<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health Science</strong></td>
</tr>
<tr>
<td>Cancer nanotechnology</td>
</tr>
<tr>
<td>Targeting and eradicating tumor cells with nanomaterials</td>
</tr>
<tr>
<td>Lymphatic injuries</td>
</tr>
<tr>
<td>Finding new approaches</td>
</tr>
<tr>
<td>Osteoporosis</td>
</tr>
<tr>
<td>Rousing a cure from hibernating bears</td>
</tr>
<tr>
<td><strong>Engineered Materials</strong></td>
</tr>
<tr>
<td>Composite aircraft materials</td>
</tr>
<tr>
<td>Understanding aircraft aging</td>
</tr>
<tr>
<td>Heat of convenience</td>
</tr>
<tr>
<td>Putting thermal transients to work in microstructural design</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td>Offshore wind generation</td>
</tr>
<tr>
<td>Transforming wind power</td>
</tr>
<tr>
<td>Interfacial phenomena</td>
</tr>
<tr>
<td>Where the action is</td>
</tr>
<tr>
<td><strong>Air &amp; Water</strong></td>
</tr>
<tr>
<td>Ballast water treatment</td>
</tr>
<tr>
<td>Protecting coastal and freshwater ecosystems</td>
</tr>
<tr>
<td>The Earth’s atmosphere</td>
</tr>
<tr>
<td>…as conduit</td>
</tr>
<tr>
<td><strong>Sensing &amp; Imaging</strong></td>
</tr>
<tr>
<td>The future of cognitive radio</td>
</tr>
<tr>
<td>Stretching the spectrum</td>
</tr>
<tr>
<td>Seismic signals</td>
</tr>
<tr>
<td>Magma-mapping to forecast volcanic hazards</td>
</tr>
<tr>
<td>Next-generation radar</td>
</tr>
<tr>
<td>More complexity, more information</td>
</tr>
<tr>
<td><strong>People</strong></td>
</tr>
<tr>
<td>Engineering Advisory Board</td>
</tr>
<tr>
<td>Terry Woychowski</td>
</tr>
<tr>
<td>Faculty highlights</td>
</tr>
<tr>
<td>Pasi Lautala</td>
</tr>
<tr>
<td>Wayne Pennington</td>
</tr>
<tr>
<td><strong>Research Centers &amp; Institutes</strong></td>
</tr>
<tr>
<td>Power &amp; Energy Resource Center—PERC</td>
</tr>
<tr>
<td>Multi-Scale Technologies Institute—MuSTI</td>
</tr>
<tr>
<td><strong>Contact Us</strong></td>
</tr>
<tr>
<td>College of Engineering</td>
</tr>
<tr>
<td>Michigan Technological University</td>
</tr>
<tr>
<td>712 Minerals &amp; Materials Engineering Building</td>
</tr>
<tr>
<td>1400 Townsend Drive</td>
</tr>
<tr>
<td>Houghton, MI 49931-1295</td>
</tr>
<tr>
<td>Telephone: 906-487-2005</td>
</tr>
<tr>
<td>Email: <a href="mailto:engineering@mtu.edu">engineering@mtu.edu</a></td>
</tr>
<tr>
<td><a href="http://www.engineering.mtu.edu">www.engineering.mtu.edu</a></td>
</tr>
</tbody>
</table>
Health Science
Ching-An Peng
Chemical Engineering

Pictured: A microscopic view of a typical neuroblastoma with rosette formation. Ching-An Peng and his research team have shown that neuroblastoma cells undergo premature death when they ingest antibody-tagged carbon nanotubes and are irradiated with 808-nm near infrared laser light.
Cancer nanotechnology

Targeting and eradicating tumor cells with nanomaterials

Many cancer treatments have their own sets of risks and consequences. Among those is chemotherapy, which introduces poisons or toxins into the body to damage, shrink, or kill cancerous cells. Unfortunately, chemotherapy also can destroy healthy cells, leaving the patient with serious, unpleasant side effects.

Phototherapy and molecular targeting are two separate methods that have shown great potential as localized—and therefore less invasive—cancer treatment. Ching-An Peng has been working to fine-tune them both.

“Among the many nanomaterials designed and synthesized for biomedical applications, the carbon nanotube, because of its unique ability to absorb near infrared light, is a promising option for localized phototherapy,” Peng explains.

When armed with a specific monoclonal antibody, a carbon nanotube can be ingested by corresponding cancer cells. This internalization occurs via a biochemical process whereby cells engulf the nanotube with their cell membrane.

Peng and his team have conducted phototherapy experiments using two different antibodies. One antibody is able to specifically target neuroblastoma cells. Neuroblastoma, a cancer of the sympathetic nervous system, is the most common cancer in infants. The other antibody is able to recognize glioblastoma stem-like cells. Glioblastoma is the most common and most aggressive primary brain tumor in adults. “Cancer cells ingested with antibody-tagged carbon nanotubes and irradiated with 808-nm near infrared laser light which can pass through the skin were all found to die under this light while other cells were unaffected,” says Peng.

Colorectal cancer is another focus for the team, which is investigating the use of prodrugs as an effective treatment. “Prodrugs are pharmacologically inactive molecules that require an enzymatic and/or chemical transformation to release a cell-killing drug,” Peng explains. The use of a prodrug strategy increases the selectivity of a particular drug for its intended target. Gene-directed enzyme prodrug therapy has expanded the range of tumors that are susceptible to prodrug therapy. “But until now, delivery of the prodrug and the gene have been conducted via separate routes. Our goal is to come up with a nanocarrier that contains both the prodrug and its activating gene.”

