apply to instances where prices increase by 300 percent or more.

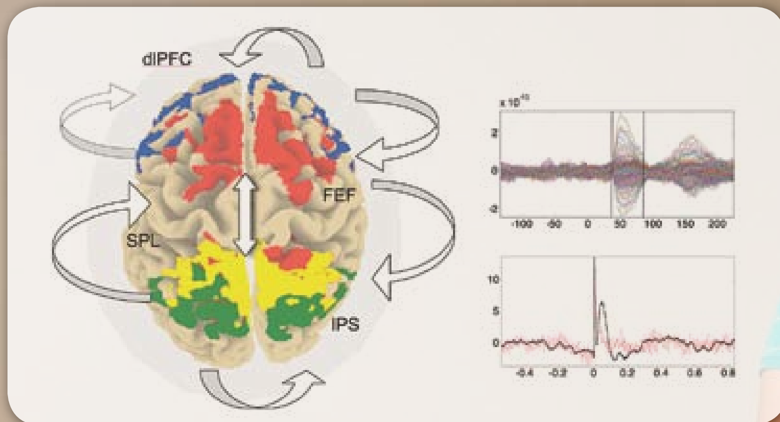
"Our concern is this high threshold. It doesn't detect a lot of times when rates are noncompetitive," says Lesieutre. "Our research is to come up with something with a much finer resolution than that."

Having identified scenarios with potential for market manipulation, the group's next step is to develop measures to determine when companies are taking advantage of those scenarios. Ultimately, Lesieutre hopes to prevent this market manipulation.

Turning down the noise helps researchers 'listen' to the brain

To study how regions of the brain communicate, neuroscientists often use a technique called electroencephalography (EEG), which reads electrical activity in the brain through sensors on the scalp.

However, the skull and the scalp blur these EEG readings. In addition, a multitude of signals from "background" processes make it difficult to pinpoint electrical activity corresponding to specific tasks. "It's like standing outside a crowded party and trying to sort out individual conversations," says Professor **Barry Van Veen**.



Van Veen *(center)* and his students use signal-processing techniques to filter out that noise and enable them to study how one area of the brain influences another *(inset graphic)*. "The brain is active all the time," he says. "It's in the midst of that background noise that you have to identify a specific set of connections associated with a task."

One research paradigm is working memory, a type of task-oriented short-term memory. For example, working memory allows a person to remember a phone number long enough to dial it, or to remember a series of notes or pattern of shapes long enough to repeat it. Neuroscientists hypothesize that several regions of the brain are connected in working memory tasks. Van Veen and his students use their signal-processing techniques to identify electrical connections from EEG data and determine how they change under different conditions, such as task difficulty or recall accuracy.

The group also is interested in how connectivity in the brain changes between waking and sleep, and more complicated activity such as language processing.

Van Veen is hopeful that, as the research progresses, his methods will provide some insight into the workings of the brain and lead to better understanding for treatment of medical conditions like epilepsy or schizophrenia.

Professor Barry Van Veen (center) with students (from left) Patrick Cheung Pam Limpiti, Andrew Bolstad and Matt Rebholz.

Weighing alternatives: Models inform worldwide nuclear energy choices

To inform nuclear-energy-related policy decisions, Associate Professor **Paul Wilson** develops and runs complex computer simulations that provide insight into the next century of nuclear energy.

In one project, he and his students are using VISION, a piece of software developed at Idaho National Laboratory (INL), to simulate how the nuclear fuel cycle will develop over the next 100 years. In particular, they are interested in how current nuclear waste policy might affect the amount and cost of space in the proposed Yucca Mountain long-term storage facility. Using a calculation they applied to the VISION code, Wilson and his students can follow spent fuel (and other material) through the fuel cycle and quickly determine, based on heat load, how much space it will need in the repository. In addition, based on the current waste fee and amount of stored waste, they can study the economics of different fuel choices based on the value of available space in Yucca Mountain. The group's research may help inform an upcoming decision by the U.S. Secretary of Energy about whether to propose a second nuclear waste repository and where to site it.

Working with INL researchers, Wilson and his students are developing a new software tool called GENIUS. The tool will enable them to model individual facilities throughout the nuclear fuel cycle, and to study the flow of material among those facilities over the next 100 years. Wilson hopes to use GENIUS to study global interactions in the fuel cycle. This more finely tuned research may contribute to dialog about the economic and diplomatic feasibility of fuel-cycle services agreements among nuclear energy providers around the world.

Strong plasma physics and fusion technology programs build intellectual capital

Dating back nearly a half-century, the UW-Madison programs in plasma physics and fusion technology are among the oldest, broadest, largest and most productive programs in the nation.

One key area of emphasis is on magnetic plasma confinement and magnetic fusion; with experts in several additional areas, the programs span three departments in two colleges. Collectively, these programs—in the Departments of Engineering Physics and Electrical and Computer Engineering in the College of Engineering and the Department of Physics in the College of Letters and Science—receive about $12 million annually in Department of Energy research funding, primarily from the Office of Fusion Energy Sciences.

By generating and harnessing plasma, or highly heated ionized gas, in a variety of fusion experiments, UW-Madison faculty, staff and students hope to develop technologies capable of delivering a clean, virtually inexhaustible source of energy. They also study the basic properties of plasma, plasma science and astrophysical phenomena, and plasma-aided manufacturing techniques.

For students, a hallmark of their educational experience is the opportunity to operate an entire fusion experiment, and to learn the hardware inside and out, as well as the relevant plasma theory. "Because of this hands-on experience, UW-Madison graduates have become central players in a lot of machines around the country," says Professor Emeritus **James Callen**.

Another hallmark of the UW-Madison plasma physics and fusion technology programs is their people. On campus, the programs include approximately 75 faculty and staff members, 60 graduate students and 30 undergraduate students whose education and research frequently cross departmental and college boundaries.

And, nearly 350 PhD recipients—more in these technical areas than any other U.S. university—are making important contributions in industry, government, universities and laboratories around the world.

Unique tool enables vibration researchers to think BIG

In just one second, Assistant Professor **Matt Allen** *(left)* can acquire vibration samples from thousands of points along a downhill ski. In a matter of several minutes, he could analyze an entire airplane wing. “What we’ve developed is a way to both acquire and interpret hundreds or even thousands of times more information at one time,” he says.

