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College of Engineering

2008

Engineering Research 2008

College of Engineering, Michigan Technological University

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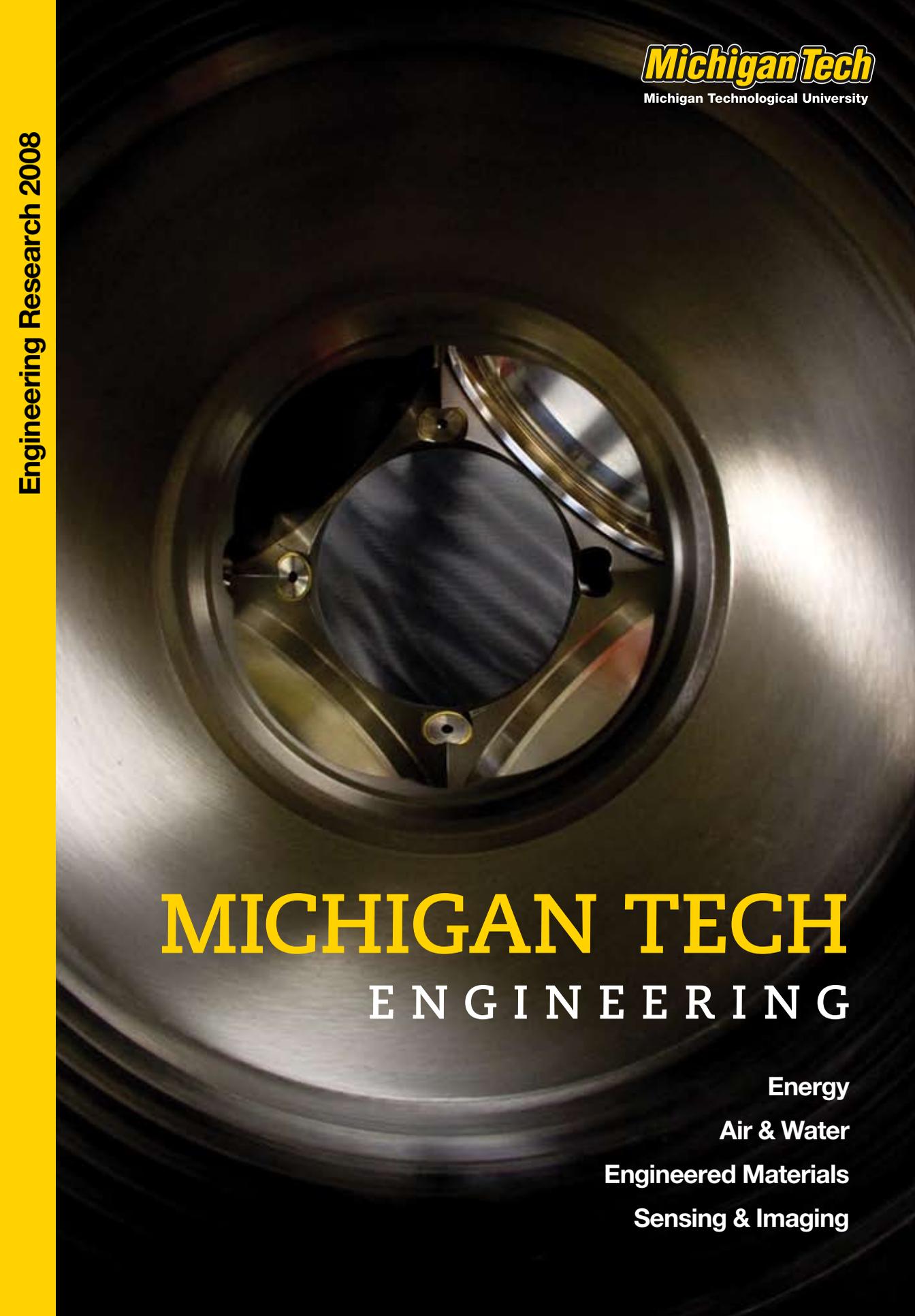
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MICHIGAN TECH
ENGINEERING

Energy
Air & Water
Engineered Materials
Sensing & Imaging



For over a century, the College of Engineering at Michigan Tech has provided relevant educational opportunities in all aspects of engineering and applied science. Today, our faculty, staff, and students are discovering new knowledge, designing new devices and systems, and delivering solutions to some of the world's most pressing problems.

Within this magazine, you will learn about the specific contributions we have made to problems in the vital areas of Energy, Air & Water, Engineered Materials, and Sensing & Imaging. Much of the work we do is inspired by our proximity to one of the largest concentrations of freshwater in the world, and the unique bio-diversity of our region. Our contributions extend far beyond the region and around the world, as well.

I hope you enjoy learning about our research and the talented faculty who lead these activities. Take a few minutes to browse these pages, and I am sure you will be impressed by the breadth and depth of our efforts.

Very best regards,

Timothy J. Schulz
Dave House Professor and Dean
College of Engineering

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Energy

Micro-thrusters

Propelling cell phone-sized satellites through space

What if we could build a satellite as small as a cellular phone? The concept is not that far-fetched. The device that is probably in your pocket right now is capable of taking photos or video, transmitting these images wirelessly over long distances, and recording its exact location using an internal GPS receiver. These are precisely the key functions of many Earth-orbiting satellites. While traditional satellites cost tens of millions of dollars and can be as large as an automobile, cell phone-sized satellites would be inexpensive, could be mass-produced, and could be deployed as large swarms that act collectively to provide global coverage. It seems the only thing your cell phone would need to function as a spacecraft is a tiny rocket engine.

Lyon B. King leads a research program whose goal is to develop micro-scale propulsion systems for use on cell phone-sized satellites. King has patented a technology to build micro-ion thrusters out of wire needles not much thicker than a human hair. Each needle emits a small stream of ionized liquid metal that is accelerated by electrostatic forces to produce a few micro-Newtons of thrust. The needles can be used individually or assembled into an array to propel the tiny vehicle.

In order to function efficiently, the micro-ion thruster needles must be very sharp—the required tip radius is a few tens of nanometers. Prolonged thruster operation can occasionally cause the tips to dull, thereby reducing the performance of the micro-thruster. While this problem has been an impediment to past research, King's group has developed and patented a method for repairing damaged tips using electric fields to shape self-assembling nanostructures. The technique uses electrostatic attraction to shape liquid metal into a sharp cone known as a "Taylor cone," then freezing the metal in place to preserve the nanometer-scale tip. The process can be repeated numerous times, enabling a spacecraft to fix itself while still in orbit.



Lyon B. King
Mechanical Engineering-
Engineering Mechanics

The smallest satellites currently in orbit, known as picosats, are four-inch cubes weighing only 2.5 lbs.



Waste heat

Generating green electricity with semiconductor alloys

The US electrical power industry generates about half of its electricity using coal-fired plants and another 20 percent using natural gas-fired plants.

