Research

MICHIGAN TECHNOLOGICAL UNIVERSITY / 2020

OCULUS

3...2...1...
Liftoff! Students, alumni, and faculty watched Oculus launch into space this summer while continuing work on two new nanosatellites.

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REGULAR FEATURES

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

Allison Mills
Managing Editor

Nicole Kelly
Creative Director

Crystal Verran
Director of Operations

Jon Halquist, Phil Mcleod
Designers

Sarah Atkinson
Photographer

John Lehman
Vice President for University Relations and Enrollment

Ian Repp
Assistant Vice President for University Marketing and Communications

Mark Wilcox
Writer

Jason Makela
Cover Photo

David Reed
Vice President for Research

Cathy Jenich
Assistant to the Vice President for Research

Jessica Brassard, Natasha Chopp
Research Office

This crucible is one of the tools from the campus foundry used to make and characterize forged materials including lightweight aluminum alloys for fuel-efficient vehicles.

RESEARCH HIGHLIGHTS 2019

This past year, Michigan Tech reached an all-time high for research expenditures, totaling $80.4 million.

New Colleges: The College of Computing opened in July 2019, then in November, two schools became the College of Business and the College of Forest Resources and Environmental Science. The growth meets demand for interdisciplinary teaching and research.

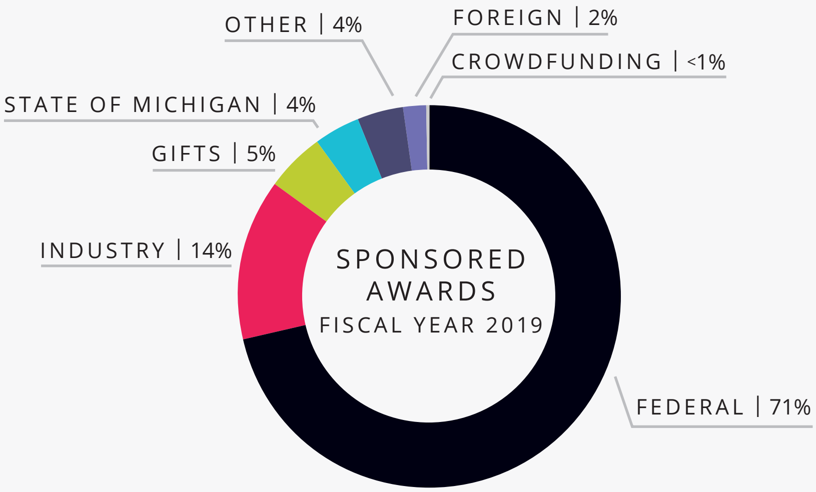
Golden Proving Ground: The Keweenaw Research Center installed a new course for military ground-vehicle testing. From steep hills to deep puddles, from rocky terrain to sand pits, the crew takes vehicles truly off road.

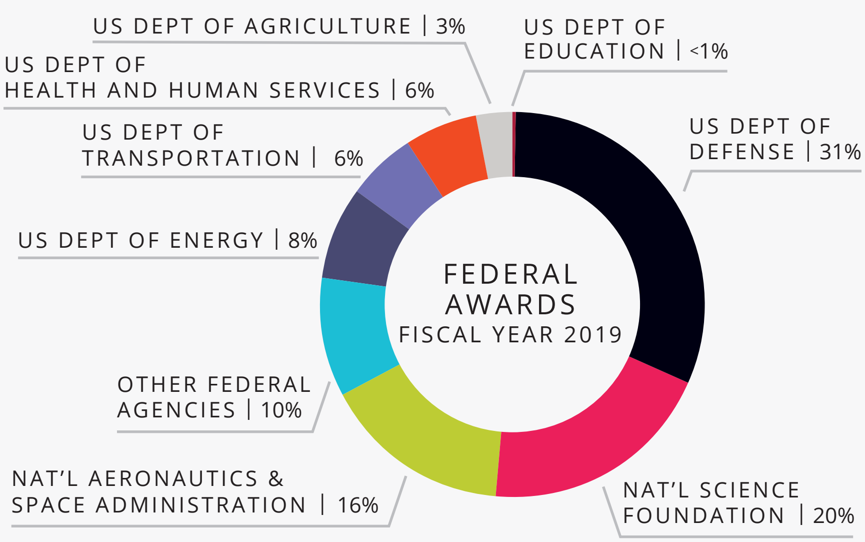
SubT Winner: Defense Advanced Research Projects Agency (DARPA) takes robots underground in the Subterranean Challenge (SubT). A team from the Michigan Tech Research Institute (MTRI) is competing in the virtual track and took second place the October 2019 round.

Mobility: The Advanced Power Systems Laboratory (APS LABS) and the Center for Technology and Training (CTT) tackle everything from the details of powertrain efficiency to infrastructure management with nearly $5 million in new federal and state agency grants this year.

Autonomous vehicles learn to drive rural roads in the Keweenaw.

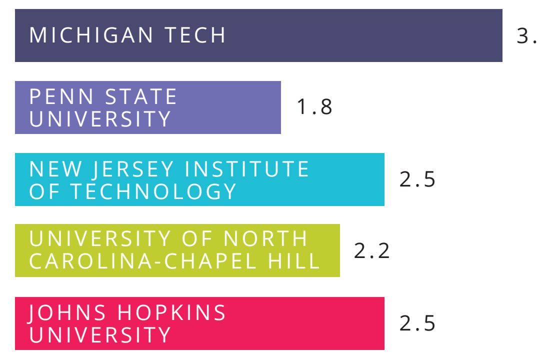
Research Statistics





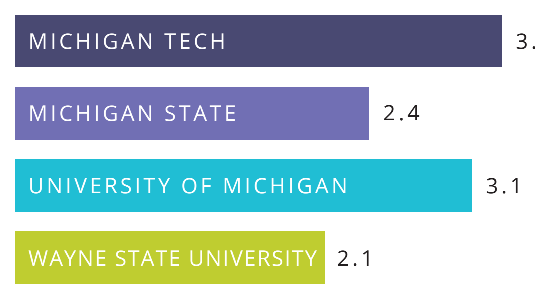
2018 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH EXPENDITURES

(COMPARED TO BENCHMARK UNIVERSITIES)



