Research

MICHIGAN TECHNOLOGICAL UNIVERSITY / 2017

THIS ISSUE

MERELANIITE

A NEW MINERAL DEBUTS

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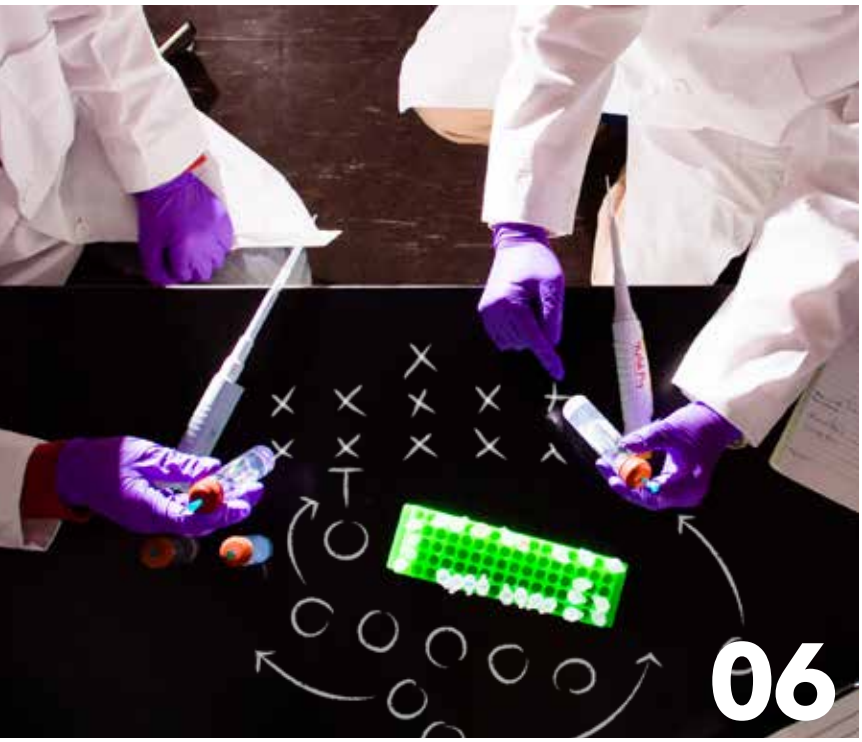

Research Spotlight

Michigan Tech

Regular Features

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Research IN BRIEF

EPA Names Michigan Tech Region 5 Environmental Finance Center

The Environmental Protection Agency (EPA) named Michigan Tech the new home of its Region 5 environmental finance center in 2016, a recognition that comes with a six-year grant of up to $5.6 million. EPA Region 5 covers Michigan, Minnesota, Wisconsin, Illinois, Indiana, and Ohio.

"The depth of engineering resources that we have, our business school's involvement, and the fact that a multidisciplinary approach is the norm here all made our application stand out," says Tim Colling. The Principal Investigator on the EPA center, Colling also directs Tech's Center for Technology & Training (CTT), part of the Department of Civil and Environmental Engineering (CEE).

There are also several co-PIs from various University departments, centers, and institutes, including CEE, the Sustainable Futures Institute, Michigan Tech Transportation Institute, and the School of Business and Economics.

The new EPA regional center—one of 10 nationwide—will help counties, cities, villages, and state agencies find better ways to manage and maintain their infrastructure and to minimize their impact on the environment.
mtu.news/2carWyo

UPDATES TO 2016 *RESEARCH* STORIES

Mi-STAR

The 2016 *Research* magazine highlighted the Michigan Science Teaching and Assessment Reform (Mi-STAR), a new science curriculum for middle school students that emphasizes applying science to real-world problems. Since then, progress on the program has continued.

Mi-STAR piloted three curriculum units in Michigan classrooms in fall 2016.

- Number of teachers piloting the units: 16
- Total number of students in all the classes where the units are being piloted: 1,679
- Number of school districts where piloting is taking place: Six
- Spring 2017: Three more curriculum units will be tested in classrooms

Revisions to Mi-STAR curriculum based on the results of the pilot testing:

- The individual curriculum unit is being tested on a broader scale
- Some changes were made to the curriculum design process which will improve the design of curriculum units that are developed in the future

The scope of the project remains the same—to achieve the vision of providing Michigan teachers with high quality, low cost educational curriculum for the middle grades (sixth, seventh, and eighth) and teacher professional development as well. Work to take Mi-STAR to other states has also started.
mi-star.mtu.edu

Cloudy Details

Professor of Physics Raymond Shaw's cloud research continues to expand. Featured in the 2016 edition of *Research* for his airborne lab, Shaw is now getting attention for work he's conducting in Michigan Tech's cloud chamber.

What makes the Michigan Tech chamber different from any other is that the cloud inside is turbulent. Researchers can keep a cloud for as long as they want, so long as they keep feeding it aerosols. Every cloud droplet in Earth's atmosphere forms on a preexisting aerosol particle, and experimenting with aerosol levels within the cloud chamber has led to an exciting discovery.

In a study published in *Proceedings of the National Academy of Sciences*, Shaw, fellow Professor of Physics Will Cantrell, graduate student Kamal Kant Chandrakar, and colleagues found that clouds with fewer aerosols have a wider variability in droplet size, making it easier for them to produce rain. This finding could have serious implications for weather and climate change.
mtu.news/2j7TULT

Portage Health Foundation

Last year, Michigan Tech's important new partnership with the Portage Health Foundation (PHF) was featured. Here are key highlights from 2016:

- Pavlis Honors College awarded 11 Undergraduate Research Internship Program (URIP) scholarships.
- Robert Larson was one of the first recipients of a Portage Health Foundation graduate assistantship that enabled him to focus on finishing requirements for his doctorate in biological sciences. Now he is a Lundbeck Postdoctoral Research Fellow, sponsored by the American Autonomic Society.
- $8,000 PHF Making a Difference scholarships were awarded to Adison Cook, Elisha Houle, Corey Miller, and Abby Sutherland. They are establishing a new collegiate HOSA-Future Health Professionals model and chapter at Michigan Tech. Members will help to prepare high school students for a variety of health-related degree programs.
- Biomedical engineer Keat Ghee Ong was named the Portage Health Foundation Endowed Professor of Technological Innovations in Health.
  phfgive.org

Michigan Tech Research Institute is 10 years old

When the Michigan Tech Research Institute (MTRI) opened its doors in October 2006, who would have thought that:

- MTRI would grow from 24 employees to nearly 60.
- The institute would expand from 7,377 square feet to 17,697.
- Over 10 years, the research facility would generate $80 million in revenue.

When the *Ann Arbor News* announced the opening of MTRI with a headline proclaiming "There's a new university in town," who could have anticipated that:

- MTRI would become a pioneer in the application of technologically advanced, mathematically rigorous sensor and information technologies to critical environmental, infrastructure, automotive, and national security needs.
- More than 200 interns would get on-the-job training at MTRI to hone their classroom skills.
- The World Bank would look to MTRI and the Department of Geological and Mining Engineering and Sciences to help them gather and analyze data on the impact of geohazards for transportation—so they could protect their multi-million dollar investment in transportation infrastructure throughout South Asia.

MTRI collaborates broadly, with researchers at Michigan Tech's main campus in Houghton, with federal agencies such as NASA, US Department of Transportation Federal Highway Administration, National Oceanic and Atmospheric Administration, Department of the Interior, Department of Defense, and the EPA, even internationally.

What's hot at MTRI as the research institute enters its second decade? Here are a few examples:

- Autonomous vehicles—remote sensing, which is at the heart of MTRI research, will play a vital role in the development of autonomous vehicles, which are going to have to safely and effectively sense and respond to each other, road conditions, and innumerable other factors.
- Arctic research, including polar bear den detection and the National Aeronautics and Space Administration's ABoVE (Arctic Boreal Vulnerability Experiment) project.
- Wildfire emissions and human health, expanding earlier research in San Diego County to the entire state of California.
- 4-D remote sensing, with the fourth dimension being time, a cooperative study with the Canadian Center for Remote Sensing.
- Noise in neonatal intensive care units, to determine how the level and type of ambient sound impacts the sleep of at-risk newborns.
- Drive-by and fly-by monitoring of bridge conditions with sensors that can be driven over the bridge in a car or truck, or flown over in a drone.
- Water erosion prediction using a new open-source modeling interface for WEPP and our online erosion modeling database.
- Waveform design for dynamic spectrum utilization, allowing radar and communication systems to co-exist in crowded spectrum.
- Enhancing soldier security by sensing buried explosive hazards.

"MTRI being part of Michigan Tech has been and continues to be a wonderful and productive experience. The University has a great leadership team who routinely provide insight and encouragement," says Robert Shuchman, co-director. "MTRI researchers have collaborated with experts on campus to address pressing problems facing our nation. As we move forward to our next 10 years and beyond as part of the Michigan Tech family, MTRI will continue our collaborations and form additional partnerships with our campus friends and colleagues."
mtri.org

THREE OF MTRI'S 60 EMPLOYEES.

> COMMERCIALIZING UNIVERSITY TECHNOLOGY IS A LITTLE LIKE PLAYING FOOTBALL.

COMMERCIALIZA

John Diebel says commercializing university technology is a little like playing football.

"It's a game of patience," the assistant director of commercialization in Michigan Tech's Office of Innovation and Industry Engagement explains. "You just try to move the ball forward one play at a time."

That's exactly what Yoke Khin Yap is doing with his high-brightness fluorophores technology and his spin-off company, StabiLux Biosciences Inc. Yap is a professor of physics at Michigan Tech.

High-brightness fluorophores are dyes that fluoresce in different colors and degrees of brightness. They are used in machines called flow cytometers to detect diseased cells in blood. StabiLux's high-brightness fluorophores can detect those cells in smaller amounts and much faster than has been possible up to now.

Professor Yoke Khin Yap (center) plans some research "plays" with Senior Research Scientist Dongyan Zhang (right) and Research Assistant Rodney Oakley (left).

The tunable or adjustable brightness enables more cells to be identified without the colors interfering with each other. And the enhanced signals they emit enable detection of cells that are not detectable using current methods.

"We are expecting a huge impact to the field of flow cytometry," says Yap. "Our high-brightness fluorophores can enhance the signal level up to 50 times. This will allow the detection of cells that are undetectable using current technology. This will mean a lot for cancer and stem cell research. We trust that our technology will help promote early disease detection from a blood sample."

Christan Carson, vice president for research and development at Becton Dickinson Biosciences, calls Yap's invention "a game changer." It's taken nearly a decade of lab work, market research, and fundraising to change the game this far. But the hard work has paid off—the product could be in the marketplace within the next year, based on additional funding.

Yap was on sabbatical in 2008, working on a nanomolecule, when he realized that it had potential for use in biomedical imaging. Five years of painstaking lab work followed, supported in part by Michigan Tech's own Research Excellence Fund.

Finally, in 2013, Yap was ready to take the next step toward a marketable product. A $44,000 grant from the Michigan Economic Development Corporation's (MEDC) Michigan Initiative for Innovation and Entrepreneurship launched that effort.

In 2014, Yap's team was accepted into the National Science Foundation's I-Corps team program, which trains scientists to do market research. The I-Corps project allowed his team to identify the market of flow cytometry and develop a viable business plan. Then the state stepped back in with grants from the Tech Transfer Talent Network (T3N), a collaboration among universities to support early-stage commercialization projects by providing funding for mentors-in-residence who assist in the business side of the research commercialization plan. At that point, in 2014, Yap established StabiLux Biosciences in partnership with Superior Innovations, a for-profit company founded with alumni donations to nurture Michigan Tech innovations.

In 2015, the University pitched in again, with a Commercialization Milestone grant and funding from the College of Sciences and Arts and Yap's Department of Physics. The following year, the first angel investor appeared, followed by the MEDC's Business Accelerator Fund and MTRAC, the Michigan Translational Research and Commercialization program.

> THE TECH TRANSFER LANDSCAPE AT MICHIGAN TECH IS LIVELY.

High-brightness fluorophores are fluorescent dyes that enable medical professionals to detect diseased cells in blood.

By 2016, Yap's project attracted more NSF funding, through its Small Business Technology Transfer Program. Then MEDC provided $30,000 from its Small Company Innovation Program (SCIP), and Superior Innovations kicked in $10,000. In all, more than $500,000 of funding has been invested into the company since its inception. And the company is debt-free.

