A transdisciplinary team led by Michigan Tech investigates Great Lakes atmosphere-surface exchangeable pollutants and their impacts through policy, socioeconomic pressures, ecosystem services, stressors like climate change and land use, and biogeochemical cycling.
Research Spotlight

10 Elasticity of Electricity  
by Kelley Christensen  
The power goes out. Why? And how can we prevent it? The security of the electrical grid comes down to building resilience in technologies, infrastructure, and communities.

18 When Can We Eat the Fish?  
by Allison Mills  
Fish consumption advisories were meant to be temporary, but mercury and other pollutants will move through Upper Peninsula soil and water for generations.

28 A Bright Future for Energy  
by Jennifer Donovan  
Yun Hang Hu takes conceptual materials for energy devices and makes them a reality. He is the dual winner of the Michigan Tech Research Award and the Bhakta Rath Research Award.

14 To Deep Space and Beyond  
by Kelley Christensen  
From take-off to orbit to space travel to Mars, Michigan Tech researchers explore the depths of space and engineer the systems to take us there.

24 Exercise for Every Body  
by Stefanie Sidortsova  
Step one: Set up a lab with lots of stationary bikes and specially-engineered exercise equipment. Step two: Get moving. Step three: Figure out the limits of the human body.
Regular Features

06 Research in Brief
30 Awards and Honors
32 Innovation Shore
34 Research Centers and Institutes
35 Research and Sponsored Activity

Research is published by University Marketing and Communications and the Vice President for Research Office at Michigan Technological University, 1400 Townsend Drive, Houghton, Michigan, 49931-1295.

David Reed
Vice President for Research

Cathy Jenich
Assistant to Vice President for Research

John Lehman
Associate Vice President for Enrollment and University Relations

Ian Repp
Director of University Marketing and Communications

Crystal Verran
Director of Operations

Allison Mills
Director of Research News

Vasilissa Semouchkina
Senior Designer

Stefanie Sidortsova
Director of Communications and Public Relations

Jennifer Donovan, Shannon Rinkinen, Cyndi Perkins
Writers

Jon Halquist, Kaye LaFond
Designers

Sarah Bird
University Photographer

mtu.edu/magazine

@michigantech
@michigan_tech

Michigan Technological University is an equal opportunity educational institution/ equal opportunity employer, which includes providing equal opportunity for protected veterans and individuals with disabilities.
Freshwater Flights Reveal What Lies Beneath

udders. Propellers. Missing hatch covers. Broken masts. The Great Lakes Research Center (GLRC) uses sonar-equipped autonomous underwater vehicles (AUVs) to probe the skeletons of historic shipwrecks. The ability to provide ultra-high resolution acoustic images brought GLRC researchers to the Thunder Bay Sanctuary in Lake Huron in summer 2017, helping find the Choctaw and the Ohio, two recently discovered nautical graveyard dwellers, about 15 miles off the coast of Michigan’s Presque Isle.

GLRC director Guy Meadows joined research scientists Jamey Anderson and Chris Pinnow aboard the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Vessel Storm. They operated the center’s IVER3 AUV, which uses an advanced sonar system, the EdgeTech 2205.

“Our portion of the mission was to use Michigan Tech’s AUV to fly close to these very deep shipwrecks and obtain sonar images of the precise dimensions and details to aid archaeologists in identifying the lost ships,” Meadows explains. “Our IVER3 performed beyond our expectations and acquired spectacular sonar images of each wreck.”

The Great Lakes Research Center uses an IVER3 underwater autonomous vehicle (UAV) to survey shipwrecks.

- Norman
  The 296-foot steel-hulled bulk freighter vessel Norman, built in 1890, was hit by the Canadian steamer Jack near Presque Isle on May 30, 1895.

- Choctaw
  Built in 1853, the 266.9-foot steel Choctaw experienced a litany of accidents—grounding, partial sinking, and a collision involving a full sinking—before the ship went down in 1915. The final resting place was lost until last summer.

- Typo
  The Typo, a 137-foot, three-masted schooner built in 1873, sank in a collision October 4, 1899 in Lake Huron. Her ship’s bell is intact; the hold is full of coal.
Ohio
The 202-foot wooden bulk carrier Ohio is an early version that evolved into an iconic Great Lakes ship following the introduction of steam propulsion as an alternative to sail power.

Wrecks Around
The Ohio met her demise in 1894; the Choctaw in 1915, both sunk in collisions with other vessels. No lives were lost on those ships, but five died on the Ironton, the schooner barge whose towline parted, causing an ill-fated collision with the Ohio. The Ironton has not been found, one of 100 or more undiscovered shipwrecks in the approximately 4,300-square-mile Thunder Bay sanctuary. In all, the Great Lakes are the final resting place for more than 6,000 shipwrecks, with only about 1,000 identified.

How many more watery graves will be articulated thanks to AUV imaging?

Funding
NOAA grant awarded to Friends of the Thunder Bay National Marine Sanctuary.

Creating a Smarter Stent

The challenge with biodegradable stents is that the same process that heals, prevents the stent from fully disappearing. That’s why Jeremy Goldman, a professor of biomedical engineering, is looking into different options.

“We jumped out of the box. Instead of manipulating the materials being used, we went with an entirely different metal—zinc.”

Goldman’s lab has looked at corrosion rates, inflammatory response, biocompatibility, surface interactions, and mechanical properties of zinc-based biodegradable stents. One of their studies—a 20-month survey of the metal in rats—shows the wire steadily corrodes, but not too quickly.

Fruit Flies and Where to Find Them

Look beyond the fruit bowl.

Thomas Werner, an assistant professor of biology, together with John Jaenike, a colleague from the University of Rochester, authored the first regional fruit fly field guide produced in nearly 100 years. Their book, *Drosophilids of the Midwest and Northeast*, covers 55 species of fruit flies, with detailed images and descriptions.

Werner’s lab work with fruit flies focuses on their genes, which offer insight into human cancer. A suite of genes can mutate in fruit flies, leading to a variety of spots and patterns. The same genes in humans can lead to cancer. Werner has received funding from the National Institutes of Health (NIH) and National Science Foundation (NSF) to study these toolkit genes in *Drosophila guttifera* fruit flies.

Hear Werner’s story about collecting butterflies and growing up in East Germany: mtu.news/2m8D1lr

Merelaniite: Mineral of the Year

Look closer! The tiny whiskers on that geological sample might turn out to be an entirely new mineral.

That was the case with merelaniite, an exotic new mineral discovered by a team of researchers led by John Jaszczak, a professor of physics.

Named for the region in Tanzania where it originates, the International Mineralogical Association declared merelaniite Mineral of the Year for 2016.

Meet the mineral: mtu.news/2inPPW5

2017 Research Highlights

- The Michigan Pipeline Safety Advisory Board unanimously recommends Michigan Tech to organize and lead state universities in an independent risk analysis of the Line 5 Straits Pipelines.

- Michigan Tech startups Orbion Space Technology firm and Novolux, a registered trademark of Stabilux Biosciences, brought home more than $500,000 from the 2017 Accelerate Michigan Innovation Competition.

- A research team starts a $1.8 million National Institutes of Health (NIH) study to understand alcohol’s effects on sleep, blood pressure, and brain activity.

- A $1 million National Science Foundation (NSF) grant will provide scholarships and program support to students from diverse backgrounds in the School of Technology.

Subscribe to weekly news updates from Michigan Tech at mtu.edu/news
Turrialba Volcano is an active volcano in central Costa Rica. Credit: Simon Carn

Volcanoes Around the World

Boots on the ground and eyes in the air reveal much about the inner workings and emissions of volcanoes.

There is no mint that can take the edge off sulfurous emissions from volcanoes, but researchers can use remote sensing to better understand volcanic breathing. Likewise, understanding the breathing patterns of volcanoes make it easier to track their near-time emissions via satellites. Simon Carn, an associate professor of volcanology, co-authored three papers in Scientific Reports and Science that detail the sulfur dioxide and carbon dioxide emissions of volcanoes around the globe using the Aura satellite and Orbiting Carbon Observatory-2 (OCO-2) satellite.

“Many people may not realize that volcanoes are continuously releasing quite large amounts of gas, and may do so for decades or even centuries,” Carn says. “Because the daily emissions are smaller than a big eruption, the effect of a single plume may not seem noticeable, but the cumulative effect of all volcanoes can be significant. In fact, on average, volcanoes release most of their gas when they’re not erupting.”

NASA featured Carn’s work in its 2017 earth observation research highlights. Monitoring changes in sulfur dioxide, carbon dioxide, hydrogen sulfide, and water vapor laced with heavy metal emissions could help better predict eruptions. It also provides insight into the internal plumbing of volcanoes.

