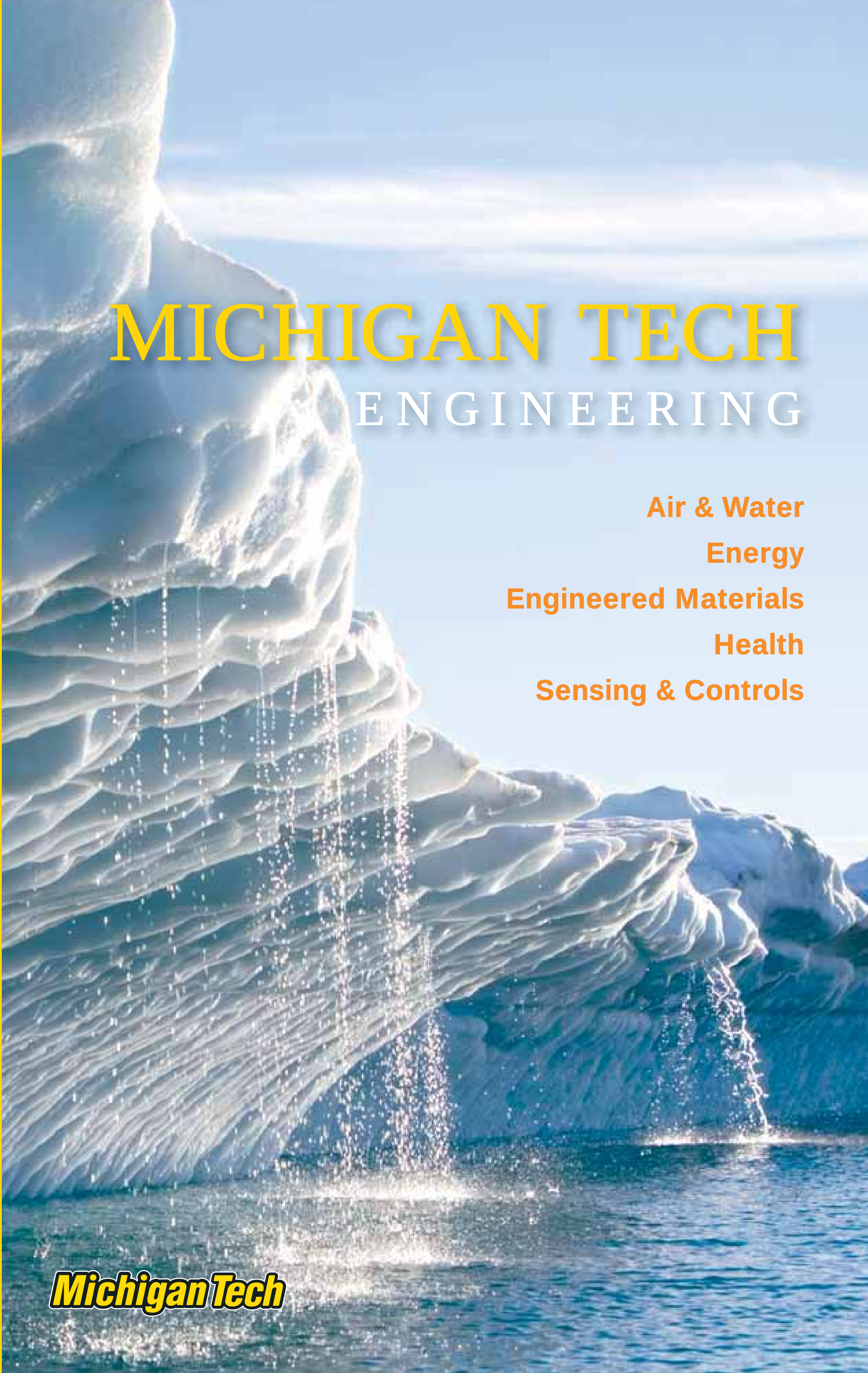
Engineering Research 2011



MICHIGAN TECH
ENGINEERING

Air & Water

Energy

Engineered Materials

Health

Sensing & Controls

Michigan Tech

At Michigan Tech, we are committed to world-class research, scholarship, and innovation. Our mission is to promote sustainable economic and social development in Michigan, the nation, and the world.

Graduate enrollment in the College of Engineering has nearly doubled over the past four years, and the accomplishments of our faculty have us poised for even more growth in the months and years ahead.

We strive to conduct research leading to the dissemination of original knowledge and the creation of new economic opportunities. In particular we devote considerable effort to important challenges in the areas of Air and Water, Energy, Health, Sensing and Controls, and Engineered Materials.

I invite you to take a few minutes to browse the pages and learn about specific contributions from many of our talented researchers.

Please contact us if you would like to learn more about these and other exciting engineering research activities at Michigan Tech.

Sincerely,

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

On the cover:

Melting water streams from an iceberg calved from the Ilulissat Kangerlua Glacier (Jakobshavn Icefjord) in Disko Bay, Greenland. Increasing temperatures in the Arctic will have a strong impact on the melting of Arctic glaciers. Louisa Kramer is identifying sources and transport routes of Arctic pollution to gain a better understanding of their climatic impact. See page 6.

Table of Contents

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

Air & Water

Air pollution in the Arctic

Identifying sources and transport routes

Climate change is proceeding faster within the Arctic region than anywhere else on Earth. Over the past few decades the average surface air temperature over the Arctic has risen at almost twice the rate as temperatures over the rest of the world during the past 100 years.

The increasing temperature will have a strong impact on the melting of Arctic glaciers. Sea ice is highly reflective, therefore melting will result in darker land and oceans being exposed, increasing the absorption of the sun's radiation, resulting in further warming and accelerated rises in sea levels.

Changes occurring in the Arctic will have ecological, social and economic consequences over the rest of the globe. The issue of climate change in the Arctic may be due to anthropogenic activities originating outside the region. Emissions of greenhouse gases from the burning of fossil fuels and wildfires in the Northern Hemisphere can be transported long distances to the Arctic, impacting the atmospheric composition. Warming in the Arctic may also lead to an increase in emissions within the region. With a reduction in the fraction of ice cover, new shipping routes could open up resulting in an increase in shipping emissions, further accelerating Arctic climate change.

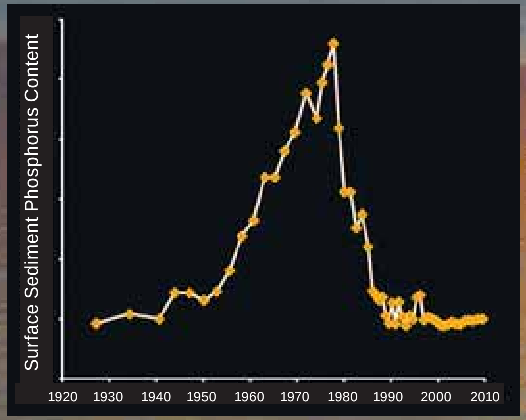
Louisa Kramer is addressing these issues by continuously measuring nitrogen oxides at the highest point in Greenland, the GEO Summit Station (3208 m altitude). Nitrogen oxides are produced during combustion processes and are a precursor to tropospheric ozone (O_3), the third most important greenhouse gas. While levels of tropospheric O_3 in the Arctic are much lower than in urban areas, they can have a strong impact on the Arctic climate. Recent studies have found that tropospheric O_3 may be responsible for as much as 50 percent of the warming in the Arctic. Understanding the O_3 budget in the polar regions is further complicated by the recent discovery that reactions in the snow can also lead to a release of nitrogen oxides to the air above, impacting background O_3 levels.

The instruments Kramer and the late Richard Honrath installed in Greenland have provided the first continuous year-round measurements of nitrogen oxides in the high altitude Arctic. The resulting data set is used to identify specific source regions of anthropogenic and wildfire emissions and their impact on the Arctic atmosphere. "Identifying sources and transport routes of Arctic pollution is essential in improving our knowledge of the contribution of various anthropogenic and natural sources to O_3 in the Arctic," notes Kramer. "We hope our research will provide the public and policymakers with a better understanding of the climatic impact of these emissions."

Louisa Kramer
Geological & Mining Engineering and Sciences

Pictured: Melting water streams from an iceberg calved from the Ilulissat Kangerlua Glacier (Jakobshavn Icefjord) in Disko Bay, Greenland.

Martin Auer (left)
Civil & Environmental Engineering



TOP: Chemical manufacturer operating on the west shore of Onondaga Lake from 1884–1986, pictured here in 1952 *(courtesy Solvay Public Library).* BOTTOM: Phosphorus levels in Onondaga Lake surface sediments, illustrating increasing pollution as the urban population increased, phosphorus management interventions in the 1970s, and lower levels of pollution today *(courtesy Susan M. Larson).*

Onondaga: "It lives."

Cleaning up America's dirtiest lake

Onondaga Lake, New York has been recognized in the Congressional Record as the most polluted water body in the United States. Efforts to control pollution from municipal (phosphorus) and industrial (mercury) waste discharges have been hampered by the presence of significant reservoirs of these contaminants in the lake's sediments. While a water body may respond quickly to reductions in pollutant influx, cleansing of lake sediments proceeds much more slowly. Over time, contaminants such as phosphorus and mercury can leak from the sediment to the water column, offsetting restoration benefits achieved through management of municipal and industrial sources.

The historical record of pollutant inputs has been preserved in the sediments of Onondaga, as contaminant-laden particles are deposited annually in layers. Thus, pollution associated with the growth of metropolitan Syracuse and local industrial operations is clearly mirrored in sediment profiles. For some contaminants, redemption for these sins is available through engineered solutions such as lake aeration or augmentation with chemicals such as alum. For others, one must simply wait for natural processes to accomplish the cleanup.