"As you can see, it takes a team to bring a research concept to the marketplace," says Diebel. The State of Michigan, federal agencies, private investors, and the University itself all are key players. There's another player now, thanks to the T3N program. It's Steve Tokarz, a mentor-in-residence. Tokarz comes from the business world. His job as mentor-in-residence is to be what he calls "a business development coach." He helped Yap on fundraising and crafted a business plan. He linked StabiLux's business to his extensive business and industry network. And he's serving as CEO-in-residence of StabiLux.

It's a new model for commercializing university technology. Tokarz explains, "You can't be a full-time faculty member and the CEO of a company. If you try, neither will be successful."

It's another example of teamwork at play. "We needed a bigger network, more people, and resources," says Tokarz. Now he is handling the business aspects of putting Yap's high-brightness fluorophores on the market, while Jonathan Leinonen, a lecturer in Tech's School of Business and Economics, serves as vice president for operations. Nazmiye Bihte Yapici, Yap's research assistant, is principal scientist and Dongyan Zhang, a senior research scientist in Tech's physics department, is working as a collaborating scientist. Zhang and Yapici were the principal investigators and entrepreneurial leads of Yap's I-Corps team. Jim Baker, executive director of innovation and industry engagement at Michigan Tech, served as mentor to the team.

Tokarz is raising $600,000 in seed money for the company and is planning to raise $2 million more by 2018. And Yap is free to work on the technical details of his product.

The tech transfer landscape at Michigan Tech is lively. StabiLux is only one example of the entrepreneurial projects being pursued by University researchers. Adrienne Minerick, a professor of chemical engineering and associate dean of the College of Engineering, has spun off Microdevice Engineering Inc. to market her portable blood typing technology. Megan Frost, associate professor of biomedical engineering and adjunct associate professor of materials science and engineering, is co-founder of FM Research Management, LLC, which is currently developing nitric oxide-releasing materials for antimicrobial applications. Craig Friedrich, professor of mechanical engineering-engineering mechanics and director of the Multi-Scale Technologies Institute, is collaborating with William Beaumont Hospital and Nanovation Partners, LLC to develop and commercialize titania nanotube surfaces with integrated nanosilver for orthopedic implants that make them better adhere to bone and are antibacterial to reduce infection. He just received a $183,672 grant for this work from Mi-TRAC, through the University of Michigan MTRAC for Life Sciences Innovation Hub.

And in 2016, MTRAC funded five new early-stage commercialization projects led by Tech faculty.

"Michigan has a wealth of brainpower in our universities that can truly impact the state's future growth," says Denise Graves, university relations director for MEDC Entrepreneurship and Innovation. "There are a lot of great things happening in university labs across Michigan, and it is important to provide researchers a pathway to the commercial market. Creating programs like MTRAC, SCIP, and T3N, in collaboration with the universities, is key to getting the research from the lab into the commercial market. It is exciting to see the progress happening at Michigan Tech."

No wonder the University is becoming known as the heart and soul of Innovation Shore.

Is commercialization of technology even an appropriate role for a university? Some say no, that a university's job is to teach and conduct research. But Michigan Tech begs to differ. In the University's strategic plan, Tech spells out its commitment to taking technology developed here out of the laboratory and into the marketplace,

where it can help the world. Under Goal 3: Research, scholarship, entrepreneurship, innovation, and creative work that promotes a sustainable, just, and prosperous world, the University vows to support economic and social development and innovation by:

- Creating a culture of responsible innovation and entrepreneurship and expand entrepreneurship in undergraduate and graduate programs.
- Supporting workforce development and social engagement through collaborative outreach and technology transfer.
- Encouraging and supporting technology commercialization and startup businesses.

That's why, at least at Michigan Tech, there's a wholehearted commitment to the concept of commercializing university research on Innovation Shore.

mtu.edu/magazine/commercialization

Nazimiye Bihte Yapici, a physics research assistant, and Steve Tokarz, CEO of StabiLux, are part of Yap's research team.

"DIGITAL MEASURES

As every academic knows, promotion and tenure reviews require a lot of information. Research, teaching, and service are evaluated. In the past, some faculty members were unsure of how to account for commercializing their research when assembling their dossiers.

That is changing, and Michigan Tech is leading the way.

Digital Measures, a program that the University uses to track the research, teaching, and service activities of its faculty members, is being revamped, and research commercialization and other innovation efforts are being added to the research component.

"We need to be able to measure the work our faculty are doing in innovation, the time and effort they are putting into commercializing their technologies," says Adrienne Minerick, associate dean for research and innovation in the College of Engineering. As assistant to the provost for faculty development, she has been tasked by Provost Jackie Huntoon with updating Digital Measures by adding a section for innovation.

"Moving research from the conceptual stage to commercialization is a valid form of scholarship," Huntoon explains. "By adding this new component to the reports that faculty members prepare each year, it will become clear to everyone that innovation is valued at Michigan Tech."

"Building a reputation is important, as is name recognition for the researcher, the department, the college, and the University," Minerick explains. "Measuring and crediting innovation will improve our reputation-building ability."

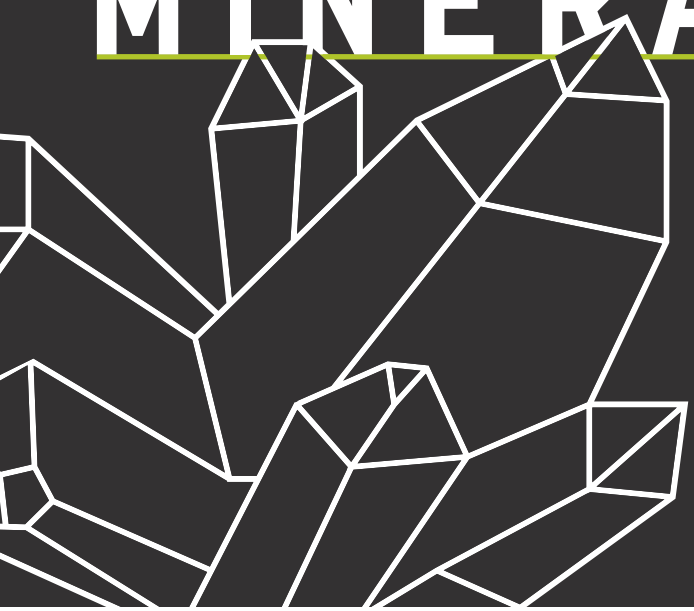
Tracking and measuring innovation initiatives also has the potential to improve the general public's and industry's understanding of academia, Minerick points out. "It also can re-energize a researcher, seeing their work transferred to the marketplace," she says. "It certainly did that for me."

The additional innovation information is slated to be implemented into Digital Measures this spring (2017).

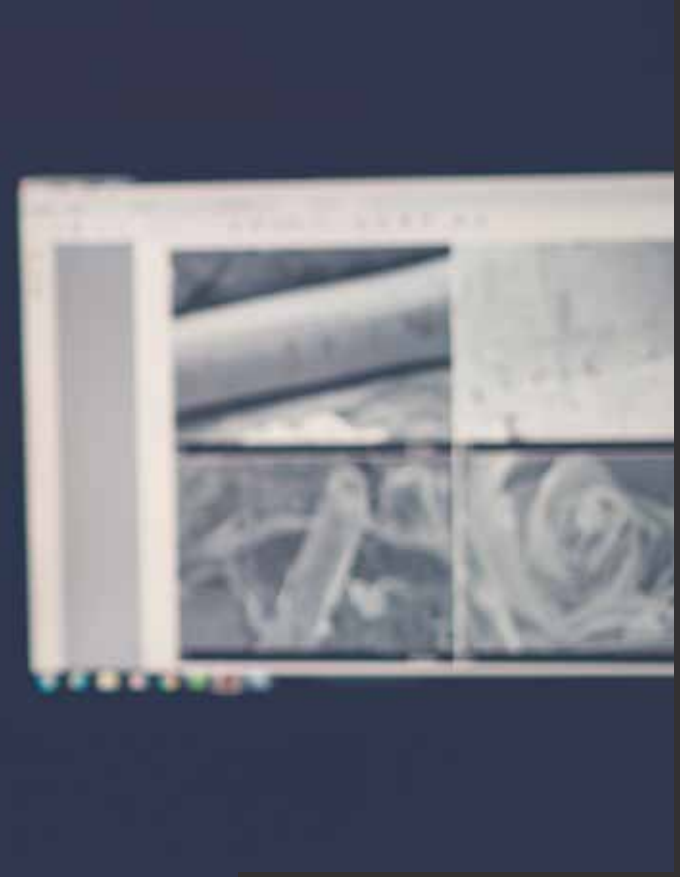
Michigan Tech physics professor John Jaszczak worked with researchers from around the world to identify merelaniite. In time, a better understanding of its chemistry may reveal useful applications.

MEET THE MINERALS

DON'T JUDGE A MINERAL BY ITS COVER. BECAUSE THAT FINE, HAIR-LIKE COATING MIGHT TURN OUT TO BE A NEW MINERAL.



At least that was the case with the newly named merelaniite, a cylindrite-group mineral discovered by a team of researchers led by John Jaszczak, a professor of physics at Michigan Tech. The tiny gray whiskers of merelaniite had been around a while, but had probably been regularly cleaned off larger, better-known crystals like the gemstone tanzanite. The name of the new mineral was chosen by Jaszczak and his colleagues after the township of Mererani, known more commonly in the mineral and gemological communities as "Merelani," in honor of the local miners working in the nearby tanzanite gem mines in northern Tanzania where the new mineral occurs.



High-resolution images reveal merelaniite's complex structure, which form a scroll-like cylinder made of neatly stacked sulfides.

The first person to spot the tiny mineral was Jessica Simonoff in 2011. Then 14 years old, she and her mineral-enthusiast father, Bob Simonoff, didn't recognize the whiskers. So, they brought the sample to Jessica's mineralogy internship supervisor Mike Wise at the Smithsonian Institution's National Museum of Natural History. Because of the high levels of molybdenum and sulfur, the team suspected the mineral was an unusual form of the mineral molybdenite. But when Jaszczak saw the mineral s photo in a news brief, he suspected otherwise.

"The long, thin wires of the minerals' shape was very unusual," says Jaszczak, who had already been studying molybdenite extensively. After meeting the Simonoffs and suggesting that further studies might be in order, Jaszczak received a small sample from Wise. Preliminary Raman spectrometry gave spectra that didn't match any known mineral. Further analyses done in Michigan Tech's Applied Chemical and Morphological Research Laboratory revealed the presence of not only sulfur and molybdenum, but also a significant amount of lead, and other elements. "It really looked like this was a new mineral," Jaszczak says.

ALL IN THE FAMILY: CYLINDRITE

"Minerals have a natural wow factor, and while we use many of them daily without thinking twice, some mineral specimens are truly natural works of art," Jaszczak says, adding that minerals like the gems tanzanite (a blue/purple variety of zoisite) and tsavorite (a green variety of grossular garnet), which come from the same mines as merelaniite, can be more eye-catching. But it doesn't negate the value of less showy minerals.

Scanning and transmission electron microscope studies of merelaniite—a member of the cylindrite group—revealed a neatly stacked layered structure at the atomic level, with sheets rolled in scrolls like tobacco in a cigar.

"Minerals also have an internal beauty in their crystal structures, and it is the crystal structure that influences their properties," he explains. "Learning about minerals with unique crystal structures grants insight into the nature of matter, and sometimes leads to new human-made materials, inspired by their naturally occurring counterparts."

TO NAME A MINERAL

There are 5,179 minerals listed by the International Mineralogical Association, and their Commission on New Minerals, Nomenclature and Classification (CNMNC) receives more than 80 proposals each year for new ones. Many turn out to be variations of existing minerals. To discern the new from the variable, mineralogists and physicists put samples through a battery of rigorous tests, particularly to discern their chemistry and crystal structure.

"It is one thing to find a mineral that is probably new; it is quite another thing to be able to perform all of the required analyses to satisfy the CNMNC for approval of its status and a new name," Jaszczak says.