Using a new twist on an instrument called a laser vibrometer, Allen and master’s student Mike Sracic *(right)* collect measurements as they sweep a laser beam continuously over the structure they’re studying. In contrast, researchers using the conventional laser vibrometry approach measure point by point. “In the time it would take to measure one point using the traditional approach, we can determine what’s happening at every point along the laser’s path,” says Allen. “This is important if we want to apply laser vibrometry to low-frequency structures such as airplanes or civil structures, because tests with conventional laser vibrometry would take too long to be practical.”

One key to their use of the approach is an algorithm Allen and Sracic developed for analyzing the mountains of data they acquire. The algorithm essentially decomposes the measurement into individual responses, so the two can post-process measurements exactly as they would for data collected via conventional laser vibrometry.

The continuous scan approach may enable researchers to measure the vibrational response of structures that contain polymers or composites. Since those materials can change over time or with temperature, the continuous scan method makes it possible to collect an entire set of measurements before the structure has time to change. In addition, the approach could speed product development and reduce costs by allowing test engineers to obtain more detailed information in less time. Engineers also could use the method to verify that noise and vibration performance meet design specifications, to calibrate computer models, or to diagnose vibration problems in the field.

The write stuff: MEPP students hone communication skills

Professor **Patrick Eagan**'s classroom has no chalkboards or desks. Instead, Eagan and Faculty Associate **Paul Ross** rely on computer monitors and phones to interact via webinars, E-mail and discussion forums with engineering students who are scattered all around the world.

Eagan and Ross teach *Independent Reading and Research in Applied Engineering (IRRAE)*, a course in the Master of Engineering in Professional Practice (MEPP) degree program. MEPP is an online master's program that emphasizes technical leadership. Designed for working professionals, the program accepts approximately 30 students per year.

In IRRAE, students develop independent projects that solve a practical problem related to their careers. Students are paired with faculty members, who assist as reviewers.

"As technology leaders, these students will be evaluating and communicating about new technologies throughout their careers," says Eagan. "The value of IRRAE is they learn to access information and write about those technologies."

Some students haven't written anything beyond a bullet-point list in years, and another MEPP course offers help. The semester before IRRAE, students take *Communicating Technical Information (CTI)* with Faculty Associates **Traci Nathans-Kelly** and **Christine Nicometo**. In CTI, students complete a research project that is often a precursor to the summer IRRAE projects.

In addition to writing, CTI helps students refine presentation skills. "You can be as brilliant as you want, but if you can't talk about a project, it's going nowhere—it's dead in the water," Nathans-Kelly says.

Many employers notice the difference in their employees. More than 50 percent of students report receiving a raise or promotion before completing MEPP. Five years after graduation, 83 percent report career advancement.

The students aren't the only ones writing papers. College of Engineering librarian Amy Kindschi, Eagan and Ross recently presented a paper to more than 100 people from the American Society for Engineering Education explaining how IRRAE equips MEPP students with strong research and analytical skills.

Information highway: Center delivers technology to road builders

Now in its 25th year of service to local officials and Wisconsin highway maintenance staff, the UW-Madison Transportation Information Center (TIC) embodies the spirit and practice of the Wisconsin Idea. With support and participation from the Wisconsin Department of Transportation (DOT), the Federal Highway Administration (FHWA) and the transportation community, the TIC provides vital training and materials for nearly 2,000 local governments responsible for maintaining more than 100,000 miles of state roads.

"Roads are the skeleton for the physical facilities that make community life possible," says Faculty Associate **Steve Pudloski**, who directs the TIC. "Good roads are necessary for a vital Wisconsin economy. High turnover in local governments and limited resources require low-cost training and accessible technical information for effective performance."

TIC offers workshops, a quarterly newsletter, how-to manuals, fact sheets, videos and on-site programs to help local officials build better roads and maintain existing roads. In 2007, TIC conducted 80 workshops for more than 5,000 local officials.

In addition, TIC researchers have developed an innovative pavement surface evaluation and rating scale, PASER, which most Wisconsin communities and communities in other states use to rate roads and prioritize construction and maintenance projects. "A balance between construction and preventive maintenance is essential, because every dollar spent on prevention saves $4 to $5 on rehabilitation or reconstruction," says Pudloski.

TIC is part of a national technology transfer program with a center in every state and seven regional centers serving tribal communities. Funded by a FHWA grant, matched by the Wisconsin DOT, and augmented by local governments through course registration fees and in-kind contributions by UW-Madison, TIC is a true partnership, extending the benefits of university transportation knowledge and research to the citizens of Wisconsin and beyond.

With merely one gallon of fuel, a train can move one ton of freight 400 miles.

Despite the astonishing fuel efficiency of trains, the railroad industry shrank dramatically in the 1970s. Today as fuel prices soar, trains again are becoming an attractive mode of transportation for freight and commuters.

As railroads make a comeback, so must railroad engineers. Currently, few universities in the United States offer undergraduate or graduate classes that teach engineers the basics in designing, building and maintaining railroads that are safe, efficient and consumer-oriented.

However, a comprehensive continuing education program is available: the Railroad Engineering Program, directed by Professor Emeritus **C. Allen Wortley**.