The gross efficiency of converting fuel into electricity is not so hot. Efficiency rates are just 30-35 percent for coal-fired, steam-cycle power plants, while state-of-the-art, combined-cycle power plants fired by natural gas can reach as high as 60 percent. In both cases, however, a significant portion of nonused energy is released to the atmosphere through the stack, condenser, or other equipment—as low-grade waste heat.

To put all that waste heat to good use, Pete Moran is engineering a material to harvest it. The goal: produce clean electricity from waste heat at a cost competitive with current fossil-fuel based generators.

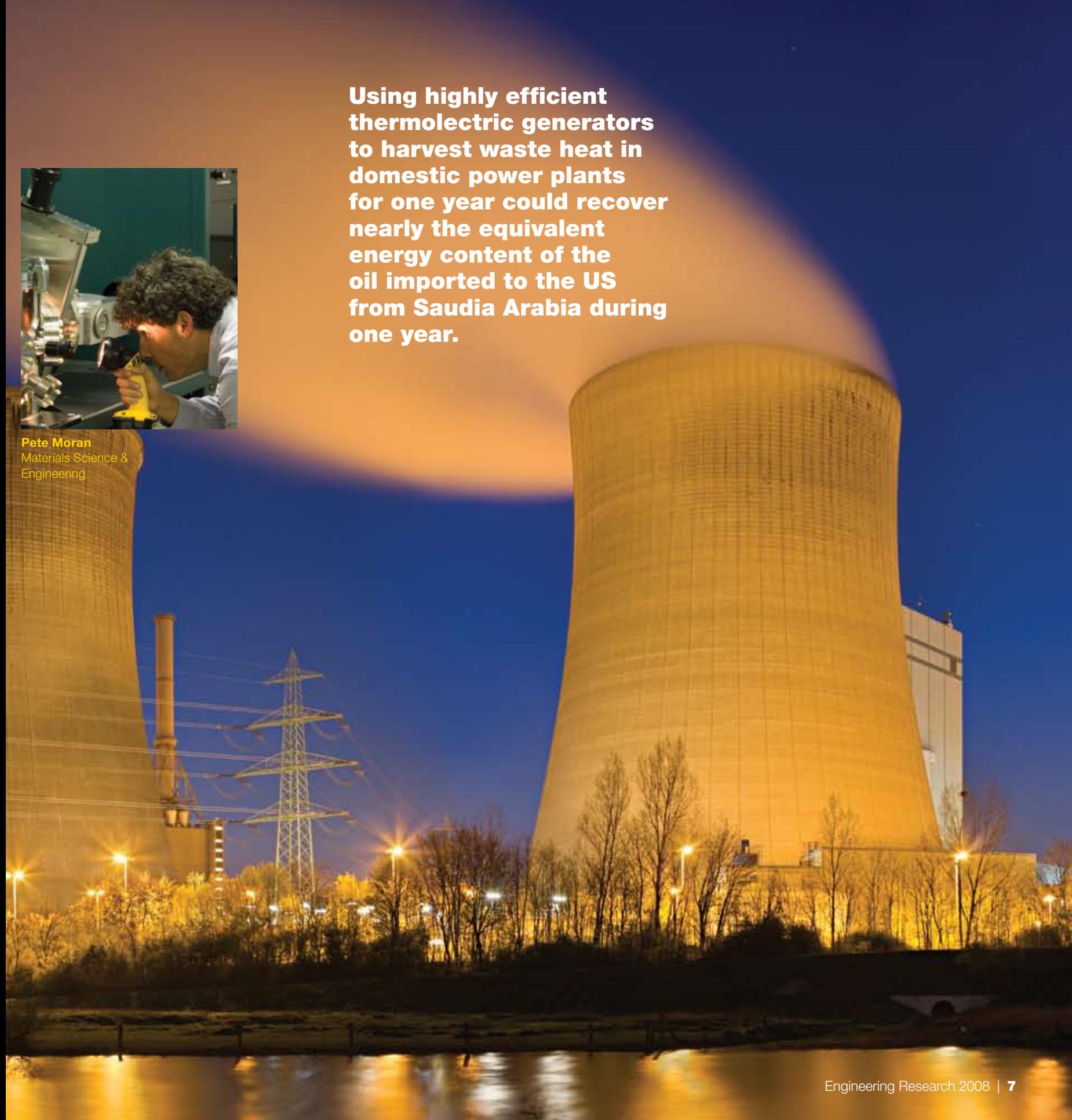
Moran is developing powder metallurgy-processing techniques that could allow for the fabrication of thermoelectric semiconductors operable at high temperatures and efficiencies. His focus is on developing materials for a thermoelectric generator with no moving parts, something that first requires an understanding of how to fully leverage the potential of two recently discovered semiconductor alloys: LAST (Lead, Antimony, Silver, and Tellurium); and LASTT (Lead, Antimony, Silver, Tin, and Tellurium). Both alloys have the potential to efficiently harvest electricity from waste heat.

Retrofitting utility plants with thermoelectric power modules—and incorporating them into plants built in the future—are just two potential applications. These modules can also be utilized by industrial manufacturing plants that use large amounts of energy while generating large amounts of waste heat, as well as the internal combustion engines of automobiles and trucks.



Pete Moran
Materials Science &
Engineering

Using highly efficient thermoelectric generators to harvest waste heat in domestic power plants for one year could recover nearly the equivalent energy content of the oil imported to the US from Saudi Arabia during one year.



Adaptable engines

Running on biofuels and beyond

Utilizing a wide variety of energy resources is essential to the sustainability, security, and progress of developed and developing nations alike. Automobile transportation, heavily dependent upon petroleum, is an especially critical area.

To help solve the problem, Jeff Naber is developing an adaptable automobile engine that will run efficiently and cleanly on a number of different fuels. "Internal combustion (IC) engines are one of the world's most versatile and scalable energy conversion technologies," Naber explains. "Engines can run on petroleum-derived fuels; natural gas; hydrogen; synthetic fuels; biofuels including biogas, biodiesels, and alcohols—even syngas derived from sources that include municipal waste."

Naber's goal is to develop advanced engine technologies that will both enhance flexibility and reduce emissions. To study critical aspects of ignition and combustion, he is building an optically accessible combustion chamber that operates at temperatures, pressures, and constituent conditions found in the cylinder of an IC engine. Instrumentation includes a high speed 1M frame/s camera, laser diagnostics, a mass spectrometer, and a remotely operated monitoring and control system. The \$2.5 million chamber, the only one of its kind in the world, will allow Naber to study the development of real-time, event-by-event combustion feedback methods. With that critical information, he will be able to design an IC engine that will continuously adapt—to changing fuels, but also environmental and engine conditions.

If all goes well, says Naber, adaptable engines could appear as soon as 2011— first in commercial trucks, and then cars.