The scientific and engineering foundations of the cleanup effort have been guided by Steve Effler and his team at the Upstate Freshwater Institute (UFI) in Syracuse. Since 1987, Marty Auer and his students have been collaborating with UFI, testing engineered solutions and developing mathematical models of the time course of natural recovery. For phosphorus, the key has been to reduce inputs from the major discharger, the Syracuse Metropolitan Treatment Plant. As phosphorus levels are lowered, algal growth and attendant decomposition are reduced and the rate of oxygen depletion from the bottom waters is lessened. Maintenance of oxygen in the water overlying the sediment supports chemical reactions, which seal the sediment surface and prevent the leakage of phosphorus into the water. Model predictions of the time course of recovery from phosphorus pollution, estimated by the UFI–Michigan Tech team at 15-20 years, have been validated by recent field measurements showing a dramatic decline in phosphorus leakage rates.

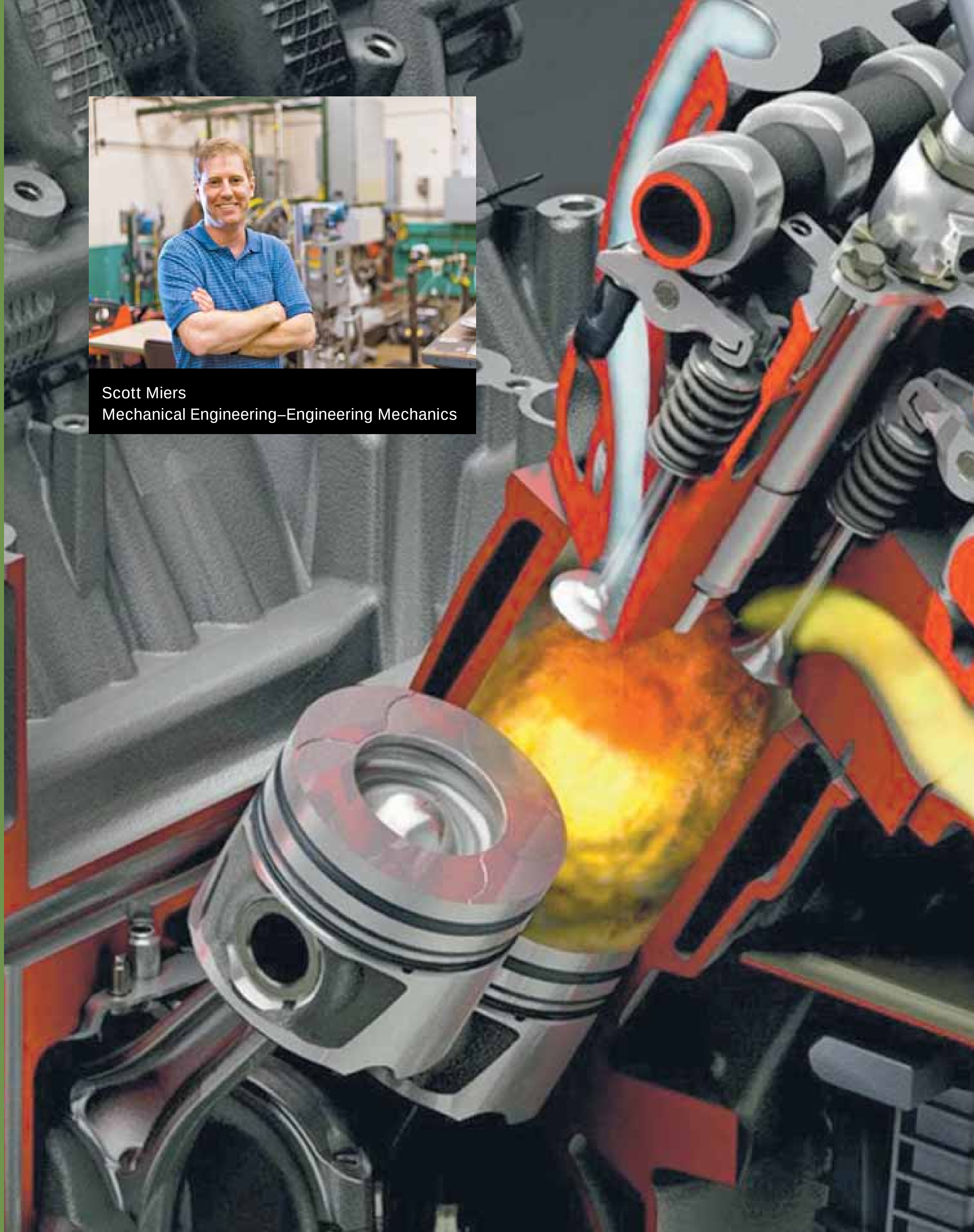
The approach is similar for mercury, i.e. maintaining levels of oxygen and/or nitrate in the water overlying the sediment to seal against leakage until the contaminant becomes buried deep in the sediment. Here, Auer and his students performed laboratory microcosm experiments to assess the efficacy of chemical augmentation with oxygen and/or nitrate in sealing the sediments. The result was positive, achieving a 60–90 percent reduction in mercury leakage.

A recent headline in Syracuse's newspaper, the *Post-Standard*, announced the success of that effort with the simple headline, "It Lives."

The benefits realized through collaboration between Michigan Tech and the Upstate Freshwater Institute extend well beyond the immediate targets of that research. UFI, a group that includes three Michigan Tech alumni (Rakesh Gelda and Susan Doerr O'Donnell who earned degrees in Environmental Engineering, and David O'Donnell, a graduate in mechanical engineering), has supported 25 Michigan Tech students conducting research on Onondaga Lake and the New York City reservoir system. These students have all earned graduate degrees, published their work in the peer-reviewed literature, and moved on to careers in environmental science and engineering.

PHOTO BY JOHN HORACEK

Energy



Scott Miers
Mechanical Engineering–Engineering Mechanics

Better biofuels

Designing fuel properties through reverse-engineering

Historically, as alternative fuels have been introduced, engine calibrations have been forced to adapt, often with suboptimal results. What if, instead, the process began by tailoring feedstock properties and then customizing the processing technique to produce a better biofuel?

Scott Miers is exploring the relationships between feedstock fatty acid profiles and alcohol structure with biodiesel properties in order to design a fuel optimized for an engine. “This approach is a major change compared to how conventional and even advanced alternative fuels are produced today,” he says. “Unfortunately, most alternative fuel development involves matching existing petroleum fuel properties, which does not take advantage of the ability to tailor fuel properties to enhance engine performance.”

Miers conducts research on internal combustion engines ranging from small displacement spark-ignition to automotive-sized diesels, with a focus on improving efficiency and reducing emissions, especially with alternative and renewable fuels.

“The unique properties of the feedstocks and variety of esters combined with the processing technique of transesterification have a profound effect on the chemical and physical properties of biodiesel, such as oxidative stability and cold flow,” Miers explains. “These effects are not fully understood at the fundamental level, yet they can play a major role in influencing future fuel and engine development.”

Miers analyzes exhaust components using a Fourier Transform Infrared (FTIR) spectrometer: modeling, analyzing, and measuring properties of biodiesel fuels as they relate to feedstock properties; utilizing regression analysis to develop correlations between feedstock profile and alcohol component with that of fuel properties; and evaluating fuel spray characteristics along with engine-out gaseous and particulate emissions.

Producing biodiesel with improved cold flow and oxidative stability properties alone would likely provide the opportunity to increase biodiesel consumption throughout the United States, notes Miers.

“Based on engine research, we have a good idea what fuel properties need to look like to maximize engine performance. We can reverse-engineer—look at the plant structure, maybe a blend of plants. We can look at the fatty acid profile of a plant before it is made into fuel, predict how it will work in an engine, and then validate through testing,” he adds. “The combustion process is where everything comes together. We will be able to predict trends, and then measure with specialized instrumentation which gives us real-time data.”

Currently the EPA regulates exhaust emissions, but only a select few—CO, NOx, hydrocarbons, and particulate matter. Miers uses the FTIR to investigate the impact of alternative and renewable fuels on unregulated components. “It’s important to understand the impacts of new fuels on non-regulated emissions. New fuels may produce exhaust components that are as detrimental or worse than currently regulated emissions components,” he notes.

“There isn’t a perfect fuel—no such thing,” adds Miers. “Most likely a suite of fuels is the answer and our future direction.”

It's all about catalysis

Cogenerating electricity and value-added chemicals from biomass feedstocks

Biofuels from lignocellulosic (woody) biomass can reduce our dependence on fossil fuels and lower greenhouse gas emissions. They are expected to be significant players in the future energy supply landscape. Biofuel refineries, or biorefineries, will also produce biomass-derived compounds such as polyols, sugars, and sugar alcohols, as well as higher-valued chemical intermediates for polymers, foods, cosmetics, detergents, and pharmaceuticals.

Catalysis is a major science behind the sustainable conversion of biomass feedstocks to biofuels and valuable chemicals. Catalysts can significantly influence the adsorption and desorption processes and lower activation energies—accelerating reaction rates (reactivity) and regulating reaction pathways (selectivity). However, at present it is still challenging for heterogeneous catalysts to selectively produce desired products, especially at the high reactant conversion rates needed for biorefineries.

Wenzhen Li and his research team are developing a novel anion exchange membrane fuel cell platform for electrocatalytic processing of biorenewable compounds. Their goal is to efficiently generate electricity and selectively produce value-added chemicals—not CO_2. This transformative research is expected to open up new avenues to maximize the utilization of biomass feedstocks—knowledge that can be widely used for catalysis, fuel cells, biofuels, biorefinery, electrolysis, chemical sensing, and green chemical techniques.

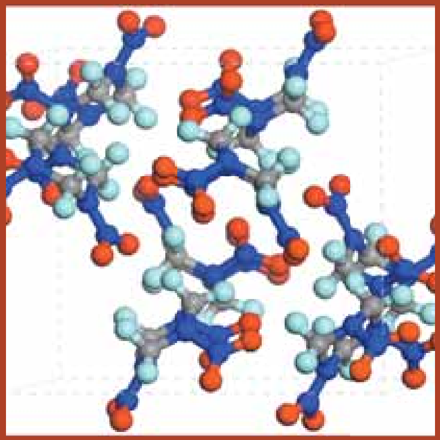
"In a high pH-anion exchange membrane fuel cell (AEMFC), the reaction kinetics and catalyst lifetime can be significantly enhanced," Li explains. "Non-platinum group metals (non-PGM) such as Ag and Fe-N_4/C have shown competitive electrocatalytic activity and durability." Li and his team have demonstrated that an AEMFC (Pt anode and Fe-N_4/C cathode) can generate eye-popping, high power density—over 140 mW/cm^2—with glycerol fuel, and simultaneously produce value-added chemicals, such as glyceric acid, tartronic acid, and glycolic acid. "This power density is two to three orders of magnitude higher than the state-of-the-art enzymatic fuel cells, and could serve as a power source for portable electronics, or self-sustainable chemical production," notes Li.