“It can take a long time to build up some magma bodies,” says Chad Deering, an assistant professor of geology. “But it may not be in an eruptible state that whole time.”

Deering co-authored a paper in Science that looks at what’s going on inside a New Zealand shallow magma reservoir lying below an active volcano. By studying the geochemistry of zircon minerals, the study found a colder, more solid place than expected.

“To understand volcanic eruptions, we need to be able to decipher signals the volcano gives us before it erupts,” says Jennifer Wade, a program director in the National Science Foundation’s Division of Earth Sciences, which funded Deering’s research. “This study backs up the clock to the time before an eruption and uses signals in crystals to understand when magma goes from being stored to being mobilized for an eruption.”

Eruptions have also had significant influence in the past. Deering is also a co-author on a paper published in Nature Geoscience that pulled together evidence for alkaline volcanism that preceded a major spike in atmospheric carbon dioxide prior to the Cambrian explosion of life.

Visit New Zealand with Deering’s lab and local K-12 teacher, Sara Moilanen: blogs.mtu.edu/geo-nz
Parity-Time Symmetry

Imagine a clock counting time into the future while its mirrored reflection runs backward. This counterintuitive construction is a simple representation of what is called a parity-time symmetry.

The new concept of parity-time symmetry and non-Hermitian engineering is shaping the research landscape in optics and photonics; engineers and physicists are using these concepts to build new types of light sources and optical sensors. The topic is the focus of two review papers in Nature Photonics and Nature Physics, both co-authored by Ramy El-Ganainy, an associate professor of applied physics.

He explains that parity-time symmetry is an example of how explorations in quantum mechanics successfully make their way into engineering application.

Saving Lives and Money: The Potential of Solar and Coal

In a study published in Renewable & Sustainable Energy Reviews, an interdisciplinary research team from Michigan Tech compared the cost of combusting coal in terms of human lives with the potential benefits of switching to solar.

By swapping solar photovoltaics for coal, the US could prevent nearly 52,000 premature deaths a year, potentially making as much as $2.5 million for each life saved.

“Unlike other public health investments, you get more than lives saved;” says study co-author Joshua Pearce, a professor of materials science and electrical engineering. “In addition to saving lives, solar is producing electricity, which has economic value.”

Weight Expectations

Ever reached for an object you anticipate is heavy, only to discover it’s actually quite light? That forceful first yank is informed by our unconscious memory, which the brain builds from a lifetime of experiences teaching us a big suitcase in the trunk of a car is going to be heavy. But what if there were a second suitcase? Your conscious memory of your experience with the first suitcase might lead you to ease the second one more tentatively out of the vehicle.

Context may not be everything, but it’s up there with content when it comes to our memories. Kevin Trewartha, an assistant professor of cognitive science and kinesiology, led a recent study about linking actions and objects, published in Cognition.

Context can alter something as basic as our ability to estimate the weights of simple objects. As we learn to manipulate, context can even reveal the interplay of two memory systems.

The study may also shed light on the long-term effects of multitasking. While distractions might not interfere with building unconscious memories, they may be keeping us from developing the robust web of conscious memories we use to remember specific experiences.
Science with a Side of Parody

Sometimes you have to sing to make your point. Using humor and song, science communicators show how gender bias in higher education plays out in The Mathematikado.

This past fall, Laura Kasson Fiss, a research assistant professor in the Pavlis Honors College, and Andrew Fiss, an assistant professor of technical and professional communication, presented a lecture on The Mathematikado at the annual meeting of the British Science Association. It’s the longest running science festival in Europe—and a great place to break the fourth wall of traditional STEM to add in A for art.

“Women in STEM was a big theme of the British Science Festival, and we were pleased to offer a historical perspective. We feel it’s important to tell stories about women being funny about science to counter some of the equally important but more dismal narratives from the nineteenth century.” Andrew Fiss and Laura Kasson Fiss on The Mathematikado

In the spirit of STEAM, Fiss and Fiss joined three colleagues to perform three songs from The Mathematikado to illustrate their lecture. The musical parody, named for Gilbert & Sullivan’s 1886 light opera The Mikado, was originally written and first performed by nineteenth-century female students from Vassar College. When they weren’t singing, the Michigan Tech researchers discussed how the authors used humor to argue that women could learn college-level math and science.

The event was sponsored by the British Society for the History of Science and the History of Science Section of the British Science Association.

Mobility

The movement of people, goods, and information

Snow. Offline. Combat. There are many real-world scenarios where mobility is needed. Interdisciplinary teams at Michigan Tech tackle research challenges in the air, on land, and even underwater.

By Air

Research scientist Colin Brooks flies unmanned aerial vehicles (UAVs) to take full-sized, high-definition digital images, and then feeds them into satellite data. Brooks led the Michigan Tech Research Institute team that developed, tested, and demonstrated how UAV technology can provide visual inspections of Michigan Department of Transportation (MDOT) infrastructure from the air. The team collected optical, LiDAR, and thermal data types to produce a detailed view of MDOT structures and locations of interest.

Under Water

A quick dive into Lake Superior is a solid first test for projects slated for polar waters, and costs much less than full Arctic research. For example, Zhaohui Wang, an assistant professor of electrical and computer engineering, develops underwater communication networks using acoustic signals. Under Lake Superior’s February ice, the signals propagate much farther than anticipated.

On Land

Paving the way on the ground, Michigan Tech is one of eight universities selected to participate in a new collegiate competition—AutoDrive Challenge—hosted by GM and SAE International.

In the challenge, students from the Robotics Systems Enterprise design, build, and test a fully autonomous vehicle. They will start with a Chevy Bolt and outfit it with sensors, control systems, and computer processors to successfully navigate an urban driving course in an automated driving mode. And they have three years to make it happen—plenty of time to master the winter driving courses at the Keweenaw Research Center.

The Keweenaw Research Center winter test track features more than 100 lane miles, both smooth and rough ice rinks, slopes graded between 15 percent to 40 percent, and a number of obstacles from curbs to rocks to telephone poles that military vehicles can traverse.

Visit mtu.edu/mobility
For many Americans, flipping a switch and knowing the lights will come on is a given. Electricity is something we take for granted, assuming that because we paid our electric bill the utility will be available—until it isn’t.

But what if fallen trees or failed transformers are the least of our worries? Terrorism, natural disasters, and cyberattacks are much bigger threats to the power grid. The nature of the US electrical grid, a highly centralized system subdivided into three expansive territories, makes it susceptible to attack. A single outage at a substation can cascade into many.

“We imagine we’re free to use as much energy as we can pay for,” says Chelsea Schelly, associate professor of sociology. “But that’s not entirely the case, because somebody else is determining the extent to which the energy is actually resilient and secure.”
Researchers at Michigan Tech are envisioning a brighter future for the grid, building in resilience, so-called Plan Bs, and more equitable access to power.

**Lights Out**

Electrical grids include generation plants, transmission lines, central control centers, substations (more than 100,000 of them), homes and businesses, and increasingly, distributed energy production like solar panels and wind turbines. Each of these nodes is susceptible to failure from accidents, disasters, or attacks, and replacing them is expensive and time-consuming.

“Traditional terms of security used in the power industry means reliability and adequate power supply to meet demands,” says Chee-Wooi Ten, associate professor of electrical and computer engineering. “It’s N minus one contingency of a hypothesized component outage: Take one line out and see if the system can withstand a disturbance.”

Ten says this contingency has been the norm for decades in planning and operation, but the complexities of cybersecurity complicate the equation. A physical attack could damage parts of the grid, but a cyberattack to interconnected substations could cripple the entire system simultaneously.

Much of the power grid was constructed through significant public investments although many utilities are privately held; major upgrades to the system to prevent hypothetical cyberattacks largely haven’t gained traction with investors. But major cyberattacks, like the 2017 Equifax data breach and 2015 Ukraine blackouts, are now a reality.

Ten wants to incentivize investments in electrical grid cybersecurity before it’s too late. Together with Yeonwoo Rho, assistant professor of mathematical sciences, and colleagues at the University of Wisconsin–Milwaukee, Ten proposes an actuarial framework of cyber risk management for power grids.

Currently, utilities are audited by the Federal Energy Regulatory Commission (FERC) based on standards set by the North American Electric Reliability Corporation (NERC). Ten and colleagues want to create a framework that includes actuarial accounting of physical threats and cybersecurity risks. Actuarial estimates would quantify the financial costs of an attack or natural disaster. Insurance against these attacks could give bond investors the confidence they need to make big investments to upgrade security measures for the grid.
Security product vendors would see a market for their products that hasn’t been available due to lack of demand.