Jeff Naber
Mechanical Engineering-
Engineering Mechanics





David Shonnard
Chemical Engineering

Wood to Wheels

Creating biofuels from forest resources

Cellulose is the most common form of organic material on earth, yet natural agents such as enzymes and microorganisms find cellulose difficult to convert to biofuels.

Wood-to-Wheels (W2W), an interdisciplinary research effort at Michigan Tech, may soon find a way to give that process a boost. W2W research spans the entire transportation life cycle, from sustainably harvesting woody biomass from highly productive forest lands, to economically converting the biomass to fuels and other products in bioprocesses, to utilizing the bio-based fuels in engines and vehicles.

David Shonnard is working to improve all of the processing steps needed to convert woody biomass resources to liquid fuels by fermentation. “Biofuels for transportation from sustainably harvested forest resources could establish a closed cycle of carbon, and thereby reduce human impacts on climate change,” Shonnard explains. “These fuels would not compete with scarce food resources as other biofuels do.”

Future commercial biorefineries will process mixtures of woody species. Research to understand mixture effects on sugar yields has been completed. However, other aspects pose challenges: Enzymes that convert cellulose in wood to sugars, called cellulases, are frustratingly slow in nature.

Shonnard’s research team is isolating the genes for those enzymes from naturally occurring microorganisms, approaching the problem using recombinant DNA techniques to engineer the enzymes to be much more active and specific in their reactions in converting cellulose to sugars.

Air & Water

Pollution plumes

Observing hemispheric impacts —and surprises

Increasing air pollutant emissions affect human health, and make it more difficult for downwind countries to meet their air-quality standards. They also affect climate forcing, due to the radiative impacts of air pollutants, including ozone and particulates. However, the magnitude of such large-scale phenomena is uncertain. Questions remain about the interplay of emissions, chemical transformations, and long-range transport.

Richard Honrath established an air-quality station on Pico Mountain in the Azores Islands to take direct measurements of atmospheric composition in urban air pollution plumes that have aged and reacted for several days. Such measurements are extremely difficult to obtain, but essential to understanding key processes. The station incorporates Michigan Tech-developed automated systems for the measurement of ozone and ozone precursors—including nitrogen oxides and carbon monoxide.

High atop Pico, Honrath identified unexpectedly high ozone levels in pollution outflow from the East Coast of the US, and quantified the important impact of urban emissions on nitrogen oxides in the remote North Atlantic region. His group's in-situ observations have produced surprises. For example, the highest air-pollution levels at the Pico Mountain station occur during summertime, from the high-latitude regions of North America, where they originate in large wildfires. "Boreal fires alter ozone levels at the hemispheric scale," notes Honrath.

Higher temperatures and drier soils—which are expected as climate changes—favor high-fire summers. It seems as though boreal fires and climate change may, in effect, draw strength from one another.



Richard Honrath
Civil & Environmental
Engineering

During high-fire summers, boreal wildfires can emit as much carbon monoxide as all mid-latitude, northern-hemisphere nations combined.

Great Lakes water

Looking at quality, quantity, and availability

In the Great Lakes region, as elsewhere, there are competing demands for a limited supply of water, including agricultural irrigation, public water supply, industrial production, and cooling in the generation of electricity. In addition to these off-stream uses, Great Lakes water is used for transporting goods, hydroelectric power generation, recreation, and fisheries. The US EPA's Great Lakes Program Office reports that the various uses of water in the region translate into total economic production of more than \$2 trillion annually.

Alex Mayer believes that freshwater is at the foundation of our economic, societal, and environmental well-being. However, water is often treated as a free resource in that no charge is imposed for withdrawing water from its source.

"Users may pay for the transport of water from its source to its place of use, and perhaps for treatment of the water and disposal of the return flows, but the water itself apparently has no value," Mayer notes.

He is leading an NSF-sponsored team to determine the impact of direct and indirect drivers on water quality, quantity, and availability in the North American Great Lakes region—and ultimately the economic value of this freshwater.

Mayer's team will use integrated physical and economic models. These models will be used to predict water availability and quality over the next thirty years—under various scenarios of population growth, climate change, land use, emissions, and governance. The team will develop cost frameworks for capturing the value (i.e., energy, materials, opportunity costs) of having a specific amount of water available at a given purity, time, and location.

"We hope to demonstrate that sufficient supplies of clean water are critical to our society, and should be valued as such," says Mayer.



Alex Mayer
Geological & Mining
Engineering and Sciences

The Great Lakes hold 21 percent of the world's supply of available fresh surface water. Despite this staggering amount of fresh water, only 1 percent of the Great Lakes' volume is replenished each year by rain and snow.



William Rose
Geological & Mining
Engineering and Sciences

Fine volcanic ash

Predicting the path of a serious hazard

Jet airplanes on Northern Pacific air routes fly over more than a hundred potentially active volcanoes. About ten days each year, volcanic eruptions create a fine ash—volcanic particles with a texture like flour and diameters smaller than 0.1 mm.

This fine ash heats the air it touches, carrying the air and the ash up—way up. Jets can't detect fine ash, and at night they can encounter it without warning. Jet engines can be stopped by such encounters and some jets temporarily lose all their engines.

William Rose has studied fluid mechanics, atmospheric science, remote sensing, and meteorology in order to understand fine volcanic ash—how it forms, how it travels through the air, and where it falls.

His inquiry entails international collaboration, and his research group is one of the world's largest scientific efforts focused on volcanology. As a result of this work, an international system of mitigation now operates around the world doing pilot communications. Rose and fifty other scientists are devising meteorological forecasting tools that will enable them to predict where the most dangerous fine particles will come to earth.

By sheer accident, a NASA research aircraft encountered a thirty-three hour-old drifting Icelandic volcanic cloud while travelling across the Arctic in February 2000. Highly instrumented for atmospheric research, the aircraft was able to obtain unique data about how volcanic ash “overseeds” rising clouds, converting them to small ice particles and a stratospheric cloud that destroys ozone. “Since jet airplanes will never willingly fly into volcanic clouds, this was a research bonanza,” says Rose.

Fine ash is a serious health hazard, as well. “We want to know where it falls,” he notes. “As we saw clearly in the 9-11 incident, the fine particles created by the blasts are a long term health hazard to rescue workers.”

Engineered Materials

500-year bridge

Transforming the concrete transportation system

Whether you ride the daily metro, commute in heavy highway traffic, or just need to run a quick errand, you are bound to encounter a concrete bridge in need of repair. Just like humans, our nation's bridges continue to age. Sustainable solutions for long-lasting and durable highway bridges are long overdue.