Railroad engineering, revived

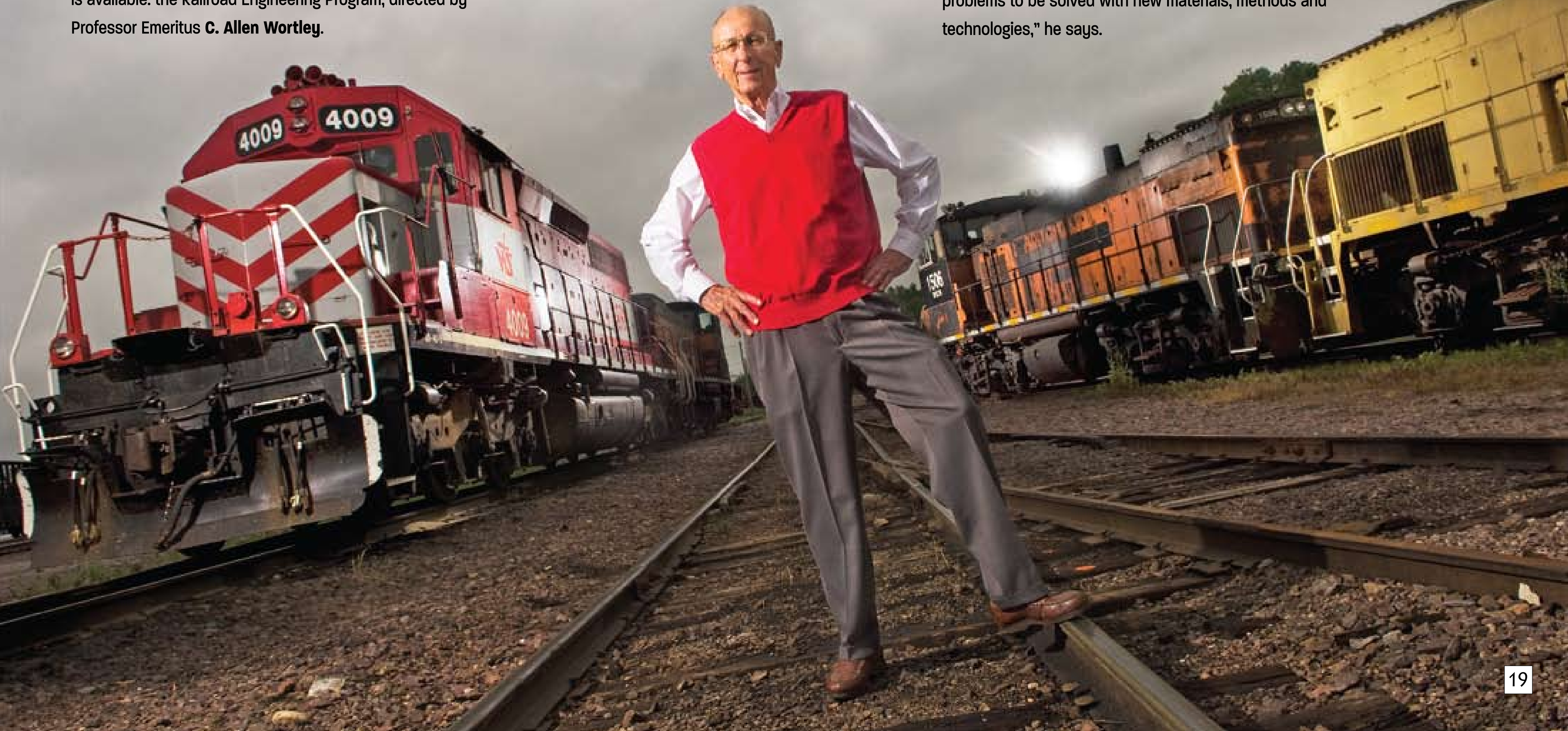
The program began in 2001 when Wortley developed a survey course covering the civil engineering fundamentals of the rail industry. More than 120 people from around the country came to Madison to sit in, and Wortley knew he was on to something.

"America's prosperity depends on a sound transportation infrastructure," says Wortley. "We must increase our commitment to rail—a key transportation component—to compete, reduce problems on our highways and skyways, reduce air pollution, save energy and meet future needs."

One course has expanded into eight annual offerings lasting two to three days each and taught by experts from the rail industry. The courses feature a variety of topics, including highway-rail grade crossing safety, railway train control and signaling, rail transit passenger systems, freight railroad operating practices, and track design and maintenance. The most recent course covers railroad bridge engineering.

The UW-Madison Railroad Engineering Program is a model for other universities in the United States and Canada. Wortley hopes to see several universities begin programs for railroad research and education.

"Although 'railroading' is nothing new, there are new problems to be solved with new materials, methods and technologies," he says.



Collaboration is catalyst for innovation in printing and packaging

A National Science Foundation-funded collaboration will ensure that Wisconsin remains a national leader in printing and packaging. Led by Professor **Raj Veeramani**, the Partnership for Innovation (PFI) in Wisconsin's Packaging and Printing Industry Clusters strives to foster economic growth in the printing and packaging industries by developing new and unique technologies, building human capital, and enhancing "enabling" infrastructure by developing lasting, mutually beneficial relationships among companies, researchers and educators.

PFI collaborators include numerous industrial partners, and faculty, staff and students at UW-Madison, the University of Wisconsin-Stout and Waukesha County Technical College. Electrical and Computer Engineering Professor **Dan van der Weide** and Civil and Environmental Engineering Professor **Marc Anderson** are among the UW-Madison researchers. The group will focus on special coatings, printable power systems, and "green" packaging and printing. Special coatings can give packaging superior properties, such as ultraviolet protection, food safety, scratch resistance, humidity control and more. Printable power systems include thin-film batteries and solar cells that, coupled with technology like radio-frequency identification (RFID) tags, could push RFID beyond identification and into sensing. And green packaging and printing includes not only exploring sustainable, environmentally conscious materials and methods, but also evaluating the environmental effects of new technologies.

The partnership enables all participants to work together for the good of the state printing and packaging industry, says Veeramani. "This project is allowing us to work together to transform knowledge from our laboratories to a point where it can be commercialized into high-value products and processes," he says. "It gives us a way to make it compelling for the companies and enhance their competitive advantage. There's tremendous leverage that's possible."

Continuing education: Web helps long-term-care staff learn on the job

When the Wisconsin Clinical Resource Center (WCRC) went live in 2007, Wisconsin nursing home staff members gained easy online access to clinical information that daily can improve the way they deliver care.

WCRC is a dynamic web-based resource developed by UW-Madison Center for Health Systems Research and Analysis (CHSRA) faculty and staff, who are renowned for their expertise in long-term care quality. Professor **David Zimmerman** directs the center.

The site enables staff at care facilities to search quickly for facts, care processes, tools, case studies, guidelines, resources and regulations for clinical issues that commonly arise in nursing homes. "It's very user-friendly, and it's really directed at staff on the floor," says Associate Scientist Allan Stegemann, who led the resource center development team. "People can get in there and get information quickly."