Although Raman spectroscopy gave Jaszczak the first hard evidence that the mineral may be new, more work needed to be done. The chemistry of the new mineral was a challenge to determine with precision because of the nature of how molybdenum, sulfur, and lead are detected in the electron microscope's x-ray detectors. "Ironically, these three elements all give very similar x-ray signatures," says Jaszczak. Furthermore, because merelaniite is composed of

two different kinds of mismatched layers at the atomic scale, and because they curve to form a scroll-like cylindrical structure, it was particularly difficult to determine the fundamental crystallographic parameters. For both of these challenges, Jaszczak needed help.

Additional samples were also needed for further studies. Fortunately, and rather serendipitously, Simon Harrison in Bath, England, with whom Jaszczak had been collaborating on a comprehensive survey of unusual minerals from the Merelani gem mines, had sent Jaszczak a suite of samples to study and photograph in December 2013. On one particularly large sample of alabandite, Jaszczak found a treasure trove of tiny merelaniite whiskers mixed with graphite crystals that provided more than enough material for additional studies.

DETAILS, DETAILS

To help with understanding the crystal structure, Jaszczak turned to Steve Hackney, professor of materials science, and Owen Mills, director of Michigan Tech's Applied Chemical and Morphological Analysis Laboratory. Hackney was able to provide crucial high-resolution images and diffraction patterns using transmission electron microscopy (TEM) on ultrathin samples prepared by Mills. The goal was to get a more refined sense of the whisker's atomic structure.

TEM allows a magnified image of the sample compared to other imaging techniques. "Think of it like looking at a beach," says Hackney. "If you stand up on a chair, you just see tan color, but if you get up real close, then you can start to see how the beach is made of individual grains of sand. The TEM gets us really close."

That process is about to get easier with a new $1.7 million transmission electron microscope being installed at Michigan Tech. The FEI Themis Titan will be able to discern single atoms in a material. The equipment is so sensitive that the University is building a new space to house it away from interfering noise, vibration, and electronics on the main campus. The mineral-finding crew is excited to test out the new equipment, although Mills and Hackney jokingly reminded Jaszczak that "your samples are still going to need to be thin."

Following their collaboration on merelaniite, Luca Bindi named another new mineral this year—jaszczakite [Bi3S3][AuS2] found in the Börzöny Mountains in Hungary, and named for Michigan Tech researcher John Jaszczak (below).

JOHN JASZCZAK

STEVE HACKNEY

OWEN MILLS

Merelaniite's tiny whiskers look like very fine hairs on other larger crystals. They have likely been regularly cleaned off their host rocks containing other more recognizable minerals from famous gem mines near Merelani, Tanzania.

Sample prep is one of the trickiest parts of the process: Take a several millimeter-long mineral whisker, mount it in epoxy, then slice off nanometer-thin samples with a diamond knife to put on a special grid that plugs into the TEM. There's a reason Mills had to do about 50 cuts. "Out of all those cuts, only one proved to be successful for imaging on the TEM," said Jaszczak. It was totally worth it. The high-resolution TEM images confirmed the layered structure, and the diffraction patterns revealed a bimodal set of spots that later proved to be vital to understanding the atomic-level structure. To make sure, Jaszczak brought in additional researchers.

GLOBAL TEAM

Jaszczak teamed up with Mike Rumsey and John Spratt at the Natural History Museum in London to determine the chemical composition of the new mineral with precision.

To vet the structure, Jaszczak and Rumsey then sought out Luca Bindi, a professor at the Università di Firenze in Italy and an expert in solving complicated crystal structures. The results from Bindi's x-ray diffraction studies, together with the TEM and chemical data, proved that the mineral was a new member of the cylindrite group, this time with atomic-scale layers of predominantly molybdenum disulfide alternating with layers of lead sulfide—a natural nanocomposite material—according to Hackney.

Future work will be needed to determine exactly how the other elements, including vanadium, antimony, bismuth, and selenium, fit into the structure.

Although not a showcase gem, merelaniite is attractive, and as the analyses show, it has an intricate, microscopic internal beauty as well. Currently, merelaniite have no human-made analog; minerals like it could be their inspiration.

For Jaszczak, simply finding something new is enough. Echoing physicist Richard Feynman, Jaszczak notes, "Science is about taking 'pleasure in finding things out' and we're delighted to have uncovered and described this beautiful new mineral."

mtu.edu/magazine/mineral

IT'S BEEN A GOOD YEAR FOR NEW MINERALS. Michigan Tech, in one way or another, is associated with five new minerals: merelaniite, jaszczakite, redcanyonite, leesite, and leószilárdite. Owen Mills worked with two Michigan Tech alumni, Travis Olds '12 and Shawn Carlson '91, on the last three. They are all small yellow crystals from Utah's San Juan Mining District, with some notable differences.

LEÓSZILÁRDITE
$Na_6Mg(UO_2)_2(CO_3)_6 \cdot 6H_2O$
(a sodium and magnesium-enriched uranyl carbonate)
Aggregates of bladed crystals up to 0.2 mm in length
Markey Mine, Utah, USA

LEESITE
$K(H_2O)_2[(UO_2)_4O_2(OH)_5] \cdot 3H_2O$
(it s a hydrated desert mineral, a companion of gypsum)
Stacked blades, radial aggregates, and occasional powdery masses up to 1 mm in length
Jomac Mine, Utah, USA

REDCANYONITE
$(NH_4)_2Mn[(UO_2)_4O_4(SO_4)_2](H_2O)_4$
(a rare uranyl sulfate)
Needles in radial aggregates
Blue Lizard Mine, Utah, USA

SMART ADHESIVES

WITH BRUCE LEE

Removing an adhesive bandage can be the stuff of nightmares. Pulled hair. Pinched skin. Toddler tears and screams.

Ironically, keeping the bandage on can often be even more of a pain—the smallest amount of moisture can destroy the strongest of adhesives.

But what if you could turn the "stickiness" of your band-aid on and off for pain-free removal? And what if the band-aid was waterproof so that it only came off when you wanted it to?

These ideas may sound too good to be true, but thanks to the work of Bruce Lee, assistant professor of biomedical engineering at Michigan Tech, "smart adhesives" may soon be a reality.

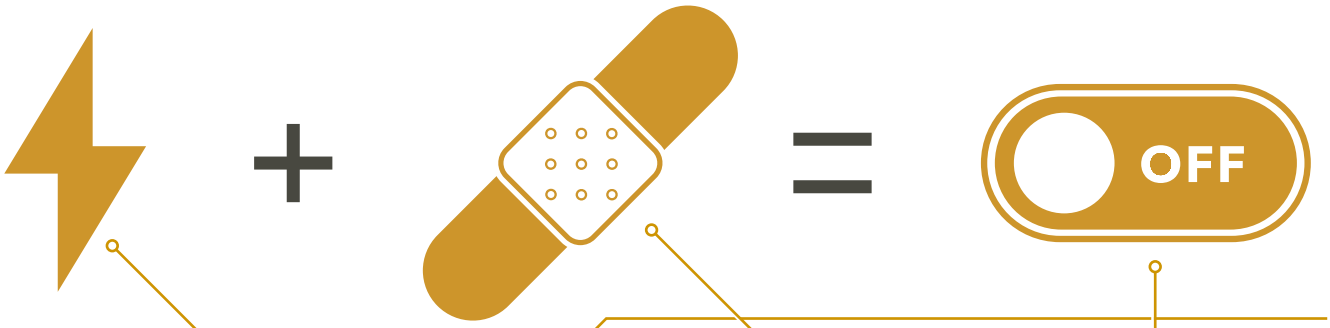
MUSSEL POWER

Lee's work focuses on adhesives inspired by nature. More specifically, the natural glues are made by mussels that anchor them to rocks, boats, and docks. Lee's past work on hydrogels and tissue adhesives led him to look more closely at what makes these adhesives work underwater—and how people could use them.

"This work is novel in the sense that there is no smart adhesive out there that can perform underwater," he says. "The chemistry that we can incorporate into the adhesive, causing it to reversibly bond and de-bond, is quite new."

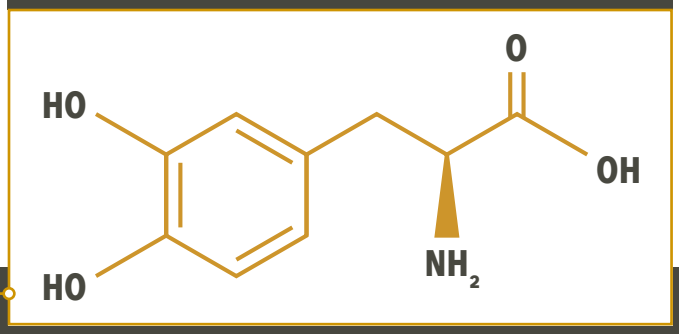
Lee's ideas caught the attention of the Office of Naval Research, which earlier this year recognized him with a Young Investigator Program (YIP) award. As a YIP participant, Lee plans to continue delving into not only what makes mussels sticky but also how to reverse that adhesion.

A custom-built JKR Indentation setup with the smart adhesive attached to the load cell.



> THE CHALLENGE NOW IS TO FIGURE OUT HOW TO APPLY AN ELECTRIC CURRENT, CAUSING THE DOPA-BASED ADHESIVE TO RELEASE, AND THEN REAPPLYING THE CURRENT TO MAKE IT GLUE-LIKE AGAIN.

Amino acid structure of **DOPA**



STUCK ON BIOMIMICRY

Lee looks at a specific amino acid found in mussel foot proteins, called DOPA (3,4-dihydroxyphenylalanine), which is related to dopamine. In past research, he and his graduate students showed that DOPA could be manipulated to design a hydrogel actuator, which is a mass of jello-like polymers lined with iron bands that enable it to move on its own.

The challenge now is to figure out how to apply an electric current, causing the DOPA-based adhesive to release, and then reapplying the current to make it glue-like again.

He adds there is also a biomedical component: "Think of a band-aid—our adhesive would be a less painful way to remove a bandage—or being able to detach or reattach a prosthetic limb or a wearable sensor."

Sean Kirkpatrick, chair of the Department of Biomedical Engineering, says Lee's work is a good example of innovative and creative research.

"The YIP program is one of the most selective research funding programs in the country," he says. "The fact that Lee received this award shows that the faculty and the research programs in the Department of Biomedical Engineering are on par with the best programs in the nation."

Recently, Lee and PhD student Ameya Narkar published some of their preliminary findings in *Chemistry of Materials*, a high-impact journal, showing the role that pH levels (acidity) play in controlling adhesive strength. "Lower pH levels result in a stronger adhesive, and higher pH levels mean a weaker adhesive, so it's a reversible process," Lee says.

"Our goal right now is to demonstrate feasibility and understand the chemistry of strong adhesion and weak adhesion in relation to wet surfaces," Lee says. "Our long-term goal is to use electricity to tune the adhesive property—or turn it on and off."

> A SMART ADHESIVE CAN BIND SENSORS UNDERWATER, IT CAN ATTACH TO A SHIP HULL, IT POTENTIALLY COULD HELP UNDERWATER ROBOTICS OR UNMANNED VEHICLES, AND INTEGRATE WITH NAVAL SYSTEMS.

BASIC SCIENCE, PRACTICAL APPLICATION

To Lee, the key to making this research project work is leaving it fairly open-ended. Basic science is about understanding the mechanism of a phenomenon—in this case, the chemical reactions driving adhesion. The materials and research can then be tailored for more specific uses.

He also says collaboration is an important part of his work and is one of the reasons he received the YIP Award.

"We have a lot of water-focused research going on through the Great Lakes Research Center (GLRC), and I'll have opportunities to collaborate with colleagues on campus," Lee says, adding that he will work closely with Guy Meadows, the center's director, to test the adhesive on underwater autonomous vehicles.

"Lee's work has the potential to change the way we connect components underwater," Meadows says, explaining that he and other GLRC researchers started working with Lee to naturally attach a camera to a living, five-foot-long Great Lakes sturgeon to learn where they go after spawning.

Lee's work also has the potential to impact the daily lives of average people.

"Think about Post-It Notes and duct tape," he says. "A Post-It Note is a weak adhesive and can be attached multiple times, but it loses its adhesive quality over time. Duct tape, on the other hand, is a strong adhesive and difficult to remove. But once you remove it, its adhesive quality is significantly diminished—in many instances, it's worthless."