Peng’s team has developed a polymeric nanocarrier that can move drugs into the cells that they are to treat. The action of a specific enzyme, turned on by the gene, converts the prodrug into a cell-killing agent that is delivered within the targeted malignant cells. The team has demonstrated the feasibility of using this nanocarrier to eradicate those few especially malignant cancer cell lines, such as those found in colorectal cancer—a major lethal disease in the American population.
Lymphatic injuries
Finding new approaches to reduce secondary lymphedema

When someone is first diagnosed with breast cancer, one of the greatest fears is often “Has it spread?” Breast cancer tumor cells in the tumor mass commonly spread to distant sites in the body through lymph nodes and lymphatic vessels. Treatment for breast cancer often includes removing lymph nodes and vessels and examining them to determine whether or not the tumor cells have metastasized.

Unfortunately, these lymph nodes and lymphatic vessels are responsible for draining fluid from the arm and breast. Thus, as a consequence of a successful surgery to treat breast cancer, the arm can become painfully swollen and disfigured as fluid that is normally drained through the lymphatic system begins to accumulate in the arm. A cure for the swelling, known as secondary lymphedema, has not been found.

Jeremy Goldman is seeking that cure. “While enormous attention has been devoted to improving cancer detection and treatments that are enabling people with breast cancer to live longer and better lives, attention to secondary lymphedema is generally lacking,” notes Goldman.

Secondary lymphedema can cause a serious reduction in quality of life. The condition is present in approximately 25 percent of patients who have had lymph nodes removed during treatment for breast cancer.

Goldman and his team are working to find a treatment that will re-establish the lymphatic network and restore the flow of fluid away from the swollen arm. One approach includes activating growth factor receptors present on lymphatic endothelial cell membranes. “Activating vascular endothelial growth factor receptors -2 and -3 may help promote lymphatic regeneration and restore fluid drainage from the arm,” Goldman explains.

The team is employing experiments on mice. Initial results are highly encouraging. Goldman’s research has helped advance the understanding that these new lymphatic capillaries may not be functioning properly. “The reduced function may be related to a lack of interstitial fluid flow, or slow moving fluid that flows through the tissue, which occurred while the lymphatic capillaries were reforming,” he says.

Interstitial fluid flow may play an important role in distributing the growth factor in a manner that directs the organization of newly regenerated lymphatics into functional capillaries. Goldman and his team are presently working to improve the effectiveness of the growth factors by increasing interstitial flow through the tissue.

“Our research may be beneficial for anyone who has undergone surgery that removes lymph nodes in any part of the body,” he adds. “For example, it is common for surgeons to remove lymph nodes from the groin and these people often end up with lymphedema of the leg.”
By 2020, fifty percent of Americans over 50 will have weak bones.

~ United States Surgeon General
According to the Surgeon General, 44 million Americans have or are at risk to develop osteoporosis. There are over 1.5 million osteoporotic bone fractures annually, representing an economic burden in excess of $18 billion dollars per year. Aging and physical inactivity increase the risk.

Seth Donahue has established hibernating bears as a model for preventing osteoporosis. Bears are physically inactive for up to seven months a year, but do not lose bone mass or strength during hibernation or with aging.

“This preservation of bone is unique among animals,” says Donahue. “Bears have evolved many unique and extreme biological mechanisms to survive hibernation. This ability isn’t limited to black bears. Grizzly bears also keep their bones strong and healthy during prolonged periods of physical inactivity.”

The porosity of grizzlies’ bones actually decreases during hibernation, adds Donahue. “That’s completely the opposite of what happens in humans. It confirms what we’ve studied in black bears.”

Bears don’t eliminate waste when they hibernate, so instead of excreting calcium that is released from their bones, they essentially put it back where they found it.

Once Donahue verified that bears possess a special mechanism that fights off osteoporosis, the next trick was to understand it. Several years ago, he cloned the gene for black bear parathyroid hormone (PTH), which he believes contributes to the bear’s preservation of bone.

One thing worth noting: nothing about hibernation itself protects an animal’s skeletal structure. Other hibernating creatures, such as bats and ground squirrels, do get brittle bones during their long winter’s nap.

Donahue and his research team formed a company, Aurosos, Inc., in Kalamazoo, Michigan, to develop a new osteoporosis drug: recombinant black bear PTH. The drug has shown promise for increasing bone mass and strength in pilot studies on mice and rats. In the most recent study, the new drug caused more bone formation in mice than an osteoporosis drug that is currently on the market.

While animal studies are promising, the drug must make it through years of clinical trials (estimated at over $100 million) to reach the marketplace. Donahue is in it for the long haul, having worked ten years on the project thus far. “Ultimately we hope to bring this new osteoporosis drug to market to reduce fracture risk and improve the quality of life for millions of Americans.”
Interfacial phenomena
Where the action is

When things get small, all of the action happens at the interfaces—where liquid meets solid or liquid meets air. When we sweat, evaporation at the air-water interface cools our skin. Nature employs interfaces for plant transpiration and sap movement in trees. Interfaces are put to good use in a multitude of devices and tools as well. From seemingly ordinary items such as house paint and duct tape to highly advanced hydrogen fuel cells, the action of interfacial phenomena is ubiquitous.