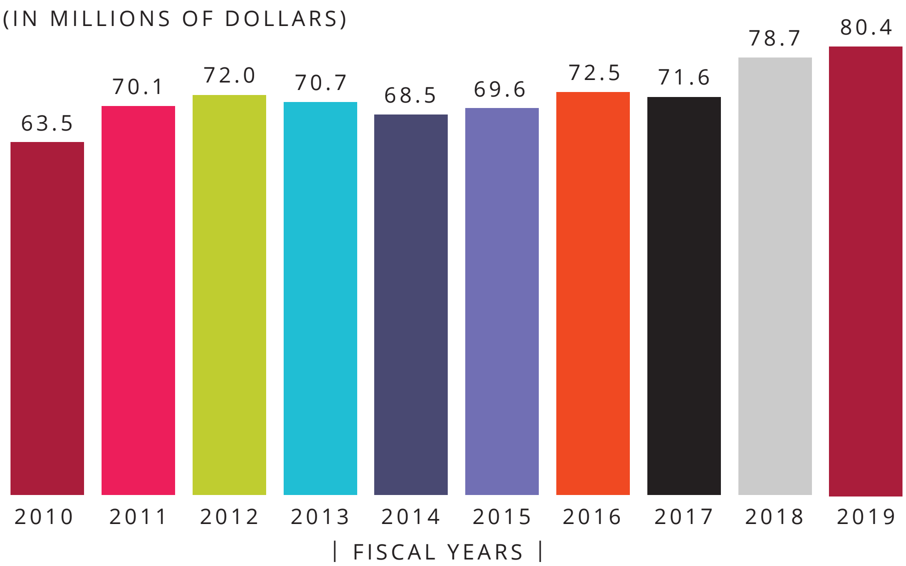
2018 INVENTION DISCLOSURES PER $10 MILLION OF RESEARCH EXPENDITURES

(COMPARED TO MICHIGAN UNIVERSITIES)



RESEARCH EXPENDITURES

(IN MILLIONS OF DOLLARS)



$80.4M
TOTAL 2019 RESEARCH EXPENDITURES

$16.9M
INCREASE OVER THE PAST DECADE

20
RESEARCH INSTITUTES AND CENTERS

279,365
SQUARE FEET OF RESEARCH SPACE

HEARTFELT TISSUE ENGINEERING

2.5 billion. That's approximately the number of times the human heart beats in 70 years. And sometimes during the course of its unrelenting contractions and relaxations, the heart muscle can no longer bear the strain.

There's more than one way to fix a broken heart. For Michigan Tech engineers, the solutions they develop in the lab could help patients recover from heart attacks. It all comes down to engineering a tissue that works: from the tissue's nutrient availability, to its growth environment, to biocompatible substrates.

If heart muscle cells—cardiomyocytes—could be repaired by cells taken from one's own body, the patient's recovery improves. But manufacturing heart cells requires an exacting process tailored specifically to an individual, and the environment that the cell is grown in matters. Parisa Pour Shahid Saeed Abadi, assistant professor of mechanical engineering, takes old petri dish growing methods into three dimensions.

"On day one we start seeing the effect of the substrate on the morphology of the cells," Abadi says, explaining she uses a process called photolithography to shape the mold to grow heart cells in. "I use microfabrication and nanofabrication techniques to tackle problems that are challenging for biologists or clinicians to address."

Interdisciplinary work is inherent within health tech development and Smitha Rao, assistant professor of biomedical engineering, turns to materials science and biochemistry to also improve ways to grow strong heart muscle cells. Her team developed an electrospun nanofiber using a specific polymer blend that creates ideal conditions for many kinds of cells.

"We're trying to simplify the process to answer a highly complex question: How do cells proliferate and grow?" Rao says. "This is our basic building block; this is the two-by-two Lego. And you can build whatever you want from there."

For Feng Zhao, associate professor of biomedical engineering, better engineering is inspired by the tissue's network of tiny veins, capillaries, and nutrient-providing microvessels.

"The significance of microvessel organization in 3D scaffolds has largely been ignored," Zhao explains. "Understanding the mechanisms behind microvessel alignment in biomaterials will help us and other biomedical engineers to create better, more refined implants and devices."

>>>Read more:
mtu.news/heart-rao
mtu.news/heart-abadi
mtu.news/heart-zhao

Smitha Rao's team makes electrospun nanoscaffolds.

Rolf O. Peterson

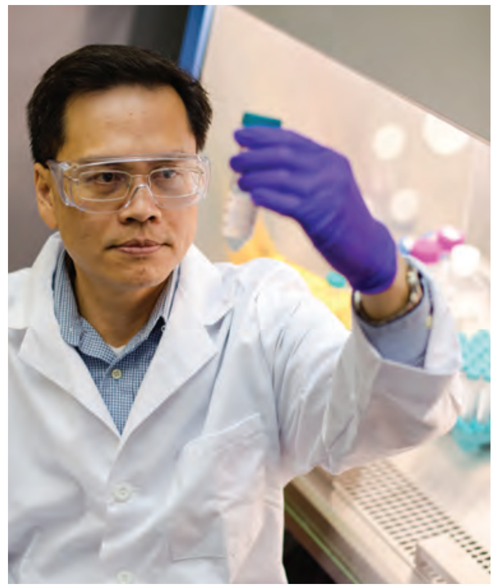
RED, GRAY, AND ISOLATED

Islands make gene pools dance. From Isle Royale in Lake Superior to Galveston Island in the Gulf of Mexico, ecologists in the College of Forest Resources and Environmental Science examine the interweaving patterns of wolf genetics.

"Our discovery that red wolf genes have persisted in Texas—after being declared extinct in the wild—was very surprising," says Kristin Brzeski, assistant professor of wildlife ecology. "It introduces both positive opportunities for additional conservation action and difficult policy challenges."

Brzeski and her team found that isolation from mainland coyotes likely concentrated red wolf genetics within a canid group on Galveston Island. Isolation was the downfall, however, for the gray wolves on Isle Royale. The National Park Service worked with regional partners this past year to bring new wolves to the remote island, now up to 17 wolves. The annual Isle Royale Winter Study, now in its 62nd year and led by researchers John Vucetich, Sarah Hoy, and Rolf Peterson, will continue to document the island's predator-prey dynamics.

>>>Read more: mtu.news/redwolf
mtu.news/isleroyale-graywolf



AI FOR NANOMATERIALS

Faster computers. Longer battery life. Wearable tech. The power to look deep into the atomic structure of materials for these uses is more accessible than ever. But getting a material to the microscope is a long road. What if new materials could be invented before they're seen?

Artificial intelligence (AI) and machine learning could make it possible. Yoke Khin Yap, professor of physics, is leading a team to model new nanomaterials, then vet, develop, and test them.

"It is complicated and it will become a very interdisciplinary collaboration between theorists, computer scientists, experimental physicists, and chemists to make the new nanomaterials," Yap says, adding that coupling AI with experimentation "brings together all the kinds of theory out there and we find there is a subset that potentially more people agree upon." Yap's collaborators are Ranjit Pati and Ravindra Pandey from physics, Susanta Ghosh from mechanical engineering, and Tim Havens from computing.

>>>Read more: mtu.news/ai-nano

Adam Johnson, brockit

SUPREME COURT OF CONCRETE

The American Concrete Institute (ACI) Committee 318 writes the building code for concrete construction. In the world of concrete, where life safety is at stake, the committee is the Supreme Court, establishing the rules that are followed universally in the US and also in many other countries around the world. The members of Committee 318 often serve for the rest of their careers and they make important recommendations for safe design and construction of buildings, which are widely adopted around the globe.