With Lee's research, simple household items like bandages, Post-It Notes, and duct tape could be used repeatedly, and even adhere to wet surfaces, reducing waste and costs.

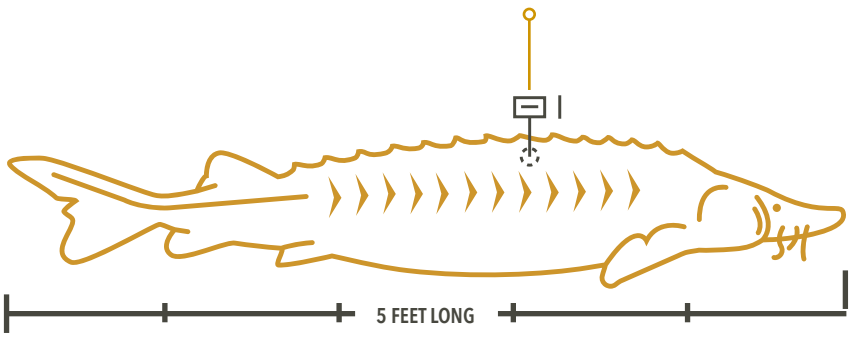
From following fish to healing wounds to monitoring submarines, Lee's mussel-inspired adhesion research is sure to stick around a while.

mtu.edu/magazine/adhesives

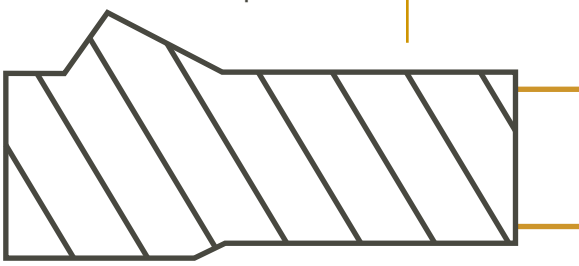
EVERYDAY APPLICATIONS

Testing the adhesive on autonomous vehicles

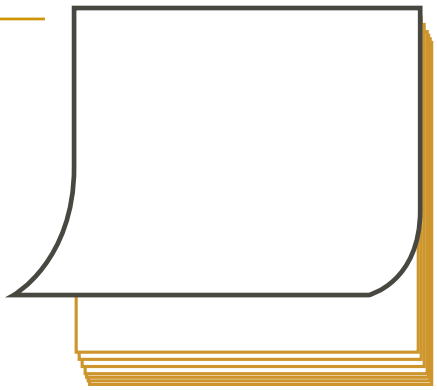
Adhesives to attach a camera to a Great Lakes sturgeon to track it after spawning



Casts and bandages that can be turned on and off during the healing process



Reusable sticky notes that can be applied to wet surfaces



THE BUTTERFLY EF

FECT

THOMAS WERNER'S JOURNEY FROM EAST BERLIN TO THE KEWEENAW HAS BEEN A METAMORPHOSIS. HIS WORK WITH FRUIT FLIES IS GIVING RESEARCHERS AN AVENUE TO EXPLORE FOR CANCER SCREENING, PREVENTION, AND TREATMENT.

Werner still has his first butterfly net—the original from his childhood in East Germany.

The small tortoiseshell butterfly is orange-red with stark black and white dots. A bright fringe of smaller blue dots curves along both wings. Named *Aglais urticae*, the butterfly is found throughout continental Europe and the UK. One summer day in 1981, a small tortoiseshell butterfly got trapped in the window pane of a ninth-floor apartment in the city of Erfurt, then in East Germany. A boy sat next to the window, woken up by the flapping. Eventually, he stood up and called for his parents to come to the room.

"I had to decide whether I was going to kill it," explains Thomas Werner, who is now an assistant professor of biology at Michigan Tech. "To collect a butterfly, you have to kill it."

TO DECIDE

Werner knew he wanted to be a butterfly biologist from a very young age when he found chasing butterflies to be a preferable diversion to missing his friends and helping his parents harvest their garden plot.

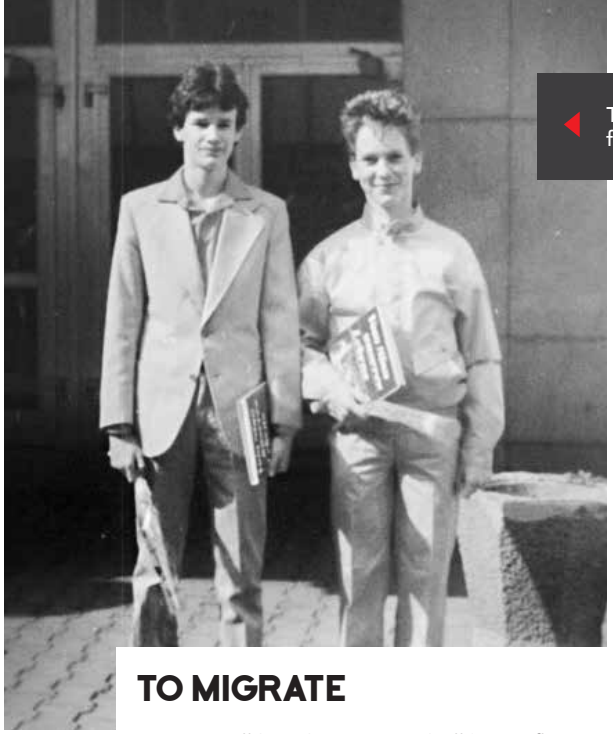
"East Germany was a gray country," Werner says, adding that his parents and many others found solace outside the cities and spy networks at summer cabins with gardens. Werner found color and focus in chasing butterflies.

But for all his ardor catching white cabbage butterflies with tea strainers and busting down the dahlia patch with a makeshift net in the garden in failed attempts to catch the faster tortoiseshells, Werner questioned whether he should catch the butterfly trapped in his window right now. He told his parents that he had to make a choice.

"I told them, 'I am 10 years old today and what if I'm 18 years old one day—and more mature—and I decide to collect butterflies,'" Werner recalls. "I will look back to this day and say to myself, 'I was stupid not to take this butterfly, for this is a once-in-a-lifetime opportunity.'"

His mother told him, "You're old enough today to make that decision."

"AT FIRST I THOUGHT FRUIT FLIES WERE JUST A TOOL FOR ME TO DO RESEARCH," WERNER SAYS. "BUT I'VE LEARNED TO LOVE FRUIT FLIES AND SEE THE BEAUTY IN THEM."



Thomas Werner (left) with childhood friend Mario Arndt.

TO MIGRATE

Werner still has the tortoiseshell butterfly specimen. He collected more specimens with his childhood friend, Mario Arndt. But in college a friend told him, "If you hold onto this dream, you will be unemployed—you have to put on a white lab coat and become a molecular biologist."

So, he changed his academic focus. While Werner was a senior in high school, East Germany unified with the rest of the country, and he suddenly had a couple years open up for study that he otherwise would have spent in the military. Then as a graduate student, he followed a lifelong dream to move to Sweden—sans butterflies. Instead, he ended up working with fruit flies, which was fine by Werner's standards.

"First, they have six legs—like butterflies, so this is a good thing," he says. "Second, they have at least two wings—although butterflies have four."

For five years during his doctoral work, Werner kept a copy of a journal article about butterfly patterns from Sean Carroll's lab at the University of Wisconsin-Madison. He was determined to pursue a postdoc there.

"Butterflies became my battery pack," Werner says, explaining that as he struggled through his chemistry, physics, and math classes, "the prospect of getting to study butterflies one day kept me going."

Female wings nearly unpigmented. Their bodies are medium-large-sized, abdomen is striped, terminal segments are black.

A male can be identified without a microscope. Their body is medium-sized, abdomens are vaguely striped, terminal segments are black.

TO FIND

Werner arrived in Madison, Wisconsin, in 2005. He arrived with nothing but two suitcases; the rest of his clothes, records, and books he had given away or tossed. At the lab, Carroll asked him if he wanted the good news or the bad, and ever an optimist, Werner took the bad news first. They had killed off their last butterfly culture, the project was no longer running—but they had a new fruit fly project.

"I said, 'Hey, Sean, I spent all day yesterday throwing my life into a dumpster and they've probably emptied it by now, so my only option is to stay here,'" Werner told Carroll. "He said at least there is a really pretty fruit fly, it has beautiful spots!"

Werner's subsequent postdoc work led to the discovery of an important set of proto-oncogenes. In humans, they can regulate tumor growth; in fruit flies, they control wing spots. Turns out that fruit flies make an excellent model species since they share the basic body building genes that all animal genomes encode. By isolating the wing spot genes in fruit flies, Werner gave medical researchers a potential avenue to explore for cancer screening, prevention, and treatment. In 2010, *Nature* published the work, featuring Werner's story on the cover.

"I love the precision and detail work of making a clean, crisp image," he says of the microscopic specimen close-ups he compiles, using more than 50 image files. "Cleaning up the raw images is winter work, though, it's something you need darkness to have patience for."

In contrast, the summer months are for catching flies.

TO GUIDE

A bottle, oozing a browned banana-yeast mixture, hangs from a tree only 10 feet off the Homestead Loop on the Michigan Tech Trails. Werner fusses with the string, a net tucked under his arm.

"You have to let it ferment a few days," he says. "They love that."

Deceptively simple, the bottle is a Chinese finger trap for fruit flies. In the Keweenaw alone, there are more than 20 different species of fruit flies; only one, *Drosophila melanogaster*, comes indoors. Werner finds a challenge and allure in them like he once did with butterflies in his parents' garden.

"At first I thought fruit flies were just a tool for me to do research," Werner says. "But I've learned to love fruit flies and see the beauty in them."

Through a mentorship with John Jaenike from the University of Rochester, Werner learned to identify fruit flies by sight and, overnight on a visit to New York in 2012, he started a fruit fly field guide for the Northeast. The guide is now a collaboration between Jaenike and Werner, and is the first one completed for the region in about 100 years.

"I LOVE THE PRECISION AND DETAIL WORK OF MAKING A CLEAN, CRISP IMAGE."

Using his banana bottle traps along with tomato and mushroom traps, Werner has gathered about 40 species, collecting males, females, and notable variations to image back in his lab.

To capture them, he taps the opened banana bottle while holding the net over it, then as the flies venture out, he swings the net back and forth with the power and accuracy of Venus Williams. He scoops the stunned fruit flies into a small vial; usually he brings them back to the lab for identification, but for the benefit of visitors, he'll separate out the males and females by size on a small white plate using very fine tweezers.

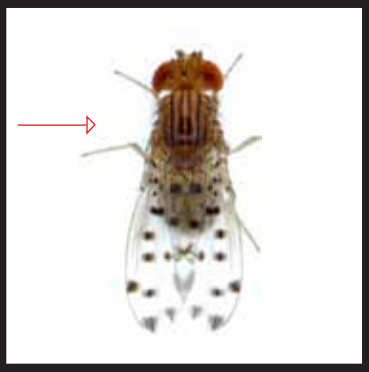
To some people, they are black dots on a white plate—a teeny nuisance to drown in soapy water or wine in the kitchen. To Werner, their stripes and bright red eyes and rounded wings with myriad patterns have come to be as lovely as small tortoiseshell butterflies.

mtu.edu/magazine/butterflyeffect

Werner (right) shows a student in his lab that fruit flies do much more than come into the kitchen with bananas—their genetics offer insight into cancer-related genes and other human diseases.

FRUIT FLY

DROSOPHILA GUTTIFERA



The organism with which Werner does his developmental genetics research to study animal color pattern development.