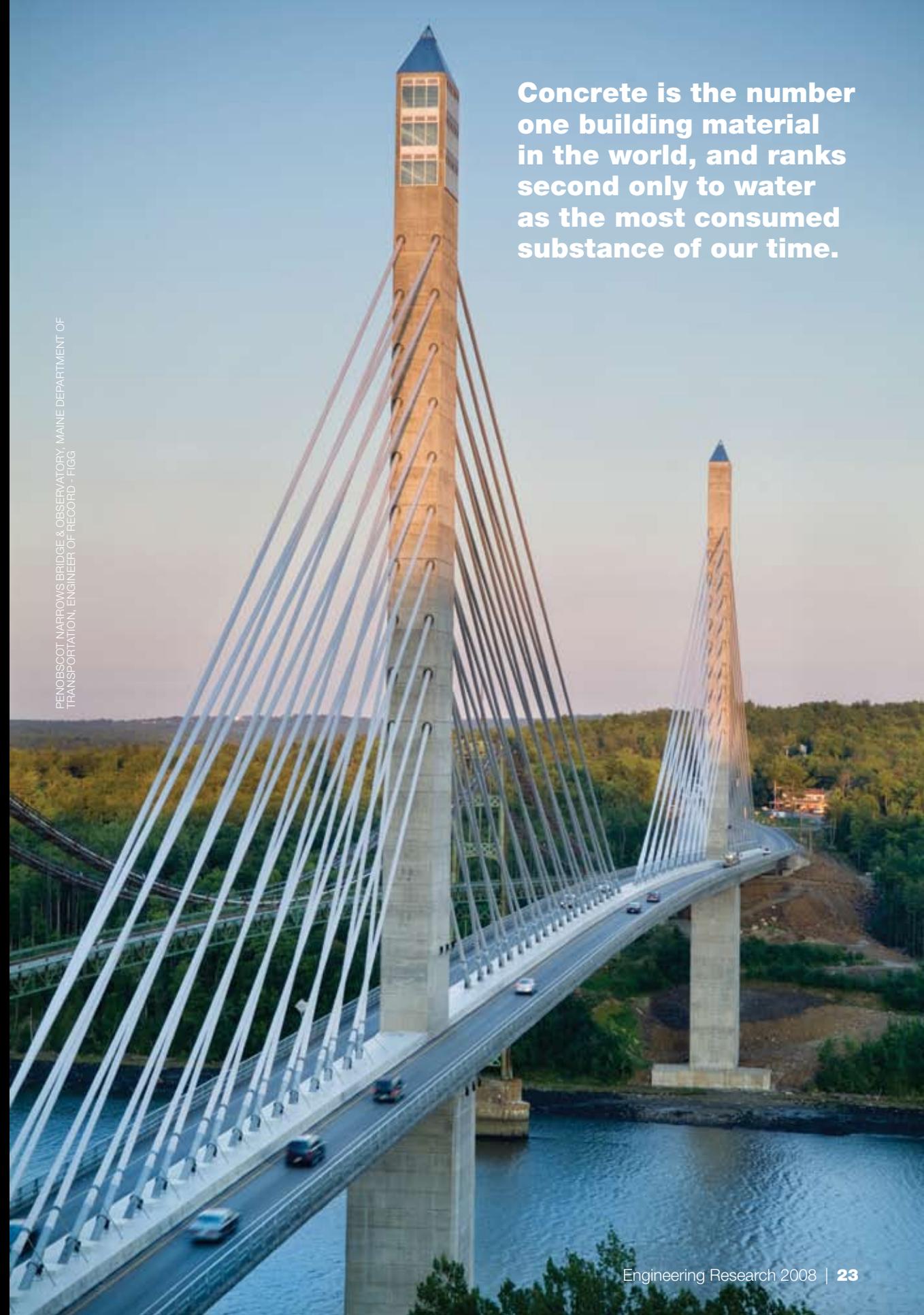
Replacing a concrete bridge in less than a month with one that will last up to five hundred years might sound like a grand challenge, but a team of researchers led by Tess Ahlborn intends to do just that. The team is working towards rapid replacement technologies with pre-decked bridge girders and deck panels that will transform the concrete transportation system by eliminating the need for casting and curing of concrete bridge decks at the construction site.

Combining those technologies with innovative materials, such as ultra-high performance concrete, Ahlborn's team is changing the way bridges are designed and built. "Construction can now be accomplished with less material—due to optimized sections, enhanced resistance, and superior strength," she explains. "Aggressive surroundings such as freeze-thaw zones, road salts, and marine environments are no longer barriers for long-term performance."

Cement production is a relatively large contributor to global CO2 emissions. Every year, almost one ton of concrete is produced for every human on the planet—and the demand is estimated to double in the next thirty years. Durable concretes, including ultra-high performance concrete, use far less cement.



Tess Ahlborn
Civil & Environmental Engineering



Concrete is the number one building material in the world, and ranks second only to water as the most consumed substance of our time.

PENOBSCOT NARROWS BRIDGE & OBSERVATORY, MAINE DEPARTMENT OF TRANSPORTATION, ENGINEER OF RECORD - FIGG



Paul Bergstrom
Electrical & Computer
Engineering

Single electron transistors, and...

Questing after nanoelectronics' Holy Grail

Many nanodevices exhibit quantum mechanical electronic behavior on a scale beneath the theoretical limits of the world standard, but few exhibit desirable operating behavior at room temperature. There are, however, promising candidates.

Paul L. Bergstrom leads a team that is developing technologies and device physics for charge- and non-charge-based nanoelectronic devices. One device under investigation, the single electron transistor (SET), has been demonstrated successfully at room temperature by the team.

Bergstrom's is the first operating SET of any kind accomplished with focused ion beam technology, the second demonstration of room temperature SET behavior in the US, and sixth in the world.

A discovery with great potential, room-temperature SETs could open up whole new aspects of the electronics industry. "Moving to nanoscaled electronic devices such as SETs that rely on quantum behavior will allow us to eliminate leakage current," Bergstrom explains. "The SET could potentially replace or supplement the MOSFET (metal oxide semiconductor field effect transistor) due to its ultra-small active device area and ultra-low power requirements."

The SET may also allow technology its continued migration toward high levels of integration—from hundreds of millions of transistors to hundreds of billions of transistors ultimately—so that cost per device will continue to drop at its historic rate, or even faster.

Bergstrom and his team are making great strides toward incorporating a full quantum-mechanical behavioral model that can be utilized by designers to design circuits and systems with SETs. They have successfully utilized ultraviolet-based nanoimprint technologies to produce hundreds of functional devices in compact arrays, leading toward large scale integration of these devices with mainstream complementary metal-oxide semiconductor technologies, or CMOS.

The effort is expanding and going beyond the SET devices, as well. "We hope to find ways to create devices ultimately that will not transfer current when they do logic," adds Bergstrom. "That is the 'Holy Grail' for nanoelectronics right now. We are taking that challenge seriously."

Pictured at left: A sub-20nm single electron transistor (SET), located at the center of three connecting, T-shaped electrodes.