Jeff Allen established the Microfluidics & Interfacial Transport Lab (MnIT) to study and advance the understanding of interfacial phenomena, particularly gas-liquid interfaces where capillary forces are important. “Capillary force typically implies that the system is small; less than a millimeter,” Allen explains. “However, capillary scale really means that surface tension forces are more important than gravitational forces at a gas-liquid interface. There are two ways to make surface tension important relative to gravity. The first is to shrink the size and the second is to shrink gravity. So capillary scale can also mean low-gravity or extraterrestrial.”

In the MnIT lab, Allen and his team are studying evaporation and condensation in low gravity. “NASA, as well as all other space agencies, would like to recycle waste water in space. The easiest method is to evaporate water out of the waste stream and condense the purified water where it can be used. This works well on Earth because gravity can be used to keep the liquid film in place while evaporating. Unfortunately, it’s not easy to keep a liquid layer stable while evaporating in space. Capillary forces become important when gravitational forces are reduced. The combination of capillary forces, internal convection, and evaporation results in destabilization of the liquid film.”

The team is also investigating how water moves through the small channels that distribute hydrogen and air in fuel cells. “We are examining exactly how water percolates through fuel cell electrodes, typically teflonated carbon paper. The channels are small enough that capillary forces are very important.” In order to carry out these studies, the team is developing advanced high-speed microscopy techniques. “Everything is small and moves fast.”

Fuel cells hold great promise for the future automobile. “Our inability to properly manage the water produced in a fuel cell results in its rapid degradation,” adds Allen. “Currently the best method for optimizing fuel cell electrodes for water management is a tough and expensive trial-and-error process. Our research enables fuel cell optimization and performance predictions to be completed before building and testing a full-size fuel cell stack—something we hope will help bring reliable, durable automotive fuel cells to consumers in the near future.”
Pictured: An example of microfluidics and interfacial effects. The spider's specialized gland is, in effect, a microfluidic chemical reactor that creates a composite 'silk' fiber. Dew drops stay attached in spherical form because at their small size, capillary forces are much stronger than gravity.
Wind-generation capacity worldwide, as a form of electrical energy, has doubled each year for the past three years.
Offshore wind generation
Transforming wind power

Siting wind farms offshore offers several advantages. Wind speeds tend to be higher, and the wind is steadier. But technological challenges are great: a corrosive saltwater environment; hostile storms and waves; and an undersea cable collection system which spans between widely dispersed generators and connects to the grid at a shore station far away.

The offshore waters of northern Europe, in particular, have a high concentration of offshore wind farms. Generator sizes in these farms are now reaching 5 MW and are expected to increase to 10 MW within the next few years.

Bruce Mork and his research team have been working in cooperation with the Norwegian University of Science and Technology (NTNU) in Trondheim for the past ten years to develop improved computer modeling tools for high-voltage power transformers. Building on their successful collaborations, Mork and his Norwegian colleagues, Hans-Kristian Høidalen and Marta Molinas, now seek to both improve electrical conversion efficiency and decrease the installed cost of generators and their collection system using the novel approach of high-frequency transformation and dc collection.

According to Mork, a high-frequency transformer could reduce weight, size, and cost of the power converter in a wind turbine—something that first requires fundamental research on the behavior of the transformer at frequencies in the range of 10 kHz. “Transformers at 400 Hz are used today in ships and airplanes to save space and weight, but to go above 1 kHz requires new solutions—specifically the development of magnetic core materials and the handling of capacitive effects,” he says.

Mork and Høidalen will take the lead on the transformer and dc collection system, while Molinas and another Michigan Tech researcher, Wayne Weaver, will address the power electronics. To facilitate wind power integration, they will mount a small, lightweight, high-frequency converter-transformer device in the generator nacelle which sits on top of the tower. “Traditional designs either would have the transformer at the base of the tower, or if the transformer was in the nacelle it would add a lot of weight and cost,” notes Mork.

“We are seeking a somewhat higher voltage output from the generator into the collection system. By going to dc instead of three-phase ac, we can come up with a much less expensive collection system which simply uses a single daisy-chain connection from tower to tower.”
Ballast water treatment
Protecting coastal and freshwater ecosystems

The Great Lakes ecosystem, a highly valued freshwater resource, is world-renown for its transportation and manufacturing industries, sport and commercial fishing, recreation and tourism. Since the 1800s, more than 160 non-indigenous aquatic nuisance species (ANS) have invaded the Great Lakes ecosystem from around the world, causing severe economic and ecological impacts.

The release of ballast water from ocean-going ships is a major transport mechanism for ANS. Approximately 96 billion gallons of foreign ballast water are discharged annually in US waters. Carried in this water are plants, animals, bacteria, and pathogens. These organisms range in size from microscopic to large plants and free-swimming fish. All have the potential to become aquatic nuisance species—and may displace native species, degrade native habitats, spread disease, and disrupt human social and economic activities that depend on water resources.

Finding a balance between safe commercial shipping and protecting the coastal and freshwater ecosystems from ANS is attainable. The answer: sound and proven water treatment practices. David Hand is using his drinking water treatment expertise to develop an emergency ballast water treatment process that can be used by the shipping industry.