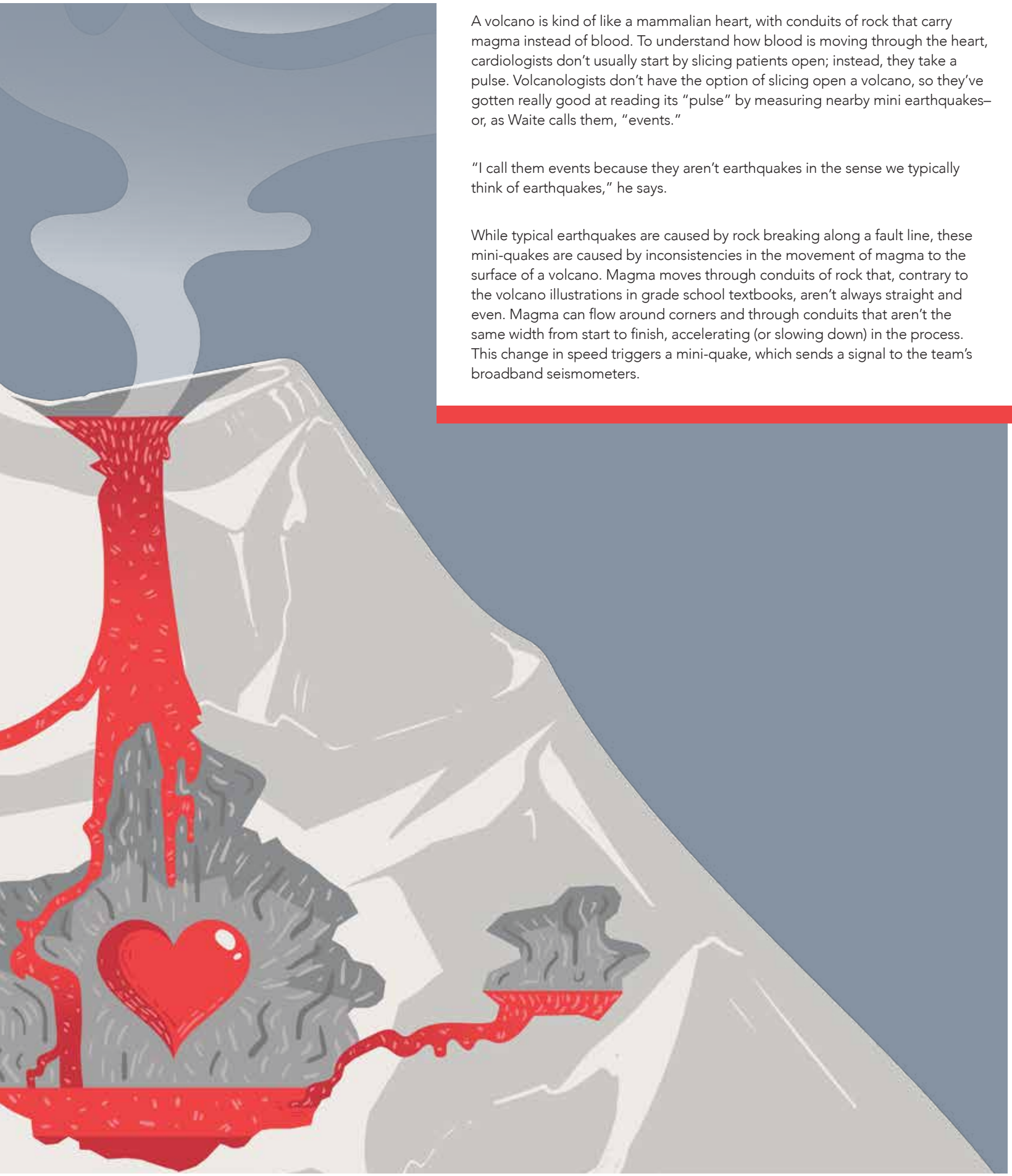
Drosophila guttifera wing crossveins, all longitudinal vein tips, and the campaniform sensilla are intensively clouded.

Tips for collecting and breeding: This species visits mushroom and tomato traps. It can be reared on sugar food with a few sprinkles of baker's yeast.

CHARACTERIZING A VOLCANO

YOU CAN'T LOOK INSIDE THE HEART OF A VOLCANO BUT YOU CAN TAKE ITS PULSE.

From Mount St. Helens in Washington to Volcán de Fuego in Guatemala, Greg Waite knows that when the ground shakes, magma is moving. Waite is an associate professor of geological and mining engineering and sciences at Michigan Tech, and he and his team study the movement of magma, or molten rock, through volcanoes by measuring mini earthquakes.

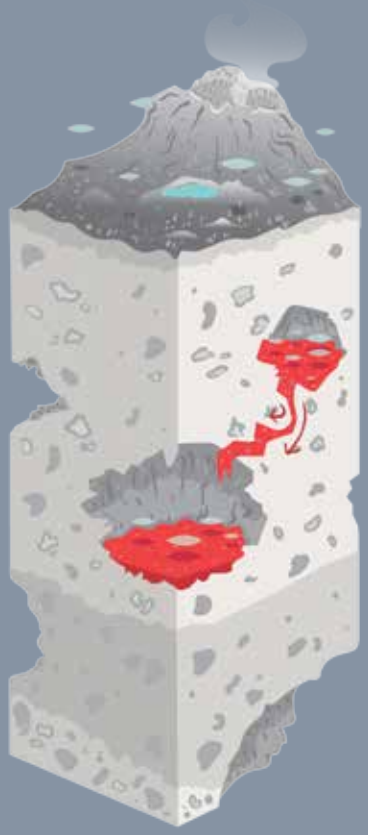


A volcano is kind of like a mammalian heart, with conduits of rock that carry magma instead of blood. To understand how blood is moving through the heart, cardiologists don't usually start by slicing patients open; instead, they take a pulse. Volcanologists don't have the option of slicing open a volcano, so they've gotten really good at reading its "pulse" by measuring nearby mini earthquakes–or, as Waite calls them, "events."

"I call them events because they aren't earthquakes in the sense we typically think of earthquakes," he says.

While typical earthquakes are caused by rock breaking along a fault line, these mini-quakes are caused by inconsistencies in the movement of magma to the surface of a volcano. Magma moves through conduits of rock that, contrary to the volcano illustrations in grade school textbooks, aren't always straight and even. Magma can flow around corners and through conduits that aren't the same width from start to finish, accelerating (or slowing down) in the process. This change in speed triggers a mini-quake, which sends a signal to the team's broadband seismometers.

VOLCÁN DE FUEGO



"CONDUITS THEMSELVES CAN ALSO EXPAND AND CONTRACT AS BUBBLES OF MAGMA PASS THROUGH."

"Anytime there's an acceleration of mass, you get a signal," says Waite.

The conduits themselves can also expand and contract as bubbles of magma pass through, and this is the more common cause of mini-quakes at the volcanoes Waite and his team study.

"Mostly what we see associated with these events that come from the conduit look like small opening and closing mechanisms," Waite says. "These temporary expansions can last anywhere from tens to hundreds to thousands of seconds."

The main hurdle for Waite and his team is that they only get glimpses of the volcano's inner workings, and they have to connect the dots.

"We really only see these events where there are changes in the conduit," he says. "With a smooth conduit you won't see much activity. Places where there's a kink in the conduit, there's acceleration of the magma around a corner, that's when we can really pick out the features."

Volcanoes with smooth, even conduits don't produce the same kind of activity. For example, Greg says that Villarica Volcano in Chile is "more like a soda straw." Waite's team didn't pick up any mini-quake signals there.

Volcanoes with the most complex and irregular conduits, then, are good ones for the team's research. In these cases, the shape of the conduit can be modeled with an impressive level of detail. Volcán de Fuego in Guatemala is a good example. There, with some powerful math and physics, Waite's team can model the opening and closing of the conduit over time.

"I always liked physics and mathematics and knew I wanted to study those fields," he says. "Early on in my undergraduate career, I began thinking about how I could make a career studying earthquakes and volcanoes." After completing his PhD at the University of Utah, Greg landed a postdoc position at the U.S. Geological Survey in Menlo Park, California, where he worked with research geophysicist Bernard Chouet. Chouet was one of the first scientists to model magma conduits using seismic data.

The ability to "see" magma with seismic measurements was a breakthrough, because traditional underground imaging techniques (like some used in the oil and gas industry) only work for large volumes of a substance. "[It's] typically pretty hard to determine exactly where the magma is unless it's in really big patches," Waite says of these techniques.

His team has further advanced the field by developing a method for using other types of data to check the accuracy of their models. For example, volcanic gas emissions can be recorded by the low-frequency sound they produce, allowing researchers to compare a record of these sounds with modeled conduit openings and closings. In theory, gas emissions should line up with conduit expansions.

"One of the questions modelers have to think about is, 'How well can I trust my model results?'" Waite explains. "It's not always an easy question to answer, but has driven us to explore ways to evaluate the reliability of models."

Webcam footage is another validation tool. Fuego and Pacaya, the two Guatemalan volcanoes Waite's team studies, have live webcams (*ovfuego-norte.geo.mtu.edu*).

Fuego and Pacaya are marked by frequent, small eruptions. These volcanoes are relatively safe to visit and place equipment on, which makes them perfect candidates for volcanology. However, the work Waite's team is doing will advance the prediction of major eruptions that threaten lives and livelihoods. As a result of their work, they contribute to a growing body of knowledge, policies, and practices informed by more accurate forecasting of volcanic activity.

Waite is quick to say that the research at Fuego and Pacaya is a true collaborative effort involving researchers from other institutions, the Guatemalan government, and local observers and volcanologists. His team simply builds on the work that Guatemalans have been doing for a long time.

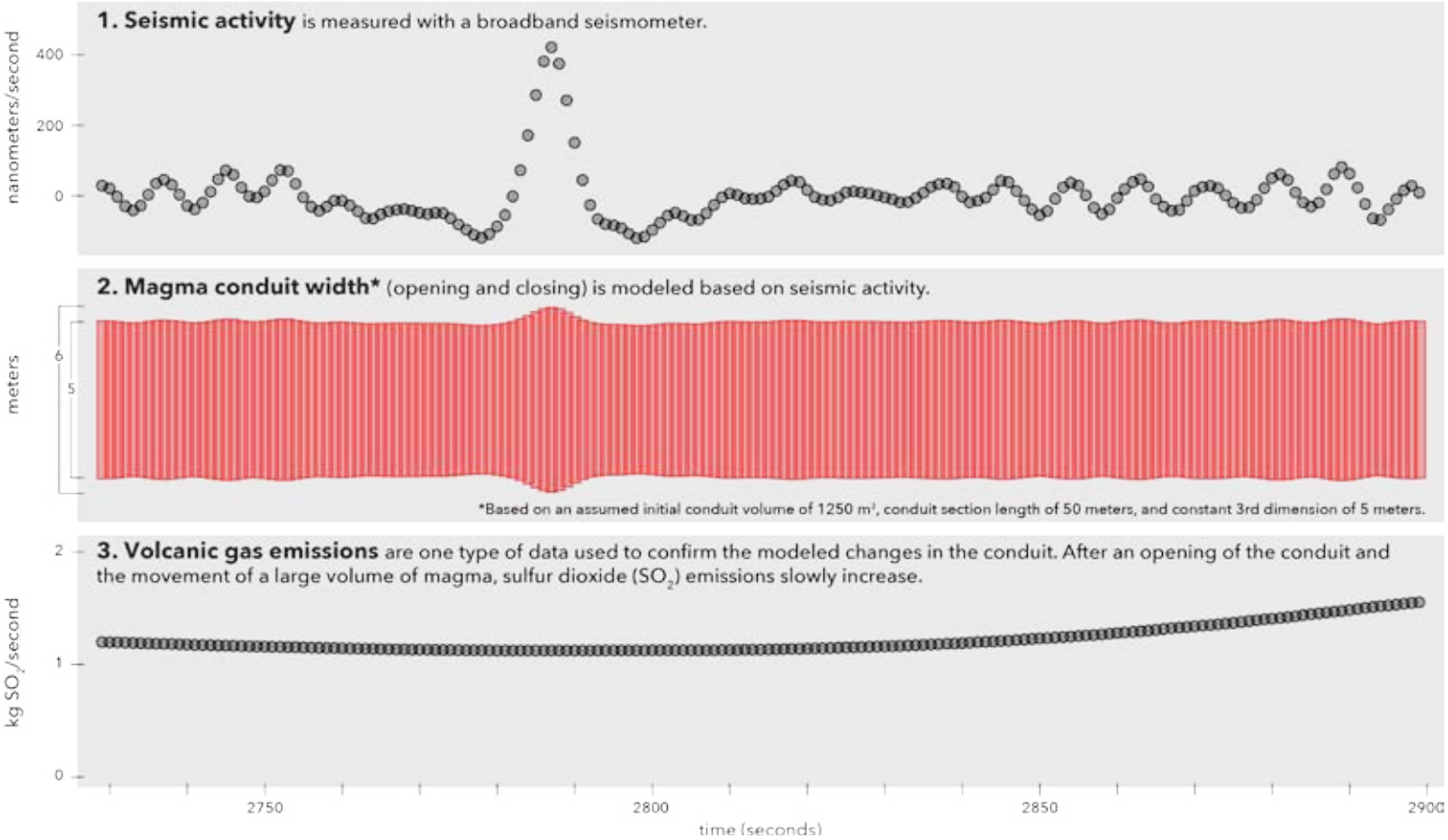
"The cooperation of scientists and engineers at the Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología have been critical to this work. The volcanologists there, led by Gustavo Chigna, know the volcanoes well and have done an excellent job of keeping people safe by anticipating changes in the behavior of the volcanoes. Our work builds on their understanding by providing some details. I think we learn much more from them than they do from us, but I hope we are able to implement some of what we learn to improve eruption forecasting."

mtu.edu/magazine/volcano

GREG WAITE

The graphic below shows measured seismic activity at Fuego volcano, the corresponding modeled changes in the size of its magma conduit, and volcanic emissions data used to confirm the model results.