Such a framework would establish what Ten calls a “sustainable ecosystem” of improved security protection with technologies for utilities. He says the key impacts include increased social welfare because the risk of grid failure would decrease. It would stimulate actuarial research on challenging models such as insurance for high-impact, low-probability events. It would also provide educational activities and workforce development.

**ILLUMINATE SOLUTIONS**

Joshua Pearce, professor of electrical and computer engineering as well as materials science and engineering, advocates for diversifying energy sources to increase security.

Reformatting the old utility model and using microgrids and renewables as Plan B will require significant policy shifts, however. Pearce thinks the private sector could solve a number of problems by allowing net metering and interconnection of renewable power sources.

“This will cost the taxpayers nothing, but will demand overcoming major lobbying efforts by special interests,” he says. “The private sector will do it because wind and solar are far less costly than coal and nuclear, easier and faster to build, and avoid the unpleasant externalities.”

In terms of building grid resiliency with renewables, Pearce says the military is the best place to start.

“A federation of microgrids using local sources of renewable power is far more secure and less costly in the long term,” Prehoda says the military has a mandate that 25 percent of energy used on domestic bases will be generated by renewable sources by 2025. She notes that military leaders see climate change as a top threat, and securing bases makes sense environmentally, fiscally, and from a national security standpoint. Additionally, communities around military bases could tap into military microgrids for power in the case of a grid failure.

“With renewables, you an have up-front investment, but operation and maintenance is low on the back end,” she says. “When storage—in other words, batteries—catch up, it’s a done deal.”

**PEOPLE POWER**

Chelsea Schelly, an associate professor of sociology, is working with Pearce and Prehoda on exploring how microgrids—civilian and military—could bolster the resiliency of the grid. Schelly argues that microgrids and alternative forms of energy are not environmentalist propositions, but just plain common sense solutions.

“I study how people in society think about their relationship to material things. If we’re thinking about community well-being and resilience, it makes a lot of sense for us to be thinking about scaling down,” she says. “Microgrids or energy systems that communities have more direct control over, and therefore can make more directly reliable and accessible for their own communities, does increase quality of life.”

Cyberattacks often seem like a game of chance; playing roulette with the energy source millions of people rely on doesn’t seem like a good bet.

“If you know cybersecurity threats are more unpredictable, more variable, you know it makes sense to design a system in which a cyberattack can affect one part of the system but not the entire system,” Schelly says. “Right now, it would take little to affect the entire system.”

She says if the system was designed to handle cyberattacks, our electrical grid would look much different than it does now.

“Our electrical grid system in some ways is a magnificent feat of hubris,” she explains. “To assume this was a system that was going to work for as long as people needed energy services—it took massive amounts of investment without concern for how it was going to be maintained or who was responsible for the upkeep.”

Building resiliency now means acknowledging the system’s shortfalls and thinking outside the fuse box for better security measures.

See a microgrid assembled in under a minute at mtu.edu/magazine/microgrid
TO DEEP SPACE AND BEYOND

MICHIGAN TECH RESEARCHERS ARE PUSHING THE LIMITS OF SPACE TECH TO PUSH THE BOUNDARIES OF HUMAN SPACE EXPLORATION.
For decades, putting people on Mars has been one of NASA’s loftiest goals. But there are many reasons it’s easier said than done. Weight limitations, radiation concerns, fuel availability, and other unknown variables are all hurdles to overcome. At Michigan Tech, a number of researchers are searching for solutions.

The tasks: Find better ways to get people and the systems that sustain them off the planet; pioneer better propulsion systems for satellites, and someday, spaceships; make sure astronauts can get home.

The Right Stuff

The first step toward extended space exploration is getting the people and their equipment off the planet. The journey to Mars will take nine months. That’s a lot of pairs of underwear (not to mention water, food, oxygen, and other necessities).

Greg Odegard, the Richard and Elizabeth Henes professor of computational mechanics and affiliated professor of materials science and engineering, says a rocket/person/lander/equipment/payload could cost as much as $1 million per pound to put a person on Mars.

“It’s hard to justify that,” he says. “What if we make the payload as light as possible? We can reduce the weight of the materials that we use.”

The issue of weight persists, despite decades of research. That’s why NASA worked with Michigan Tech to establish a Space Technology Research Institute. Odegard serves as the director of the Institute for Ultra-Strong Composites by Computational Design (US-COMP), a partnership of 11 universities, two companies, and the Air Force Research Laboratory.

The team is working with carbon nanotubes and polymers to create an ultra-light, ultra-strong composite material that possesses a tensile strength stronger than diamonds. However, carbon nanotubes are so small, it’s difficult for the polymer to grip them.

“Our job as an institute is to form this material in a better way that will allow us to take advantage of carbon nanotube strength,” Odegard says.

But testing the materials is expensive. The workaround is computational modeling.

“We can model these materials at an atomic level on a computer very accurately,” he says. “We can predict what their properties would be if we made them in bulk. Computers are relatively inexpensive and fast, so we can predict how the molecular structure affects the properties without going into the lab and making anything.”

Odegard says the team is modeling a number of different nanotube-polymer composites, with the intent to provide NASA with three material designs.

“At Michigan Tech, our specialty is computer modeling at the nanometer level. All this is done on Superior, a high-performance...
FINDING FUEL: TO MARS AND BACK

“It’s not rocket science, but it is rock(et) science, because we can make rocket fuel out of rocks.”

L. BRAD KING

computer,” he says. “Specifically, we use specialized software packages to simulate the structure, motion, and interaction of the atoms in our material.”

During the months Superior is puzzling away, colleagues at other universities take the designs through the next levels of development. The other aspects of the project are training graduate students to become the next generation of aerospace materials researchers and contributing to the Materials Genome Initiative. The initiative takes the computational tools and materials the team develops and makes them available to the public—the more brains working on the issue, the better.

HAVE FERROFLUID, WILL TRAVEL

It’s said that the average human interacts with a satellite 36 times daily. Do you check the weather, use GPS to navigate, or send text messages? All these seemingly earthbound activities require space tech.

L. Brad King, the Ron and Elaine Starr professor in space systems, studies new methods of propulsion in space where there isn’t much resistance, but there are gravitational pulls, especially for “cube sats” and other small satellites.

“A satellite can’t stop at a gas station,” King says. “We focus on increasing the fuel efficiency of the engines.”

King says currently 25 percent of a satellite’s weight is fuel. Ferrofluid thrusters offer a way to bring that down to about 5 percent. Ferrofluid thrusters use magnetic fields to shape a magnetic liquid into a certain geometry, then use electric fields to form a jet of propellant. Several hundred thrusters can fit in an area the size of a postage stamp and can generate enough force for a shoebox-sized satellite. Though ferrofluid thrusters are still in development, this technological advance means a cube sat needs a fuel tank the size of a pack of gum—and saves a satellite mission a million dollars.

Ferrofluid thrusters don’t offer much in the way of speed, but they are very efficient for a long time. Satellite missions are often aggregated onboard a single rocket, and tiny satellite hitchhikers aren’t necessarily released at the desirable orbiting altitude. Ferrofluid thrusters can be used to move each satellite into its desired orbit and then, once there, extend the mission by fighting drag; what goes up must eventually come down, after all, and that includes satellites.

Once off-world, humanity can only get so far on tanks filled with rocket fuel, so engineering other ways to maneuver in space is essential.

“The engines we work on have high fuel efficiency, but very low thrust,” King says. “Physical laws prohibit both. We can go a long way on a little propellant, but it would take a long time.”

IT’S ROCK(ET) SCIENCE

Though accounting for the variables of a mission to Mars would make even the most experienced project manager’s head spin, the true challenge isn’t getting there, but getting back. And few astronauts are willing to share Matt Damon’s experience in The Martian. One solution is to carry only enough fuel to get to Mars, and rely on robots and rocks to have enough fuel ready and waiting for the trip home, says Paul van Susante, a senior lecturer of mechanical engineering and co-principal investigator on a NASA Early Stage Innovation grant.

By combining hydrogen atoms mined from the water in gypsum on the red planet with atmospheric carbon dioxide, van Susante proposes that robots could manufacture methane for rocket fuel on Mars in advance of a human mission. In a controlled environment, robots could excavate a soft rock like gypsum, blasting it with water jets to break the rock into smaller pieces and heating it, a process which releases the bound water from the mineral. This method complies with planetary protection mandates and avoids wear-and-tear on excavation machinery.