"About 10 weight percent crude glycerol is generated as a low-value byproduct in biodiesel production," he adds. "It is difficult to dispose of, which places a burden on biofuel manufacturers. But we have proven that glycerol can become a valuable asset through electrocatalytic processing."

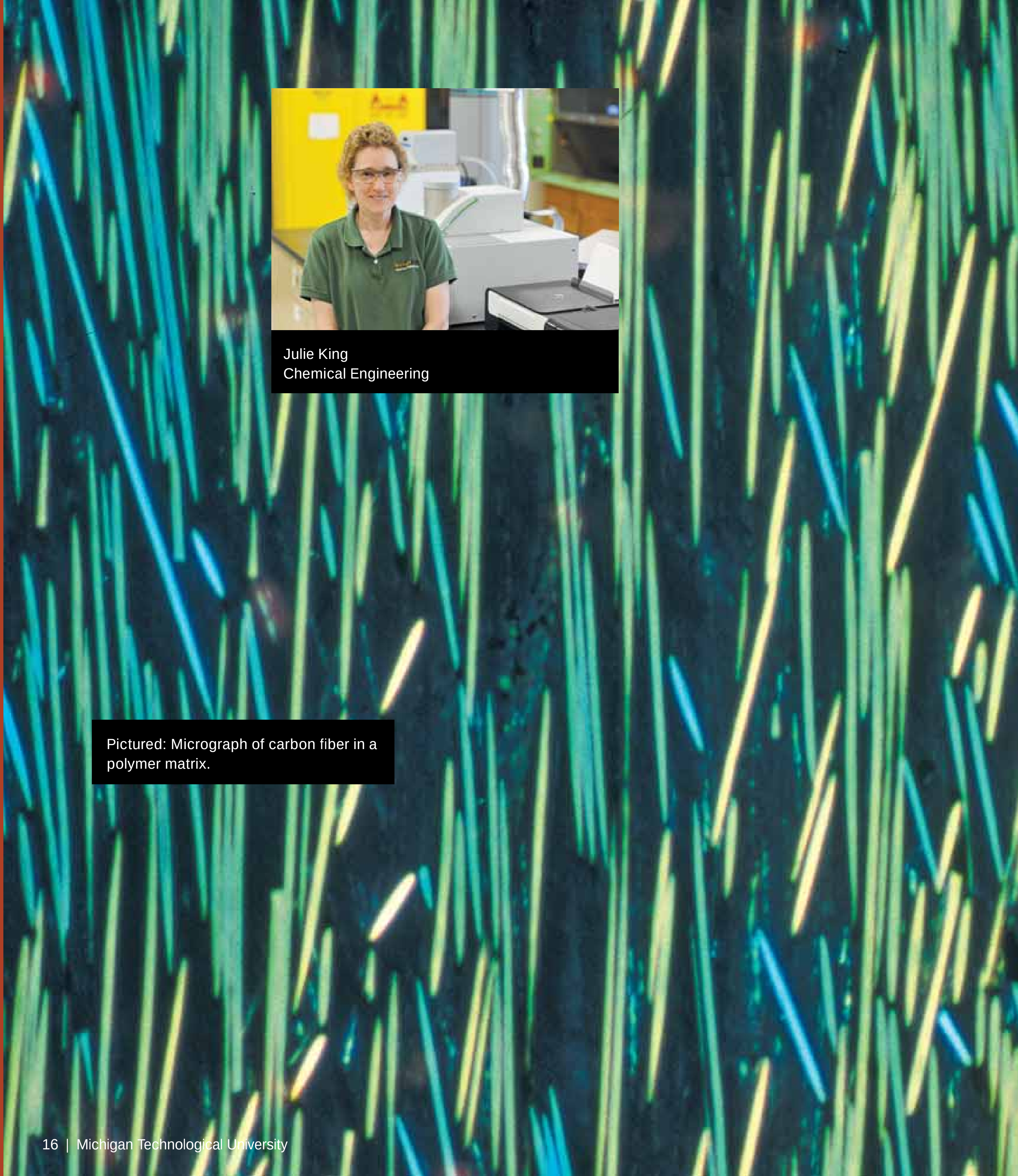
Li's team is working to better understand relationships between potential catalyst structure and catalytic functions. They also hope to develop PGM nanocatalysts such as nanowires, nanoleaves, and core-shell structures, as well as non-PGM catalysts such as nickel and silver to efficiently generate both electricity and value-added chemicals from biomass feedstocks and biofuel residues.

Wenzhen Li
Chemical Engineering

Pictured: Li's anion exchange membrane fuel cell, powered with glycerol fuel, generates impressive high power density—over 140 mW/cm^2—while simultaneously producing value-added chemicals.



Engineered Materials



Julie King
Chemical Engineering

Pictured: Micrograph of carbon fiber in a polymer matrix.

Boosting conductivity

Discovering synergistic effects in composites

The proton exchange membrane fuel cell is one of the most promising alternative fuel technologies to power cars and buses. Bipolar plate technology plays a key role in fuel cell technology. The bipolar plate separates one cell from the next, carrying hydrogen gas on one side, and air (oxygen) on the other.

Julie King develops and models new thermoplastic-based materials containing several different carbon fillers to meet all the properties required for bipolar plates.

“Most polymer resins are thermally and electrically insulating,” notes King. Using combinations of different carbon fillers, King has discovered new synergistic effects that greatly increase a composite’s electrical conductivity and shielding effectiveness. Combinations of different fillers have a positive synergistic effect. King uses a combination of carbon fibers, carbon black, carbon nanotubes, and synthetic graphite particles, mixed with polymers including polycarbonate, nylon, polypropylene, and a liquid crystal polymer. By varying the combination of fillers and polymers, King has been able to increase the thermal conductivity by a factor of 100, and decrease electrical resistivity by an astounding factor of 10^{18}.

“It’s possible that additional pathways form between the highly-branched, high-surface area carbon black, the thermocarbon particles, and carbon fiber—resulting in greatly enhanced electrical conductivity,” King explains.

The voltage generated from one single cell is typically 0.7 volts. Since commercial electric motors often operate at 300 volts, the fuel cells are stacked in series. Often 430 bipolar plates are needed for a 300 V fuel cell assembly. “Thermoplastics can be formed into thinner bipolar plates,” she adds. “Ideally bipolar plates should be as thin as possible to minimize electrical resistance and make fuel cells stack small.”

With many new technologies, cost can be a significant challenge. At present, a bipolar plate can run about $8, but the US Department of Energy has set a target of $2 per plate ($10 per KW) to facilitate affordable integration of fuel cell technology into public transportation. King’s thermoplastic-based resins can be recycled, so used plates and any scrap generated in the manufacturing process can be remelted and used to produce new bipolar plates, bringing costs down further.

Predicting detonation

Calculating the properties of crystals

For more than a decade, Warren Perger has collaborated with a team of researchers at MIT and Washington State University to understand how deformations in crystals ultimately lead to the initiation of a shock and, consequently, a detonation. Researchers at Washington State are performing IR, Raman, and optical absorption studies of energetic crystals; MIT is performing femto-second resolution experiments of the shock-to-detonation transition; and Perger is developing theoretical predictions for these phenomena.

What sets off any given explosive can be quirky. One particularly dangerous material, PETN, is made up of a very complicated crystalline lattice. "It has a weird property—you can hit it in one direction and it is stable, but will easily detonate if you hit it from another," notes Perger. His mathematical models have made some remarkably accurate predictions.

Perger began his work by making calculations to determine material safety and longevity on a quantum mechanical level. "It's important to understand why a material has particular properties in the first place," he explains. To develop that understanding, Perger needed to get inside a working group of software developers capable of doing the computation. He found one at the University of Turin, in Italy—a team who had created a software program able to predict the stability, storage, and fundamental science behind mechanical deformation of energetic substances. Ten years later, Perger is now a coauthor of the software, aptly named CRYSTAL. "It's predictive materials science at a computational level," he says.