MAGMA CONDUIT WIDTH AT FUEGO VOLCANO, GUATEMALA



ANDREW BARNARD '04 '06 HAS BEEN ALL ABOUT THAT BASS, SOUND

THAT TREBLE, AND ALL FREQUENCIES IN BETWEEN EVER SINCE HE WAS A KID GROWING UP IN DOOR COUNTY, WISCONSIN.

"I was a musician, so I was into acoustics without even knowing it," says Barnard, an assistant professor of mechanical engineering–engineering mechanics with an ear for the sounds of science.

His avocation got an early start, beginning with six years of piano lessons followed by playing in his high school band (three different instruments). He also sings tenor in the Michigan Tech Concert Choir and, back in 2001, as the wag Nicely Nicely in Tech's staging of *Guys and Dolls*.

"I've always liked sound," he says, but never imagined making it his profession. That changed when he enrolled in former mechanical engineering professor Mohan Rao's acoustics and noise control class. "He sparked my interest," says Barnard. "I realized I could take my hobbies and engineering and mesh them together in a career.

After completing a BS in Mechanical Engineering–Engineering Mechanics and an MS in Mechanical Engineering at Michigan Tech, Barnard left for the only university in the country that offered a PhD in acoustics. At Penn State, he earned his doctorate and found a home in the Applied Research Lab, which is partially funded by the US Navy. There, his work focused on silence, reducing noise of naval vessels, torpedoes, and other underwater hardware.

Then one morning in July 2014, Barnard heard from Michigan Tech. Would he like to apply for the faculty position recently vacated by his mentor, Mohan Rao?

It wasn't a tough decision. "I grew up on the Door Peninsula, and I worked all summer at my grandparents' resort in Egg Harbor," he says. "I missed the big water.

He would also be able to widen his perspective. Now, his research repertoire at the University ranges from exploring the underwater soundscape of the Great Lakes to acoustic applications of carbon nanotube thin films.

"I like to try new stuff," Barnard says. "Whatever it is, if it has anything to do with sound, I'm interested. I'll work on anything.

Cool Sounds, Hot Nanotubes

Next to Barnard's computer is a small device that looks vaguely like a pair of mini goalposts. Two pencil-sized copper rods are mounted on a stand, with a band of transparent black gauze stretched between them. He double clicks on a sound file, and the device begins whispering AC/DC's "Back in Black.

The gauze is actually an ultra-thin sheet of aligned nanotubes called a carbon nanotube thermophone, which can warm up and cool down up to 100,000 times a second when plugged into a power source. That heating and cooling causes the adjacent air to expand and contract, pushing air molecules around and making sound waves.

Why a nanotube speaker instead of the usual kind? It's flexible and stretchable, with no moving parts, and you can put it practically anywhere. Plus, it weighs next to nothing. Four ounces of the material will cover an acre.

Those attributes might also make it a go-to material for the auto industry, which is eyeing active noise control technologies that can make any vehicle rumble like a '69 Camaro.

Active noise control can quiet a vehicle's exhaust system by neutralizing noise with noise, a bit like a matter/anti-matter reaction. Sometimes, however, drivers don't want to run silent. Sometimes they want to imagine they are idling at the start of the Indy 500.

"The hot new thing for exhaust systems is to tailor the sound," says Barnard, whose group is engineering just such a system using nanotube thin films. Its work is being supported by a Michigan Translational Research and Commercialization grant from the Michigan Economic Development Corporation and by Michigan Tech's Research Excellence Fund. "And we're talking with some top-tier suppliers interested in funding the research further, Barnard says.

Shh! Hard Drives at Work

Sometimes, too much noise makes computer hard drives fail. So, when the people at Tyco Fire Protection Products in Marinette, Wisconsin, discovered that the loud whoosh of their fire extinguishing system was hurting hard drives, they came to Barnard to find out why.

You can't use sprinklers to put out a fire in a room full of electronics. Instead, Tyco forces inert gas through a nozzle into the space, displacing the air and smothering the blaze. "But that nozzle was making a lot of noise, so in trying to protect the hard drives from fire, they were damaging them with sound, Barnard says.

To determine what was going on, his team blasted hard drives with various sound frequencies and volumes. When they identified what made them fail, they gave their results to Tyco.

"They came up with a nice, quiet nozzle design," Barnard says. And together they published a white paper on the subject, so other manufacturers can design systems that play nice with hard drives.

Navy Labs Offer New Career Path for Michigan Tech Grads

Think of careers in the Navy, and "engineer" probably isn't at the top of the list. Barnard expects to change that at Michigan Tech.

With a $600,000 grant from the US Navy, Barnard is establishing a Naval Systems Experience program at the University. The aim is to interest students in civilian careers in Navy research labs, which, like auto companies, hire lots of engineering graduates for a multitude of design projects.

Barnard is collaborating with other faculty members to develop a minor in naval systems engineering. He is also working to connect Tech students with staff at research labs and interest them in civilian Navy careers. He's even putting together a Summer Youth Program session in marine technology.

The grant is also helping to support the new SENSE Enterprise (Strategic Education through Naval Systems Experiences). For their first project, the team is developing a near-shore robotic rescue device.

"It would go out and provide flotation for someone who is about to drown," Barnard says. The robot would be guided by a first responder, and while it would work on any shoreline, it's specifically designed for the Great Lakes.

"On the East and West Coasts, there are lots of trained water rescuers, but not on the Great Lakes," he said. Too often, someone drowns for lack of life-saving assistance, or worse, an untrained first responder tries to help and they both drown. "It's a bad situation.

The idea of the robotic lifesaver was first floated by Aanikoosing Inc., The economic development company is affiliated with the Keweenaw Bay Indian Community, which borders plenty of shoreline. "It's a terrific concept," Barnard says. "It falls well within our Navy purview, and it helps out a local community.

"TWO SUMMERS AGO, WE COULD HEAR THE PROP ON AN ORE BOAT, A 1,000-FOOTER, FROM 60 TO 100 MILES AWAY."

Barnard (left) and the University-National Oceanographic Laboratory System (UNOLS) team on the deck of the R/V *Blue Heron*.

The team works with a multi-corer that uses gravity and spring-loaded cylinders to extract cores of mud from the lake bottom.

Barnard measures the sound pressure levels on the work deck of the *Blue Heron*. They range from 75 to 80 dBA.

Voices of the Big Lakes

It's noisy in the depths of the Great Lakes, but no one knows exactly how noisy. Barnard is among those aiming to find out.

"We have a wealth of acoustic knowledge on the oceans, because the military has been interested since the 1940s, he says. "But we don't know much about the Great Lakes, because submarines don't go there.

Two winters ago, Barnard worked with Michigan Tech's Great Lakes Research Center to install an under-ice microphone system, gathering information on everything from the track noise of snowmobiles to the crackle of breaking ice.

In all weather, he heads out to sample the sounds of Lake Superior: background noises, ice noises, the sounds of shipping traffic, and power plants on shore.

"Some of those sounds propagate across the whole lake," he says. "Two summers ago, we could hear the prop on an ore boat, a 1,000-footer, from 60 to 100 miles away.

Last summer, he spent five days aboard NOAA's Research Vessel *Blue Heron*, part of the University-National Oceanographic Laboratory System, gathering sonic information from Lakes Michigan and Superior. In addition to taking sound measurements, he also learned about such matters as seasickness and the perils of leaving an expensive underwater instrument untended while the boat makes a hard turn. (You lose it.) Barnard journaled about his experiences in Michigan Tech's research blog, *Unscripted*.

Why go to all the trouble? Sounds affect the underwater environment and human communication systems. They might also be affecting fish, specifically, efforts to count them.

Government agencies estimate fish numbers using sonar systems in boats. Lately, Barnard has been working with Guy Meadows, director of the Great Lakes Research Center, to see if noise from those boats could be skewing fish census numbers, which are used to write fishing regulations.

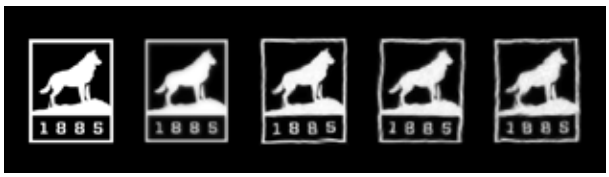
"Some of those boats are old chuggers," says Barnard. "Could we be driving fish away before we can count?"

There's also a wider reason to delve into the sounds of the watery world off Michigan Tech's shoreline.

"Lake Superior has been speaking to us for centuries, Meadows says. "Now we're finally beginning to listen.

mtu.edu/magazine/acoustics

Awards RECEIVED BY MICHIGAN TECH RESEARCHERS



Distortion takes many forms: the turbulence in the first logo is ten times greater than the rest but is isoplanatic; the rest of the logos show anisoplanatism shifting from low to high to extreme levels.

Air Force Young Investigator Research Program (YIP) award: Jeremy Bos

Jeremy Bos, an assistant professor of electrical engineering at Michigan Tech has won an Air Force YIP Award for his work in atmospheric turbulence—distortion that comes from the way light interacts with shifting air.

In some situations, the interference is so bad an image's pixels become blurred. This severe turbulence is called anisoplanatism. "In my work, I'm looking at an extreme case where every single pixel in an image potentially has a different blurring function associated with it," Bos says.

With his YIP award—a highly competitive program for early career scientists and engineers through the US Air Force—Bos is piecing together images affected by anisoplanatism over long distances of at least 300 meters.

"Relative to the Air Force, and to this problem in general, the objective is to see better and farther," Bos says, adding that enhancing optical communications is another potential application, "and to defend against threats using light." Laser weapons and shields are simply concentrated light. Whether as a shield around a jet or a *Star Wars*-style laser beam, the technology comes down to manipulating light waves.

"But in order to do that, you have to account for the atmosphere," Bos says. "And, because you're operating horizontally, you have to account for the volume of atmosphere—and that's a wicked, hard problem."

Office of Naval Research Young Investigator Research Program (YIP) award: Bruce Lee

For his work on reversible underwater adhesives, the Office of Naval Research recognized Assistant Professor of Biomedical Engineering, Bruce Lee from Michigan Tech with a Young Investigator Program award.

Lee focuses on adhesives inspired by nature. More specifically, the natural glues made by mussels that anchor them to rocks, boats, and docks. Lee's past work on hydrogels and tissue adhesives led him to look more closely at what makes these adhesives work underwater—and how people could use them.
(See story, page 14.)

As a participant in the Office of Naval Research Young Investigator Program, Lee continues to delve into not only what makes mussels sticky but also how to reverse that adhesion.

"This work is novel in the sense that there is no smart adhesive out there that can perform underwater," he says. "The chemistry that we can incorporate into the adhesive, causing it to reversibly bond and de-bond, is quite new."