Osteoarthritis commonly affects middle-aged and older people, striking most after age forty-five.

Osteoarthritis

Slowing—even preventing—a crippling disease

Evidence of osteoarthritis has been found in ice-aged skeletons. Today, over twenty-seven million Americans suffer from osteoarthritis, the most prevalent form of arthritis. It is often a result of knee-joint damage such as tearing of a ligament or meniscal cartilage. The articular cartilage that covers the ends of bones in the knee joint deteriorates, causing pain and loss of movement as bone begins to rub against bone.

Osteoarthritis in the knee is typically associated with loss of articular cartilage, and research has focused on both preventing that loss and treating that damage. Tammy L. Haut Donahue has reason to believe that the knee-joint meniscus may contribute much more to osteoarthritis than previously thought.

Menisci are two c-shaped rings of fibrocartilage in the knee that primarily function to protect the underlying articular cartilage by distributing the load in the knee. Haut Donahue has shown that knee-joint damage, such as a ligament tear or meniscal tear, causes the menisci, among other tissues, to produce elevated levels of an inflammatory molecule, interleukin-1, that can degrade the matrix of the meniscus and prevent it from protecting the underlying articular cartilage.

“Blocking the action of interleukin-1 at its receptors can arrest the degradation of the meniscus, enabling it to continue to function and protect the underlying articular cartilage from wearing away,” notes Haut Donahue.

Future studies will focus on whether this treatment can slow or prevent osteoarthritis associated with traumatic knee damage. The inquiry has the potential to revolutionize how clinicians treat patients. By understanding the biology and biomechanics of the knee-joint meniscus—and the response of the knee-joint menisci to knee damage—the work of Haut Donahue and her team could give patients an additional five to ten years of function before the need for artificial joint replacement.



Tammy L. Haut Donahue
Mechanical Engineering-
Engineering Mechanics

It is estimated that up to 400,000 Americans live with spinal cord injuries; approximately 11,000 new injuries are reported every year.



Ryan Gilbert
Biomedical Engineering

Spinal cord injuries

Testing new protective approaches to treatment

Victims of spinal cord injury (SCI) suffer two damages: the initial trauma sustained by the impact of surrounding vertebrae into nervous tissue, as well as secondary injury response, which is caused by such factors as inflammation and edema (flow of fluid into the injury site).

SCI leads to severe disability, including loss of movement, sensation, and bowel/bladder control. Individuals with spinal cord injury are usually young people, mostly male, who often live with their disabilities for many years.

SCI damages or destroys axons, the portion of the nerve that transmits signals to other cells. Currently, there is no treatment available that effectively reduces the secondary injury response.

Ryan Gilbert is developing and testing biomaterials with the goal of improving both regenerative and protective outcomes. He has developed a novel hydrogel—a network of polymers that are effective in tissue engineering. Mostly water, the hydrogel shows promise when infused into the damaged spinal cord to slowly release therapeutics over time.

While these hydrogels may improve regenerative outcomes, guidance structures may further assist regenerating neurons grow through damaged tissue. Gilbert has developed techniques to produce highly aligned guidance structures that have shown excellent promise in directing the outgrowth of neurons.

Sensing & Imaging

On an average day in the United States, auto accidents kill 116 people and injure over 7,900.



Chunxiao (Tricia) Chigan
Electrical & Computer
Engineering

Intelligent transportation

Making driving smarter, more cooperative, and safer

The US spends more health-care dollars treating vehicular crash victims than any other cause of illness or injury. With an annual economic impact of close to \$200 billion, the US Department of Transportation has declared the reduction of vehicular fatalities its top priority.

A new form of distributed wireless technology, Vehicular Ad Hoc Network (VANET), provides inter-vehicle communications capability that could achieve smarter and safer traffic operation.

Chunxiao (Tricia) Chigan is a 2007 National Science Foundation CAREER Award winner. Her project addresses major challenges in VANET-related secure communication technology.

“VANET has genuine life-saving potential,” says Chigan. “It is able to form a dynamic communication system anytime, anywhere, and without preestablished communication infrastructures such as the optical network and the cellular network.”

Cooperative driving will soon be made possible with VANET, which also holds the potential to provide real-time collision avoidance by notifying drivers of road hazards, road blocks, traffic conditions, auto accidents, and rush-hour rerouting.

“VANET has great potential for emergency crews, who can quickly establish a network when working at a disaster site,” she adds. Another bonus: VANET could help reduce fuel usage. Smarter, VANET-supported cooperative driving could mean less driving time and therefore less carbon in the atmosphere.

Nano-pairings

Forging molecular detectors from unlikely partners

Revealing disease at its earliest onset can provide the best chances of defeating it. Being able to detect extremely low concentrations of biomarkers with nanosensing technology may allow noninvasive detection using saliva—which is derived from blood and contains many of the same biomolecules.

In order to create such nanosensors, Craig Friedrich takes materials that were never formally introduced to each other by natural processes, and make them work together. For example, the optical protein bacteriorhodopsin harvested from the cell membrane of an extremophile bacteria converts light to electrical voltage. When illuminated, this protein is capable of activating microtransistors and quantum-based nanotransistors.

By influencing the activity of the protein upon binding with a target antigen in the environment, such as a toxin or perhaps someday a disease biomarker, a generic nanosensing platform can result. The change in the transistor's output forms the basis of a highly compact and efficient method for molecular detection.