WCRC currently addresses eight areas, including pain management, pressure ulcers, falls and others, with more in the works. In addition to clinical information, the WCRC contains companion training programs that enable nurses, nursing assistants and other staff who work directly with care facility residents to improve or reinforce their clinical knowledge. The modules include mechanisms for self-evaluation, as well as discussion questions, examples and case studies, all of which are designed to help users apply their knowledge. "The website has been used by staff to gain specific information about particular conditions, to update policies and procedures, and to help staff work through the assessment process to determine specific resident needs," says Stegemann.

The site also includes guidelines from the American Medical Directors Association. Sponsored by the Wisconsin Health Care Association and the Wisconsin Association of Homes & Services for the Aging, WCRC is available to all members of the two organizations—or most Wisconsin nursing homes.

Pilot decision-making study takes wing

Associate Professor **Doug Wiegmann** is studying how pilots think when their heads are in the clouds—yet their feet are firmly on the ground. With a new flight simulator and a grant from the Federal Aviation Administration, Wiegmann hopes to reduce small aircraft accidents due to weather shifts. According to Wiegmann, around 10 percent of general aviation accidents are fatal, and a primary factor in fatal accidents is pilots flying in adverse or deteriorating weather.

"The analysis of weather-related accidents suggests there's a variety of reasons why a pilot would continue to fly into weather that they're not qualified to fly in," says Wiegmann. Reasons range from the pilot being unaware of changing forecasts to misdiagnosing weather changes to knowingly risking inclement conditions.

To study pilots' decision-making process under dynamic conditions, Wiegmann will invite local private pilots to take a ride in the simulator. They will plot a course and check weather forecasts, just as in a real flight, but during the simulation the weather will change. Through scenario recording, eye-movement tracking and observation during the flight as well as discussion with the pilots after the flight, Wiegmann hopes to understand pilots' thought processes and develop interventions for helping them fly more safely.

"Part of this is figuring out whether pilots realize they're taking the risk. Do they realize the weather has changed? That the situation they're flying into is not what they expected it to be?" asks Wiegmann. "Then, if and when they know what they're doing, what are the cognitive processes underlying their choices? To divert, to go around it, to land and wait for it to pass?"

Wiegmann and two of his graduate students built the simulator by merging top technologies, from the motion-capable seat to the flat-panel monitors, sound system, computer software and hardware. "We're taking this technology to the next level with its integration," says Wiegmann.

What's that molecule? Future biosensors may have the answer

Like voice-sensing technology that can recognize an individual speaker, Assistant Professor **Izabela Szlufarska** hopes to perfect biosensors that can identify a specific molecule.

Each biosensor resonates at a characteristic frequency. When a molecule touches a biosensor, the frequency changes. Therefore, researchers know that when the resonance changes, a molecule is present—but they don't know which molecule, like a sound sensor that registers a voice but can't identify the speaker. To unlock the science that could make biosensors more sensitive and specific, the National Science Foundation granted Szlufarska a Faculty Early Career Development Award.

Szlufarska is using molecular dynamics simulations to study how resonance frequency depends on the type of molecule that the sensor detects. Working with carbon-coated sensor surfaces developed by Chemistry Professor Robert Hamers, Szlufarska studies specific molecular systems to determine the mechanisms responsible for energy dissipation at the sensor interface, which causes frequency changes. Armed with that knowledge, she can then create models that quantify the amount of resonance for specific molecules, like an acoustic expert could map the unique timbre of a person's voice. Her models will enable researchers to predict relative frequency changes caused by a specific target molecule. "The ability to predict relative resonance shifts will enable design of structures capable of real-time biosensing," says Szlufarska.

Real-time biosensors have many applications in health-care, since carbon-based sensors could be implanted in the body to monitor levels of a specific protein or hormone. They also could have applications for the military and national defense.

For ultra-high-temperature alloys, new coating turns up the heat

Researchers in Professor **John Perepezko**'s lab have shown their new oxidation-resistant coating can take the heat. Ultra-high-temperature metals and alloys treated with this coating could enable new components for technologies ranging from airplane brakes and turbines to space vehicles.

Today, efficient combustion, greater energy efficiency and reduced emissions are the gold standard—and engines and turbines functioning at higher temperatures can accomplish all three. However, to reach those high temperatures, engine components, for example, have to be made of materials that can withstand extreme heat and pressure.

Nickel-based alloys are the industry standard for high-temperature applications, but current materials are at the limits of their potential, prompting researchers to investigate other alloys. Molybdenum alloys, particularly those with silicon and boron (Mo-Si-B), show great promise for ultra-high-temperature applications, since they maintain their strength at much greater temperatures and pressures than nickel alloys. However, even Mo-Si-B materials show some oxidation under the extreme conditions they might face in aerospace applications.

Perepezko and his students have developed a surface coating for Mo-Si-B alloys that prevents cracking, peeling, delamination and oxidation, even under extreme temperature and pressure conditions.

"According to the models, these coatings should work at very high temperatures—up to 1,800 degrees Celsius," says Perepezko. "That's like a tungsten filament in a light bulb. That's hot."

Surprisingly, the researchers' tests exceeded what their models predicted. Oxygen torch tests have shown that both the metal and coating survive with no sign of wear at more than 2,000 degrees Celsius (about 3,600 degrees Fahrenheit).

"This is a good example of true discovery, which you wouldn't get with any computer simulation," says Perepezko.

From defect to effect: Optimizing an organic semiconductor material

Most people think of "organic" and "electronic" as contradictory. For Assistant Professor **Paul Evans** *(right)*, they work in harmony.

Evans and graduate student Soonjoo Seo *(left)* are studying organic semiconductors useful for transistors, diodes and solar cells as low-cost alternatives to conventional semiconductors. Organic semiconductors can be more stable in their interactions with air, water and other environmental elements than silicon, giving them great potential as sensors and in other applications.

Defects in crystal structure can hinder material performance. Researchers don't know why. "Researchers know that somehow the materials that have lots of defects are worse, but they know so little about what the defects are, it's hard to know what makes them worse," says Evans.