The process Hand has developed consists first of adding simple household bleach (sodium hypochlorite) in small quantity to the ballast water of a ship to inactivate ANS, followed by neutralization of the residual bleach using ascorbic acid (vitamin C) prior to discharge of the ballast water. “This process is both safe and cost effective,” he notes. “The drinking water treatment industry has been using this process for disinfection of drinking water for many years.”

With good initial results, Hand tested his method on the Ranger III, a National Park Service vessel that shuttles visitors and staff between the mainland and Isle Royale National Park. The Great Ships Initiative (GSI) has since conducted independent lab tests on his system at the University of Wisconsin–Superior to help determine whether it is safe, effective and inexpensive. Other partners in the effort are the National Park Service and the US Fish and Wildlife Service.

Further shipboard tests are now being conducted by GSI and Siemens to evaluate the use of an onboard sodium hypochlorite generator. This would enable ships to make the sodium hypochlorite just prior to injection into the ballast water so they do not have to transport it onto the ship.

Hand is working to develop a standard operating procedure that will be adopted by the shipping industry to curb the spread of ANS in US waters within the next three years.

“We all need to protect the resource. We really need something for all ships, as well as pleasure boats. In Lake Superior, for instance, there are five different species of lake trout on Isle Royale. We don’t want to lose that.”
The Earth’s atmosphere

...as conduit

How are energy and chemicals such as pesticides, carbon dioxide, and water transported from one region of the environment to another?

“The chemical and biological processes that take place on the Earth’s surfaces are intimately coupled with the overlying air,” explains Judith Perlinger. “An intense and complex exchange takes place when atmospheric chemicals, heat, and momentum interact with land and water surfaces.”

Perlinger conducts micrometeorological air-water exchange flux measurement above Lake Superior onboard Michigan Tech’s R/V Agassiz and the US Environmental Protection Agency’s research vessel, the R/V Lake Guardian, using the measurements to better understand environmental processes. She and her team have designed, fabricated, and tested multicapillary collection devices (MCCDs) which they use to collect semivolatile organic compounds (SOCs) present in trace concentrations in the atmosphere. The devices provide rapid, low-cost, and low-impact means to collect the compounds, and can be re-used.

This new technology has also enabled the first air-water exchange flux measurements of trace persistent organic pollutants (POPs) to be made in locations in and around Lake Superior. “Although gaseous concentrations of POPs such as PCBs and pesticides are extremely low in the remote regions, the air is, nevertheless, their primary source to the lake, and thus to the lake’s foodweb,” notes Perlinger. For example, concentrations of dieldrin, toxaphene, polychlorinated biphenyls (PCBs), and dichlorodiphenyl-trichloroethane (DDT) in Lake Superior’s water currently exceed the State of Michigan’s water quality guidelines by factors of 19, 15, 2.3, and 1.3, respectively.

Perhaps counterintuitively, the air is also the primary avenue for removing POPs from the lake once emissions have been reduced sufficiently to maintain gas-phase concentrations at low values. “Air-water exchange is an important pathway,” says Perlinger. “Because of this, national and international government policies that reduce atmospheric POPs not only help clean the air we breathe—they help clean up the waters of Lake Superior as well.”

The same micrometeorological techniques being applied to trace organics can also be applied to more abundant substances. Perlinger is applying micrometeorological techniques to study water evaporation rates and the biogeochemistry of carbon in the Great Lakes region, as well.
The future of cognitive radio

Stretching the spectrum

Cognitive radio (CR) is increasingly recognized as an emerging disruptive technology for alleviating today’s spectrum scarcity problem. Zhi (Gerry) Tian is working to solve that scarcity problem with a new paradigm of cognitive radio networks.

“CR communications and networking hold great potential to dramatically enhance spectrum utilization efficiency,” says Tian.

Radio frequency spectrum is an increasingly valuable resource tightly regulated by governments. The US and UK governments raised $17 billion and $22.5 billion respectively in their auctions of third-generation mobile phone licenses.

“On the other hand, radio access technologies are currently built on fixed spectrum allocation, which causes severe spectrum underutilization when a dedicated spectrum is idle.”

Tian cites a recent study which showed the average spectrum occupancy of all bands from 30MHz to 3GHz measured in New York City was just 13 percent during a peak period. “The imbalance between spectrum scarcity and spectrum underutilization is especially undesirable today, when significant amount of radio spectrum is needed to provide the ubiquitous wireless high-speed connectivity that we have come to expect.”

An emerging paradigm, dynamic spectrum allocation (DSA) ushers in new forms of spectrum-agile cognitive networks. Key to this paradigm are cognitive radios that are aware of the radio frequency environment and can dynamically program radio parameters to efficiently utilize vacant spectrum without causing harmful interference. Devices might include wireless sensors and radio frequency identification chipsets for monitoring and tracking applications, as well as wireless telemedicine radios for remote healthcare and emergency response. But CR research today is still at a conceptual stage. “While a key hindrance in programmable radio design has been the front-end circuit interface, the emerging open access paradigm brings up new technical challenges,” notes Tian.