Tess Ahlborn, professor of civil and environmental engineering, is Committee 318's latest addition.

Following the 1906 earthquake in San Francisco, buildings made of concrete reinforced with steel, known as rebar, spread across the nation and world because of how well they withstand the forces of nature. Today, concrete is the number one building material.

"We think of concrete almost as rock, but a big part of it is the steel," Ahlborn says. "It's a steel frame encased in concrete. And people the world over need to know, 'How do I design with it?' and 'How does it behave?' The code has happened with over 100 years of research."

>>>Read more: mtu.news/concretecourt

MOBILITY IS THE MOVEMENT OF GOODS, PEOPLE, AND INFORMATION.

TRANSPORTATION IS MORE THAN STARTING THE IGNITION. IN TERMS OF INFRASTRUCTURE, BRIDGES ARE A CHALLENGE.

In the latest American Road and Transportation Builders Association report, more than 47,000 bridges in the US are structurally deficient and need repairs. Across Michigan, 75 percent of highway bridges are at least 40 years old. The Michigan Department of Transportation (MDOT) has partnered with research scientists at Michigan Tech Research Institute (MTRI) and Michigan Tech engineers.

3DOBS BRIDGE DECK ASSESSMENT

3DOBS is a cinema-quality camera attached to a pole braced on a vehicle trailer hitch that rises up nine feet above the ground. The RED 8K camera captures up to 60 frames per second and picks up details as small as millimeter-wide cracks in the pavement as the truck drives over the bridge deck. 3DOBS is one way to ensure timely bridge monitoring.

As team leader and MTRI research scientist Rick Dobson puts it, "On any vehicle with a standard trailer hitch, you can mount the camera and go."

>>>Read more: mtu.news/bridge-camera

3D BRIDGE APP

Drones make bridge inspections safer and easier to document. A complementary 3D bridge app developed by MTRI also streamlines defect records. There is no replacing people in the assessment—human eyes and judgement are necessary—but technology can speed up and make bridge inspections safer, helping set aside more time and money to fix structurally deficient bridges.

"We need to know if we can get from point A to point B," says MTRI research scientist Colin Brooks. "An important component of mobility is being able to understand whether or not the transportation system you're looking at can effectively move goods and people based on the condition of the infrastructure."

>>>Read more: mtu.news/bridge-drone

CONNECTED VEHICLES

"Connected vehicle technologies also have the potential to optimize traffic, reduce congested areas, and promote reduced fuel consumption," says Aurenice Oliveira, associate professor of electrical and computer engineering.

Newer cars are most likely connected: GPS navigation, infotainment panel, wireless network—they're all ways for a vehicle to provide information, whether to give directions, ping other vehicles, or check in with infrastructure like traffic signals, signs, or bridges.

All of this data creates the potential for connected cars to help transportation planners.

Kuilin Zhang, associate professor of civil and environmental engineering and affiliated associate professor of computer science, fills in the data gaps by reconstructing a vehicle's missing location-duration-path choices.

>>>Read more: mtu.news/bridge-cv and mtu.news/houghtontrafficsignals

MICHIGAN TECH RESEARCH AROUND THE WORLD

DISASTER RELIEF IN INDIA

India is in a unique position with climate change. It's a densely populated country that is prone to geohazards like earthquakes, tsunamis, landslides, and floods. Because of that density, one disaster can hurt a lot of people, as happened last August when a mudslide in southern India killed 66 people and flash floods displaced at least 360,000.

Mumbai alone has a population of 19 million people, but only one university there, the Tata Institute of Social Sciences (TISS), offers a degree in disaster management and mitigation.

"This is a pressing need," says Thomas Oommen, associate professor of geological and mining engineering sciences and affiliated associate professor of civil and environmental engineering at Michigan Tech. "Technologies used today in disaster management need to be taught to students so they can be ready for when a disaster hits a community this large."

Oommen was given a grant from the US Consulate General in Mumbai to travel there, along with Tim Frazier from Georgetown University and Himanshu Grover from the University of Washington, to meet with faculty and administration from TISS as well as Indian officials. For two weeks in August 2019, they worked to identify gaps in the TISS program and develop a state-of-the-art disaster management curriculum to be implemented at TISS. They continue to meet via an online portal every month to continue work on the curriculum, which they hope can then be replicated at universities across India to train more people to handle the disasters to come.

DROUGHT AND NANOTECH IN EL SALVADOR, DENMARK,SINGAPORE

The National Science Foundation's International Research Experience for Students (IRES) dives into interdisciplinary research.

IRES Denmark and IRES Singapore

- Led by Caryn Heldt, director of the Health Research Institute and the James and Lorna Mack Chair in Bioengineering, and Erin Smith, director of the Humanities Digital Media Zone
- Three cohorts: 2017-2019
- Collaborators: Aarhus University in Denmark and the National University of Singapore
- The teams examined biomedical applications of nanotechnology for detecting and treating viral diseases.
- A communications student also joined the team each summer to produce a short documentary and help the STEM-focused members learn effective social media and outreach tools.

>>>Learn more: iressingapore.mtu.edu

IRES El Salvador

- Led by John Gierke, chair of the Department of Geological and Mining Engineering and Sciences, with the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) and Lutheran World Relief (LWR)
- Three cohorts: 2020-2022
- Collaborators: Luke Bowman, geology; Kari Henquinet, Pavlis Honors College; Angela Carter, social sciences; Frank Liu, forestry; David Watkins and Alex Mayer, civil and environmental engineering; researchers at the University of El Salvador FMP in San Vicente; CUAHSI and LWR professional staff
- The teams seek to understand the impacts of drought and extreme weather on water use in rural agriculture communities in the Central American Dry Corridor and explore adaptation strategies to improve water access.

>>>Learn more: cuahsi.org/projects/ires

Gov't of Kerala, India

HAIKUS FOR THE TREES

Enjoy a few poems inspired by research at the Ford Center and Research Forest.

What is a research forest?

A space to observe the natural environment. A place to modify key variables. A laboratory that lives and breathes without walls around it.

At Michigan Tech, we have 5,866 acres of research forest within 50 miles of campus. That means our researchers have a spacious, all-natural lab close at hand to study invasive species, climate change, silviculture, and wildlife behavior.

"GIVEN OUR CHANGING WORLD, WE WORK TO ADDRESS THE CHALLENGES IN NATURAL RESOURCE SUSTAINABILITY THROUGH EDUCATION AND TRAINING, RESEARCH, INNOVATION, AND OUTREACH."

—ANDREW STORER
DEAN, CFRES

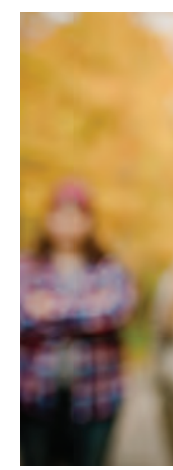
One particular site, the Ford Center and Research Forest in Alberta, Michigan, is a hub for faculty research, student research, and at 3,700 acres, is Michigan Tech's biggest classroom. It's part of the reason the University's forestry program ranks in the top five in the nation; it's where students from the College of Forest Resources and Environmental Sciences (CFRES) come each year for the annual Fall Camp; it's where they conduct senior design projects alongside faculty and industry partners. Overall, more than $2 million of federal and state funding has supported dozens of active research projects at the Ford Center.