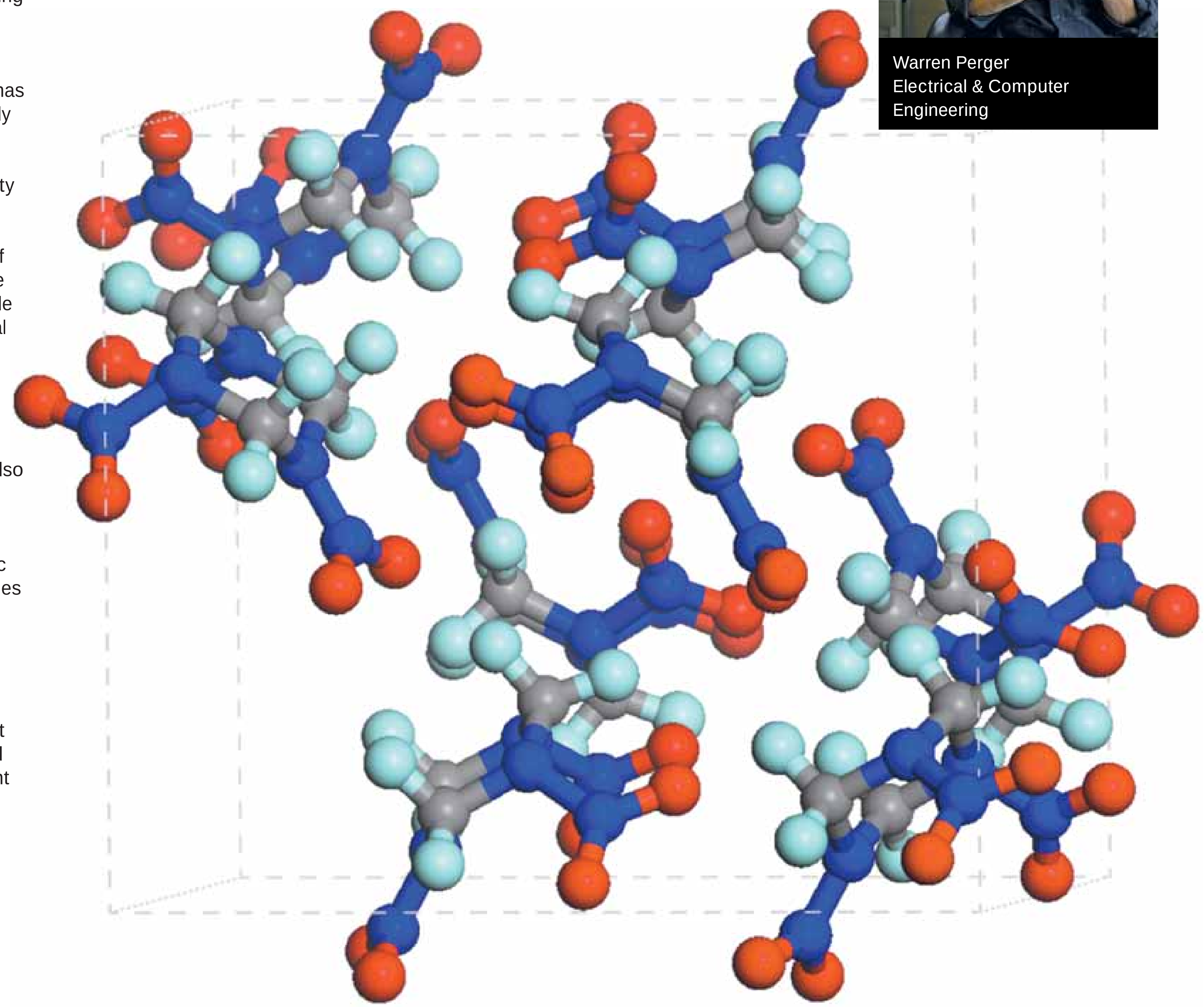
In the last three years, Perger's work on using the CRYSTAL program for calculation of second-order elastic constants has become much more widespread. Perger authored an equation-of-state program, which is now also embedded within CRYSTAL and it, too, has seen widespread use.

The most exciting breakthrough, however, has taken place in recent months. Perger has found the key to the difficult problem of calculating properties accurately for van der Waals-bonded systems and, with post-doc Loredana Valenzano, created a way to accurately calculate material properties at room temperatures (as opposed to the 0 Kelvin results that CRYSTAL typically produces).

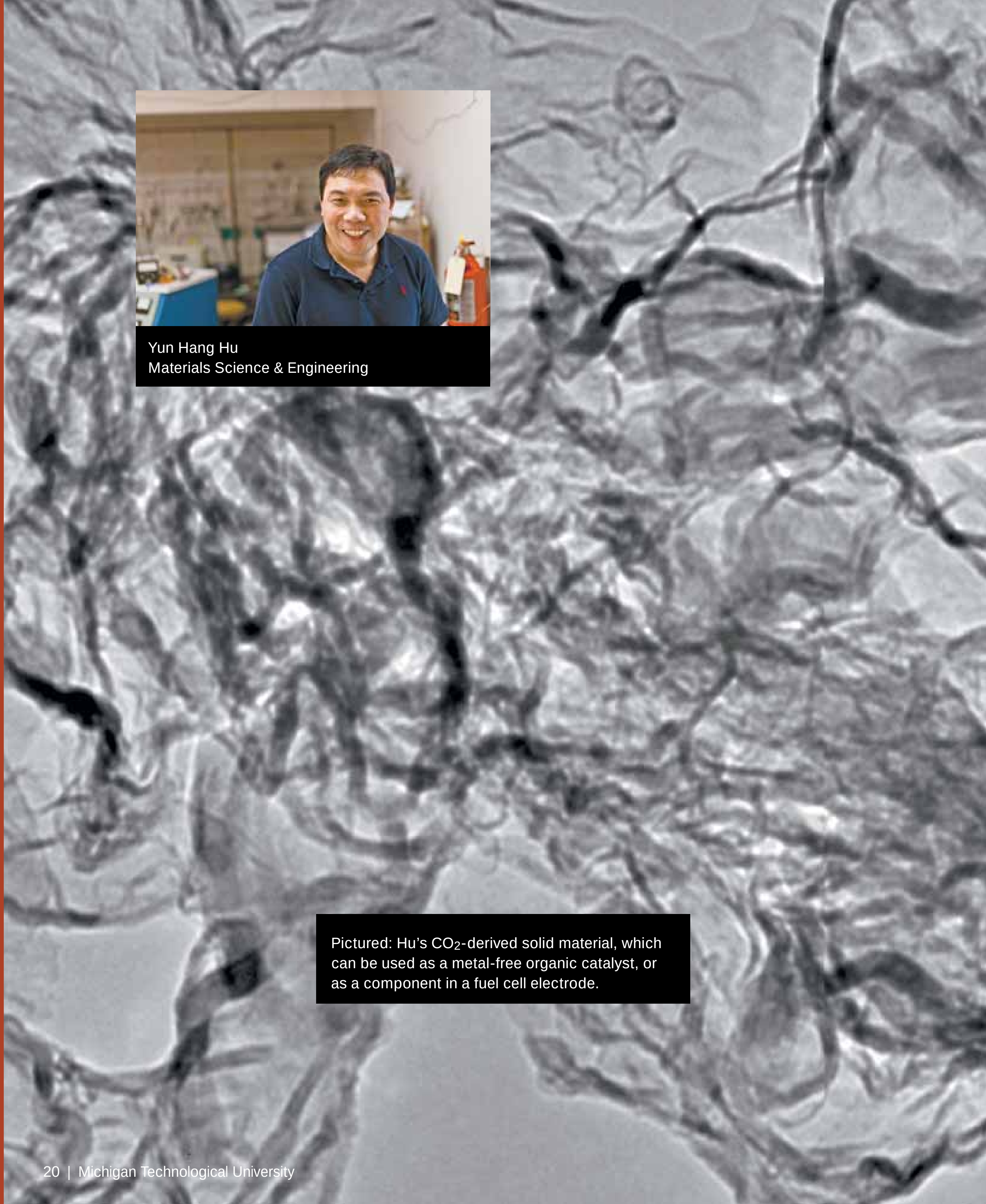
As Perger began adding the physics of temperature to the model, he discovered the mistake that was holding the field back. "For years, calculations contained two errors which just by chance cancelled each other out—and the cancellation was huge—between 10 and 20 percent. Now that the error is out of the basis set, we can clearly see the roles of basis set and exchange-correlation potential. The answer is much closer to the experiment for the right reasons," he says. "With calculations, we want them to be predictive, and not rely on the experiment," notes Perger. "Theory must maintain a proper separation from the experiment, otherwise intellectual biasing can take place."

"It's a major breakthrough," he adds. "Not an incremental step, but a big step."

Warren Perger
Electrical & Computer Engineering



Pictured: Cyclotrimethylene trinitramine, an orthorhombic structure with 168 atoms per unit cell. Otherwise known as Research Department Explosive (RDX), it is considered to be one of the most powerful and brisant high explosives.



Yun Hang Hu
Materials Science & Engineering

Pictured: Hu's CO_2-derived solid material, which can be used as a metal-free organic catalyst, or as a component in a fuel cell electrode.

Grand challenges

Solving energy and environmental issues with advanced materials

Human development is strongly connected to certain special materials, i.e., the Stone Age, the Bronze Age, the Iron Age, and the Silicon Age.

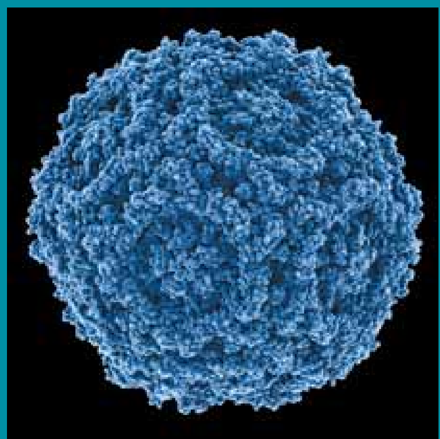
Now, more than ever, discoveries of novel and effective materials are needed to reduce greenhouse gas emissions, achieve long-term security of our energy supply, and maintain economic growth.

Yun Hang Hu's research is centered on using chemical and physical approaches toward the synthesis and characterization of advanced materials. His goals, somewhere between impressive and stunning, are threefold: to convert CO_2 into valuable materials; to produce and store hydrogen fuels; and to convert solar energy into electrical energy.