One common defect occurs when a molecule is missing from the crystal structure, a phenomenon known as a vacancy. Using a scanning tunneling microscope, Evans and Seo can visualize vacancies on the surface of a thin film of pentacene, a model organic semi-conductor. They have found that the molecules near the vacancies are slightly shifted, relaxing around the open space.

"That turns out to be relevant to where the electronic energy levels are in these crystals," says Evans.

With a better understanding of what the defects are and how they alter the properties of the crystal, researchers could develop strategies for growing the crystals to minimize unwanted defects—or use them advantageously.

For example, Evans is collaborating with Assistant Professor **Padma Gopalan** to induce a specific "defect" by creating an interface between pentacene and the carbon molecule C_{60}. The defect changes the electronic dynamic and enables applications like organic solar cells, opening the door to technologies where organic materials are not only components of electronic devices, but also help produce energy.

Mirror image: Self-assembling micro tiles look promising as optical devices

Associate Professor **Tom Krupenkin** is developing materials with multiple personalities. With Senior Scientist J. Ashley Taylor and colleagues at Bell Labs, Alcatel-Lucent, Krupenkin is exploring new ways for liquids and solids to interact.

In addition to developing "nanonails" that repel liquid totally until voltage is added *(read more on the inside cover)*, Krupenkin's team has developed microscale liquid mirrors. When voltage is applied, these micromirrors can change their focal distance and position. They maintain their reflectivity even when shaken or deformed.

To make a micromirror, the researchers use gold-covered silicon wafers to fabricate hexagonally shaped micro-tiles. Sandwiched between oil and water, these tiles—dubbed "Janus tiles" by the team—self-assemble into a highly reflective micromirror. When introduced into the liquids, the tiles flip back and forth between their hydrophilic and hydrophobic sides, eventually settling into a honeycomb shape that covers the concave curve of the liquid like a carpet.

Similar optofluidic devices known as liquid lenses now are used in some cell phones and disposable cameras. Unfortunately, those lenses require the refractive index contrast between two liquids to be very high, limiting their applications. A mirror does not have such restrictions, but it is challenging to form a mirror out of liquid. The best reflector is liquid mercury, a toxic substance—and Krupenkin and his colleagues developed the Janus tiles as a safe alternative.

By varying voltages and tile types, Krupenkin could develop a new family of optical devices. Applications could include projectors able to cast images on curved or moving surfaces, or projectors small enough to fit in a cell phone. Other applications might be optoelectronic devices such as light detectors or homogenizers that create more uniform laser beams.

Shape optimization software makes thin components easier to model

When UW-Madison vehicle teams design custom parts, they start by making a computer model. The 3-D modeling software they use, which incorporates finite element analysis, will simulate, for example, the effect of fatigue loading or rapid acceleration on various parts.

The standard software works until the team tries to apply it to thin parts, like chassis or other beam-like components. Thin parts are notoriously difficult to design because current technologies rely on processes meant to analyze objects with three closely matching dimensions. Also, even a minor design change warrants a painstaking reanalysis.

Associate Professor **Krishnan Suresh** is developing the next generation of shape optimization software to make the design process for thin structures and other geometrically complex shapes more efficient and sophisticated—meaning engineers easily can design parts with varying thicknesses or geometries.

Supported by a 2008 Faculty Early Career Development Award (CAREER) from the National Science Foundation, Suresh and his team are creating a new mathematical framework based on two innovative concepts: feature sensitivity and dual representation.

Feature sensitivity allows design changes to be made efficiently. Currently, if a small change is made to an approved design, it can take weeks or months to reanalyze and verify the entire design. An engineer using feature sensitivity could add a rivet to a completed design and know immediately how the stresses or frequency of the object changed.

Dual representation blends 3-D geometry with 1-D physics, giving engineers working with thin structures the best of both modeling options.

New shape optimization technology has cross-disciplinary, industry and military applications. The UW-Madison SAE formula and hybrid vehicle teams will be the first case studies, which is a win-win situation: While Suresh tests his software, students will learn the underlying concepts of shape optimization and create cutting-edge vehicle designs.

Uncovering the real dirt on granular flow

A handful of sand contains countless grains, which interact with each other via friction and impact forces as they slip through your fingers. When a handful becomes a load in an excavator bucket, those interactions multiply exponentially.