A research forest—both organically beautiful and carefully measured—can be hard to capture in words. But there is a reason that nature has inspired haiku poems for hundreds of years. So, here are a few research-inspired haikus about some of the CFRES projects happening at the mtu.edu/forest

Small Mammal Traps

milk cartons hold mice
like unbooked Airbnbs
weights and vitals, please

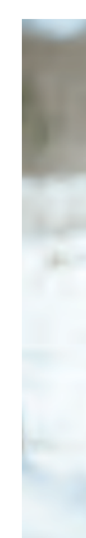
Lead researchers: Kristin Brzeski and Jared Wolfe
What: The smallest creatures reveal big impacts on forest ecosystems
Funding: USDA McIntire-Stennis, MTU start-up, MTU Ecosystem Science Center



Harvesting Forests

take only the top
can logging be like growing
broccoli at home?

Lead researchers: Yvette Dickinson, Robert Froese, and Chris Webster
What: Whole-tree logging and modern silviculture to protect trees
Funding: NCASI, Weyerhaeuser Company, NHSEED, USDA McIntire-Stennis, USDA-NIFA, USFS, MTU start-up, MTU Ecosystem Science Center



Bird Banding
nets like gossamer
snare the subjects for banding
released, again, wings

Lead researchers: Jared Wolfe and Kristin Brzeski
What: Bird banding station; small, metal bands help ecologists track bird populations
Funding: USDA McIntire-Stennis, MTU start-up, MTU Ecosystem Science Center

Forest Road Surfaces
run off challenges
pumped and powered sprinklers mist
geogrid forest

Lead researcher: Matt Kelly
What: Controlling the rain is no easy feat, but necessary to study runoff
Funding: USDA-NRCS CIG, MTU start-up

Climate Oaks
brought from as far South
as deep West Virginia
acorns tell stories

Lead researcher: Carsten Külheim
What: Oaks from around the country could aid Upper Peninsula forest resiliency
Funding: Superior Ideas, USDA-NIFA, MTU start-up, MTU Ecosystem Science Center

Zoe Thacker

MISSION(S) ACCOMPLISHED

At 2:30 a.m. on June 25, 2019, Michigan Tech's student-built Oculus-ASR nanosatellite rode the SpaceX Falcon Heavy from Cape Canaveral Pad 39A into orbit. It's a University first, but by no means the last.

The new space race is driven by commercialization, tech miniaturization, and cost optimization. Space is easier and cheaper to reach than ever before. However, there's still nothing simple about building a satellite.

At 90-plus current members with more than 800 alumni, one satellite in orbit, and two more missions in the works, Michigan Tech's Aerospace Enterprise team has worked through the challenges and experienced the triumphs. It's one of the largest and most successful teams in Michigan Tech's 20-year Enterprise Program. Started at the request of students roughly 18 years ago, it's also one of the oldest. Nearly two decades of training in small-satellite development, from concept to launch-ready, has positioned students among the next generation of aerospace leaders. Here's how they got their first nanosatellite, Oculus-ASR, into space last summer and their plans for two new missions, Auris and Stratus.

"We have an established presence in the field," says current team program manager Marcello Guadagno. "You're working on something that until very recently was in the domain of large corporations and governments. You get to see your work in space; people don't get to see that too often."

Oculus-ASR rides the Falcon Heavy rocket into orbit June 25, 2019 at Cape Canaveral.

NOT YOUR PARENT'S SPUTNIK

In the system concept and critical design review phase, research is paramount. The initial step, deciding what you want your satellite to do and how that aligns with a funding agency's mission, can take months, as can diving deep into what has worked and what hasn't. Be it with a military branch, National Aeronautics and Space Agency (NASA), or private entity, the team is tasked with creating a compliant proposal that meets all criteria. In the assembly, integration, and test phase, the spacecraft comes together, employing both off-the-shelf and custom components created in-house. In the environmental test phase, the satellite is shipped for bake out, thermal cycling and vacuum, and vibration testing—a violent process commonly referred to as shake-and-bake that simulates the rigors of launch and orbit in the space environment. These steps all lead to the coveted launch and missions operations phase.

Read more about the nuts and bolts of the Aerospace Enterprise missions on the University research blog Unscripted: mtu.news/aerospace

MISSION: OCULUS-ASR

Oculus-ASR is fittingly named for its role to help the US Department of Defense (DoD) improve its vision when monitoring satellites; the ASR stands for attitude and shape recognition. Its mission is one of the first dedicated to providing a cooperative target for ground observatories as a means to help telescopes gauge imaging capabilities. Six months into its nine-month mission, the 150-pound satellite now orbits in Low Earth Orbit (LEO is 99 to 1,200 miles above the planet's surface) changing shape and performing complex maneuvers to present an ever-shifting target for ground telescopes.

The mission kicked into high gear with winning the University Nanosat 6 competition in 2011. This netted the team the Air Force Office of Scientific Research (AFOSR) contract to launch Oculus under the guidance of the University Nanosatellite Program (UNP) for the Air Force Research Laboratory (AFRL). Graduate Jesse Olson '17, who started building rockets when he was 12 years old and served as the chief engineer for Oculus as a student, now heads the UNP.

"I knew I was going to join the team before I even got to Michigan Tech because I knew I wanted to do aerospace. When I came into the process, the whole satellite was completely designed. A lot of the people who designed it had already graduated," Olson says. "There was a learning curve to catch up. Debugging, fixing, trying to understand why designers made the choices they did.

"That's one of the biggest challenges across all UNP and university projects," he notes. "Teams working through multi-year projects have to come up with ways to combat that through documentation and training."

Olson now guides a new generation of Aerospace Enterprise students through the very program that resulted in the successful Oculus launch. In its 20-year history, UNP has worked with 38 universities and has 15 satellites and seven launches under its belt. Olson is currently working with 12 universities on 14 missions.

Working on the Oculus project as an undergrad showed Olson the inherent give-and-take of the effective mentoring techniques he uses today. "I'm always getting advice from other people. This is not a one-man show," Olson says. "And while I don't see him as often as I used to, I still regard Dr. Brad King as a mentor."

Olson, King, and King's son savor the historic occasion.

King, the Henes Endowed Professor in Space Systems, has been the Aerospace Enterprise team advisor since the group formed. Over the years students have made their mark in the industry—and also left their mark in laboratory work spaces. King shows a scribbled piece of paper that reads, "Oculus means family—and that means nobody goes home."