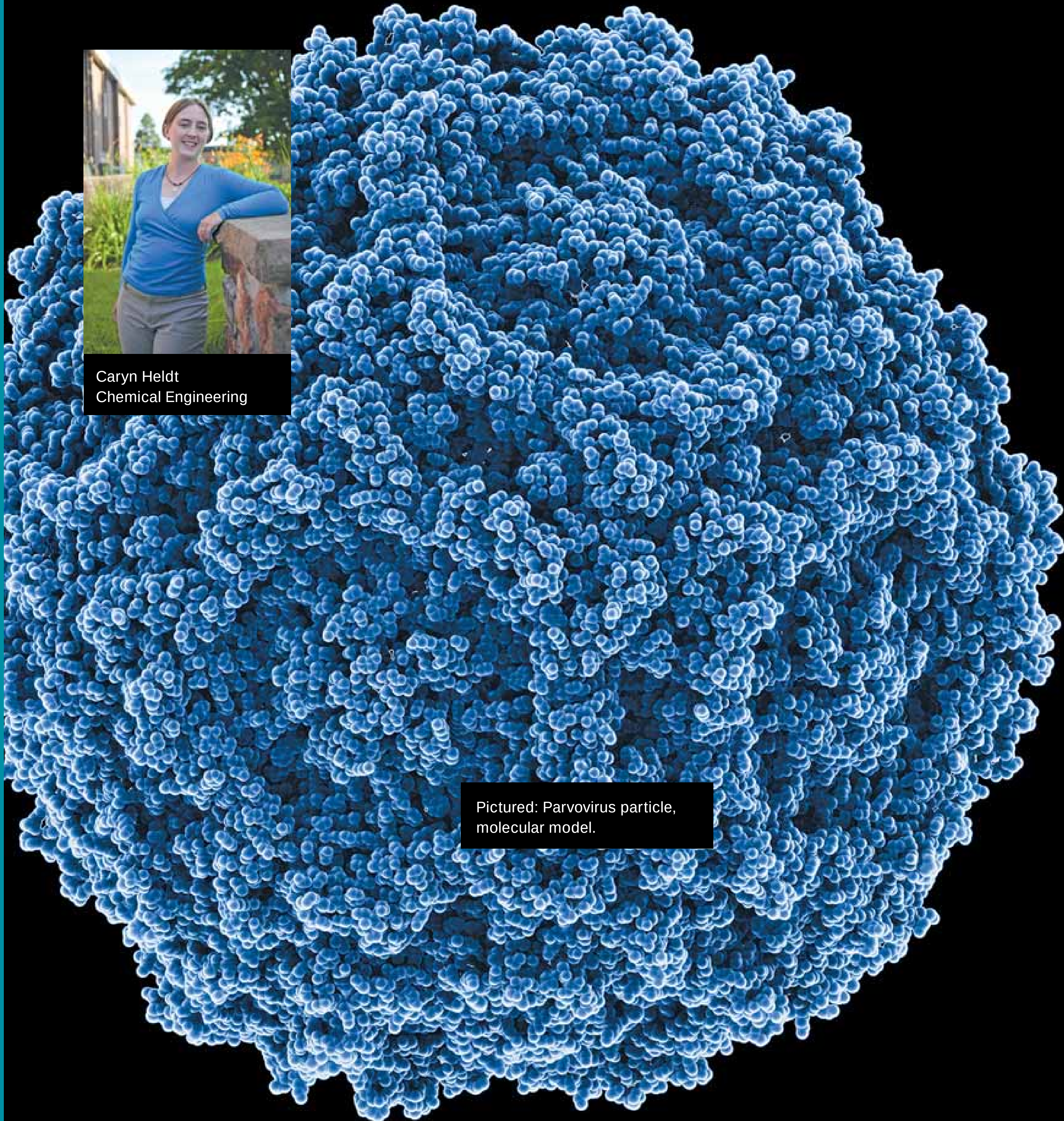
"Developing an effective hydrogen storage technology—one that provides high storage capacity and fast kinetics—is a critical factor in the development of hydrogen fuel for transportation," Hu explains. Hu and his team are focused on two types of novel solid materials for hydrogen storage: Li-N-based compounds and metal-organic frameworks (MOFs). They have invented several effective materials with high reversible hydrogen capacity. Their research has also revealed the hydrogen storage mechanism in Li-N-based materials, now widely employed as a theoretical base. Currently Hu is fine-tuning both Li-N-based compounds and MOFs in order to obtain temperatures suitable for onboard hydrogen storage.

Utilizing atmospheric CO_2 is another key area. Hu and his team have devised a novel approach for converting CO_2 into a solid material. "It is generally recognized that amorphization of solid materials at ambient temperature requires an ultra-high pressure (several GPa)," Hu explains. "But we first demonstrated that MOFs could be irreversibly amorphized at room temperature by employing a low compressing pressure of 3.5 MPa—one hundred times lower than what is required for the amorphization of other solids." The team is now exploring the applications of amorphous MOFs for CO_2 adsorption and conversion. Their new CO_2-derived materials can be used as metal-free organic catalysts, or as components in a fuel cell electrode.

"We are also investigating graphene, a rapidly rising star in materials science," adds Hu. "Graphene is a two-dimensional material that exhibits low resistance, excellent optical-transmittance, and high mechanical and chemical stabilities—all qualities that give it great promise for potential applications in photovoltaic devices." Hu and his team are developing novel approaches for the synthesis of graphene, and also exploring graphene applications, including use as transparent electrodes, and as electronic promoters for solar cells.



Health



Caryn Heldt
Chemical Engineering

Pictured: Parvovirus particle, molecular model.

Infectious diseases

Binding peptides to pathogens for detection and removal

Millions of people die every year from infectious diseases. Illnesses such as AIDS or West Nile are caused by viruses. Bacteria, including cholera or salmonella, can also be deadly. The incident of disease transmission, be it through contaminated water or food, touching a contaminated surface, or through a blood transfusion, could be reduced by the creation of specific and custom-tailored removal and detection devices.

Caryn Heldt is examining methods to bind peptides to pathogens. Her goal: To discover a better sensory element—an alternative to antibodies—that can be applied in an economical device.

"Peptides are small pieces of proteins, like antibodies, but due to their small size, are more stable," she explains. The peptides under investigation are composed of the same twenty different naturally-occurring amino acids as antibodies, giving them a similar diversity as antibodies to bind using multiple functional groups. Heldt and her team are not only interested in discovering new sensor peptide elements, but also hope to use these sensory elements in unique devices to remove and detect pathogens in a manner that is economical and environmentally sustainable.

"Many such devices today are based on specific antibodies that bind to pathogens for detection or removal," she notes. Pitfalls for such devices include a short shelf life, required refrigeration, and/or specialized laboratory equipment to analyze results.

Heldt is currently using porcine parvovirus as a model virus to test the removal and detection ability of different devices. Small peptides are being added to different membrane surfaces to create a virus filter that could purify water without the need for high pressure pumping—something that could potentially reduce the cost of producing clean water for personal use or for larger populations.

The team is also investigating the use of peptides as a specific sensor surface to create a low-power device that can detect a virus in minutes instead of hours or days, reducing clinical delays. Other virus removal techniques are being pursued for more specialized applications, as well, such as the removal of viruses from biotherapeutics, including virus precipitation and extraction.

"All of these methods rely on the specific binding of small peptides to detect or remove viruses," adds Heldt. "These sensory elements could also be discovered for different pathogens and used to remove pathogens from the environment. We hope to reduce the number of deaths that are caused every year by infectious diseases."

Health

Say yes to NO

Using nitric oxide to create safer implants that promote healing

Polymeric materials are used to make numerous biomedical devices that contact tissue and fluids through the body. Once the polymer is in contact with the body, a biological response is inspired that can interfere with the functioning of the biomedical device and often leads to complete failure of the device.

Megan Frost and her research team are developing polymeric systems that actively release nitric oxide (NO), a free radical gas that is a potent signaling molecule. NO was long thought to be nothing more than a toxic pollutant, but in 1987 was identified as a naturally produced signaling molecule. Since then, NO has been shown to have a wide variety of biological functions in vivo, including functioning as a neurotransmitter, fighting bacterial infection, controlling blood pressure, and acting as an anti-tumor agent. NO is also a potent inhibitor of platelet adhesion and activation and is released by the healthy cells that line all blood vessels. NO has been implicated in mediating the inflammatory response in subcutaneous tissue and has been shown to be important in the wound healing process. In 1992, NO was named the "Molecule of the Year" for its diverse and ever-increasing number of identified roles in physiological functions.

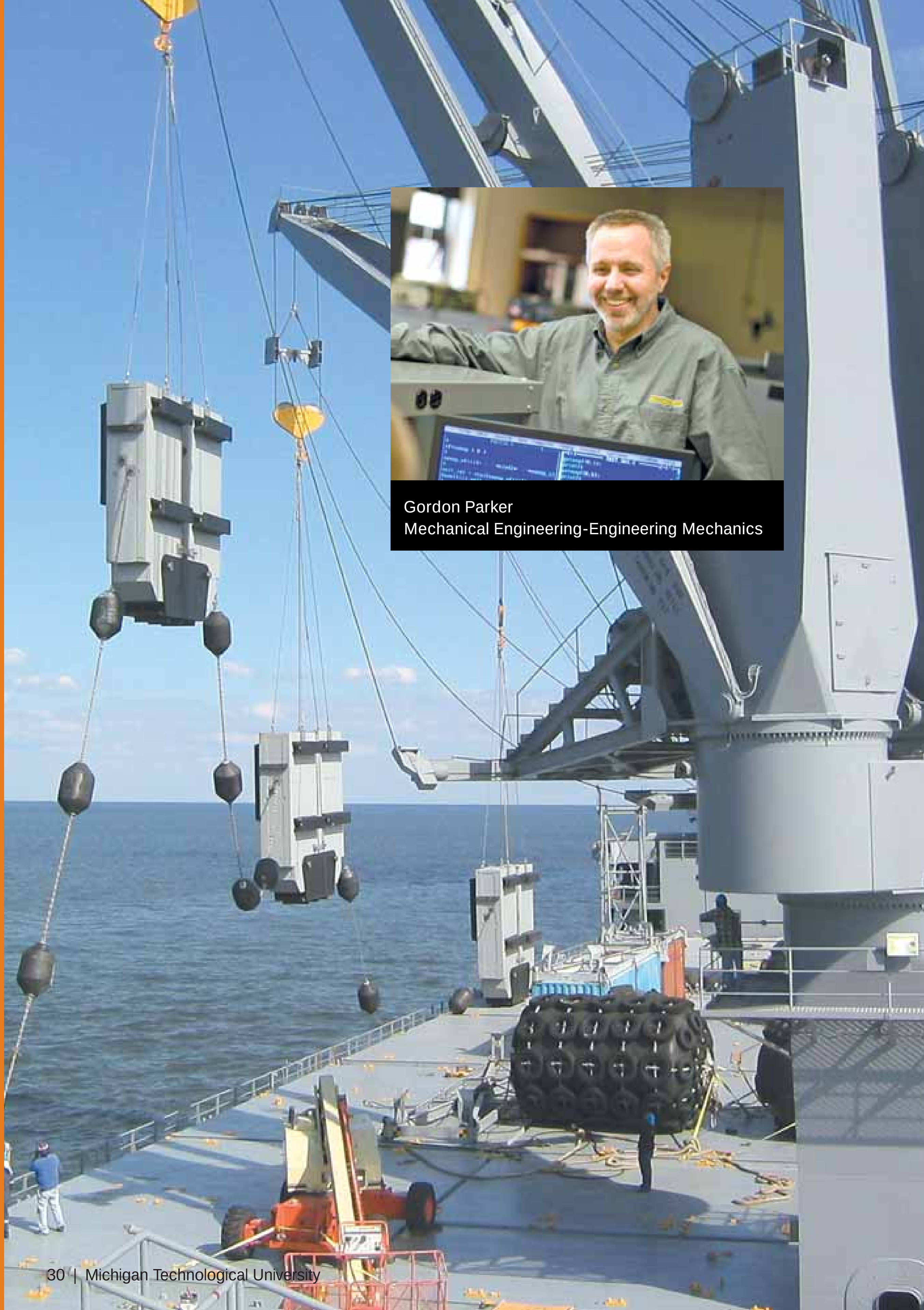
Frost and her team of researchers are working to harness the positive effects of NO by developing polymers that release NO in a very controlled manner. "NO release can be tailored to mediate biological response in specific medical applications," Frost explains. "We have developed a series of photosensitive NO-donors that are incorporated into polymeric materials so that when light impinges on the polymers, NO is released in a controlled manner. More irradiation releases more NO, less releases less NO."