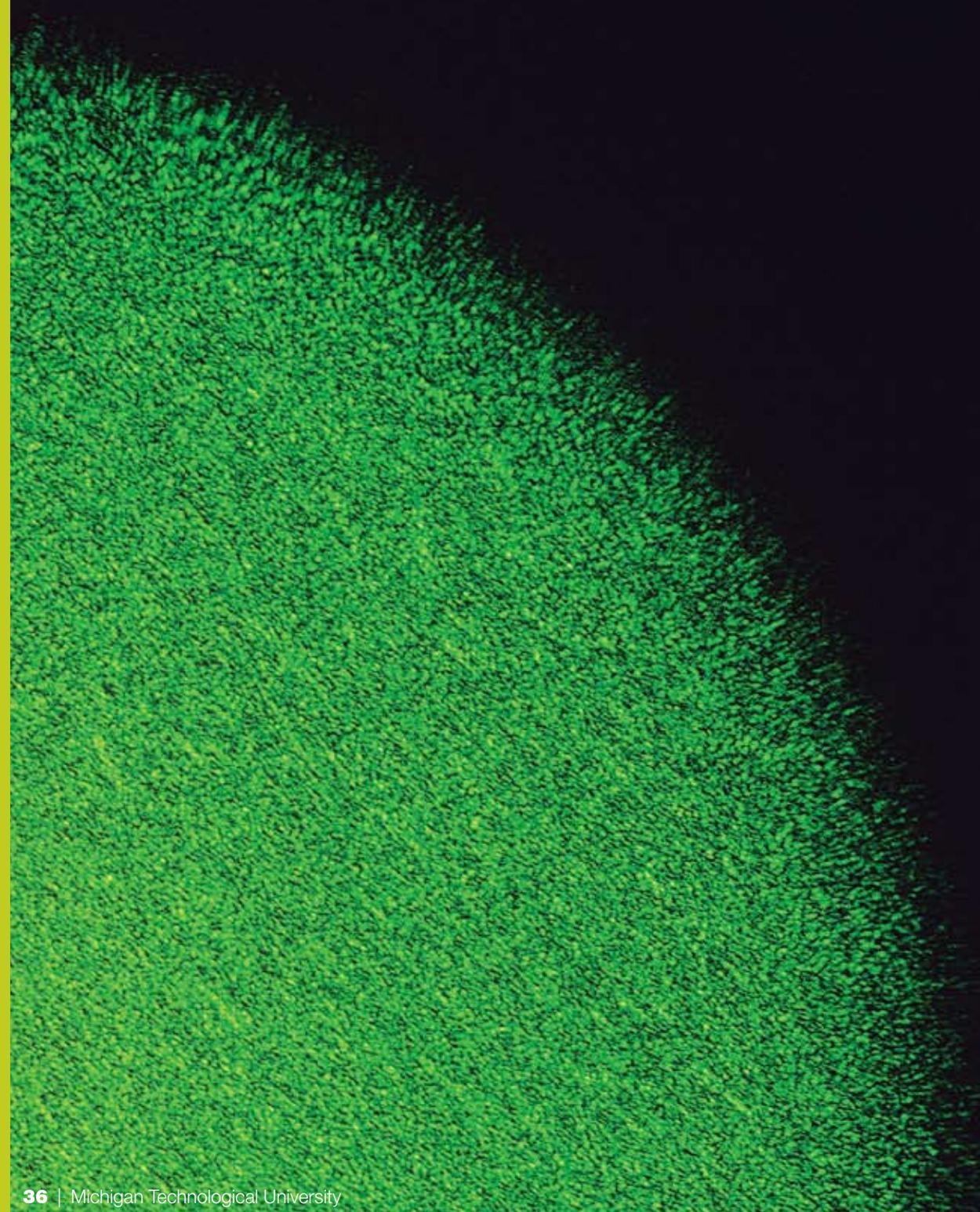
Friedrich's team is developing several methods to modulate the optical protein electrical activity upon molecular binding. One method uses chemically bound quantum dots for nanoscale illumination of the protein. Binding with the target molecule can cause a change in the quantum dot light output and therefore a change in the electrical output of the optical protein and transistor.

A second method fuses a sensing protein directly to the optical protein. Binding with an antigen may cause a large shape change in the optical protein, rendering it inactive. This fused protein-sensing material can be mass-replicated by directing *E. coli* to build the complex molecule.

Both methods hold promise for biomolecular sensing of toxins or potential disease biomarkers. "Perhaps some day a person will be able to buy detection kits off the shelf similar to glucose monitors today," says Friedrich.



Craig Friedrich
Mechanical Engineering-
Engineering Mechanics



Mike Roggeman
Electrical & Computer Engineering

Laser communications

Extending their use and range

It's not always possible to run wires, fiber optics, or cable. If your setting is inaccessible—atop a mountain, out on a drillings rig, or at a remote international weather station, for instance—and you need to transmit photos, videos, or other large data files, you're mostly out of luck.

Laser communications could soon change all that. Mike Roggeman is investigating how turbulent outdoor conditions affect the real-world performance of laser communications—wireless connections capable of transmitting bandwidth-intensive imagery through the atmosphere. His goal: to extend their range and understand their performance in any kind of weather. Michigan Tech's north woods location on Lake Superior is uniquely suited to the job. "We've got it all here. Remote locations, blizzards, thunder storms, heat waves, you name it," he notes.

Roggeman and his research team have developed a laser communications test bed to evaluate adaptive optics algorithms, installing it atop an eight-story building in nearby Hancock. The system directs a laser beam 3.2 km to a receiver located on campus. They will spend the next few years monitoring atmospheric turbulence, scattering, and weather to understand how such factors fluctuate in the real world. Their web-based interface also allows researchers around the country to plan and execute experiments remotely, and obtain the data for their own uses.

Research Centers

- Advanced Power Systems Research Center (APSRC)
- Advanced Sustainable Iron and Steel Making Center (ASISC)
- Biotechnology Research Center (BRC)
- Carbon Technology Center
- Center for Environmentally Benign Functional Materials
- Center for Fundamentals and Applied Research in Nanostructured and Lightweight Materials
- Center for Integrated Systems in Sensing, Imaging, and Communication (CISSIC)
- Center for Science and Environmental Outreach (GEM Center)
- Center for Structural Durability (CSD)
- Center for Technological Innovation, Leadership and Entrepreneurship (CeTILE)
- D80 Center: Engineering Development for Humanity
- Ecosystem Science Center (ESC)
- Keweenaw Research Center (KRC)
- Lake Superior Ecosystem Research Center (LaSER)
- Michigan Tech Center for Water and Society (MTCWS)
- Michigan Tech Concrete Initiative (MTCI)
- Michigan Tech Volcano Observatory
- Power and Energy Research Center (PERC)
- Product and Process Architecture Alignment Consortium (P2A2 Consortium)
- Transportation Materials Research Center (TMRC)
- Western UP Center for Science, Mathematics and Environmental Education



MTRI designed the sensor that has enabled the Bureau of Land Management to accurately measure and analyze the melting of Alaska's Bering Glacier.

Research Institutes

- Aggregate Research Institute
- Computational Science and Engineering Research Institute (CSERI)
- Institute for Engineering Materials (IEM)
- Institute of Materials Processing (IMP)
- Materials in Sustainable Transportation Infrastructure (MiSTI)
- Michigan's Local Technical Assistance Program (LTAP)
- Michigan Tech Transportation Institute (MTTI)
- MTRI: Michigan Tech Research Institute (Ann Arbor)
- Multi-Scale Technologies Institute (MuSTI)
- National Institute for Climatic Change Research (NICCR)
- Remote Sensing Institute
- Sustainable Futures Institute
- Technology Development Group (TDG)
- Tribal Technical Assistance Program (TTAP)

MTRI: Michigan Tech Research Institute (Ann Arbor)

Based in Ann Arbor, MTRI is a recognized leader in the research, development, and practical application of sensor and information technology. The research institute solves critical problems in the areas of national security, protecting and evaluating critical infrastructure, bioinformatics, earth sciences, and environmental processes.

MTRI's thirty scientists and their student interns design and test sensors that can measure water quality, help mitigate traffic congestion, eliminate road hazards, assess factors contributing to global climate change, protect natural resources, and more.