"That perfectly captures the perseverance of the team," King says. There were many moments when the end-goal seemed doubtful. "The number of near-failures are too numerous to list. I can't count how many times we were on the brink of missing a key deadline, or we were out of funds with no clear path forward, or we damaged an irreplaceable component during testing. Somehow they always found an alternative path."

The hardest decisions involved descoping critical components or functions to reduce budget or meet a government deadline. "These decisions involved abandoning something that part of the team spent years developing, in order to ensure success of the core mission," says King. "In the end, all of the decisions proved to be justified and correct."

LAUNCH: OCULUS-ASR

In spring 2019, SpaceX announced a June 24 launch window beginning at 11:30 p.m. for the DoD Space Test Program-2 mission, managed by the US Air Force Space and Missile Systems Center. The mission would deliver 24 satellites to space with Oculus first off the rocket. Nearly 40 alumni and their advisor headed to Cape Canaveral.

The five-year wait was over. Almost.

Delayed by a ground hydraulics system issue, liftoff took place three hours into the four-hour launch window.

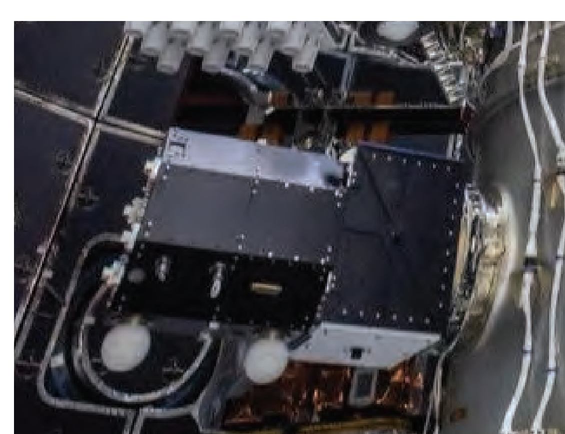
"WHEN THE LAUNCH DATE FINALLY CAME, CURRENT AND FORMER STUDENTS TRAVELED ACROSS THE COUNTRY TO BE TOGETHER AGAIN AND WATCH THEIR SATELLITE HEAD OFF TO DO ITS JOB."
—BRAD KING

"So much energy and anticipation, and now we had to cool our heels for a few hours," says King, who watched with his son from a balcony at the Operations Support Building II located next to the Space Center's iconic Vehicle Assembly Building.

Roughly five miles away, about 40 Aerospace alumni played the waiting game at the Banana Creek Launch Viewing Area, situated on a lagoon overlooking the launch site. The live broadcast announced 30 seconds. Then 15.

"Ten, nine, eight, seven, six," alumni counted down together, "five, four, three, two, one, zero … Wooooo!"

Oculus-ASR was first off the SpaceX payload at approximately 315 kilometers altitude.



Falcon Heavy blasted into the sky. The lagoon gleamed, briefly illuminated brighter than day then returning to darkness as the flash of the rocket flare was swallowed in the low horizon of billowing steam rising from the launch pad.

Their eyes were on Oculus.

“It’s difficult to describe,” says Guadagno. His phone video captures the elation of the moment—bright voices in the dark—as the rocket carrying a milestone accomplishment for so many steadily ascends toward the stratosphere, encouraged every step of the way: “Here we go!” “Yes!” “Go, baby, go, baby, go!” There was applause as the boosters separated and fell to Earth accompanied by four sonic booms.

Back at the Space Center, King watched the video livestream. Oculus was scheduled for release 13 minutes into the mission. Seconds before deployment the video stream cut out as the rocket passed beyond line-of-sight from ground control. Another antenna picked up the feed a few minutes later.

“When the video stream came back, Oculus was gone!” King says. “While it was frustrating to miss seeing her release, it was striking to notice the empty spot where she used to be located.”

The celebration, including a group photo and high-fives, continued at Banana Creek.

“It was so much fun!” says 2018 graduate Sarah Wade, an electrical engineer with Space Dynamics Laboratory in Utah. The launch wasn’t her first Oculus-induced adrenaline rush.

Several years earlier, Wade, a double major in electrical and computer engineering, was among the small group that worked tirelessly to get the nanosatellite shipshape when the call for environmental testing at Kirtland Air Force Base came unexpectedly in summer 2017: After six years of development and hundreds of undergraduate R&D hours, it was go time.

The deadline: four weeks to reassemble, test, and ship the nanosatellite. Olson, who would go out to Kirtland himself not long after, remembers the pressure as well as the satisfaction of accomplishing the goal. The team was short on members—most had already left campus for the summer—but powered through in one intense week.

“There were six of us. It was like six 16-hour days in a row. We made it—got it on the truck in time!” Olson says. Shipping, in a truck with a driver likely not accustomed to transporting spacecraft, was more nerve-wracking than shake-and-bake.

Falcon Heavy waits on iconic launch pad 39A, where the Apollo missions lifted off.

Jesse Olson

"Even though we do beat the satellites up [at AFRL], these are very controlled environments, conducted with the proper equipment and trained personnel," says Olson, adding that the hurry-up-and-wait syndrome continues with securing a launch vehicle. "We were launch-ready for several months. Oculus was isolated from the world, first in a clean room, then in a shipping container under a nitrogen purge."

"THE AEROSPACE ENTERPRISE HAS HELPED ME IDENTIFY WHAT I WANT TO DO IN MY CAREER, AND I AM EVER GRATEFUL FOR THE OPPORTUNITY TO WORK ON SUCH A TEAM. PLUS, WE GET TO PUT STUFF IN SPACE!"
—MATTHEW SIETSEMA

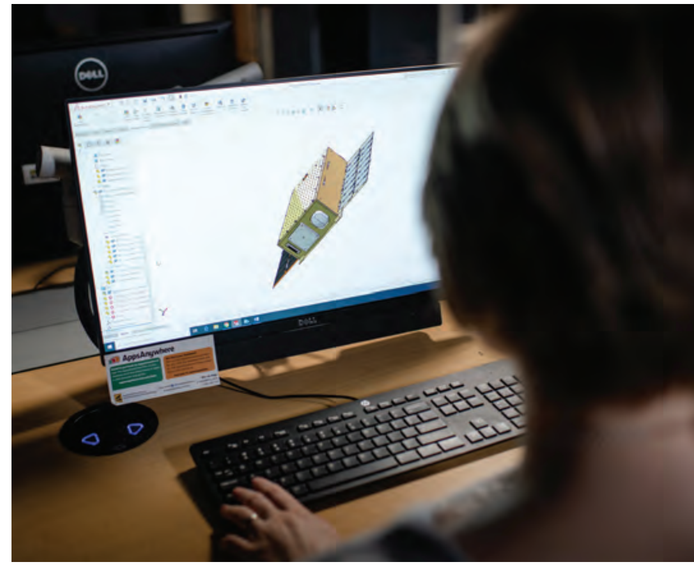
Olson is among those who have been keeping an eye on Oculus since the launch. "We had successful sphere deployment, and the ground telescopes collected some light curves as Oculus flew overhead," he says. Data coming in continues to indicate that Oculus is doing its job. "So far everything seems to be functioning as expected."