Tian is systematically investigating algorithms for efficient spectrum management in CR networks. She is also conducting fundamental research to cope with major hurdles in spectrum sensing, programmable radio platforms, and adaptive dynamic spectrum allocation. By exploring compressive sampling, she hopes to develop effective signal processing techniques that exploit various elements of sparsity inherent to CR networks.
More than 500 million people, or about 10 percent of the world’s population, live within 100 kilometers of an active volcano.
Seismic signals
Magma-mapping to forecast volcanic hazards

Volcanoes produce a rich variety of seismic signals in addition to those generated during normal earthquakes. The signals that result from movement of magma or other volcanic fluids, or the resonance of fluid-filled cracks, have distinct characteristics. These characteristics make volcanoes difficult to analyze using the same methods employed to study the earthquakes that occur in such places as California’s San Andreas Fault. Yet understanding these volcanic earthquakes is paramount to determining the dynamics of magmatic plumbing systems—and ultimately to forecasting volcanic hazards.

Gregory P. Waite is using 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 and his research team hike high onto the flanks of erupting volcanoes to place seismometers, which detect ground vibrations, and infrasonic microphones, which detect low-frequency pressure waves in the air.

Their work at Mount St. Helens led to a new model to explain the cause of shallow, repetitive earthquakes associated with the recent minor eruption—an eruption that continued for several years, from 2004 to 2008.

They showed that the source of these earthquakes might consist of a shallow hydrothermal crack, filled with a mixture of meteoric and juvenile steam that is pressurized by the magmatic activity. Over a period of three to five minutes, gas pressure rises until a threshold is reached and steam is forced from the crack, causing the crack to partially collapse and resonate. The collapse of this crack, which is adjacent to the magma conduit, triggers a second type of earthquake in the magmatic system, the source mechanism of which indicates a corner in the magma conduit where the pathway deviated from that which fed earlier eruptions.

Waite’s research team is applying these techniques to study volcanic earthquakes in other areas—such as at Pacaya and Fuego volcanoes in Guatemala—and integrating data from volcanic gas emissions to better understand the role of magmatically-derived gas in the generation of volcanic earthquakes. Ultimately, this work should lead to an improved eruption prediction at hazardous volcanoes worldwide.
Next-generation radar
More complexity, more information

Dan Fuhrmann is working to develop signal design and signal processing methods for next-generation radar systems. “Radar systems are a technology for seeing things at a distance using electromagnetic waves. That is the basic principle,” he says. “What people are trying to do now is take advantage of the flexibility that new technology gives us.”

“We are basically shining a very intelligent flashlight, that sends energy where you want it to go, and not where you don’t,” Fuhrmann explains. “With new radar systems, multiple transmitters and receivers work together, cooperating, synchronized, each seeing reflections from the others. It gives a tremendous amount of flexibility in how you illuminate an area you are trying to search,” he says.

There are several key differences. Unlike a flashlight, radar systems operate at different frequencies (i.e. microwave). Radar can look over very long (or short) distances of 10s or 100s of kilometers. “But from my point of view, the most interesting thing about radar systems is that the illumination is very structured. There is a time structure to the transmitted signals.”

Just as in TV, radio or cellular telephone signals, radar signals carry information. “One feature of radar is that allows the user to gather a lot more information in return from the signals that come back,” he notes. “But here’s what’s new—we are adding more and more levels of complexity to transmitted signal in order to get more and more information in return.”

With traditional radar signals, everyone sees the same signal. With the new systems, different signals are sent in different directions. “It’s an interesting characteristic, in that someone at one location can’t tell exactly what a transmitter at another location is doing. They don’t necessarily have all the information,” adds Fuhrmann. “There is also flexibility in how you illuminate any small target that you are trying to track. We can direct illumination on a particular object, with either a narrow beam or a broad spotlight, depending on how it is moving.”

A radar beam can be as narrow as a pencil or even a laser pointer, though in that case, “We need to know what we’re looking at.”

Modern radar systems include high-speed digital-to-analog, or D/A, converters. “We might be able to compute a signal that you want to transmit to the tracked object, and then D/A conversion will translate the computed waveform into a transmitted signal.” New radars may compute signals “on the fly” as well. The advantage? Being able to select the transmitted signal adaptably to achieve a particular surveillance objective. “A tracking radar operates just like a spotlight following an actor on a stage,” Fuhrmann points out. “The more control one has over the spotlight, the better.”

Signals can be adapted to the environment to minimize the amount of clutter (reflections from the ground); to keep energy on the target; and finally, to illuminate only the target object and nothing else. “We want the data coming back to be informative. You can learn a lot about what you’re trying to see by using the appropriate signal.”
Next-generation radar system beampatterns, depicted using visualization tools written in the programming language MATLAB. The upper panel shows the beampattern for one transmitter, and the lower panel shows the composite beampattern created by multiple transmitters working together.
Engineered Materials
Composite aircraft materials

Understanding aircraft aging

While the average age of a commercial aircraft in the US is fifteen years, the age of a plane in the US Air Force fleet is twenty-three years on average—and the age of many transport aircraft and aerial refueling tankers is over forty years. Under current plans, some planes may be in use for as long as eighty years before being retired. And, since the price for next-generation planes has risen faster than inflation, average aircraft age will continue to climb.

The long-term durability of the composite materials commonly used in military and civilian aircraft, however, is somewhat of a mystery. Many aircraft are made at least partially out of polymer composite materials—very strong carbon fibers embedded in a polymer matrix.

Greg Odegard is using multiscale modeling tools to simulate the process of aging in polymer composite materials. “These materials are tough and lightweight, which is important for safe and fuel-efficient aircraft,” says Odegard. “But exposure to long durations of elevated temperatures and harsh environments can take a significant toll on polymer composites, limiting the lifetime of aircraft structural components.”