MTRI was purchased from the Altarum Institute by Michigan Tech with a gift from the House Family Foundation, established by former Intel executive Dave House, a Michigan Tech alumnus. Its work is funded entirely by research grants and contracts with agencies such as the US Bureau of Land Management, NASA, the Department of Agriculture, the Natural Resource Conservation Service, the Michigan Department of Transportation, and the Department of Defense. For more information, visit <http://mtri.org>



ENGINEERING ADVISORY BOARD

John Soyring

ECE alumnus brings strategic IBM partnership to Michigan Tech

The global marketplace is changing dramatically, employing new technologies, and demanding new skills. To meet those challenges, IBM has named Michigan Tech to its IBM Partnership Executive Program (PEP) for Universities, formalizing and expanding a partnership that has been growing between the University and the IT and services company for nearly a decade.

Instrumental in forging the new partnership is John Soyring, a College of Engineering advisory board member and Michigan Tech alumnus. Soyring is IBM's vice president of solutions and software.

Soyring, who earned a Bachelor of Science in Electrical Engineering from Michigan Tech in 1976, recommended that Michigan Tech be considered for the partnership. IBM works with more than three thousand of the world's leading educational institutions, but only a small percentage are chosen.

As the very nature of innovation changes, demanding broader collaboration across geographic and disciplinary boundaries, the need for skilled professionals is growing more rapidly than the supply, Soyring explains. According to the US Bureau of Labor and Information Technology Association of America, the world will face a shortfall of 32 million technically specialized workers between 2010 and 2020.

"The skills that coming generations of professionals will need are changing too," adds Soyring. "There's an increasing demand for specialists in fields that didn't even exist a few years ago—services science, for example—and by the time students starting college today complete their degrees, they will need the skills to do jobs not even imagined today."

IBM is working with Michigan Tech and other universities around the world to develop a services science, management, and engineering program. The new curriculum addresses the mushrooming of the services sector of the economy, which comprises more than 75 percent of US jobs.

Soyring has held a variety of positions during his long career with IBM. He was previously vice president and senior executive for software services and support, a global business unit delivering professional services for clients and business partners. In his current position, he provides global business leadership for a multi-billion-dollar portion of IBM's software business. He has also completed graduate studies in computer science, electrical engineering, and business administration at the University of Minnesota and the State University of New York. Soyring is Michigan Tech's partnership executive at IBM.

FACULTY

**Jeffrey Allen**

2008 CAREER award-winner

Jeffrey Allen has received a five-year \$400,588 National Science Foundation CAREER Award.

His project, “Gas-liquid Interface Dynamics and Dissipation Mechanisms in Capillary-scale Two-phase Flow,” will advance his investigations in capillary flow—how and why gases and liquids move (or fail to move) through tiny channels, such as those found in hydrogen fuel cells.

Two-phase flow, a branch of fluid mechanics, examines systems such as boilers, in which a gas and a liquid are present. Allen investigates two-phase flow through very narrow tubes, which has applications in microelectrical-mechanical systems (MEMS), microscale heat exchangers, space-based processing and thermal control technologies, as well as fuel cells. Two-phase flow at this very small scale is not well understood.

With this CAREER award, Allen aims to develop design tools that will improve the engineering of these systems. Ultimately, he expects to develop advanced technologies that will improve water management in fuel cells; an issue which remains a major obstacle to the commercialization of fuel-cell powered vehicles.

**John W. Sutherland**

Sustainable Futures Institute

John W. Sutherland conducts research designed to reduce the environmental impact of manufacturing processes, to promote remanufacturing and recycling, and to develop product designs that support used product recovery and remanufacturing.

Sutherland also works to develop model corporate and networking systems that support sustainability. The Sustainable Futures Institute that he heads is a nexus for discussion and innovation in sustainability research, education and outreach. It supports the NSF-funded IGERT program (Interdisciplinary Graduate Education and Research Traineeships), which emphasizes interdisciplinary research by diverse groups of students.

Founded in 2003, SFI addresses an ambitious array of topics related to sustainability: materials, design, and manufacturing; water; the built environment; public policy; renewable and alternative energy; developing world issues; community outreach; and campus ecoimprovements. In just five years, SFI has grown rapidly, garnering more than \$15 million in external funding, and engaging nearly two hundred faculty, staff, and students from across the campus of Michigan Tech.

Sutherland has published over two hundred technical papers in various journals and conference proceedings and has mentored seventy students to the completion of their graduate degrees.

He is the Henes Chair Professor of Mechanical Engineering.

S. Komar Kawatra

Advanced Sustainable Iron & Steel Making Center

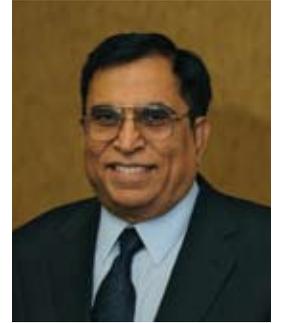
Professor S. Komar Kawatra, chair of the Department of Chemical Engineering, has recently founded the Advanced Sustainable Iron & Steel Making Center (ASISC). The NSF funded, industry-university cooperative research center will operate as a partnership between Michigan Tech and the University of Utah, with Michigan Tech serving as the lead institution. Its goal is to improve sustainability in the iron and steel industry by making maximum use of renewable resources and developing innovative methods to prevent pollution and reduce emissions while increasing energy efficiency. Thirteen companies have already committed to participating.

Kawatra is an accomplished chemical engineering researcher, teacher, and lecturer. His primary areas of research are instrumentation and online analysis for monitoring and control of chemical and particulate process plants, as well as treatment/remediation of chemical and industrial wastes.

He has served as principal investigator on twenty-two funded research projects, and he has received eight prestigious awards for his research. He has authored or edited numerous books and over 150 technical publications.

“My general philosophy is to carry out research in close cooperation with industry—and to make sure that all of my students start with fundamental research, and carry it all the way to implementation in operating plants,” Kawatra explains.

Kawatra serves as editor in chief of the *Minerals & Metallurgical Processing Journal* and the *Mineral Processing & Extractive Metallurgy Review Journal*. He plans to maintain his active research program while serving as chair.





In 2006 (the most recent year for which data is available) Michigan Tech generated 9.3 invention disclosures per \$10M of research, according to the Association of University Technology Managers, 1.8 times the national average.

Recent start-ups

Aursos, Inc.

Michigan Tech partnered with life science business accelerator Apjohn Group LLC to found a startup company, Aursos, Inc. The new company is developing next-generation osteoporosis therapies based on discoveries made by Seth Donahue, who remains active in developing this technology.

CPRM

A Senior Design team, advised by Ryan Gilbert, has developed a cardiopulmonary resuscitation (CPR) mattress that promises to greatly improve the effectiveness of CPR conducted in hospital settings. Their design improves efficiency of chest compressions by 28 percent, reduces time to initiate CPR by twenty seconds, and reduces number of staff

needed to successfully administer CPR from three or four down to one or two. It incorporates a sealed foam bladder connected to a vacuum pump via a quick-disconnect coupling. With this design, the mattress deflates underneath the chest cavity, making the mattress a rigid surface.