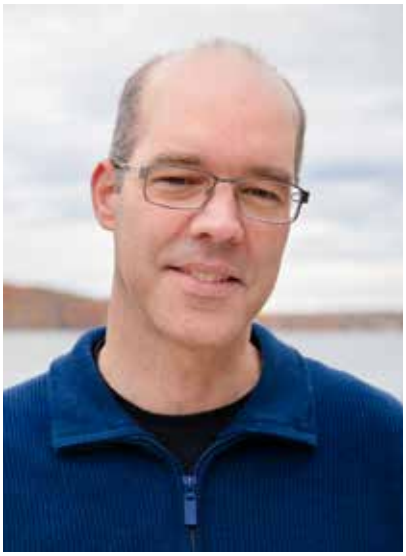
Tarun Dam (left) and Melanie Talaga's glycobiology research is a body of work that includes three papers. One shows that current thyroid cancer assays may have inaccurate readings. The second advances a concept that may potentially streamline drug development, and the third focuses on the team's methodology that could help expose apparently overlooked molecular events.

2016 Bhakta Rath Award: Melanie Talaga and Tarun Dam

Two Michigan Tech researchers were honored with the annual Bhakta Rath Research Award, established in 2010 by an endowment from Bhakta T. Rath and his wife Sushama Rath. Bhakta Rath '58 dedicated his career to promoting science, engineering, and research. Each year, a Michigan Tech PhD graduate student and his or her advisor are recognized for "exceptional scientific and technological research in anticipation of the future needs of the nation while supporting potential advances in emerging technology."

Melanie Talaga, who completed her PhD in Chemistry in spring 2016, and Associate Professor of Chemistry Tarun Dam won the 2016 award for their work in Glycobiology.

"My dissertation research focused on using sophisticated biophysical techniques to understand how molecules behave," Talaga says, explaining the behavior is difficult to detect. "This research lays the foundation for future improvements for cancer detection and drug design."



"Research is really inspiring. Nature is so profoundly beautiful and subtle. It is a privilege to spend so much of my time trying to understand bits and pieces of it." –*Raymond Shaw*

2016 Research Award: Raymond Shaw

The expression "head in the clouds" generally means someone lacks focus and is not being realistic. For Michigan Tech researcher Raymond Shaw, winner of the University's 2016 Research Award, the expression means it's just another day at the office.

Shaw's dedication to cloud research is so strong that when he can't get to the clouds and can't get the clouds to come to him, he has a third option. Michigan Tech has a cloud chamber, where Shaw and his team can study made-to-order clouds. Unlike other chambers that exist in laboratories around the world, the one at Michigan Tech creates clouds that are turbulent and that can persist for hours or even days, rather than the more typical time of a half hour or less.

Shaw, a professor of physics and director of Tech's atmospheric sciences PhD program, says that while he is appreciative of the award, the research itself and the collaborations with researchers at Michigan Tech and throughout the world, is the ultimate reward.

Research Fellowship Winners

In 2016, four Michigan Technological University students received Graduate Research Fellowships (GRF) from the National Science Foundation (NSF) and a fifth won an honorable mention.

Winners included Zachary John Morgan, materials research; Ian Thomas Cummings, computer engineering; Michelle Terese Hoard, chemical engineering; and Mitchell A. Kirby, biomedical engineering. Roger John Guillory, biomedical engineering, received an honorable mention.

GRFs are one of the most prestigious and competitive programs supporting graduate study in science and engineering.

The competition received close to 17,000 applications, and 2,000 awards were made. Fellowships include a stipend of $34,000 per year and a $12,000 cost-of-education allowance of $12,000 per year for three years of the winner's choosing within a five-year award window.

In addition, undergraduate Cindy Fiser, ecology and environmental science, won an EPA Greater Research Opportunities Fellowship for her research on bees.

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/asisc
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
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Earth, Planetary, and Space Sciences Institute (EPSSI)
mtu.edu/epssi
Director: Will Cantrell
Physics
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Ecosystem Science Center (ESC)
mtu.edu/forest/esc
Director: Andrew Burton
School of Forest Resources and Environmental Science
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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
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Life Science and Technology Institute (LSTI)
lsti.mtu.edu
Director: Victor Busov
School of Forest Resources and Environmental Science
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Michigan Tech Research Institute (MTRI)
mtri.org
Co-directors: Robert Shuchman and Nikola Subotic
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nsubotic@mtu.edu

Michigan Tech Transportation Institute (MTTI)
mtti.mtu.edu
Director: Pasi Lautala
Civil and Environmental Engineering
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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/rise
Co-directors: Susan Amato-Henderson and Bradley Baltensperger
Cognitive and Learning Sciences
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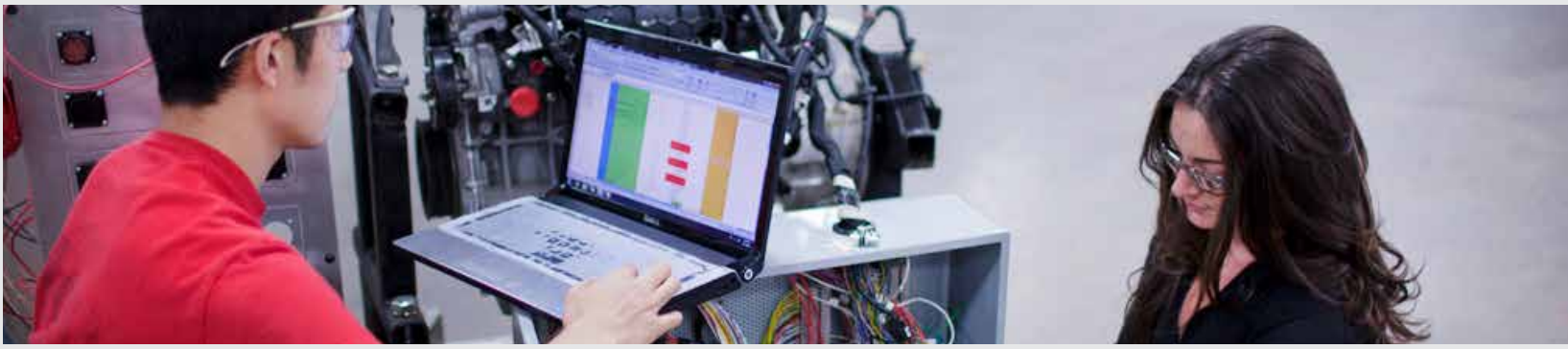
brad@mtu.edu

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

Research Centers and Institutes Spotlight



ADVANCED POWER SYSTEM LABORATORIES (APS LABS)

APS LABS at Michigan Tech are a multidisciplinary collaborative that fosters research efforts in the development of clean, efficient, sustainable power-systems technologies. Its researchers are advancing the fundamental and applied knowledge required for the next generation of low-emission, high-efficiency power generation systems.

Research Areas

Combustion:
The combustion lab, housed at the Alternative Energy Research Building, is home to a 1.1 L optically accessible constant volume combustion chamber. Using this combustion chamber, studies can be conducted on spark ignition; diesel and gasoline fuel injection, alternative fuel ignition, combustion, and emissions; and interaction of spray jets with pulsed injections. Data can also be analyzed to characterize droplet, spray, vaporization, and soot using optical and laser-based diagnostics.

Engine:
The engine laboratory contains six modern engine dynamometers and testing equipment for spark ignition and diesel engines. All the standard engine measurements, including emissions and combustion analysis, can be obtained. In addition, both the physical and biological characteristics of diesel exhaust can be obtained.

Emissions:
Advanced aftertreatment and emissions for medium- and heavy-duty industry consortium research is conducted at our Advanced Power Systems Research Center facility in the diesel engine laboratory to collect standard engine measurement information. In addition, our automotive engine laboratory has emission measuring and high-speed data acquisition capabilities. Our two-stroke marine engine laboratory is a dynamometer facility devoted specifically to research associated with two-stroke engines with emission measuring and high-speed data acquisition measuring equipment to collect the right information for your research and development needs.

Power Transmission:
The Powertrain Research Laboratory features two 465-horsepower dynamometers for testing automotive torque converters and transmissions. The facility offers full LabVIEW automation of all tests, which includes dynamometer controls and hydraulic-system controls. A full suite of state-of-the-art, data-acquisition hardware systems, including a microwave telemetry system, is available to lab users. Studies performed in the lab include cavitation studies and dimensional-analysis correlation, turbine-noise studies, and pump, turbine, and stator pressure-map testing. Any element of a torque converter can be instrumented and tested under nearly any test condition.

Vehicle Lab:
A fully equipped vehicle lab is used for contract projects requiring vehicle level integration. Vehicles are instrumented and updated with experimental hardware or software prior to being tested. The shop is sized to accommodate vehicles from snowmobiles and ORVs to Class 8 Tractor Trailer combinations and off-road equipment. The lab includes two chassis dynamometers (automotive-sized and motorcycle ORV-sized), an automotive-sized cold room, two automotive lifts, and additional tools and equipment.

Mobile Lab:
The mobile lab consists of an expandable semi-truck trailer and includes two fully functional powertrain dynamometers and a fleet of 30 vehicles. It is used for hands-on professional development courses, product and technology awareness, STEM outreach, and research.

Energy:
Issues of energy and sustainability are at the front of everyone's minds—and it's especially true for Michigan Tech researchers. Scientists and experts from countless disciplines come together at Michigan Tech to tackle some of today's most vexing problems. Involving researchers from almost every academic unit, energy and sustainability is one of the most interdisciplinary areas of research at Michigan Tech. And given the complex, interconnected nature of energy and sustainability, that's precisely what makes our research excel.

At Michigan Tech, researchers from biology, chemistry, physics, forestry, and environmental science, and nearly every engineering discipline collaborate in order to study issues of energy and sustainability. Scientists study our planet's resources and find novel ways to transform them into the energy that powers our evolving society. From investigating alternative energy sources, like wind and bioenergy, to studying high-energy particle astrophysics, to the sociology of adopting renewable energy sources and recycling programs, research at Michigan Tech reaches across departmental divisions to provide solutions to monumental problems.

Biomass and Waste to Energy:
APS LABS researchers have developed a combined torrefaction-pyrolysis process that produces bio-oil devoid of organic acids and reduced oxygen, resulting in a high-quality and enhanced biofuel. The main advantages are very little degradation of the biofuel and high calorific value of the fuel. This material can be used either as-is in compression engines or further upgraded in a biorefinery to produce transportation fuels, identical to the ones used in spark ignition engines. The concept has been tested successfully at 1 kg/hr system and is now upscaled to 50 kg/hr. In the upscaled system, biomass wastes, such as agricultural waste and forest residue, as well as municipal solid wastes are used as feedstock. These types of wastes are considered renewable and are low- to negative-cost as they impose an ecological hazard.

Rail:
The Rail Transportation Program (part of MTTI) collaborates with APS LABS at Michigan Tech to provide an independent review of a proposed High Pressure Heat Exchanger (HiP-HEX) System for use on rail locomotives. A group of mechanical engineering faculty, staff, and students are engaged in a theoretical review of the waste energy available at the engine manifold and how much of that energy can be captured and converted to electrical energy to help drive a locomotive, without adversely affecting engine performance.

apslabs.me.mtu.edu

Research Centers and Institutes Spotlight

SUSTAINABLE FUTURES INSTITUTE (SFI)

The Sustainable Futures Institute was established at Michigan Tech as an incubator for research, education, and outreach efforts related to sustainability. SFI addresses sustainability from multiple disciplines—fitting the discipline to the challenge, rather than expecting the challenge to fit pre-established disciplinary methods.

SFI is an education and research leader on sustainability initiatives related to water, air, and energy; industrial ecology; environmentally conscious manufacturing; green engineering; public policy; the built environment; sustainable development that includes issues of the developing world; pre-college education for students and teachers; community outreach; and university campus eco-improvements. SFI has more than 100 participating campus members and oversees more than $15 million in research projects addressing all areas of sustainable systems development.

Research Areas

SFI facilitates collaborative research between Michigan Tech faculty, global organizations, and industry partners in 11 countries. Research is focused on unique, multi-perspective sustainable development.

International/Developing World Sustainable Development:
How can the SFI foster sustainable development in other regions of the world and encourage best practice adoptions or creation of home-grown, localized solutions?

Manufacturing and Materials Sustainability:
How can systems be developed to maximize the utility of materials while minimizing environmental and social impacts?

Systems Analysis for Sustainability:
What are the best methods to use to analyze complex, interrelated sustainability issues in a particular system and how might those issues affect other systems?

Sustainable Energy:
What sources of energy offer the best combination of low environmental impact, high economic return, and social acceptability?