Odegard and his research team are simulating motion and interaction of individual atoms, as well as the resulting performance of large-scale structural aircraft components. “This process links the molecular aging mechanisms with predicted bulk-level mechanical behavior,” he explains.

The team runs molecular simulations continuously on several high-performance computers. Individual simulations can take up to several days to complete. “Although these simulations only predict events on the nanosecond time scale, they can provide a tremendous amount of physical insight into the influence of aging on mechanical behavior when combined with experimental data,” he adds.

“During the aging process, polymer composites can absorb moisture, become densified, and/or chemically break down via oxidation. All of these mechanisms work to weaken the material. A better understanding of key aging processes could lead to improved material design and performance. Over the next couple of decades, these research results could be used by commercial and military aircraft manufacturers, the US Air Force, and NASA to guide improved aerospace material development and aircraft material inspection procedures.”
Heat of convenience
Putting thermal transients to work in microstructural design

Temperature is one the most important tools available to manufacturing engineers as they process materials into useable forms with specialized properties. Temperature is used to melt materials prior to casting, to soften materials in order to facilitate deformation and shaping, and to heat-treat materials to establish a property mix appropriate for specific applications.

In applying each of these processes individually, energy is often redundantly applied and expended in multiple steps. Many processes utilize concentrated sources of heat that dissipate through the work piece as it is fabricated. Typically, this heat is removed and discarded as an artifact of the process.

Stephen Kampe is applying strong computational modeling to reveal the thermal history at any point within a workpiece. “This information can be combined with traditional metallurgical knowledge to create microstructural predictions as a function of exact position and time,” he explains. “With creative use of manufacturing protocol, material properties can be varied and customized at specific locations within the piece. For example, we can create a tough, notch-insensitive form of a material where needed near a fastener or filet, and a strong, load-resistant material elsewhere in the same component.”

Kampe’s research focuses on the creation of structurally-effective, position-customized microstructures that rely on the kind of transient thermal environment that is created as a byproduct of the fabrication process. “The heat that is produced as an artifact of friction-stir processes can be used to create precipitation-hardened aluminum alloys,” he explains. “Or—titanium alloys undergoing melting and solidification during laser manufacturing processes can be heat-treated point-to-point if the heat input and removal can be described and managed.”

An electron beam selected-area diffraction (EBSD) image of a laser-processed titanium alloy shows a microstructural transition from a slowly-cooled, coarse structure (right) to a more rapidly cooled, finer structure (left).
Terry Woychowski

We can do something.

Certain problems can seem overwhelming—so large they often feel as though any personal effort would make no difference at all. But that’s not true, says Terry Woychowski, vice president, global vehicle program management at General Motors. We may not be able to solve the entire problem, but we can do something.

Last spring, at Woychowski’s urging, Michigan Tech joined hands with GM and the Engineering Society of Detroit to offer a one-semester course in advanced propulsion technology. The goal: to enable displaced engineers from all three Detroit automakers and the supplier base to meet the growing demand for workers skilled in green automotive technologies. Students learned the fundamentals of controlling and calibrating hybrid vehicle powertrains to meet fuel economy and emissions targets. Michigan Tech provided full scholarships for all sixty students to cover the cost of tuition and fees.

The course will be offered again this fall to an additional 100 engineers backed by federal funds through the Michigan Department of Energy, Labor and Economic Growth and the Michigan Academy for Green Mobility.

“People who can create these advanced propulsion systems and calibrate them are rare and will be in great demand,” adds Woychowski, a mechanical engineering alumnus of Michigan Tech. The course includes online lectures by Michigan Tech faculty and hands-on labs at the GM Milford Proving Ground and Pontiac Powertrain Headquarters run by volunteer GM engineers, including some recent retirees.

Further demonstrating his ability to overcome hurdles, Woychowski recently put the resources of his family foundation behind a Michigan Tech student Senior Design project to make a grain mill that can withstand the challenges of African village life.

Traditionally, African farmers have had two choices: hauling grain to the local mill and paying to have it ground into flour, or grinding it themselves by hand with a mortar and pestle.

Ten-year-old Solomoni Mafuta, of the village of Sentani in the Republic of Malawi, hauls his family’s maize on foot for ten miles (one way) to a diesel-powered mill to be ground. The time-consuming task has pulled him away from his studies and to the verge of flunking out of school.

Woychowski has a special interest in advanced propulsion systems, which are notable for their complexity. But when he offered to underwrite the effort to build a grain mill that would work in Africa, he stipulated that it had to be low tech: simple, cheap and made with materials available locally. Students were forced to think differently about design. Every dollar, not just every hundred dollars, counted.

In the end, they built a mill with Solomoni in mind. Powered by an old bicycle, a ten-year-old boy could hop on and grind his family’s maize just by pumping the pedals. It produces a fine flour, which is cooked in boiling water. The end result is nshima, a staple dish in Malawi and many sub-Saharan countries that is similar in consistency to mashed potatoes.

Jamie Woychowski, Terry’s daughter and executive director of the Woychowski Charitable Foundation, traveled to Zambia to transfer the design plans and spearhead the manufacturing of the first five mills. “Our design will be improved upon by the inhabitants of this region,” Michigan Tech student Nathan Fetting predicted, since they know the local materials and how best to use them. If the effort is successful, many more will be built, in partnership with the World Hope International Foundation.