Frost developed the first polymers to allow continuously variable control of NO release. "This is a breakthrough that allows precise temporal and spatial control over NO delivery," adds Frost.

Her team is currently applying these materials to understand the biological responses from different cells and tissues. Their goal: To make safer and more effective implanted biomedical devices, including intravascular oxygen sensors and implanted glucose sensors, catheters to deliver IV fluids, sutures to close wounds, and tubing to filter blood.

Megan Frost
Biomedical Engineering

Sensing & Controls



Gordon Parker
Mechanical Engineering-Engineering Mechanics

An age-old problem

Controlling motion during at-sea cargo transfer

Some of the oldest problems still present challenges to modern engineering. Moving cargo from ship-to-ship under extreme conditions is an example. The problem with at-sea operations is simple. Both the crane ship and the target ship move according to ever-changing sea conditions.

Unfortunately, resupply operations frequently need to happen in rough sea conditions, making them dangerous and slow at best and impossible at worst. Control systems using embedded computing, control algorithms, and sensors offer the promise of new ship-to-shore cargo transfer systems that can expand the resupply operational envelope.

Gordon Parker is developing and testing new control systems for ship crane and autonomous vehicle cargo transfer that improve at-sea cargo transfer. Control systems are typically a combination of computer algorithms and sensors that measure a system's behavior and then automatically modify its inputs to increase its performance. His goal: Use active control system design principles to demonstrate improved capability for a wide range of extreme scenarios.

Parker is currently examining two completely different approaches. The first focuses on control strategies for existing ship cranes. Individually, these devices can lift up to 36 tons with an outreach of 120 feet. Up to four cranes on a single ship can be linked together increasing their lifting capacity, but greatly complicating their behavior. A typical operation requires the operator to move a container from the crane ship to another target vessel. The crane ship motion causes the load to swing dangerously making its landing onto the moving target vessel difficult.

The second system uses autonomous parafoils that can deliver 1000 lb. loads from supply ships several miles inland and return them to the original vessel. Air-dropped parafoils currently exist for this purpose. The challenges of the ship-based approach are its launch from a ship deck and then towing it up to several thousand feet before its release. The tow-up operation is particularly difficult due to an instability condition called 'lock out' that occurs when the direction of parafoil travel is not in line with the tow cable. When a misalignment threshold is exceeded, there is no way to recover stable flight and the parafoil crashes swiftly.

"Although these two systems seem entirely different, they have some common features making their solution approach similar," Parker explains. "The differential equations that describe their motions in response to the available inputs are nonlinear. This limits the ability to use off-the-shelf control strategies. They each have well-defined controllable inputs, as well. For the cranes, it's their hydraulic drive systems and for the parafoil, it's the tension in the tow cable and the ability to actively change the shape of its airfoil." In addition, control system implementation of control strategies on both systems requires multi-axis sensing and signal processing methods.

Parker and his students have found that research workflow is identical for both systems—computer modeling and simulation, control system algorithm design and simulation, sensor deign, small scale testing, and finally field-testing.

"The knowledge created so far has been significant," he adds. "For the crane system, we have developed and tested a new sensor system in an at-sea environment, which allows the control strategy to focus on removing load swing energy without responding to unimportant parasitic motions. We've also quantified mathematically the 'lock out' instability of the parafoil by developing a method that not only assesses it, but also increases the lock-out threshold."

Body sensor networks

Any test, anywhere, anytime

Recent significant progress in wireless sensing and monitoring, as well as in wearable/implantable biosensors, have led to the development of the body sensor network—a tool that can aid physicians as they make important decisions about patient care. Thanks to its miniature size and flexible nodes, a body sensor network can provide real-time, context-aware, noninvasive health monitoring—ideal for early detection, evaluation, and diagnosis of heart disease.

Jindong Tan has developed an innovative body sensor network that efficiently collects and utilizes context information to help detect the most significant waveform in an electrocardiogram, or ECG—the QRS complex. Typically, an ECG has five deflections, arbitrarily named "P" to "T" waves. The Q, R, and S waves occur in rapid succession, and are usually considered together.

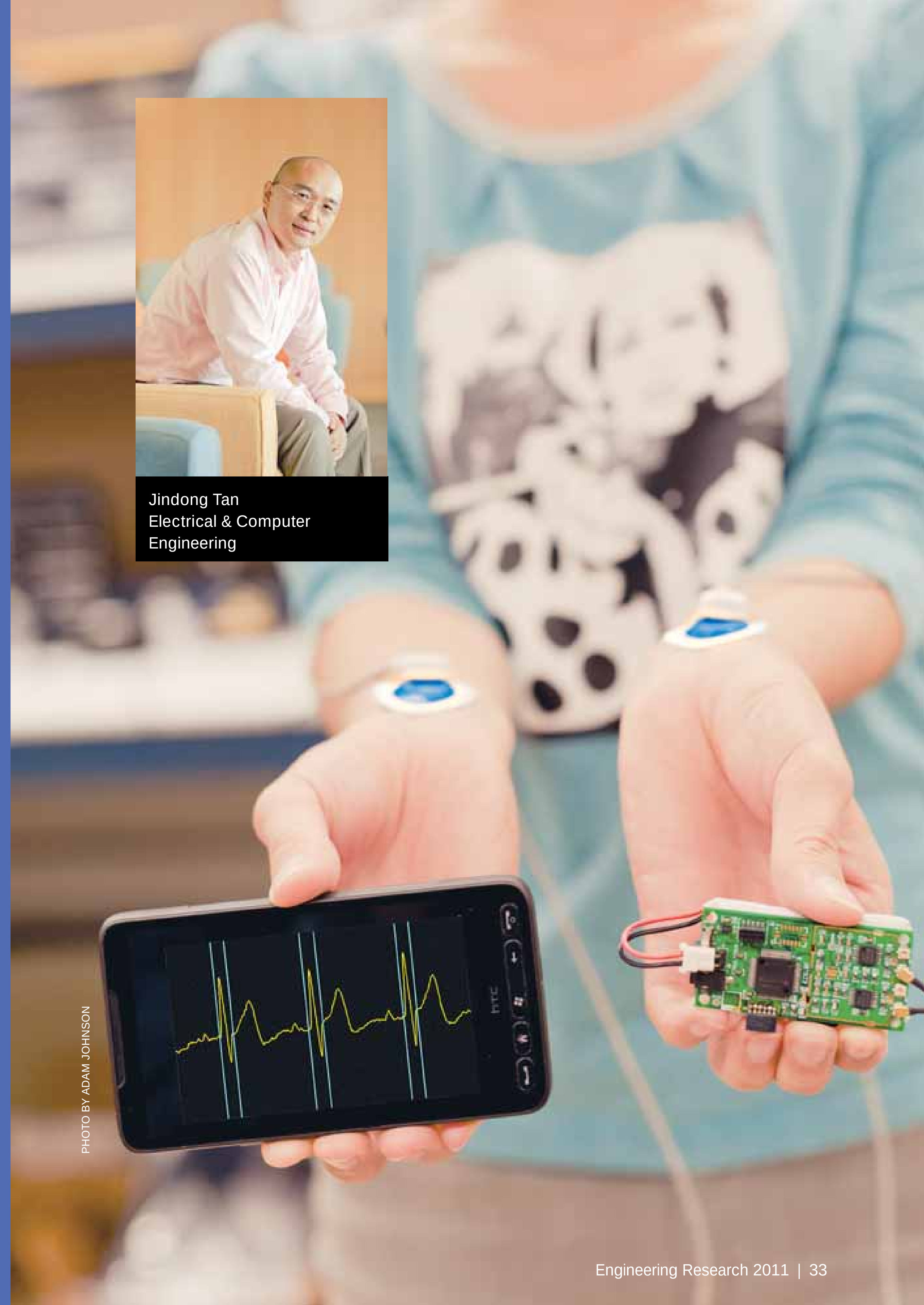
"A body sensor network can consist of several implantable or wearable biosensors, including an ECG, EEG (or electroencephalogram, which measures and records brain electrical activity), a glucose sensor, an accelerometer, blood pressure and oxygen saturation sensors, a temperature sensor, and even ingestible camera pills," says Tan. "These sensors continuously monitor vital signs and report data to a powerful external device, such as a cell phone, PDA, or bedside monitoring station. Heart function reacts to all kinds of incoming stimuli, such as daily activities, physical stress tests, mental stress, and environmental changes," he adds. "A body sensor network continuously senses, records, and analyzes different vital signs that represent the heart's reactions—it's even capable of evaluating a patient's heart function and diagnosing potential problems."