By the numbers, van Susante calculates that filling a fuel tank would take 16
L. Brad King says that a year ago, 15 companies filed for licenses with the Federal Communications Commission to fly a combined 9,000 satellites in the next five to seven years. Within those seven years, there will be more satellites launched than in the history of humankind. And Michigan Tech students are currently building three of them. One launches this spring.

mtu.news/2jcj8KO

metric tons of water gathered during 480 Mars days—33 kilograms a day—combined with 19 metric tons of atmospheric carbon dioxide to generate methane, with liquid oxygen as a handy byproduct. The time span would provide engineers on Earth enough time to confirm a fuel tank has been filled before sending a human mission to the red planet.

“It’s not rocket science, but it is rock(et) science, because we can make rocket fuel out of rocks,” he says.

THE ORIGINS OF DARK MATTER

“Dark matter is difficult to detect. Dark matter is elusive. We don’t see it.”

FROM A GALAXY FAR, FAR AWAY

Physics researchers Petra Huentemeyer, associate professor, and David Nitz, professor, examine cosmic events far beyond our solar system. Their contributions to the High-Altitude Water Cherenkov (HAWC) and Pierre Auger collaborations were published in three articles this past fall, all in the journal Science.

Huentemeyer, together with Hao Zhou ’15, who now works at Los Alamos National Laboratory, looked at the possible origins of dark matter. They worked on a new particle diffusion model and calculated the gamma-ray emission morphology, which helped the HAWC Gamma-Ray Observatory rule out the Geminga pulsar pair as the source of positron excess. While the results in their Science paper do not affirm the detection of dark matter, they do confirm that positron excess measured by the observatory is not explained by a pulsar nebula throwing off the particles.

“There are all kinds of efforts all over the globe to detect dark matter directly,” Huentemeyer says. “Dark matter is difficult to detect. Dark matter is elusive. We don’t see it.”

She explains that the reason we think it exists is because taking what physicists know about gravitation and then looking at the velocity of stars traveling around the center of disk galaxies, they are not traveling at the speeds we expect from visible matter. There must be dark, non-light emitting mass somewhere that causes this.

In another galactic mystery, Nitz and collaborator Brian Fick, another physics professor at Michigan Tech, contributed to the resolution of the 50-year-old question about whether cosmic particles travel from outside the Milky Way galaxy. Understanding cosmic rays and where they originate can help us answer fundamental questions about the origins of the universe, our galaxy, and ourselves. A collaboration of researchers at the Pierre Auger Observatory discovered the particles’ origin is much farther than the Milky Way.

Nitz works on the electronics that record the signals in the water tanks at the observatory, which is made up of an array of 1,600 detectors spread across 3,000 kilometers in Argentina. He has written the code that is programmed into the circuits, which converts the Cherenkov light in the water tank detectors into digital signals. This enables the hardware to make rapid decisions about the signals recorded in the tanks and whether they’re worth further analysis.

“I really enjoy this kind of science. But I’m a hands-on guy,” Nitz says. “I visualize how we go from concept to actually building an instrument so we can address that science.”
When can we eat the fish?

Answer: It’s complicated.

Cold—it’s the first feature anyone notices about Lake Superior. Then there are the rocks; reds and blacks spewed by ancient volcanism and shaped by waves, granites shrugged off the shoulders of the Canadian shield. On the Keweenaw Peninsula, some of those rocks glint with copper, and hemlocks grow on the slopes up and away from the beach. Tree-covered ridges rise inland while the water stretches out—a deep, dark blue curving beyond the horizon. Sunsets, the northern lights, storm clouds seem to fill the whole sky.

In a word, beautiful. Although not necessarily pristine.

“The KBIC Natural Resources Department raises several species of fish in their hatchery outside L’Anse."

“The Keweenaw Bay Indian Community (KBIC) fishes local waterways in all seasons.”

“Talking about the fish is a ploy. What we’re really talking about is the health of the land and the water—and they matter.”

Dave Kauppila, KBIC Natural Resources Department
For as cold, clear, and clean as Lake Superior appears, it is not as isolated as some of its rural communities feel. All of the Great Lakes are connected—to each other and the rest of the world. This is particularly true when it comes to atmosphere-surface exchangeable pollutants (ASEPs). Mercury; polychlorinated biphenyl; polycyclic aromatic hydrocarbons; persistent organic pollutants. ASEP molecules are invisible, tasteless world-hoppers that can travel great distances to eventually migrate to Lake Superior, where they move through the air, land, small lakes, big water, sediments, insect nymphs, crawdads, birds, fish, and humans. Researchers can describe ASEP movement and impacts through policy, socioeconomic pressures, ecosystem services, stressors like climate change and land use, and biogeochemical cycling.

For the local Indigenous community, the complexity comes down to one question: When can we eat the fish?

The problem in the Keweenaw is two-fold: With a global background that continuously supplies local fluxes of the mobile contaminants, efforts to mitigate ASEPs are minimally effective on a regional scale; at the same time, the peninsula’s ecosystems and people remain some of the most sensitive and vulnerable in the world.

Judith Perlinger, professor of environmental engineering, is the lead researcher of a project funded by the National Science Foundation (NSF) that set out to investigate the migration of ASEPs around the world and its local impact on people, especially in fish-reliant populations like the Keweenaw Bay Indian Community (KBIC). Their research focused on mercury is part of a special issue of Environmental Science: Processes & Impacts, a journal published by the Royal Society of Chemistry. The work reflects how global issues have local impacts.

“Defining ‘safe’ fish consumption for the most vulnerable people helps protects us all,” Perlinger says, adding that her work is embedded in a large, transdisciplinary effort—six institutions, 36 researchers, and 11 partnering organizations—all seeking to better understand ASEPs. “Although they have uses, their point of use and the damage they cause are separated by time and space, which is why studying ASEPs here is important.”

**ASEP: Atmosphere-Surface Exchangeable Pollutant**

“We want to make sure that the people who have the heart and care for this land also have the tools to do so—scientific tools, history tools, policymaking tools.” Lynn Aho, Dean of Keweenaw Bay Ojibwa Community College, ASEP research partner

“Models aren’t crystal balls . . . But they are useful tools for trying to synthesize our current state of knowledge about the world and exploring what-if questions given a set of assumptions, which gives us new hypotheses for how the world works.” Amanda Giang, MIT postdoc, ASEP researcher and GEOS-Chem modeler

**Think globally, sample locally**

The sunrise this morning refuses to let go of its magenta edges. As dusk shifts blue, the waves coming into Eagle Harbor kick up sediment,
Predicted mercury deposition in the Great Lakes in 2050

Output from the GEOS-Chem model, which incorporates changes in mercury emissions from human activities, show that mercury regulations currently in place and under consideration will only decrease mercury deposition in the Great Lakes region by 20 percent by 2050, which is not enough for the KBIC to safely consume fish at desired levels.

% change from present

-75 0 75

Aspirational Policy in Action Minimal Regulation

This scenario assumes mercury emissions around the world stop tomorrow.

This scenario is based on emissions limits currently in place and under consideration.

This scenario assumes that mercury emissions are minimally regulated.

beating a brown rhythm against the shore past the Michigan Department of Natural Resource’s Eagle Harbor State Dock. About a hundred yards in, chainlink fence marks off a yellowed, weedy square encircled by a deck topped with tall, silver boxes that look like space-age trash cans. Stepping onto a deck stair, no one seemed to bother with varnishing the planks, and although only installed three years ago, the pine has grayed.

“There’s good reason for that,” says Don Keith, a local Eagle Harbor retiree with a southern drawl from his Florida roots, pointing at the deck and then four feet down to a tangle of spotted knapweed and tansy. “Everyone asks why I don’t keep down the weeds, but I can’t.”

That’s because this is an atmospheric sampling station. Gas from a weed-whip, or deck sealant, or engine fumes from boats leaving the public dock, gum up the filters resting inside the silver boxes. Keith reaches to the side of one where a metal arm holds up a small sensor; the heat of his hand triggers the machine inside and it opens like the gullwing doors on a fancy sports car. Inside, a small glass and metal tube rest, passively gathering air and locking it away. Keith moves from silver rectangle to silver rectangle as the sky’s magenta finally fades, explaining the nuances of each. This one is a high-volume air sampler, the latch on this filter freezes every storm, mercury coming in on the jet stream from coal-burning in China gets captured in this one. He would know each piece of equipment well; Keith has been coming out to the station once a week for 25 years to gather the samples, record meteorological data, and ship them off for processing.

The data gleaned from Eagle Harbor, and nearly 200 other sites around the country, as well as many others around the world, help inform global atmospheric models, including the one used by Perlinger’s team. They use GEOS-Chem, a global three-dimensional Eulerian chemical transport model that has been widely used to better understand tropospheric chemistry and composition. For ASEPs, GEOS-Chem helps sift through the sources, migration, exchange rates, and resting places of the pollutants. It is coupled with a mass balance modeling to understand the aquatic dynamics of the system.