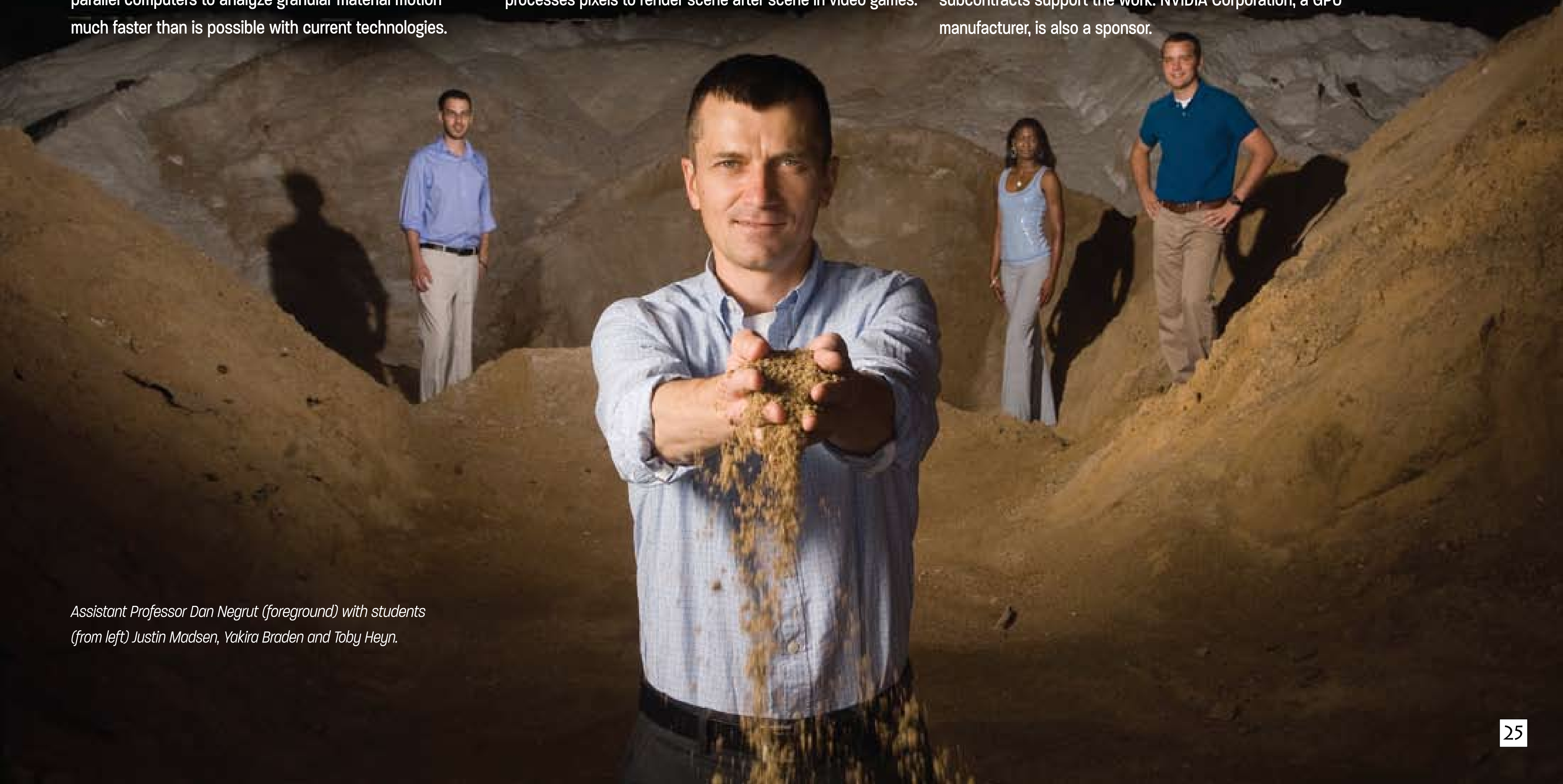
By solving large sets of differential equations, researchers can predict how sand or other granular material will move. Assistant Professor **Dan Negrut** and his team at the UW-Madison Simulation-Based Engineering Laboratory are developing innovative computer simulation methods for parallel computers to analyze granular material motion much faster than is possible with current technologies.

Even a supercomputer takes days to run a simulation charting the motion of millions of sand grains. Negrut hopes his simulation will analyze millions of grains in a single day, if not a matter of hours.

The difference lies in how parallel computers approach the task. The central processing unit of a regular computer processes information sequentially, so grains are analyzed one after another. Parallel computers rely on the graphics-processing unit (GPU), which can simultaneously execute one command multiple times. This is how a graphics card processes pixels to render scene after scene in video games.

Negrut uses GPU computation to determine in-parallel sand movement. He and his students assembled a fast computer from scratch that handles almost 50,000 parallel computational threads at any given time.

Understanding the dynamics of granular material has a variety of applications, especially for improving vehicle designs. Beyond vehicle applications, researchers could use such simulations to study atomic particles, pebble-bed nuclear reactors, pressure in silos and crystals in prescription pills. The National Science Foundation and U.S. Army subcontracts support the work. NVIDIA Corporation, a GPU manufacturer, is also a sponsor.



Assistant Professor Dan Negrut (foreground) with students (from left) Justin Madsen, Yakira Braden and Toby Heyn.

In addition to its nine departments, the College of Engineering has six degree-granting programs with strong emphasis on interdisciplinary studies. Participating UW-Madison faculty members are based in the following schools and colleges:

Environmental Chemistry and Technology

www.engr.wisc.edu/interd/ect

Marc Anderson *(Chair)* **Tel: 608/263-3264**

This interdepartmental graduate program offers both an MS and PhD. Participating departments include civil and environmental engineering (primary department), chemical and biological engineering, chemistry, soil science, and geology and geophysics. Program activities are centered in the Water Science and Engineering Lab on Lake Mendota, where researchers examine the applications of chemistry to problems in environmental and engineering systems.

The program has four areas of specialization: aquatic chemistry, which studies the chemical processes in lakes, rivers and watersheds, and organic chemicals, trace metals and nutrient elements; environmental technology, which studies the application of chemistry and biotechnology to development of technologies for water and air treatment, sensors, and energy-storage devices; air-pollution chemistry, which studies sources, characterization, reactions and fate of air pollutants, as well as air-water interactions; and terrestrial chemistry, which studies chemical and biogeochemical processes in soils and sediments and their influences on land-water and air-water interactions.

Graduates from this program are prepared for a variety of careers, including teaching, research, pollution control, and resource management.

Geological Engineering Program

www.engr.wisc.edu/interd/gep

Tuncer B. Edil *(Chair)* **Tel: 608/262-3491**

Geological engineering integrates two disciplines: geology and engineering. Geologists study the earth—its origins, composition and evolution. Engineers apply scientific principles to practical ends. Geological engineers help solve earth-related technical problems while protecting the environment.

Although housed in the Department of Civil and Environmental Engineering, the Geological Engineering Program (GLE) relies on faculty in the College of Engineering, geology and geophysics (College of Letters and Science), and soil science (College of Agricultural and Life Sciences). Specific areas of study include designing structure foundations in soil and rock, dams, tunnels and other caverns; mitigating hazards such as earthquakes, landslides and coastal erosion; and protecting the environment through proper waste disposal, remediation of contaminated groundwater and sites, erosion control and groundwater quality maintenance. GLE offers an accredited BS degree. It also offers MS and PhD programs.

Graduates are prepared for employment with consulting firms, the petroleum industry, federal and state laboratories and agencies, and others. Most will spend part of their time working outdoors enjoying nature. GLE students can opt for a second major in geology, since the program's required geology credits often satisfy the BS degree in geology. Graduates are eligible for professional engineer (P.E.) and professional geologist (P.G.) licensing.

Limnology and Marine Science Program

www.engr.wisc.edu/interd/limnology

Chin H. Wu *(Chair)* **Tel: 608/263-3264**

UW-Madison is recognized worldwide as a leader in limnology and aquatic ecology. The program continues the university's 100-year tradition of research on lake ecosystems by combining research and teaching from several fields and departments to develop a greater understanding of oceans and inland waters—their origins, inhabitants, phenomena and impact on human life.