A body sensor network can also process accelerometer readings to classify a patient's daily activities. "The result is first fed to a lead selector to eliminate those leads with low SNR, or signal-to-noise ratio, and then to a selector to select a proper QRS detector according to the noise level," Tan explains. "Other context information such as blood pressure, ambient and body temperature, and brain activity are collected and added to the ECG annotations, providing each patient with a context-aware, personalized heart diary."

A coronary arteriogram is traditionally considered to be the gold standard of diagnostic tests. Other invasive procedures, including coronary angiograms, bypass surgery, and angioplasties are widely used as tests and therapies for heart disease. "These surgeries are not only expensive, aggressive, and traumatic for patients, but are sometimes overused and unnecessary, according to several recent studies," notes Tan. A body sensor network, on the other hand, which is noninvasive, safe, and affordable, can help physicians decide whether to refer a patient for more invasive testing and therapy.

"A typical cell phone is equipped with a relatively powerful CPU, which can process the data to identify a potential abnormality. Our approach is to process the largest amount of data locally at the wearable sensors to avoid the transmission of raw sensing data by the cell phone. Wireless data transmission is the key factor to extending a sensor's battery life. If any abnormalities are observed, as a back-up, raw data will be requested from wearable sensor units and forwarded to medical professionals via cellular networks."

Currently, exercise tests and corresponding ECG processing are performed in a lab environment under the supervision of a physician. "Right now, most tests are performed occasionally, due to issues of cost and schedule," adds Tan. "By introducing a body sensor network, tests can be done anywhere, any time."



Jindong Tan
Electrical & Computer Engineering

PHOTO BY ADAM JOHNSON

People

Gregory P. Waite
Geological & Mining Engineering and Sciences

Pictured: Waite and his team at Chile's troublesome Villarrica volcano. "As researchers, we are fortunate that we can look down into a volcano that is bubbling all the time," he says. "Once in awhile a bubble bursts and splatters lava. We are measuring the mini-earthquakes from these bubble bursts."

Gregory P. Waite

CAREER Award | Predicting volcanic earthquakes

The College of Engineering at Michigan Tech is proud to announce the tremendous achievement of Assistant Professor Gregory P. Waite, who has been awarded a Faculty Early CAREER Development Award from the National Science Foundation.

The CAREER award carries with it a grant for $415,000 for his research in the next five years. Waite will use the award to reduce the uncertainties related to volcanic earthquakes.

Waite uses syneruption volcanic earthquakes to map magma conduits by modeling high-fidelity recordings of the events. This is only possible from recordings made at close range. To collect these data, Waite, his students, and colleagues hike high onto the flanks of erupting volcanoes to place seismometers, which detect ground vibrations, and infrasonic microphones to detect low frequency pressure waves in the air. Improved models of the deformation field from these events—broadband ground translation and rotation—provide insight into the dynamics of small-scale eruptions. Waite and his students will collect data on sulfur-dioxide emissions, low-frequency sound, and ground tilt, along with seismic data to better constrain these models. "Ultimately this work will push waveform modeling of volcano seismic signals into wider use," says Waite.

The people living near volcanoes are the ultimate beneficiaries of the research: local populations who need to be informed and warned of impending eruptions. Adoption of his methods, Waite believes, will lead to better understanding of hazards and their mitigation.

Waite joined the Department of Geological & Mining Engineering and Sciences at Michigan Tech in 2007. He earned a Bachelor of Arts in Mathematics at St. Norbert College, and a Masters and PhD in Geophysics at the University of Utah. He was a Postdoctoral Fellow with the US Geological Survey. Waite's research integrates seismology with other geophysical and geological techniques to develop models for active processes.

Veronica Webster Griffis

CAREER Award | Understanding flood risks

The College of Engineering at Michigan Tech is proud to announce the tremendous achievement of Assistant Professor Veronica Webster Griffis, who has been awarded a Faculty Early CAREER Development Award from the National Science Foundation.

The CAREER award carries with it a grant for $415,000 over the next five years. Griffis will use the award to develop a statistical model for projecting future flood risk in the northeastern US.

"My goal is to gain a deeper understanding of the relative impacts of natural climatic variation and anthropogenic activities on flood risk," Griffis explains. She will use statistical models based on observed data, along with physically-based hydrologic models used to simulate flood series under future scenarios, in order to create a physical-causal based statistical framework for flood risk projection. This framework will enable needed advances in water resources and stochastic hydrology, and allow for cost-efficient impact assessments. The project will include field trips for area ninth graders, and development of an interactive web module and corresponding lesson plans intended to increase student awareness of human impacts on water resources. Graduate and undergraduate students will participate in community outreach activities, and the research will be integrated into undergraduate water resources coursework.

Griffis joined the Department of Civil & Environmental Engineering at Michigan Tech in 2006. She holds a Bachelor of Science in Civil Engineering from the University of Vermont, and a Masters and PhD in Civil Engineering from Cornell University. Her research interests include flood frequency analysis and the evaluation of other extreme events.

In particular, she is interested in the impacts of climate variability, climate change, and land use changes on the magnitude, frequency, and timing of flood flows—as well as the effects of such changes on stream ecology and water quality.

Veronica Webster Griffis
Civil & Environmental Engineering

Pictured: destruction from the recent flooding in Vermont, the researcher's home state, located along Route 4 between Killington and Mendon, Vermont.

PHOTO BY LARS GANGE/MANSFIELD HELIFLIGHT

Ron Van Dell '79

Alumni spotlight | A new way to harvest solar energy

"A lot of people think of solar panels as being all there is to solar," says Ron Van Dell, President and CEO of Austin-based SolarBridge Technologies. "They tend to think if panels were cheaper, then solar would be affordable. But, with the price of solar panels falling fast, what used to be the dominant cost is now less than half the total." Of the rest, the most important part, according to Van Dell, is the power inverter that converts dc current generated by the panels to ac current for household use.

"In a typical solar array there are many panels connected in series," explains Van Dell. This poses problems. "When one panel goes down, it can bring down all the others, much like a string of christmas lights." But not anymore. SolarBridge has created a system in which each panel is wired with its own small inverter at the solar panel factory. As a result, each panel is able to perform its own power conversion, and one does not affect the other.

Other benefits are that the system can be added to heterogeneously and progressively over time. And, because the SolarBridge technology converts each individual panel to standard ac wiring, the system is much safer to install and maintain than the high-voltage, dc-wired systems now in widespread use.

Another major strength: SolarBridge ties users directly into the smartgrid. "Everyone talks about the smartgrid, but no one is quite sure what it means," notes Van Dell. "To us it means providing a utility the ability to converse with a PV system up on the rooftop, in order to optimize overall grid performance. That's what creates a smarter grid."

SolarBridge's Power Manager serves as the communications hub of the array, continuously monitoring the performance of every panel in the PV system. It communicates directly with other devices as well as the company's Power Portal, a Web-based management system that enables users to monitor system performance 24/7 through Internet-connected computers and mobile devices.

Even on a damp and cloudy day, solar panels still churn out electricity at the new Michigan Tech Solar Photovoltaic Research Facility. Van Dell and SolarBridge provided the microinverters as well as its Power Manager/Power Portal for managing and monitoring the system. Dow Corning, of Midland, MI, and Hemlock Semiconductor, based in Hemlock, MI, donated PV panels from five different manufactures to the facility.

Van Dell predicts the facility will help drive solar power closer to widespread use. "This is a beginning platform for Michigan Tech," he says, adding that he expects the program to draw investigators from many engineering disciplines, as well as business. "All kinds of skills are needed to advance the state of solar technology."

With an annual snowfall averaging 200-plus inches, Houghton, Michigan might not seem like the ideal spot to study photovoltaic systems. But SolarBridge tests their equipment in all kinds of conditions, from Antarctica to the American West. Snow can actually be a benefit, Van Dell said, since it reflects sunlight.

The facility will also provide opportunities for undergraduate work. Michigan Tech has a small weather station, and students in the undergraduate Alternative Fuels Group Enterprise team will correlate the solar cells' output with local weather conditions.

More about Ron Van Dell

Ron Van Dell graduated with a Bachelor of Science in Electrical Engineering, with honors, from Michigan Technological University in 1979. He serves on Michigan Tech's College of Engineering Advisory Board, and is a member of the Department of Electrical and Computer Engineering's Academy.

With more than 30 years of experience, Van Dell has an exceptional track record of leadership and success. Before joining SolarBridge Technologies, Van Dell served as president and CEO at Primarion, president and CEO at Legerity, general manager for Dell Computer's Dimension product line, and vice president-general manager of the Communication Products Business at Harris Semiconductor (now Intersil Corporation). Van Dell has also held previous international management positions in the US and in Europe at Groupe Schneider, Square D Company and General Electric.

A SolarBridge Pantheon™ microinverter mounts on the back of each solar panel.