The question becomes how do people and smaller-scale ASEPs movements fit into the bigger picture. For even though the Keweenaw has some of the cleanest water and air in the world, the region still accumulates the world’s pollution.

“Birds do not read fish consumption advisories.”

Val Gagnon, research assistant professor of social sciences, Michigan Tech
Along Keweenaw Bay

The winds are so strong that car doors whip close, which is common along the shores of Keweenaw Bay in the Ojibwa Recreation Area. Gravel paths wander through swales built up around a pond next to a gray beach. Bright heads of black-eyed susans and the rattling stalks of coneflowers sway below petite, seven-year-old pincherry trees. Sometimes the gusts bring an extra bite. Flakes of stamp sand—the grayish-black leavings of past mining operations on the water’s edge, concentrated with heavy metals—are so sharp that they slice through the plants like tiny razors. The KBIC Natural Resource Department (NRD) staff now do clump planting, and the first line of defense against wind, waves, and sand are stands full of “warrior species” that protect other plants. Throughout the site, each stand features a small plaque with the plant’s Ojibwa name, Latin name, and common name.

“The restoration not only protects the shoreline ecosystem, but also buffers the wetlands where wild rice beds, cranberries, and many medicinal plants, and wildlife live,” says Evelyn Ravindran, one of the KBIC-NRD staff who often leads tours and volunteer plantings. She explains, along with Lori Ann Sherman, director of the KBIC-NRD, that the Ojibwa Recreation Area shows why the community needs both traditional knowledge and scientific knowledge.

“Traditional knowledge is gained from our elders and is learned by doing and experience. There is cross-over with scientific knowledge and there needs to be,” Sherman explains. “As Anishinaabe people, we are stewards of this land.”

Anishinaabe means “Original People” and stewardship is part of the original instructions imparted to all living things in the Anishinaabe creation story. Each nation—human, fish, bird, plant—all take care of each other.

“Traditional knowledge fosters our beliefs and values; it nurtures our connection to this place, with teachings of respect, reciprocity, and enduring sustainability. These beliefs and values guide us in our questions and where we choose to put our efforts,” Ravindran says. “Scientific knowledge provides more of a worldview and helps us to better understand how outside influences, such as legacy mining, affect our landscape and way of life.”

From an Anishinaabe perspective, the natural environment is an extension of the community’s relatives; the tribe’s responsibility then is to be accountable for the human nation’s impact on the health and well-being of other nations. The ASEP project similarly acknowledges that humans are not separate from nature; in technical terms, they say ASEP deposition is part of a dynamic, coupled human-natural system. In order to describe all the elements within that system—including the Indigenous community’s perspective and their desired fish consumption rates at target ASEP pollutant levels—they sought to come up with a meaningful question that resonated with both the research goals and KBIC’s needs. That’s how the question, “When can we eat the fish?” came in.

Quickly injured, slow to heal

“It will likely take multiple generations to reach levels considered safe by the KBIC in Lake Superior fish,” says Noel Urban, professor of environmental engineering and an ASEP project researcher who focuses on the biogeochemistry of the pollutants. “How much can a landscape absorb? That varies geographically. The landscape in this environment is particularly sensitive to mercury deposition.”

That’s because even though mercury deposition is low, the Upper Peninsula landscape has a long memory and recovery time. Also, based on the analyses by Urban’s team of more than 100 Upper Peninsula water bodies, mercury behaves differently in small inland lakes compared to larger bodies of water; Lake Superior is practically its own category. Other contaminants like polychlorinated biphenyl (PCB) compounds also vary.
Chronic exposure is the problem. Occasionally eating smoked lake trout at a tourist stop is not the same as eating trout, walleye, and whitefish multiple times a week because it’s both an accessible and cultural food staple.

Urban’s goal is to extrapolate fish mercury concentration data from lakes and estimate mercury in fish from similar water bodies based on pH, phosphorus, and Secchi disk depth readings. He works with the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), one of the ASEP research partner organizations. The team focused on three different policy scenarios that would impact Great Lakes mercury deposition: an ideal, aspirational target; a policy-in-action target; and a minimal policy target. Less action, more pollution. However, none of the scenarios will make fish safe to eat by the KBIC’s standards by 2050.

From academia to agencies to citizen scientists, what all of the ASEP researchers are quick to point out is that mercury, PCBs, and other atmosphere-water exchangeable pollutants are not new. The issue is that they are not going away any time soon, and decades-old conversations about temporary stop-gaps have not progressed. Plus, local and regional efforts to reduce ASEP pollution simply can’t compete with global background levels. To better articulate an answer for the KBIC, the research team turned to one of the earliest policy measures—fish consumption advisories.

Rethinking fish consumption advisories

All 50 states, many Native American tribes, and federal agencies have established more than 4,000 fish consumption advisories in the United States. However, quantity is not quality, and the policies were never meant to be long term. Which is why social scientist Valoree Gagnon and historian Hugh Gorman do not advocate for getting rid of fish consumption advisories, but instead, seek a future in which fish consumption advisories will no longer be necessary. To achieve such a future, science and policy require a shared focus on eliminating sources of contamination. They want to remind others that the advisories were not intended to be permanent.

“Advisories have been shown to have a minimal impact,” says Gagnon, a research assistant professor of social science, “especially when they impede tribal treaties and reserved fishing rights.”

Gagnon and Gorman, who is the chair of the Department of Social Sciences, are ASEP project researchers and co-authors on a policy brief titled “Eliminating the Need for Fish Consumption Advisories in the Great Lakes Region” (read it at mtu.edu/asep-policy). Emma Norman from Northwest Indian College is also a co-author.

Their take-home message:

In the Great Lakes region, health officials first issued fish consumption advisories in the early 1970s. At the time, these advisories were considered temporary, necessary to protect the health of the fish-consuming public until sources of contamination in the Great Lakes basin could be eliminated. However, even after most local sources of contaminants were eliminated, the problem remained.

This is the crux of Keweenaw ASEP mitigation. The policy work spans geographical scales from local to regional to national to international. To answer the KBIC’s localized question—when can we eat the fish—requires global action like worldwide conventions to staunch the sources and remediate pollution.

“Neither the Minimata Convention nor the Stockholm Convention state that we want to get past fish consumption advisories,” Gorman says, explaining that the idea has become implicit in ASEP-related policy. “It’s...
hard to pursue a goal when it’s not fully articulated.”

Likewise, ASEP research itself must be fully articulated; science works through collaboration, sharing ideas, and new knowledge. The transdisciplinary team working on the ASEP project deepens the understanding of the pollutants’ cycling and the accuracy of modeling, evaluates multi-scale policy, and offers insight into the best practices for engaging local Indigenous communities in global research.

This information is not limited to scientific literature either—joining with the National Park Service, K-12 classrooms, and online teaching platforms, ASEP educational materials take the science-for-scientists template and shapes a different path to bring the research out of the laboratory. Doing so is yet another reflection of how Lake Superior and the Keweenaw are not isolated from the rest of the world. Indeed, the connections made here span the globe.

See the big picture of ASEP science explained at mtu.edu/magazine/fish

Policy Points

The following is an excerpt from “Eliminating the Need for Fish Consumption Advisories in the Great Lakes Region,” a policy brief co-authored by Valoree Gagnon, Hugh Gorman, and Emma Norman.

1. Toxic contamination is an invisible health concern made visible by fish consumption advisories, and as long as fish contain unsafe levels of contaminants, the need for advisories will remain.

2. Fish consumption advisories are not a permanent policy solution to address health concerns associated with fish contamination.

3. Actions at all geographical scales—regional, national, and international—are essential if we are to eliminate the need for fish consumption advisories.

4. Eliminating the need for fish consumption advisories is a long-term goal that will take multiple generations to accomplish.

5. Tools of adaptive governance are required to coordinate and sustain the efforts needed to eliminate the need for fish consumption advisories.

6. The path forward necessitates a global policy framework that links regional, national, and international efforts and unites ecosystem and chemical-based goals.

Read the policy brief mtu.edu/asep-policy

Minaadowenjigaaaziwaat gidoo giigookeneninii-minaanik ...

A Fishing Community: the relationship between the Tribe and the environment has existed since time immemorial; each and every family today is woven to fishing in some way. As their ancestors did before them, subsistence fishermen continue harvesting for their families and community members as well as provide for both ceremonial and communal feasts. Fishing is the strand of cultural core that ties history to present day to future; it is a vital part of the foundation for cultural beliefs and values, traditional lifeways, and even individual identity.