The biggest change will come about if Africans themselves incorporate the mills into their local economies. “The real win would be if someone starts a microbusiness to manufacture these,” said Woychowski. “Then the people who make them could earn enough to buy one.”
“We may not solve the entire problem, but we can do something. Just like the closing remark in the famous starfish story by Loren Eiseley, ‘I made a difference for that one.’”

~Terry Woychowski

Terry Woychowski, a 1978 mechanical engineering graduate of Michigan Tech, is vice president, global vehicle program management at GM North America.
Pasi Lautala directs Michigan Tech’s innovative Rail Transportation Program. One of the first rail programs in the nation, its mission is to advance both education and research across disciplines.

“The railroad industry is hungry for young people with interest and education in rail transportation,” says Lautala, a research assistant professor who earned his PhD at Michigan Tech.

He brought the railroad bug with him when he came to the university from Finland in 1996 as an exchange student working on his Master’s degree. The son of a locomotive engineer, Lautala had grown up in a culture that embraced rail transportation as a sustainable public transit option as well as an efficient way to move freight.

While the US still has the most extensive and efficient freight rail system in the world, the development of railroads was “forgotten” for decades, while the rest of the world kept moving forward, he observes. “Freight rail transportation is enjoying a renaissance in this country and it seems that passenger rail is finally starting to make a serious comeback. Rail just makes sense, and it’s something this country needs.”

Under Lautala’s guidance, the Rail Transportation Program has attracted strong support from the railroad industry. Corporate sponsors include Canadian National Railway (CN), CSX Corporation, and Union Pacific. CN recently gave Michigan Tech $250,000 to establish the Rail Transportation Education Center, a physical home for the program.

Lautala also founded and leads the program’s innovative Summer in Finland, which integrates an international component to rail education. In its first six years, ninety-five students from multiple universities and disciplines have completed the intensive five-week program, a collaboration among Michigan Tech, the Tampere University of Technology, and the North American and Finnish railroad industry.

IBM recently unveiled plans for its Global Rail Innovation Center in Beijing, China, inviting Lautala to join the center’s new advisory board. Other new members include: Massachusetts Institute of Technology Professor Joseph M. Sussman; Judge Quentin L. Kopp, chairman of the California High Speed Rail Authority; the German railroad Deutsche Bahn; Motorola; Railinc Corporation (a subsidiary of the American Association of Railroads); and Sabre (a travel network).

“IBM is modeling a new way of thinking about rail transportation, one that is not bound by national borders,” says Lautala. “Countries worldwide are recognizing the importance of rail transportation and accelerating their efforts to develop twenty-first century rail systems.”

Lautala worked for two years with the Finnish Railway system and five years as a railroad and highway engineering consultant in Chicago before earning his doctorate in civil engineering.

Railroad systems research is a top priority: “There are many possibilities—everything from infrastructure, with automated track-monitoring systems and recycled materials in railroad ties, to more-efficient equipment and operations,” he notes. One of Lautala’s current projects involves the synthesis of railroad engineering best practices in deep seasonal frost and permafrost areas.
Wayne Pennington
Jefferson Science Fellow

Wayne Pennington, chair of the Department of Geological & Mining Engineering and Sciences, has been named a Jefferson Science Fellow by the US Department of State. The Jefferson Science Fellowship was established to create opportunities for substantial engagement of tenured scientists and engineers from US academic institutions.

Pennington will serve a one-year assignment working full-time as a Senior Engineering Advisor with a group at USAID, the Agency for International Development. He will help improve methods of infrastructure development for increased capacity building, particularly in post-disaster and post-conflict settings in Pakistan and Afghanistan. His focus will be primarily on improved energy development and distribution, and on earthquake hazard mitigation.

A geophysicist, Pennington’s research is centered on the response of Earth materials to changes in physical conditions, such as stress, saturation, and temperature. The applications of this work are found in induced seismicity, deep earthquakes, as well as oil and gas exploration and development.

Pennington has worked in both academia and in industry and has conducted fieldwork at sites around the world. In the 1970s, he studied tectonic earthquakes in Latin America and Pakistan. In the 1980s, at the University of Texas at Austin, he studied the relationship of earthquakes to oil and gas production. Following that, he worked at the research laboratory for Marathon Oil Company, studying techniques to improve the identification of, and production from, oil and gas reservoirs. Since 1994, he has been at Michigan Tech, teaching and conducting research into geophysical observations of oil and gas production.

He has served as the first vice president for the Society of Exploration Geophysicists, published over thirty papers, and coauthored a book (with his students). His degrees are from Princeton University, Cornell University, and the University of Wisconsin-Madison.
The words of Thomas Jefferson in an inscription on the southeast interior wall of the Jefferson Memorial in Washington, DC.

I AM NOT AN ADVOCATE FOR FREQUENT CHANGES IN LAWS AND CONSTITUTIONS. BUT LAWS AND INSTITUTIONS MUST GO HAND IN HAND WITH THE PROGRESS OF THE HUMAN MIND. AS THAT BECOMES MORE DEVELOPED, MORE ENLIGHTENED, AS NEW DISCOVERIES ARE MADE, NEW TRUTHS DISCOVERED AND MANNERS AND OPINIONS CHANGE, WITH THE CHANGE OF CIRCUMSTANCES, INSTITUTIONS MUST ADVANCE ALSO TO KEEP PACE WITH THE TIMES. WE MIGHT AS WELL REQUIRE A MAN TO WEAR STILL THE COAT WHICH FITTED HIM WHEN A BOY AS CIVILIZED SOCIETY TO REMAIN EVER UNDER THE REGIMEN OF THEIR BARBAROUS ANCESTORS.
Although nanoscience has been studied and practiced for centuries as chemistry, biology, and physics, the promise of applying these sciences to engineered materials and living systems is truly exciting.