Current Highlighted Projects

Research Coordination Network for Science, Engineering, and Education for Sustainability:
Many communities and countries are adapting to the opportunities and challenges presented by local biofuels development. While the particular aspects of each biofuels case may be different, many aspects of these emerging markets and technologies can create useful experiences that should be shared widely to benefit many different groups. This project is focused on creating a community of researchers across the Pan-American region with interests in several aspects of bioenergy sustainability.

Partnerships for International Research and Education (PIRE):
From Canada to Brazil, the PIRE team analyzes several bioenergy development case studies to evaluate environmental and socioeconomic impacts. Similarities and differences among the case studies in different regions are assessed to learn more broadly about biofuels development across the Pan American region.

Sustainable Energy Pathways (SEP):
This project is the latest in the line of SFI research activity in our "Wood to Wheels" integrated program. Research across the woody bioenergy life cycle—from plant genetics to engine research—will be combined with a broader view of the sustainability of the entire bioenergy life cycle in order to assess socioeconomic and environmental impacts of these new biofuels technologies.

Sustainability Assessments with Industrial Partners:
SFI has developed a successful track record of consulting research with companies interested in obtaining third party, critical reviews of their product or process configurations to assess environmental sustainability. SFI staff and affiliated faculty have expertise in life-cycle assessment (LCA) methodology to quantify environmental impacts of a system according to internationally accepted standard practices. Most projects have focused on the alternative energy sector, but the approach is adaptable. Some of the current and previous project partners include: LanzaTech, UOP, GTI, General Motors, Frontier Renewable Resources, Walmart, and API.

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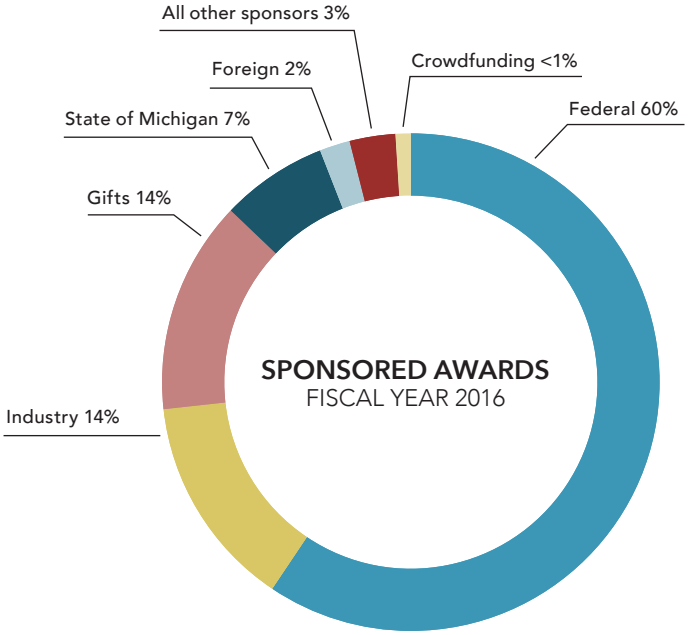
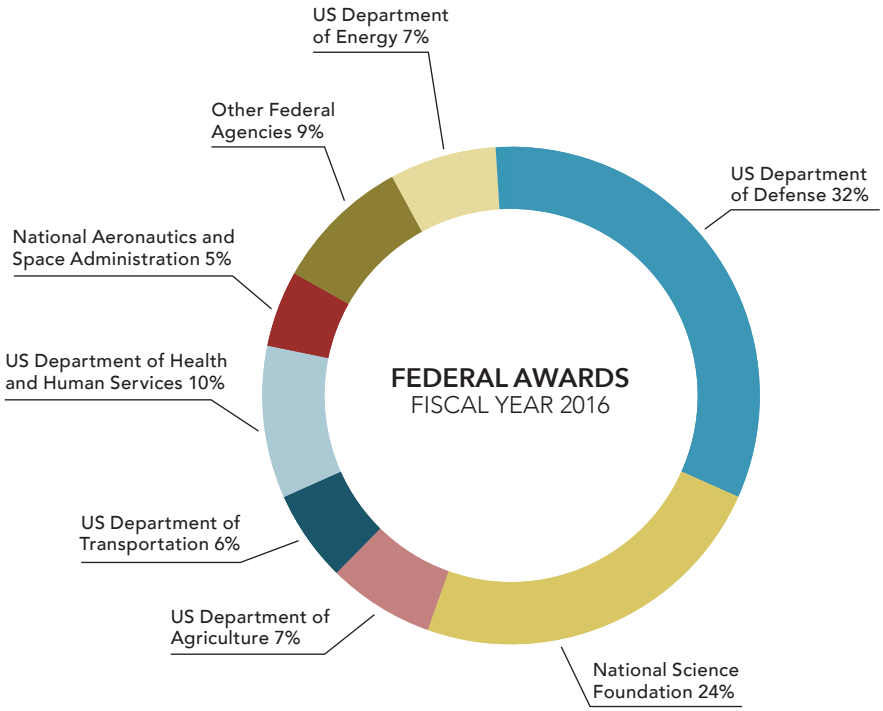
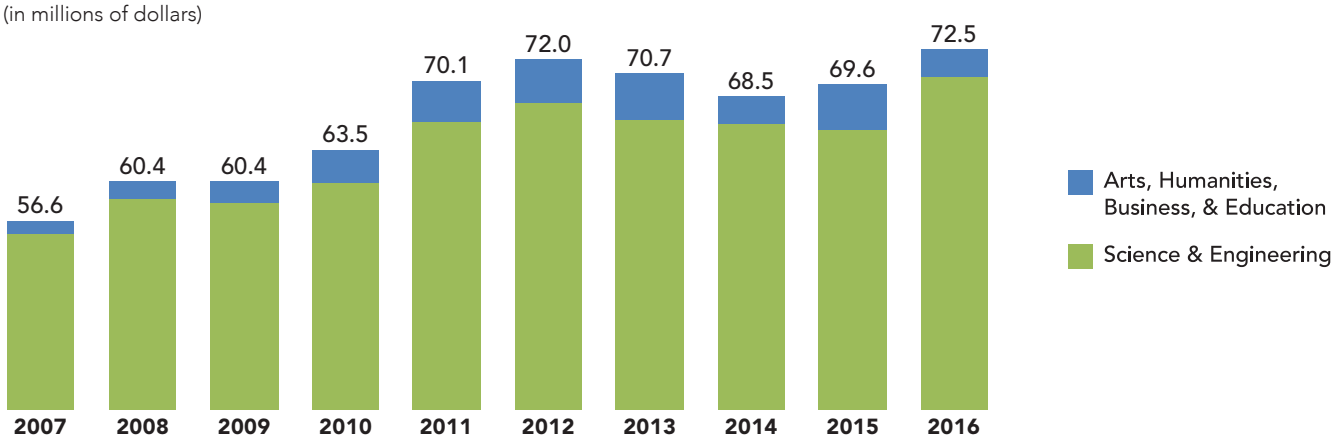
Research and Sponsored Activity





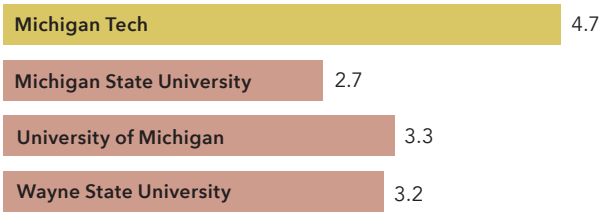
RESEARCH EXPENDITURES

(in millions of dollars)



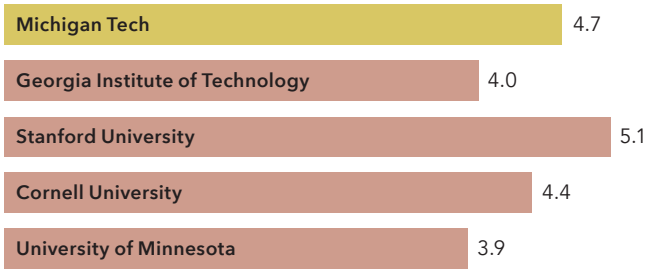
2015 invention disclosures per $10 million of research expenditures

(Compared to Michigan universities)



2015 invention disclosures per $10 million of research expenditures

(Compared to benchmark universities)



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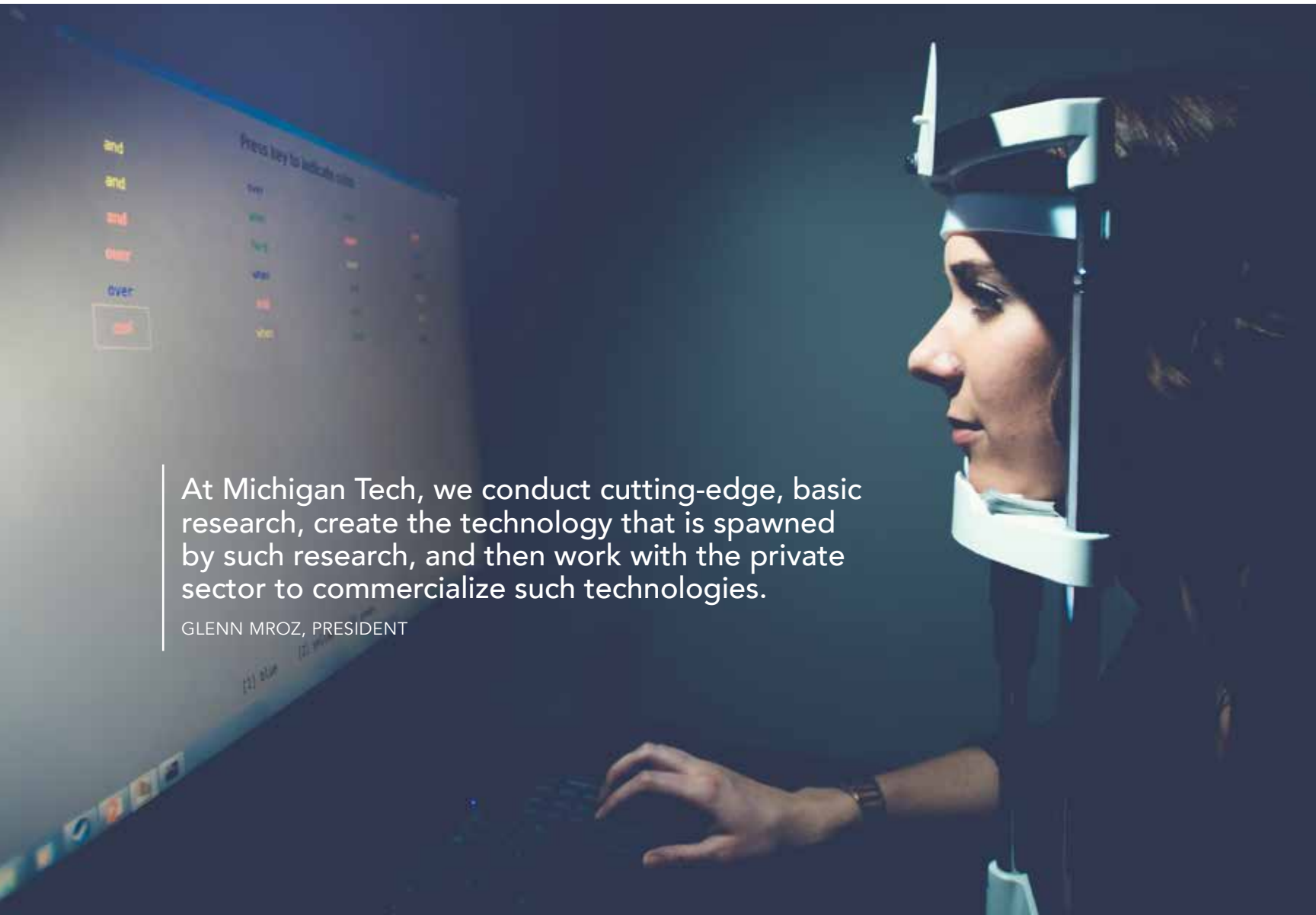

At Michigan Tech, we conduct cutting-edge, basic research, create the technology that is spawned by such research, and then work with the private sector to commercialize such technologies.

GLENN MROZ, PRESIDENT