… With hearts as deep as Gitchigami, they must all be remembered.

—excerpt from the Fishermen’s Tribute Memorial at Buck’s Marina, Baraga
EXERCISE FOR EVERY BODY
Steve Elmer’s lab, researchers explore the limits of the human body in a quest to make people move—and feel—better. Elmer’s team designs cutting edge equipment and training regimes to help every body reach its highest potential, regardless of age, profession, or ability.

The benefits of strength training are many and well known: Strength training helps you maintain a healthy weight. It protects your bones and preserves your muscle mass. It helps develop better body mechanics, boosts your energy, and improves your mood. It even plays a role in disease prevention and pain management.

In fact, strength training is so beneficial that the American College of Sports Medicine (ACSM) recommends adults engage in a strength-training program a minimum of two non-consecutive days each week. And their recommendations don’t stop there—ACSM outlines specific types of strength-building exercises and target numbers for repetition.

So everyone should be strength training, right?

While it’s easy to say everyone should, not everyone can, at least not in a “traditional” manner.

Take, for instance, someone who uses a wheelchair or someone who has recently undergone knee surgery. Finding effective lower-body strength-training exercises that don’t overtax the heart, lungs, and joints can be a challenge. And many with old injuries run into the same problem.

Michigan Tech researchers have found a solution. Steve Elmer is an assistant professor of kinesiology and integrative physiology, an affiliated assistant professor of biological sciences, and an affiliated assistant professor of mechanical engineering. His lab is interdisciplinary, where students, participants, and researchers explore the edges of physiology.

Using a blood pressure cuff, Michigan Tech researchers study the impact of restricted blood flow on muscle strength and size.
In Elmer’s exercise physiology laboratory, researchers study and seek to understand how muscles in the legs and arms work. This is important for restoring function after injury, maintaining health, and improving performance.

**Restriction Training**

PhD student Matt Kilgas studies the impact of restricted blood flow on muscle strength and size. Study participants lift light weights with a blood pressure cuff around the working muscle; the cuff is tightened just so, making sure enough blood is coming in, but not all is going back out.

Preliminary data shows that restricting the blood flow this way increases the size and strength of the muscle—helping to restore balance between limbs—even though the exerciser is only lifting light weights.

“This research has excellent applications,” Elmer says. “Not only can it be used for rehabilitation, it can also be used by older adults, athletes, anyone who wants to get stronger.”

Kilgas’ research was partially funded by the Blue Cross Blue Shield Foundation, which provides PhD candidates with up to $3,000 for research aimed at improving the health of Michigan residents. Kilgas also received a student grant from the Michigan Space Grant Consortium—his research may have important implications for astronauts, whose muscles atrophy quickly in space and have to exercise many hours a day to prevent muscle loss.

Elmer’s research equipment and graduate students were funded in part through the Portage Health Foundation. The infrastructure grant helps improve research facilities and the assistantships recognize outstanding doctoral students promoting the wellness of Houghton, Keweenaw, Baraga, and Ontonagon communities.

**Accessible and Adjustable**

Regular exercise is important for maintaining health, especially for wheelchair users. However, wheelchair-friendly exercise equipment is not always readily accessible, adjustable, or effective.

For the past two years, Elmer has led a team of mechanical engineering, kinesiology, and physical therapy students who collaborated to develop new exercise equipment for wheelchair users—bridging the gap between engineering and rehabilitation.

With funding from the ACSM, Elmer’s team brought 10 wheelchair users to campus to use the specially designed exercise equipment and measure how it impacts upper body muscles. The equipment uses a specialized motor-driven arm cycle to provide a high-intensity workout for upper body muscles, without overtaxing the heart and lungs.
Wheelchair users can do this type of exercise regardless of their fitness level to help strengthen their upper body muscles. Having increased strength and fitness can help individuals be more independent and ultimately have better quality of life. With additional funding from the National Science Foundation, Elmer, Kilgas, and Michael Morley, Michigan Tech’s director of technology commercialization, teamed up to look at the commercial needs. The three talked to more than 100 people—including clinicians, wheelchair users, and equipment manufacturers—to determine what the needs are for wheelchair equipment and how Michigan Tech can adapt technology to fit that need.

**Marathon Minutes**

Can a human run a marathon in under two hours? In May 2017, all eyes were on Milan, Italy, as three of the world’s best marathon runners set out to answer that question. When runner Eliud Kipchoge crossed the finish line, we knew this much: We’re not there yet, but we’ve only got 25 seconds to go.

Kipchoge ran the marathon in 2:00:25, setting a world record and shaving two and a half minutes off the previous record in the process. But long before Kipchoge and fellow runners Lelisa Dedisa and Zersenay Tadese had laced up their Nikes (the athletic apparel giant sponsored the experiment, known as Breaking2), Michigan Tech students had been grappling with the two-hour marathon question. During the past few semesters, they got help from Mayo Clinic physician-researcher Mike Joyner, a world-renowned expert on human performance and exercise physiology. Joyner was one of the expert consultants on Breaking2.

Exercise physiology undergraduate and graduate students set out to build the ideal runner and present their ideas to Joyner. When their projects—and runners—were complete, the undergraduates met with him as a class via Skype. The graduate students participated in a small-group workshop with Joyner and received feedback from him in March 2017. When Kipchoge, Dedisa, and Tadese ran Nike’s Breaking2 race two months later, the graduate students received real-world confirmation that much of what they predicted was true.

Elmer, Joyner, and Jason Carter, chair of the KIP department, worked together to debrief how the mental exercise worked in the classroom. They have written a paper on the subject, published in *Advances in Physiology Education* last summer.

“This is a great example of the problem-based learning we do here in KIP,” Elmer says. “We then build upon that research so it becomes discovery-based learning.”

Humans Like Us—Baby, We Were Born to Run

Or walk. Or climb a few flights of stairs when we’re short on time.

More than a decade ago, scientists declared that humans are not built for sitting. Our physiology shows that we’re made to move, and move a lot. In the not-so-distant past, humans ran or walked nine to 15 kilometers a day.

Many of our modern-day health problems, Elmer says, come from lack of movement. “Compare humans with chimpanzees. Chimpanzees are built to be sedentary. They have short bursts of movement here and there, but for the most part, they’re very lazy, and they can get away with it. Humans, on the other hand, were not made to be still.”

But this doesn’t mean we have to make drastic changes. Add in movement where you can, Elmer recommends. “Ten minutes here, five minutes there. It all adds up. As long as the total is more than zero, you’re going in the right direction.”

Elmer says 30 minutes of movement a day is a great goal, but if that’s not possible, consider going up several flights of stairs once or twice a day. The movement and the increase in your heart rate bring great benefits.
A BRIGHT FUTURE FOR ENERGY

First-time Dual Winner
Yun Hang Hu
Charles and Carroll McArthur Professor, Materials Science and Engineering

The highest research honor given at the University, the Michigan Tech Research Award, commends Hu’s internationally recognized work. The Bhakta Rath Research Award is a team effort, given out annually to a PhD student-advisor duo based on the quality and significance of their work together. Wei Wei, a recently graduated PhD materials science student, and her adviser, Hu, set a high bar earning the 2017 award for their work on sodium-embedded carbon.

What I do: Innovate the processing of hydrogen production, hydrogen storage materials, greenhouse gas conversion, and energy conversion and storage

Why I do it: To address some of the most challenging energy issues, including new materials, sustainability, and carbon capture and storage

Sometimes the limitations of materials create roadblocks in energy research. But that does not daunt Yun Hang Hu, the Charles and Carroll McArthur Professor within the Department of Materials Science and Engineering.

Hu’s groundbreaking work has led to several brand-new materials and processes. The innovations will help in a number of applied technologies—from supercapacitors that run elevators to solar cell banks to computer data storage to making hydrogen fuel from water and sunlight. The breadth and rigor of Hu’s work has been recognized with Michigan Tech’s highest research award honor this past year—the 2017 Research Award. He was also selected for the 2017 Bhakta Rath Award with his recently graduated PhD student, Wei Wei. Hu is the first faculty member to receive both awards simultaneously.
The key to Hu’s success is that he is willing to push the boundaries; he takes what could be and turns ideas, conceptions, and models into reality. Stephen Kampe, chair of the Department of Materials Science and Engineering, calls Hu “an international leader in energy research for his innovative processing of materials. He is one of the few researchers to excel in both theory and experimental work.”

Considering a new material and then creating it in a lab is no small feat. And Hu has synthesized several new materials along with novel reactions for others. One example is a new class of memristor materials, which are electrical circuits made of molybdenum disulfide nanosheets that can potentially store massive amounts of data in a miniscule amount of space on a computer. Memristors could make today’s iPhones as powerful as a supercomputer.