Although members of the senior design team graduated in May 2007, the project did not stop there. Through a selective, paid internship with the MTEC SmartZone, an interdisciplinary team of five entrepreneurial students completed a thorough market assessment, competitive analysis, and cost/revenue models for the commercial CPR mattress product. The University has filed for patent protection and the students have made formal presentations to Stryker and Hill-Rom, market leaders in hospital beds and mattresses. Commercial feasibility was confirmed and the team took the official 'leap', creating a new business, CPRM.

The next steps for CPRM: develop and test additional prototypes, conduct more market research, and formalize a business plan.

Upcoming technologies

Enhanced biomorphic helmet

Gopal Jayaraman has designed a new helmet that protects the human skull by mimicking the protection mechanisms already provided by the bio-system of the brain, scalp, skull, and cerebral spinal fluid. Several prototype models are being fabricated

and will be tested to evaluate performance, and then compared with current sports helmets under a wide range of impact conditions.

Microammeter

Two graduate students working with Lyon B. King have recently created a business plan focused on device-manufacturing utilizing technology developed under an Air Force-sponsored research proposal. The device will measure current in high voltage systems using microammeter (nano to milliamp range) measurements technology.

Rechargeable nickel-based batteries

A Michigan Tech research team is completing the development of a battery comprised of electrodes made of carbonaceous foam impregnated with nickel hydroxide. Such batteries operate better than previous nickel-based battery chemistries and are rechargeable. Replacing nickel current collector with light, cheap, and readily available carbon foam can also cut the weight of a rechargeable battery by up to 25 percent while providing high life cycles and higher operating voltages. This design avoids the inherent



fire danger found in lithium batteries. The Michigan Universities Commercialization Initiative (MUCI) provides support to the team, comprised of Michael Mullins, Anthony Rogers, and Bahne Cornilson.

Bioactive-Vibrational-Tunable (BVT) coating technology

Kheat Ong and Rupak Rajachar have developed a coating technology capable of storing and releasing antibacterial and other therapeutic drugs in combination with a tunable, vibrational coating that prohibits cell adhesion. The coating is expected to be used on catheters, intravenous therapy, and other applications currently being studied under ongoing collaborations with Mayo Clinic and a major manufacturer of biomedical devices.

Fluidic oscillator for PEM fuel cell

One of the major technical impediments to the commercial development of fuel cells is managing water, which can accumulate in reactant flow channels.

Proper water management in a Polymer Electrolyte Membrane (PEM) fuel cell is critical to efficiency, reliability and durability. The goal is to keep the membrane hydrated while keeping gas diffusion layers and gas flow channels free of liquid.

Jeffrey Allen has invented a simple means to keep the water moving by using a fluidic amplifier/oscillator when gas flow through the channels isn't high enough to keep water droplets from pinning to channel walls. The



fluidic oscillator uses a simple system of self-feedback to direct pressure where it is needed to clear the channels.

With support from the Michigan Universities Commercialization Initiative (MUCI), Allen and his students have built a demonstration fluidic oscillator and gathered data to demonstrate the effectiveness of the invention. A patent is pending.

At Michigan Tech, our mission in the College of Engineering is to graduate innovative, world-class engineers and conduct cutting edge research. Industry and government partners are integral to our success.

Industry partnerships

Technology & Economic Development (TED)

Connections between Michigan Tech's research capabilities and prospective industrial partners are supported by the University's Department of Technology & Economic Development. TED also manages TechFinder, a searchable database of

technologies available for license.

www.techfinder.mtu.edu

Corporate development

Affiliations between companies and academic units across campus are facilitated by the Department of Corporate Development, enhancing support for scholarships, diversity, academic programs, and instructional facilities.

www.mtf.mtu.edu/corporate

Senior design

Our Senior Design program connects students and industry through challenging, open-ended, industrial projects. The program is structured more like a 'first job' rather than a 'last class', as teams of four to six engineering students strive to develop innovative solutions to real-world industry challenges throughout their senior year.

www.doe.mtu.edu/seniordesign

Enterprise Program

Enterprise represents a truly unique and innovative approach to enhancing engineering education at Michigan Tech. Enterprise teams, comprised of sophomore through senior-level students from diverse disciplines, operate like real companies, serving a wide range of industries and market segments. This fast-growing educational program has over 650 students actively participating in twenty-eight different teams across campus, including Blue Marble Security, International Business Ventures, Aqua Terra Tech, and Alternative Fuels Group.

www.enterprise.mtu.edu



Nearly 40 percent of invention disclosures processed by Michigan Tech involve students and 20 percent involve undergraduates.

MTEC SmartZone

In the late 1990s, SmartZones were established throughout the state of Michigan to facilitate the transfer of technologies developed in public universities to the commercial marketplace.

The MTEC SmartZone aims to stimulate the growth of technology-based businesses and jobs in Upper Michigan. It offers space with flexible leases to attract start-ups and corporate branch offices, as well as business-development programs designed specifically for entrepreneurs—investment forums, educational workshops, and networking. All have access to financial, legal, business, and marketing consultants and service providers, often at reduced rates. A total of sixteen

companies are now being incubated in MTEC's three local SmartZone facilities.

Extreme Tool & Engineering and Hawk Technologies Inc. have recently come on board to focus on research and development. Other tenants, including Consistacom, The LaSalle Technology Group, SWH Consulting, and Up & Running Systems Services, have expanded this year.

Michigan Tech students play an important role in SmartZone success. Entrepreneurial internships and co-op opportunities provide real-world experiences to the students and inexpensive quality assistance to incubating companies.

www.mtecsmart.com



Office of the Dean

College of Engineering
Michigan Technological University
712 Minerals & Materials Building
1400 Townsend Drive
Houghton, MI 49931-1295
Telephone: 906-487-2005
Fax: 906-487-2782
Email: engineering@mtu.edu
www.engineering.mtu.edu

Timothy J. Schulz,
Dave House Professor and Dean

Carl L. Anderson
Associate Dean for Research
and Graduate Studies

Leonard J. Bohmann
Associate Dean for Academic Affairs

Department Chairs

Michael R. Neuman
Biomedical Engineering

William M. Bulleit
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Komar S. Kawatra
Chemical Engineering

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Partner
Arnold & Knobloch LLP

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Global Services Manager
Network Appliance Inc

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Vice President, IBM Solutions &
Software
IBM Corp.

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President and CEO
Primarion – California

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Dr. Terry J. Woychowski
Executive Director and Vehicle Chief
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General Motors Corporation

**College of Engineering
Michigan Technological University
712 Minerals & Materials Building
1400 Townsend Drive
Houghton, MI 49931-1295**



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