The Multi-Scale Technologies Institute (MuSTI) at Michigan Tech promotes interdisciplinary research and the implementation of nanotechnologies and microtechnologies into deployable systems. This presents many challenges where physically and functionally compatible devices and components differ in size by thousands or millions of times. The design, fabrication, integration, and testing of such systems are of particular importance.

Nano researchers at MuSTI investigate a wide range of topics, from wood products that reduce environmental impact and proteins that activate quantum-based nanoelectronics to nanostructured orthopedic implant surfaces.

Research laboratories support inquiry into many areas: nanomaterials, molecular electronic materials, nanoelectronic components, microsensors and nanosensors, thin-film deposition and lithographic processing, electron and ion optical systems, ion propulsion systems for spacecraft, and advanced modeling and computing.

The Institute’s faculty and graduate students publish papers in leading journals and present at conferences on multi-scale technologies. A new graduate certificate in nanotechnology became available in Fall 2008.

MuSTI also supports the undergraduate minor in nanoscale science and engineering, which gives students hands-on exposure to the tools and techniques of nanotechnology, including systems from the nano, through the micro, and into the macro domain.

Contact Craig Friedrich, director, at 906-487-1922; email craig@mtu.edu. Visit MuSTI online at www.me.mtu.edu/institutes/MuSTI.
Increased focus on alternative and renewable energy, development of new energy technologies, restructuring and deregulation of the utility industry—all are creating a wealth of technological and educational challenges for the power engineer.

Environmental issues and other recent events have expanded the focus to include public policy, system security and reliability, and economic and social concerns. Michigan Tech’s Power & Energy Research Center (PERC) was created to address all those challenges—and more.

PERC is a cross-disciplinary organization focusing on electrical energy, energy conversion, and related technologies and issues. Renewable energy research initiatives at PERC include photovoltaics, windpower, and microgrids.

PERC was formed in 1996 as an outgrowth of the electrical engineering power area at Michigan Tech. While maintaining its strengths in traditional power grid issues, it has expanded to include business and economics, control systems, communications systems, environmental engineering, mechanical engineering, and power electronics. Federal funding comes from the National Science Foundation and the Department of Energy.

The Center recently welcomed two new partners, Lawrence Livermore National Laboratory and Schweitzer Engineering Laboratories, Inc. Other partners include Consumers Energy, American Electric Power, and ITC Transmission.

For more information, contact Bruce Mork, director, at 906-487-2857; email bamork@mtu.edu. Visit PERC online at www.ece.mtu.edu/perc.
Research Centers & Institutes

**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 (CEBFM)
- Center for Fundamentals and Applied Research in Nanostructured and Lightweight Materials (CNLM)
- Center for Integrated Systems in Sensing, Imaging, and Communication (CISSIC)
- Center for Science and Environmental Outreach (CSEO)
- Center for Structural Durability (CSD)
- Center for Technological Innovation, Leadership and Entrepreneurship (CenTILE)
- 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

**Research Institutes**

- Computational Science and Engineering Research Institute (CSEI)
- Earth, Planetary and Space Sciences Institute (EPSSI)
- 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)
- Multi-Scale Technologies Institute (MuSTI)
- National Institute for Climatic Change Research (NICCR)
- Sustainable Futures Institute (SFI)
- Technology Development Group (TDG)
- Tribal Technical Assistance Program (TTAP)
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

Wayne D. Pennington
John S. Gierke (Interim)
Geological & Mining Engineering and Sciences
Mark R. Plichta
Materials Science & Engineering
William W. Predebon
Mechanical Engineering-Engineering Mechanics

Engineering Advisory Board
Mr. George C. Aram
Vice President, Quality, Neurological Sector
Medtronic Inc.

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

Mr. Peter Farner
Founder and Principal
TGap Venture Capital LLP

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

Dr. Thomas R. Hanley
Professor of Chemical Engineering
Auburn University

Mr. Randolph Hill
Vice President of Operations
Ziehm Medical

Ms. Holly Hillberg
Chief Technology Officer
Carestream Health

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

Ms. Susan B. Kiehl
Director, F-16 Greece and Italy Programs
Lockheed Martin Aeronautical Co.

Mr. Charles S. Knobloch
Partner
Arnold & Knobloch LLP

Mr. Kenneth G. Murray
Global Services Manager
Network Appliance Inc.

Mr. Louis H. Pomerville
Detroit Edison Company (retired)

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

Mr. William R. Van Dell
President and CEO
Primarion – California

Mr. Mike Waara
IBM Corporation (retired)

Dr. Terry J. Woychowski
Vice President, Global Vehicle Program Management
General Motors Corporation

Department Chairs
Michael R. Neuman
Biomedical Engineering

William M. Bulleit
Civil & Environmental Engineering

S. Komar Kawatra
Chemical Engineering

Daniel R. Fuhrmann
Electrical & Computer Engineering

Jean-Celeste Malzahn Kampe
Engineering Fundamentals

CONTACT US
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.