MISSION: AURIS

The microsatellite Auris is one of 10 in Phase A of the four-phase AFRL UNP process. Huskies have already cleared one hurdle in this preliminary phase: the system concept review to help the team develop mission objectives and goals.

Stratus, Auris, and Oculus are all nanosatellites. But at 10-by-20-by-30 centimeters with a preliminary estimated mass of 15 kilograms, Auris is a much smaller satellite than Oculus-ASR, which has been compared to a mini-fridge. Auris, Latin for ear, will monitor communications emissions from geostationary satellites. Listening, in an increasingly congested space environment, will allow researchers to spatially map the power radiated from high-frequency emissions of spacecraft in high orbit to determine how it impacts ground receivers.

Olson and a team of fellow engineers from AFRL came to campus in December for preliminary design review. Additional reviewers participated remotely in the eight-to-10-hour series of team presentations.



A CAD model of microsatellite Auris, which underwent preliminary design review in December

"A satellite has value for the research and science it can do; it needs to be compliant [with the requirements for its mission]. The feedback from formal design reviews helps guide students," Olson says.

Aerospace Enterprise team chief engineer Matthew Sietsema, a double major in electrical and computer engineering, says the group was looking forward to demonstrating the maturity of the project and the progress made since the last review.

MISSION: STRATUS

Stratus, named for its cloud-imaging mission, is funded through NASA's Undergraduate Student Instrument Program and the CubeSat Launch Initiative. Sietsema says there are no specifics on a timeline yet, but that Stratus will be launched from the International Space Station.

The 10-by-10-by-30-centimeter and 4.4-kilogram CubeSat (named for its cube-like configuration) is a three-axis-stabilized thermal infrared telescope designed to provide a low-cost solution to imaging atmospheric clouds. Cloud fraction, top wind, and top height data are used to reconcile climate models. If all goes as planned, more Stratus spacecraft could be deployed to gather hyper-local weather data.

The CubeSat underwent and passed its critical design review by a NASA-Goddard Spaceflight Center team in December 2018. "While we suffered a few nicks and dings from the event [as is common during CDR]," King wrote in an Aerospace blog, "we passed and can now move

on to system integration in preparation for an upcoming launch."

Stratus is currently on track for completion in December 2020. Its payload subteam has integrated with the software subteam; full satellite functionality tests are underway in the clean room.

Sietsema interned as a multidisciplinary systems engineering intern at Space Dynamics Laboratory in Logan, Utah, in summer 2019. "My success in that position can be wholly attributed to my work with the Enterprise. The Aerospace Enterprise has not only shaped the form of my future career, it is the foundation upon which it will be built," he says. "Working as the chief engineer on both Stratus and Auris has given me a unique insight into spacecraft design, large-scale collaborative projects, and the importance of systems engineering as a tool to structure complex systems. When I first joined the Enterprise, I had only a vague idea what each of those are; now, I look forward to a career dealing exclusively in those areas."

A prototype of Stratus, the CubeSat destined for launch from the International Space Station

LAUNCH: ENTERPRISE FOR STUDENT SUCCESS

There are many moving parts to business ventures as well as satellites. Like all Enterprise teams, Aerospace Enterprise operates as a real business.

"During the early years, I played an active role in creating our design processes, management structure, and overall culture," says long-time team advisor King. "Working together with students, and also mentors from AFRL and NASA, we created a systems engineering infrastructure that's become a skeleton for all of our design projects."

The system defines and tracks requirements. It gives team leaders templates to manage the schedule and budget of a large team. It includes a self-sustaining leadership and management hierarchy.

"With this system in place, the Aerospace Enterprise is now run entirely by the students," says King. Current leaders mentor their successors, providing year-to-year continuity. A peer-evaluation system provides feedback and promotes advancement within the team, and King says the Enterprise has taken on a life of its own. So much so that his role is now more of an outside evaluator, observing the team's activities and trying to forecast upcoming problems that perhaps are not on their radar.

"The students have created an institution that is resilient," King says, "and can endure the inevitable personnel changes of a school environment while still tackling and solving major engineering challenges."

As the Aerospace Enterprise's software team leader Dante Paglia puts it: "All of us joined not knowing how to write software for a satellite. It's not taught in classes. You get to say your code is in space. Not every undergrad can say that."

With two more spacecraft in process and ever-expanding opportunities on the horizon, the Aerospace Enterprise team continues to design, build, and launch both satellites and careers. The thrill of the first success remains and Olson says the coolest part of his job so far was watching Oculus launch. "That was incredible. The Falcon Heavy is currently the most powerful operational rocket in the world. Seeing it launch, feeling it, was all around an amazing experience."

Deploying high-frequency radar in one of Michigan's most turbulent waterways.

RADAR AND RISK IN THE STRAITS OF MACKINAC

As Great Lakes water levels rise to record highs, remotely monitoring currents and waves grows in importance.

The currents of the Straits of Mackinac are known for their volatility; they have for millennia pushed the birch bark canoes of Native Americans and voyageurs alike off course and forced lake freighters aground.

The currents are also part of the complex lake system that links Lake Michigan to Lake Huron. Monitoring currents and waves in the Straits—and throughout the Great Lakes—is of great interest to scientists, municipal managers, the shipping industry, environmentalists, and government agencies.

In late May 2019, the waters of the Straits were calm, ruffled only by wind and boat wakes, on a brilliantly sunny day. Aboard the *S/V Osprey*, one of Michigan Tech's survey vessels, testing was underway to measure a radar pattern across the water from temporarily installed high-frequency radar antennae.

During the visit to the Straits of Mackinac, Lorelle Meadows, dean of the Pavlis Honors College and an oceanographer by training, and Guy Meadows, founding director of the Great Lakes Research Center (GLRC) and the Robbins Professor of Sustainable Marine Engineering, conducted the first test of an onshore high-frequency radar system specifically tuned to map complex current patterns in the Great Lakes.

GREAT LAKES GEOMETRY

High-frequency radar is a shore-based remote sensing system used to measure currents offshore by sending a low-power electromagnetic pulse over the water.

Developed on ocean shorelines, the electromagnetic wave interacts with marine surface waves, which scatter the radar signal. By measuring the return pulse bounces from marine waves back to the radar antenna, researchers are able to map the speed and direction of the underlying currents.

High-frequency radar has not been implemented as a routine tool for measuring currents in the Great Lakes because, in comparison with salt water, the electromagnetic pulses travel shorter distances. High-frequency radar works in freshwater between six to eight kilometers (about four to five miles). Where the distance between coastlines narrows, the geometry makes high-frequency radar more effective and there are many such locations in the Great Lakes.

The Straits of Mackinac, where Lake Michigan and Lake Huron meet underneath the towers of the five-mile-long bridge, are known for their unpredictable currents and winds. The bottleneck of the Straits is kept busy by freighter traffic and the ferries that take tourists to and from the famed Mackinac Island. Not only do the Great Lakes provide shipping lanes, but more than 30 million Americans rely on the lakes for drinking water.