This program offers curricula leading to the MS, PhD or PhD minor in limnology and marine science. Applicants must have had at least one year of college-level biology, chemistry, physics and calculus, as well as substantial preparation in one area of limnology/oceanography. Interdisciplinary in nature, each individualized program provides graduate training in aquatic sciences while integrating a variety of courses in related sciences.

The program is administered by the College of Engineering and sponsored jointly by the College of Letters and Science and the College of Agricultural and Life Sciences, including more than 25 faculty members in civil and environmental engineering, botany, food science, geology and geophysics, atmospheric and oceanic sciences, plant pathology, and zoology.

Manufacturing Systems Engineering Program

www.msemadison.org

Ananth Krishnamurthy *(Director)* **Tel: 608/262-4709**

The Master of Science in Manufacturing Systems Engineering (MSE) is recognized internationally as a provider of cross-functional engineers and leaders equipped to manage manufacturing in the global marketplace. More than 400 MSE alumni lead operations and drive change worldwide.

The MSE degree is multidisciplinary, integrating courses in engineering, business, computer sciences and statistics. Alongside a flexible self-designed curriculum, students experience frequent practical interaction with leading manufacturing firms, engaging in team projects in the field, internships, and industry collaborations.

MSE students experience:

- Hands-on problem-solving in the areas of design, development, implementation and operation of modern manufacturing systems;
- Computer-aided design, manufacturing and engineering;
- Engineering and management issues via case studies, seminars and guest lectures by leading private-sector executives;
- An integrated learning environment in the capstone course—a unique, team-based project sited on the shop floors and management offices of our corporate partners.

Master of Engineering (Polymer Engineering & Science)

rrc.engr.wisc.edu/PolEngSci.html

A. Jeffrey Giacomin *(Co-Director)* **Tel: 608/262-7473**
Tim Osswald *(Co-Director)* **Tel: 608/263-9538**

Organized under the Rheology Research Center (RRC) and affiliated departments of chemistry, chemical and biological engineering, engineering physics, and mechanical engineering, the Master of Engineering (Polymer Engineering and Science) degree is ideal for students wishing to complete a bachelor of science plus master's degree in a total of five years. All the degree credits required can be taken through the College of Engineering Office of Engineering Outreach.

Many corporations sponsoring research at the RRC are also participating sponsors of the National Technological University. These corporations encourage employees to take polymer courses that are broadcast to customer sites.

In the future, the entire degree will be available to students who cannot attend classes on campus.

Practicing engineers and scientists on a short sabbatical leave from their positions in industry will find the degree an excellent opportunity to advance their knowledge of polymer engineering. At least six approved courses are offered each semester.

Materials Science Program

www.engr.wisc.edu/interd/msp

Ray Vanderby *(Director)* **Tel: 608/263-1795**
Donald Stone *(Associate Director)* **Tel: 608/263-1795**

The Materials Science Program (MSP) is a nationally recognized interdisciplinary graduate program in a burgeoning field that applies principles from traditional scientific and engineering disciplines to create advanced materials and devices. Progress in these areas hinges upon controlling the preparation of compounds and interfaces at the atomic level and above to tailor the chemical and physical properties of materials and devices to produce the desired properties and performance.

MSP personnel are at the cutting edge of research in advanced metals and polymers, atomic imaging, surface science and biomaterials. Their research results have had a national impact. Faculty, staff and students have invented nuclear-powered nanobatteries for microelectromechanical devices, used plasma-aided engineering to protect food-industry surfaces from bacteria, boosted the potential of the superconducting material magnesium diboride, developed a technique for cheaply/simply manufacturing DNA chips, and studied the use of nanostructured surfaces on cell behavior.

Students entering the MSP generally have undergraduate degrees in physics, chemistry or an engineering discipline. They design a curriculum from cross-campus offerings with input from their research advisors, and select thesis research topics based on materials and interfaces that involve polymers, superconductors, advanced metals and alloys, semiconductors, ceramics, composites and biomaterials.

www.engr.wisc.edu/services/development

A world of opportunity

As you probably know from your own experiences, engineering is not a solitary profession. Rather, engineers practice in a global marketplace. They interact with colleagues, collaborators, clients and suppliers who live and work around the world. Together—though often miles apart—those groups develop solutions to some of the greatest challenges of our time.

The engineers who will populate the workforce in the coming years must be problem-solvers. They must have solid, current, discipline-specific knowledge—yet their education should include depth and breadth that enables them to tackle global challenges in multicultural, multidisciplinary teams.

In the University of Wisconsin-Madison College of Engineering, we aim to prepare our students to be *the* leaders of the future. Increasing globalization and the rapid pace of technological change are challenges in engineering education, but we view them as opportunities.

The UW Foundation engineering development team (from left): Ann Leahy, Eric Yin, Deb Holt and Kelly De Haven.

Via its COE 2010 initiative, the College of Engineering is in the midst of a curricular transformation that will ensure our graduates are prepared immediately to contribute to, and to excel in, the future of engineering.