PHOTO BY ADAM JOHNSON

Centers

Advanced Power Systems Research Center (APSRC)
www.me.mtu.edu/research/power

Advanced Sustainable Iron and Steel Center (ASISC)
www.chem.mtu.edu/asisc

Biotechnology Research Center (BRC)
http://biotech.mtu.edu

Paul and Susan Williams Center for Computer Systems Research (CCSR)
http://www.mtu.edu/cs/research/ccsr/

Center for Environmentally Benign Functional Materials (CEBFM)
http://www.sfi.mtu.edu/cebfm/

Center for Fundamental and Applied Research in Nanostructured and Lightweight Materials (CNLM)
http://www.chem.mtu.edu/cnlm/index.htm

Center for Integrated Systems in Sensing, Imaging, and Communication (CISSIC)
www.ece.mtu.edu/pages/CISSIC

Center for Water and Society (CWS)
www.mtcws.mtu.edu

Ecosystem Science Center (ESC)
http://ecosystem.mtu.edu/

Keweenaw Research Center (KRC)
http://www.mtukrc.org/

Lake Superior Ecosystem Research Center (LaSER)
www.bio.mtu.edu/research/LSERC

Power & Energy Research Center (PERC)
http://www.ece.mtu.edu/perc/
Solar Research Center

University Transportation Center for Materials in Sustainable Transportation Infrastructure (MiSTI)
http://www.misti.mtu.edu

Institutes

Computational Science and Engineering Research Institute (CSERI)
www.cse.mtu.edu/cseri.html

Earth, Planetary and Space Sciences Institute (EPSSI)
http://www.epssi.mtu.edu

National Institute for Climatic Change Research (NICCR)
http://niccr.mtu.edu

Institute for Leadership and Innovation (ILI)
http://www.iis.mtu.edu/

Institute of Materials Processing (IMP)
http://www.imp.mtu.edu/

Michigan Tech Research Institute (MTRI)
http://www.mtri.org/

Michigan Tech Transportation Institute (MTTI)
http://www.mtti.mtu.edu/

Multi-Scale Technologies Institute (MuSTI)
http://www.me.mtu.edu/Institutes/MuSTI/

Sustainable Futures Institute (SFI)
http://www.sfi.mtu.edu/

University Transportation Center for Materials in Sustainable Transportation Infrastructure (MiSTI)

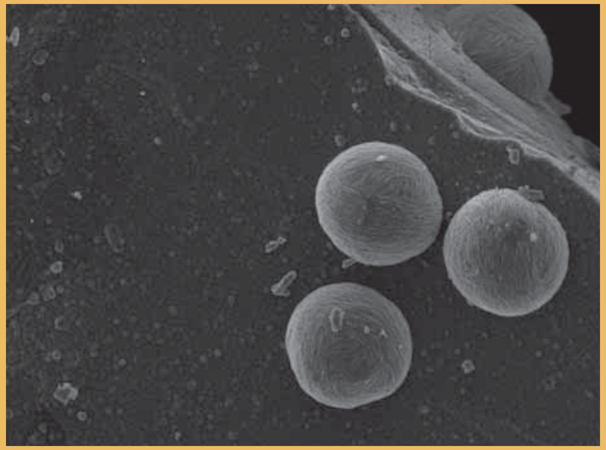


PHOTO BY JERRY ANZALONE

Outer space? Actually no. What you're looking at are zeolites formed on the surface of an aggregate approximately the size of a grain of sand. Researchers in the University Transportation Center are working to determine the effects of chemical deicers on concrete and mortars used in transportation infrastructure. Examining material at the microscopic level will help scientists identify ways to increase the life of infrastructure. Visit the MiSTI website at www.misti.mtu.edu

Research Centers & Institutes

Advancing knowledge of computing

Paul and Susan Williams Center for Computer Systems Research

Computer engineering and computer science are both key to advancing knowledge of computing. Engineers focus on design and integrating software and hardware, while scientists concentrate on analysis and the fundamental nature of computing.

Now, with the enthusiastic support of the Department of Computer Science, the Department of Electrical and Computer Engineering is creating a space where Michigan Tech's computer engineers and scientists can put their heads together.

The new Paul and Susan Williams Center for Computer Systems Research occupies the entire fifth floor of the Electrical Energy Resources Center (EERC). "We're excited about working with the computer science department on this," said Dan Fuhrmann, chair of electrical and computer engineering. "We'll be looking at experimental architectures, new applications, and new ways of doing computing."

Paul Williams, '61

Equipment and furnishings for the 10,000-square-foot center were made possible by a gift from Paul Williams, a 1961 electrical engineering graduate. Williams, of Torrance, Calif., is a retired engineer who spent nearly his entire career with Hughes Aircraft. Major gifts from the James Fugere Foundation and the Dave House Family Foundation, and numerous other donations alumni have made over the last several years covered the cost of construction and remodeling. "The fact that this is made possible completely by alumni donations is inspiring," said Fuhrmann.

A total of eighteen faculty members with expertise in a wide range of areas are participating in Williams Center research: software engineering; programming languages; computer architecture and compilers; embedded systems; robotics and control; mobile and wireless ad-hoc networks; VLSI CAD; bioinformatics; artificial intelligence; algorithms; real-time digital information and multimedia processing; high performance systems; and parallel processing.

"Our aim is to bring together people from all parts of campus with a common interest in computing systems research," adds Fuhrmann. "The Williams Center will be for faculty and students alike, for graduate students and undergraduates. It represents a huge leap forward in realizing Paul Williams' vision of state-of-the-art facilities in electrical engineering, computer engineering, and computer science."

For more information, please visit the Paul and Susan Williams Center for Computer Systems Research online at www.mtu.edu/cs/research/ccsr/

Office of the Dean

College of Engineering
Michigan Technological University
712 Minerals & Materials
Engineering 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

Sean J. Kirkpatrick
Biomedical Engineering

David W. Hand
Civil & Environmental Engineering

S. Komar Kawatra
Tony N. Rogers (interim)
Chemical Engineering

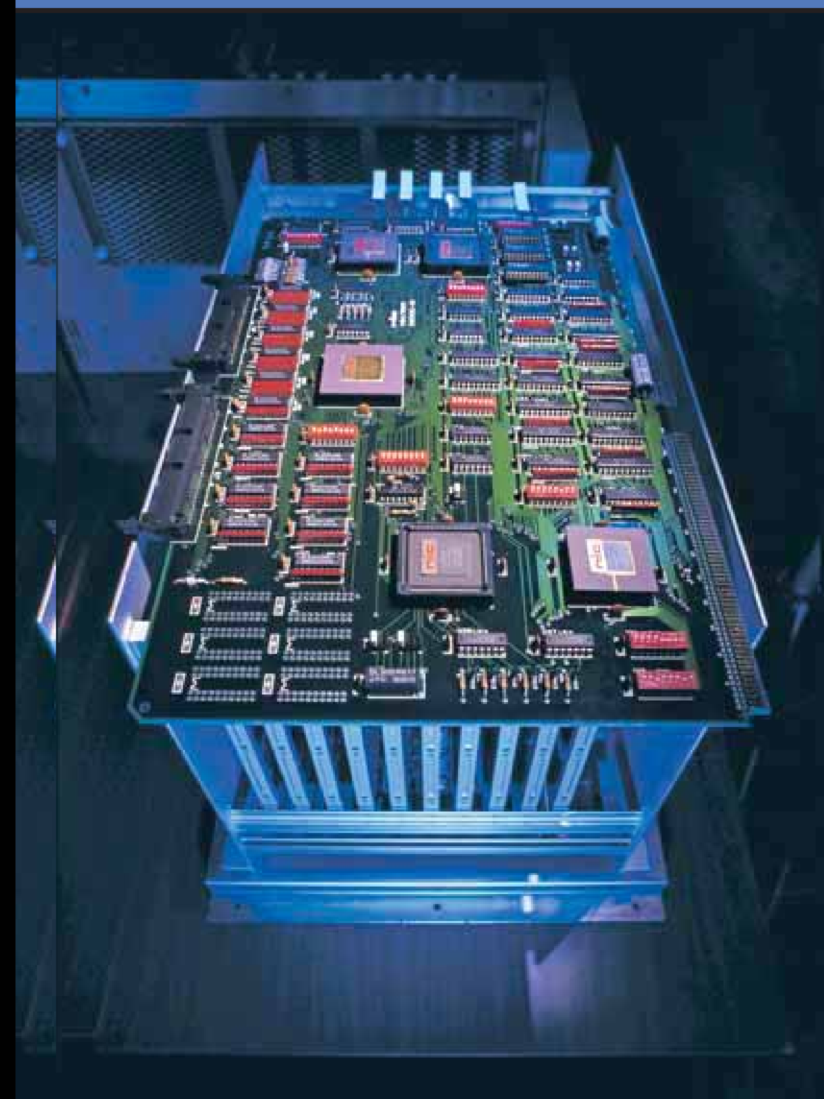
Daniel R. Fuhrmann
Electrical & Computer Engineering

Jean-Celeste Malzahn Kampe
Engineering Fundamentals

Wayne D. Pennington
Geological & Mining Engineering and Sciences

Mark R. Plichta
Materials Science & Engineering

William W. Predebon
Mechanical Engineering-Engineering Mechanics



Engineering Advisory Board

George C. Aram
Vice President,
Quality & Compliance
Medtronic Neuromodulation
Medtronic, Inc.

Paul Dean II
Senior Operations Director
Dow Manufacturing and Engineering
The Dow Chemical Company

Paul DeKeyser
Vice President & General Manager,
Water Business Group
CH2M Hill

Peter Farner
Founder and Principal
TGap Ventures, LLC

Charlotte Field
Senior Vice President,
National Communications
Engineering & Operations
Comcast Cable

Thomas R. Hanley
Professor of Chemical Engineering
Auburn University

Randolph (Randy) Hill
Principal
Randy Hill Consulting, LLC

Holly Hillberg
Vice President,
Product Development
Johnson & Johnson

Daniel R. Kapp (Chair)
Director, Powertrain Research
Advanced Research
& Innovation Center
Ford Motor Company

Susan B. Kiehl
Vice President, Earned Value
Management Systems
Lockheed Martin Aeronautics Co.

Charles S. Knobloch
Business & Intellectual Property
Attorney, Partner
Arnold & Knobloch LLP

Kenneth G. Murray
Senior Vice President,
Sales & Marketing
DecisionOne Corporation

John A. Soyring
Vice President,
IBM Solutions & Software
IBM Corporation

William R. Van Dell
President and CEO
SolarBridge Technologies

Mike Waara
IBM Corporation (retired)

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

PRESORTED
FIRST-CLASS MAIL
U.S.POSTAGE PAID
SEATTLE, WA
PERMIT NO. 1445

Engineering Research 2011

www.engineering.mtu.edu

Michigan Technological University is a leading public research university, conducting research, developing new technologies, and preparing students to create the future for a prosperous and sustainable world. Michigan Tech offers more than 120 undergraduate and graduate degree programs in engineering, forestry and environmental sciences, computer sciences, technology, business and economics, natural and physical sciences, arts, humanities and social sciences.