The bulk of Hu’s research, however, focuses on energy-related materials. He created solid solution catalysts for natural gas conversion, highly efficient materials for energy devices and hydrogen storage, and novel processes for hydrogen production and capturing carbon dioxide. In one finding, Hu and his lab detailed how carbon dioxide can also be used to synthesize 3-D graphene and create tiny surface dents in it—a balance of micropores and mesopores increases the surface area available for adsorption of electrolyte ions.

“The new 3-D surface-microporous graphene solves the difficulty of limited charging time in activated carbon,” Hu says, explaining it comes down to how quickly an electrolyte can diffuse and recharge in a supercapacitor electrode material. “The interconnected mesopores are channels that can act as an electrolyte reservoir and the surface-micropores adsorb electrolyte ions without needing to pull the ions deep inside the micropore.”

It is also well-known that a large accessible surface area and high electrical conductivity are both required for ideal functioning of electrode materials in energy devices. But the materials traditionally used in these electrodes—activated carbon and graphite—offer one but not the other. The activated carbon has a large surface area but low conductivity; graphite has high conductivity but a low surface area. The solution, Hu says, is sodium.

“Doping alkali metals into carbon materials was demonstrated several decades ago to create highly conductive carbon materials,” Hu explains. “However, as the metals are located on the carbon surface, they can be easily oxidized, leading to a decrease in conductivity. I thought that, to solve this issue, alkali metal atoms must be completely surrounded by carbon atoms to form an alkali-metal-embedded carbon material.”

To synthesize alkali-metal embedded carbon, Hu figured that the alkali metal atoms must be present in the reaction system before carbon formation. Along with his recently graduated PhD student, Wei, who is now an assistant professor at Wichita State University, Hu was able to establish a reaction between sodium metal and carbon dioxide that could generate sodium-embedded carbon nanowalls. The work to maximize surface area and electrical conductivity—along with close to twenty other papers they co-authored during Wei’s study—earned the duo the Bhakta Rath Research Award. The award is given each year to a Michigan Tech doctoral student-advisor pair for cutting-edge research and focuses on the social contribution of the work.

“Hu and Wei used novel approaches based on their invented reactions to synthesize unique electrode materials,” says Joshua Pearce, the materials science and engineering professor who nominated them for the award. “Not only did they successfully create new processes and materials, but they kept their larger objective in mind: to assess the workability in real energy devices.”

In Hu’s lab, the boundary is thin between what is and what could be. By working at the interface of theory and experiments, Hu is building a bright future for energy devices and technology.
Awards and Honors

**Jason Carter**  
Assistant to Vice President for Research for Research Development  
Chair and Professor  
Kinesiology and Integrative Physiology  

**What I do:** Participate in an 18-month fellowship to build up researchers in academic leadership  

“Selection for this important national program was very competitive. Jason is a recognized leader for innovative solutions to reduce administrative burden.”  

–Dave Reed, Vice President for Research, Michigan Tech  

mtu.news/2EBGuew

**Zhaohui Wang**  
Assistant Professor  
Electrical and Computer Engineering  
Great Lakes Research Center  

**What I do:** Work with intelligent, eco-friendly acoustic communication and networking systems underwater  

**Why I do it:** To remotely and wirelessly communicate with sensors in lakes and oceans, including the Great Lakes during icy months  

mtu.news/2o5MoXz

**Xiaohu Xia**  
Assistant Professor  
Chemistry  

**What I do:** Refine tests that detect biomarkers for cancer and infectious diseases, using corrosion-resistant metals  

**Why I do it:** To make clinical diagnostics more simple and more precise  

mtu.news/2jrKBLm

**Lucia Gauchia**  
Assistant Professor  
Electrical and Computer Engineering  
Mechanical Engineering–Engineering Mechanics  

**What I do:** Use ecological tools to better understand battery aging  

**Why I do it:** For longer-lasting battery technology, for applications ranging from electric vehicles to repurposed batteries for grid applications  

mtu.news/2lvdxzM  

**Faculty Early Career Development Program (CAREER) Award Recipient, National Science Foundation (NSF)**
Stephen Techtmann  
Assistant Professor  
Biological Sciences  
Great Lakes Research Center

What I do: Gather water samples from ports around the world, looking for unique microbes

Why I do it: For a better way of monitoring maritime provenance of small ships

mtu.news/2HfINGL

Young Faculty Award Recipient, Defense Advanced Research Projects Agency (DARPA)

Connecting the University with the Community

Portage Health Foundation helped fund three endowed professorships—learn how they’re improving the future of health sciences for Innovation Shore and beyond:

Qiuying Sha  
Endowed Professor of Population Health

How? Use statistical models for personalized medicine

We live in the age of big data. Using vast datasets, Sha is able to study the genetic risk for individuals and the prevalence of diseases in a given population. She has applied statistical genetic analyses to hypertension, type II diabetes, and neurodegenerative diseases like Alzheimer’s and ALS. The goal is to provide tools for more targeted and preventative interventions for overall community health in the Keweenaw.

mtu.news/2xaSBTx

Keat Ghee Ong  
Endowed Professor of Technological Innovations in Health

How? Make smarter health technologies

Ong’s biomedical engineering research gets at the universal well-being of all people. He wants everyone to have access to better technologies that can improve their recovery from surgery and injury. But he also says he is equally invested in making an impact in the Keweenaw region. Building community along with stronger bones is a key goal of his new responsibilities that goes beyond the indirect benefits of bringing in research dollars, more students, and supporting local business.

mtu.news/2clfxS1

William Cooke  
Endowed Professor of Preventative and Community Health

How? Simple solutions with a big impact

Eat less, move more. Simple-sounding advice from Cooke, an exercise physiologist, who looks specifically at how nerves coordinate blood flow through the heart and brain. Cooke has worked with astronauts and world-class athletes. Now he’s helping confront the Keweenaw’s most prevalent health concerns including diabetes, heart disease, and smoking.

mtu.news/2xb5dKw
Innovation Shore

Institute of Computing and Cybersystems

Twenty-seven grants, $7.5 million in funding, and 59 supported students, with 51 dedicated faculty members from 12 different schools and departments—impressive numbers for the Institute of Computing and Cybersystems (ICC), which formed just three years ago. Equally impressive are the interdisciplinary collaborations taking place on and off campus.

“We are beginning to see the benefits of our efforts to bring together the many areas of computing at Michigan Tech,” says Min Song, ICC founding director. “It brings faculty and students in sub-disciplines together to discover new knowledge in computing.”

Projects in five specialized centers promote research and learning experiences for the benefit of the University, industry, and the world at large: cyber-physical systems, cybersecurity, data sciences, human-centered computing, and scalable architectures and systems. Machine learning, medical informatics, smart grids, human-robotic interactions, privacy protection—ICC is a computer-research hub where logical match-ups happen. Case in point: researchers who collect data provide it to those who analyze data.

“ICC is the focal point for research in computer-related areas. It fits the Michigan Tech model of research centers that reach across multiple academic boundaries,” says Dave Reed, Vice President for Research.

ICC members develop project proposals and lead research direction. But students—graduate and undergraduate—are also major players, especially in running simulations and experiments. Experience working on National Science Foundation, National Institutes of Health, and Department of Defense-funded projects, for example, can be a career game-changer.

The institute’s goals for the coming year and beyond focus on growing membership and fueling collaborations to take computing research at Michigan Tech to the next level.

Meet researchers, explore projects, and subscribe to get the latest news at icc.mtu.edu

Experience: In the Lab

Exercise science undergraduate Stephanie Dietrich received one of 30 Undergraduate Research Internships (URIP) this past year. She worked one-on-one with Jason Carter, Department Chair of Kinesiology and Integrative Physiology, over a 20-week period designing experiments, gathering data, testing hypotheses, and disseminating results.

URIP students showcase their work during a spring Undergraduate Research Symposium. Dietrich placed first for design, implementation, and presentation of her research on “Subjective and Objective Assessments of Sleep Differences in Male and Female Collegiate Athletes.” The URIP program is made possible through funding from the Portage Health Foundation, the DeVlieg Foundation, along with the management and support of the Pavlis Honors College.
Create the Future

Undergraduate Student

Looma, the nutrition-and-wellness startup co-founded by computer engineering major Kyle Ludwig, comes to iOS in 2018. The app provides specific, optimized meal plans for busy 18-to-24 year-olds—with a swipe feature some have jokingly referred to as the Tinder of menus. It’s been in the works for three years under different iterations. Ludwig and co-founder Chetan Chaurasiya, a 2017 computer engineering graduate, finessed interface design, ease of use, and conducted independent research. But what truly propelled forward momentum, Ludwig says, is Michigan Tech mentorships and program resources through the Pavlis Honors College, including the National Science Foundation Innovation Corps (I-Corps). The startup was refined through research that centers on designing and developing products around the customer, an oxymoron to the Steve Jobs “I know what users want,” mentality. Processes Ludwig was introduced to in the 2016 Michigan Tech I-Corps Site Program eventually resulted in a name-change (“TRU was always a placeholder”), and the intent of the project (previously focused on personal medical diagnostics).