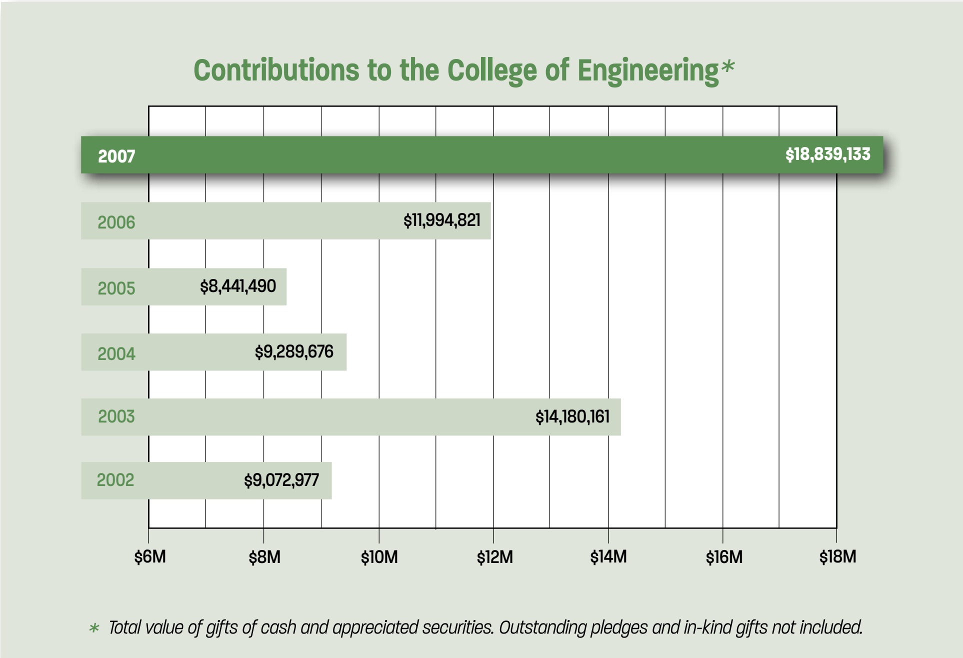
Among recent developments, the college has funded proposals that enable faculty and staff to:

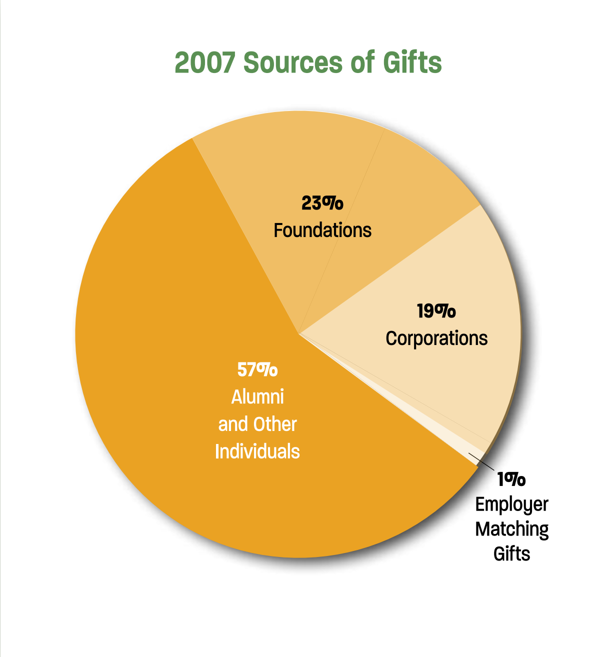
- Develop certificate programs in such areas as energy sustainability and reliability, risk and uncertainty.
- Institute an eight-credit, eight-week summer study-abroad program at Zhejiang University, Hangzhou, China.
- Create cross-college courses in such areas as energy sustainability and integrating biology and engineering.
- Teach 98 freshmen in five sections of the new course, *Introduction to Society's Engineering Grand Challenges*, designed to inspire students to become engineers for the benefit of society.

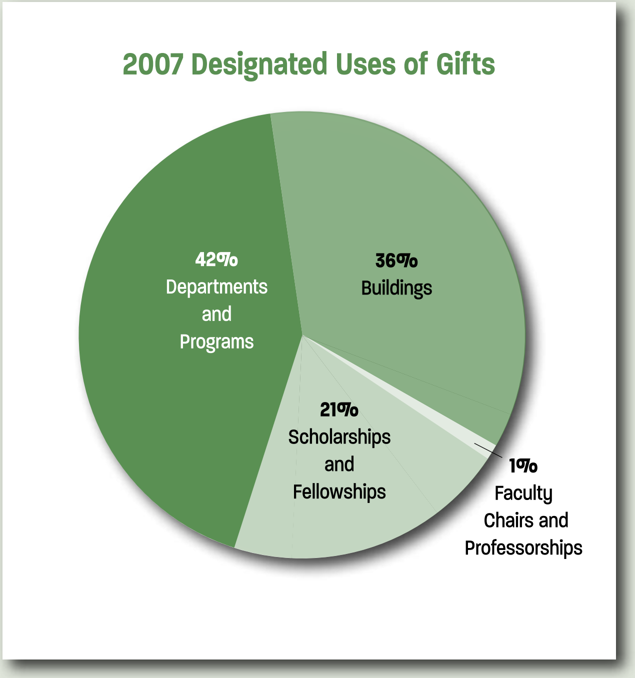
Not only do we aim to deliver an educational experience that enables our graduates to be the best engineers *in* the world—we hope to give them the skills and tools to be the best engineers *for* the world.

We hope you will consider becoming a partner in our commitment to a new future for engineering education in the UW-Madison College of Engineering. Your support will help us develop the people, programs and facilities key to accomplishing our goals. Together, we can create a world of opportunity—for everyone.

Deb Holt







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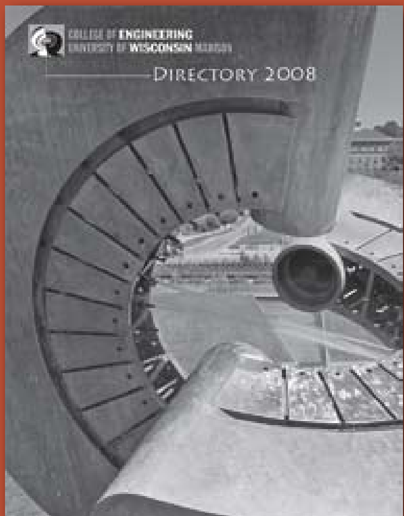
This list of College of Engineering **CONSORTIA, CENTERS and SERVICES** is current as of September 2008



Read detailed information about these entities in the annual report companion publication, the 2008 COLLEGE DIRECTORY. If you would like to obtain a free copy, please contact:

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You can download a PDF of the directory at: www.engr.wisc.edu/news/ar

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geoserver.cee.wisc.edu/fauga

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Members of the college Industrial Advisory Board are professionals in government, industry and academia. They provide advice to college faculty, staff and administrators on academic programs and cooperative efforts with industry, and assist the dean with strategic planning. They also bring to the college the latest concerns and challenges of industry, information that is vital in preparing graduates for their careers. We thank them for their valuable service to the College of Engineering.

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