"A lot of the infrastructure in the Great Lakes that gives us drinkable water is within a few miles of the coastline," Lorelle Meadows says. "A system like this could be valuable in different strategic locations. I could imagine it in southern Lake Huron near Port Huron and Sarnia, at the Detroit River, or the Chicago waterfront—any place you want to have insight into the way the currents are moving."

In May 2019, with funding from the Great Lakes Observing System (GLOS), Lorelle Meadows and a team of scientists temporarily installed two 14-foot CODAR SeaSonde high-frequency radar antennae, one on each side of the Straits just west of the Mackinac Bridge. Because of its sheer size, there was the potential the bridge would interfere with the radar signal; field testing showed the bridge did not directly interfere, a big step in moving the radar project's viability forward.

Lorelle Meadows, dean of the Pavlis Honors College, has worked on high-frequency radar for decades.

Drifting along the shadow of the bridge, Travis White, research engineer at the GLRC, sat at the *Osprey's* helm, ensuring the vessel kept a precise trajectory along waypoints to test the radar signal. Mike Garcia, systems engineer with CODAR Ocean Sensors, spoke on a two-way radio with Lorelle Meadows about the strength of the radar signal.

Unlike buoys, which provide single-point measurements, high-frequency radar antennae use broad beams that intersect over the water surface to create maps of an entire area.

"Each station individually can only tell you the speed at which a current is traveling toward or away from it," Lorelle Meadows says. "An individual antenna only provides the radial component of the current. But by combining the two stations together, we achieve the full surface current vector."

Not meant to replace the buoy's current measurements, the radar antennae provide more data to gain better understanding of complex lake systems.

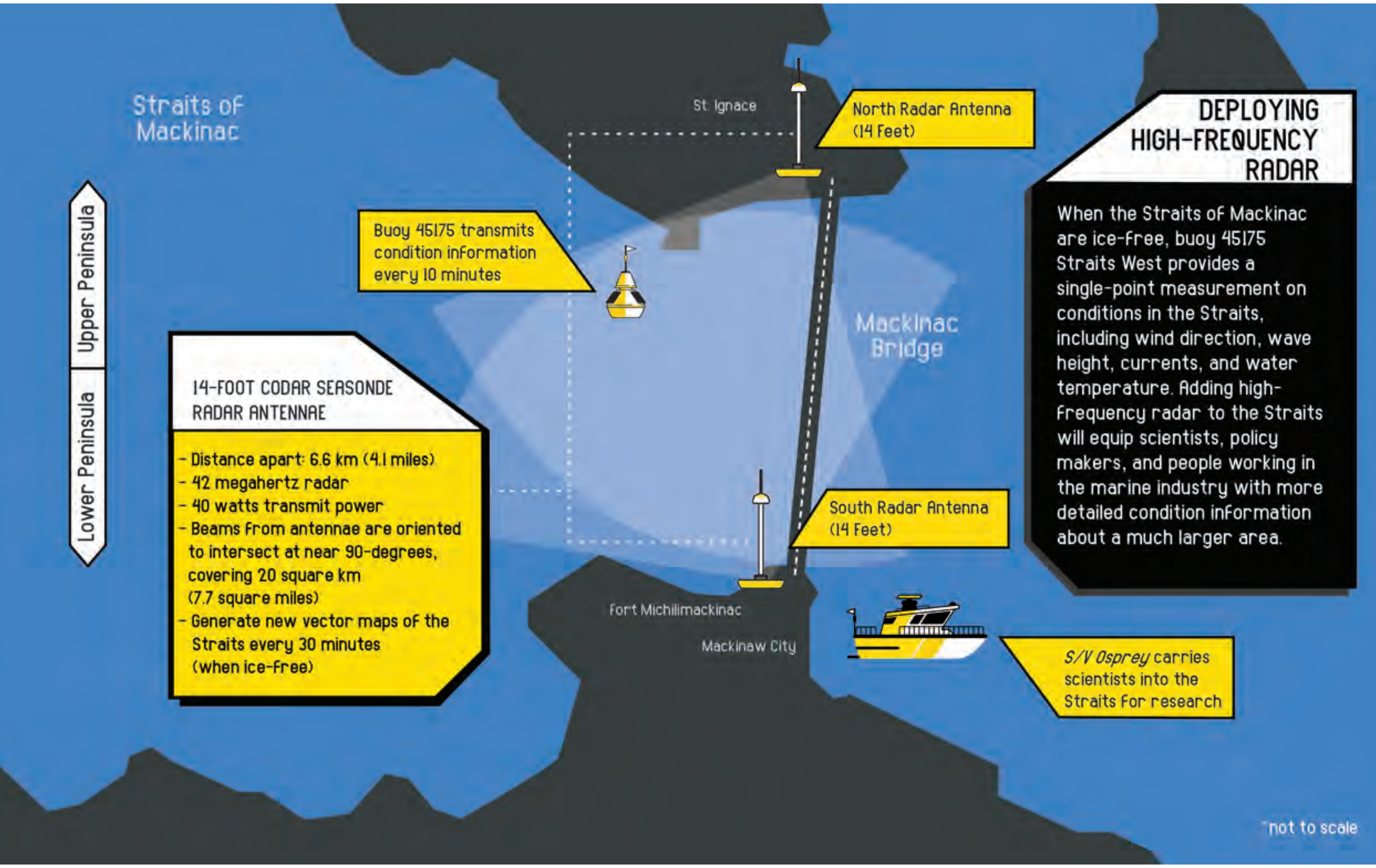
The pilot testing of the temporary radar antennae also took the *Osprey* the better part of a mile from the Mackinac Bridge to the west alongside one of Michigan Tech's buoys, 45175 Straits West. Tethered to the lakebed during Michigan's spring, summer, and autumn, the buoy tracks wind speed, direction, and gusts as well as wave height and direction, water currents, water and air temperature, wind chill, and dew point. As the *Osprey* bobbed beside the buoy, it was readily apparent how vast the Straits are. Just as the Mackinac Bridge is more impressive from a boat floating beneath it than from a car driving across it, the Straits seem to stretch on, despite being a narrow point in the Great Lakes. The vividly yellow buoy provides crucial information, but from just one point. Radar coverage could be more comprehensive.

"The hope is to produce vector maps every half hour," Guy Meadows says. "The Straits West buoy reports conditions at a single point every 10 minutes. This system has the capability to create a new vector map of currents every 30 minutes, every day."

A LIFE'S WORK

For Lorelle Meadows, the high-frequency radar pilot test was the culmination of 20 years of research. Her graduate research focused on the application of radar in freshwater systems and, while she was certain high-frequency radar had important uses in the Great Lakes, funding agencies saw only the limitations of freshwater without salt to conduct the electromagnetic pulses farther out over the water. As a result, freshwater high-frequency radar research in the Great Lakes was shelved.