“The hardest part was getting over ourselves and understanding what users wanted,” says Ludwig, who’s been eating for optimal work performance since he graduated high school. “What product do we make first for the people who want it the most?”

Slated to graduate in May 2018, the Pavlis Honors College New Venture Pathway student transferred here from Traverse City, Michigan, in 2015. “Kyle has done an amazing job developing a network of advisors, mentors, and team members to bring his company through a series of transformations and accomplishments on the path from idea to reality,” says his Pavlis mentor-advisor, Jim Baker, executive director of innovation and industry engagement. Ludwig interned at Ford’s Research and Innovation Center in Palo Alto, California, in summer 2017, where he developed mobile apps and led groups in patent ideation using design-thinking principles gained as a Stanford University Hasso Plattner Institute of Design University Innovation Fellow (UIF) in October 2017. The two-time Accelerate Michigan semi-finalist (2016 and 2017) won the best technology award in the 2016 Michigan Tech’s Bob Mark Elevator Pitch competition. He earned a spot on the annual 14 Floors Silicon Valley Experience that pairs established innovators with up-and-coming entrepreneurs.

Graduate Student

“Any time you put stents inside of arteries there is naturally going to be a reaction,” says Roger Guillory. In his second year of the biomedical engineering PhD program, he continues the research that captivated him in 2013: identifying candidate metals for bioabsorbable stents by looking at the performance and efficacy of degradable materials in live systems.

“I remember the first time I saw it was during a freshman seminar class. I was taken aback by the fact that they were doing all of this at Michigan Tech, fabricating different metals and alloys and testing them in vivo systems,” Guillory says. “The presenter, Jeremy Goldman, put up a couple cross-sections of arteries with wires in them and I was fascinated. I emailed him, and I’ve been working with him ever since.”

In 2016, the Houston, Texas, native received an honorable mention from the National Science Foundation’s Graduate Research Fellowship Program (NSF-GRFP). In 2017, he was one of three Michigan Tech students who earned the highly competitive fellowship.

Biodegradable stents address long-term complications for patients, including restenosis, or renarrowing of the artery. But stents are arterial remodelers; the process can take six months to a year, so the material used won’t degrade quickly. Medicine’s first degradable stents were made of polymers, which weren’t strong enough. Zinc on its own has the same problem, hence the exploration of alloys.

“We work with the Department of Materials Science and Engineering closely. They develop zinc and zinc-based alloy wires, give them to our group in a useable form, and we do biocompatibility testing,” he explains. Wires are implanted in rat aortas; the arteries are later removed for histological analysis of wire, tissue, and tissue-wire interface.

“Being interdisciplinary is so rewarding,” Guillory says. “To have a successful product, you have to work with other people who don’t do what you do. In medicine, you’re going to have to collaborate.”
Research Centers and Institutes

Advanced Power Systems Research Center (APSRC)
apslabs.me.mtu.edu
Director: Jeff Naber
Mechanical Engineering-Engineering Mechanics
jnaber@mtu.edu

Advanced Sustainable Iron and Steel Center (ASISC)
chem.mtu.edu/assisc
Co-directors: S. Komar Kawatra and Timothy Eisele
Chemical Engineering
skkawatr@mtu.edu, tceisele@mtu.edu

Center for Agile and Interconnected Microgrids (AIM)
aim.mtu.edu
Co-directors: Wayne Weaver and Rush Robinette
Electrical and Computer Engineering
Mechanical Engineering-Engineering Mechanics
wwweaver@mtu.edu
rdrobine@mtu.edu

Center for Leadership and Innovation for Transformation (LIFT)
mtu.edu/research/about/centers-institutes/lift
Director: Lorelle Meadows
Pavlis Honors College
lameadows@mtu.edu

The Elizabeth and Richard Henes Center for Quantum Phenomena (CQP)
mtu.edu/quantum
Director: Jacek Borysow
Physics
jborysow@mtu.edu

Computational Science and Engineering Research Institute (CSERI)
mtu.edu/research/about/centers-institutes/cseri
Director: Warren Perger
Electrical and Computer Engineering
wfp@mtu.edu

Center for Technology and Training (CTT)
ctt.mtu.edu
Director: Tim Colling
Civil and Environmental Engineering
tkcollin@mtu.edu

Earth, Planetary, and Space Sciences Institute (EPSSI)
mtu.edu/epssi
Director: Will Cantrell
Physics
cantrell@mtu.edu

Ecosystem Science Center (ESC)
mtu.edu/forest/esc
Director: Andrew Burton
School of Forest Resources and Environmental Science
ajburton@mtu.edu

Great Lakes Research Center (GLRC)
mtu.edu/greatlakes
Director: Guy Meadows
Geological and Mining Engineering and Sciences
gmeadows@mtu.edu

Institute of Computing and Cybersystems (ICC)
icc.mtu.edu
Director: Min Song
Computer Science
mins@mtu.edu

Institute of Materials Processing (IMP)
mtu.edu/materials/research/imp
Director: Stephen Kampe
Materials Science and Engineering
kampe@mtu.edu

Keweenaw Research Center (KRC)
mtukrc.org
Director: Jay Meldrum
jmeldrum@mtu.edu

Life Science and Technology Institute (LSTI)
lst.mtu.edu
Director: Victor Busov
School of Forest Resources and Environmental Science
vbusov@mtu.edu

Michigan Tech Research Institute (MTRI)
mtri.org
Co-directors: Robert Shuchman and Nikola Subotic
shuchman@mtu.edu
nsubotic@mtu.edu

Michigan Tech Transportation Institute (MTTI)
mtti.mtu.edu
Director: Pasi Lautala
Civil and Environmental Engineering
ptlautal@mtu.edu

Multi-Scale Technologies Institute (MuSTI)
mtu.edu/research/about/centers-institutes/musti
Director: Craig Friedrich
Mechanical Engineering-Engineering Mechanics
craig@mtu.edu

Pre-College Innovative Outreach Institute (PIOI)
mtu.edu/research/about/centers-institutes/pioi
Director: Cody Kangas
Center for Pre-College Outreach
ckangas@mtu.edu

Research and Innovation in STEM Education Institute (RISE)
mtu.edu/research/about/centers-institutes/riise
Co-directors: Susan Amato-Henderson and Bradley Baltensperger
Cognitive and Learning Sciences
slamato@mtu.edu
brad@mtu.edu

Sustainable Futures Institute (SFI)
sfi.mtu.edu
Director: David Shonnard
Chemical Engineering
drshonna@mtu.edu
Research and Sponsored Activity

SPONSORED AWARDS
FISCAL YEAR 2017

- Federal 73%
- Industry 12%
- Gifts 7%
- State of Michigan 3%
- Foreign 2%
- All other sponsors 3%
- Crowdfunding <1%

FEDERAL AWARDS
FISCAL YEAR 2017

- US Department of Defense 29%
- US Department of HHS 4%
- US Department of Education 1%
- Other Federal agencies 6%
- National Aeronautics and Space Administration 7%
- US Department of Transportation 7%
- US Department of Agriculture 9%
- National Science Foundation 26%

RESEARCH EXPENDITURES
(in millions of dollars)

- 2008: 60.4
- 2009: 60.4
- 2010: 63.5
- 2011: 70.1
- 2012: 72.0
- 2013: 70.7
- 2014: 68.5
- 2015: 69.6
- 2016: 72.5
- 2017: 71.6

2016 invention disclosures per $10 million of research expenditures
(Compared to Michigan universities)

- Michigan Tech: 4.7
- Michigan State University: 2.9
- University of Michigan: 3.1
- Wayne State University: 2.9

2016 invention disclosures per $10 million of research expenditures
(Compared to benchmark universities)

- Michigan Tech: 4.7
- Penn State University: 1.8
- Stanford University: 4.8
- Georgia Institute of Technology: 4.1
- University of Minnesota: 4.3
Happy Anniversary.
The Isle Royale Wolf and Moose Study is in its 60th year.
It’s the longest running predator-prey study of its kind in the world.