Hayden Henderson '19, left, and Mike Garcia, CODAR systems engineer, set waypoints to test the high-frequency radar system.



But as concerns about environmental contaminants in the Great Lakes grew, so did interest in deploying the system. If it could mean reducing risk and better understanding the lake systems themselves, what was there to lose? GLOS approached Lorelle Meadows with a request to fund a pilot system.

"For a long time, we've been asking people to listen to the story that this technology is valuable in this space," she says. "The fact that we were finally heard and we can make an operational capability for the Great Lakes is huge for freshwater science."

NEXT STEPS

Beyond their use to scientists, vector maps can be used by many different interests: providing warnings to ships about currents that might force them aground or off course, giving vital information to search and rescue operations, tracking a hazard spilled into the water, tracking ice flows, or monitoring harmful algal blooms to protect municipal water intakes.

Vector maps, like buoy readings, provide information beneath the surface of the waters, which might appear calm above, hiding turbulence below. During the pilot test in late May, staidly drifting clouds in the sky shimmied and dipped in the cold water of the Straits. The *Osprey* darted to the side of the towers of the Mackinac Bridge, the reflection mixing like watercolors, smeared by the wake of a passing lake freighter. The scene belies how differently wind and current might behave on a given day.

Back at the GLRC, the researchers are processing data and have applied for permanent GLOS and State of Michigan funding for the radar antennae, which will operationalize this capability for the Straits and also allow the researchers to explore further uses of the technology in freshwater.

GLOS is following up on their $300,000 grant in 2019 to purchase, site, and test the high-frequency radar system. In project year 2019-20, GLOS granted Michigan Tech an additional $150,000 to install and operate the system.

"High-frequency radar data is new to the Great Lakes," says Kelli Paige, GLOS chief executive officer. "By funding the permanent installation in the Straits, we hope to see long-term benefits for those living near the bridge and beyond in lakes Huron and Michigan." Specifically, the technology helps by providing information that can be used for safe boating, spill response and cleanup, and research.

"Our ocean coasts are instrumented with these towers," Lorelle Meadows says. "This is our opportunity for the Great Lakes coastline to be."

>>>Watch the installation: mtu.edu/magazine/radar-straits

>>>Learn more: mtu.edu/greatlakes

Mathematicians
Sarah Kitchen,
Susan Janiszewski,
Yang Yang

MATH SINGS ITS OWN ARIA

STEM: science, technology, engineering, and of course, mathematics. It's time for math to take centerstage.

When most people talk STEM, they're likely focused on S-T-E. If math is at all mentioned, it's a polite—perhaps intimidated—nod to the orchestra pit. Because math, as the popular attitude goes, should be left to the nightmares of seventh-grade algebra. Not surprising given that the National Institutes of Health report 93 percent of adults in the US experience some level of math anxiety.

There *are* those who enjoy a bit of numerical play. We expect them to become engineers (because, of course, engineers have to like math). But straight-up mathematicians? They're a rare and different breed.

And to see research problems through their eyes is to know truth and beauty. Math is as much an art as it is a major influence on other STEM fields. Particularly with applied math, where models and algorithms provide foundational support in scientific and technological endeavors, the M of STEM joins the chorus or keeps behind the curtains to work the grand sets of modern research. The show could not go on without mathematics.

So in these pages, applied math sings its own aria.

OVERTURE UPON DETONATION

A surprising problem in the field of partial differential equations is that of instantaneous detonation.

Take a two-meter-long tube, for example. If an explosion sets off in one end, how quickly does it travel through the rest of the tube? In true Hollywood style, the blast would be nearly instantaneous—and with just enough time, the main character jumps away. But the problem is that if we zoom in on the explosion, slowed the scene way down, and tried to measure the fiery movement tick-tick-tick down the tube, we wouldn't be able to come up with a precise mathematical model that perfectly replicates what we observe in real life.

This bothers mathematicians.

"Math always tells you the truth," says Yang Yang, an associate professor of applied mathematics, explaining one solution to the instantaneous detonation problem is to add more ticks in the measurement, which creates its own challenge. "With more variables, you need more equations."

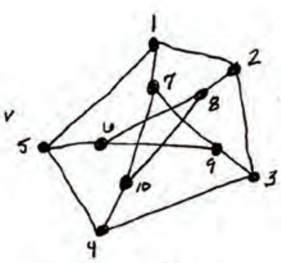
Enter one of the most common misconceptions about mathematics: Math is entirely about numbers. That's like saying singing is about the notes. So, throwing in more numbers or more variables to a mathematical model is not always ideal, although greater computing power with facilities like the Michigan Tech high-performance computing facility *Superior* and advances in math theory have certainly expanded research horizons with more data and complexity. However, what applied mathematicians like Yang are truly interested in is how to streamline and verify models.

"Engineers use mathematical models to solve concrete problems—math is a tool," Yang says, clarifying that in his world, math is a mindset. "Applied mathematicians need to understand those engineering problems and ensure the math is consistent. The solution you find should follow common sense."

Yang, who contributes to research in chemical engineering and cosmology, says models are less about numbers and more about relationships. Whether he is

$$\mathbb{R}\Gamma(X, \rho^{\circ} i_{+} \tau) \simeq \Gamma^{equi}_{K,S_x}\left(\mathrm{Ind}^{g,S_x}_{p_x,S_x}(T_x \tau \otimes \Lambda^{top} \bar{u}_x)\right)[d_Q]$$

$$A(u,v) = \begin{cases} 1 & \text{if } u \text{ is adjacent to } v \\ 0 & \text{else} \end{cases}$$



$\simeq$

$$D(u,v) = \begin{cases} d_u & \text{if } u=v \\ 0 & \text{else} \end{cases}$$

$$L(u,v) = D - A \implies \mathcal{L}(u,v) = \begin{cases} 1 & \text{if } u=v \text{ and} \\ \frac{-1}{\sqrt{d_u d_v}} & \text{if } u \text{ and} \\ 0 & \text{else} \end{cases}$$

$$0 = \lambda_0 \leq \lambda_1 \leq \ldots \leq \lambda_n$$

$$\rho_t + (\rho u)_x = 0$$
$$m_t + (mu + p)_x = 0$$
$$E_t + ((E+p)u)_x = 0$$

COMPRESSIBLE FLOW IN GAS DYNAMICS

classical model

"The solution you find should follow common sense."

> "I WORK WITH EQUATIONS THAT DESCRIBE THE WORLD AROUND US."
> **—BENJAMIN ONG**

developing models for the shift of stars, or the movement of oil in a rock formation, or compressible flow in gas dynamics, he seeks to preserve the observable physical properties of variables while upholding the truth of the mathematical relationships. There is no "close enough" in this perspective. When a blast goes off in one end of a tube and we try to predict the movement, the model is either right or wrong. Since it's still wrong, there are seemingly infinite opportunities to improve, and plenty of job security in applied mathematics.

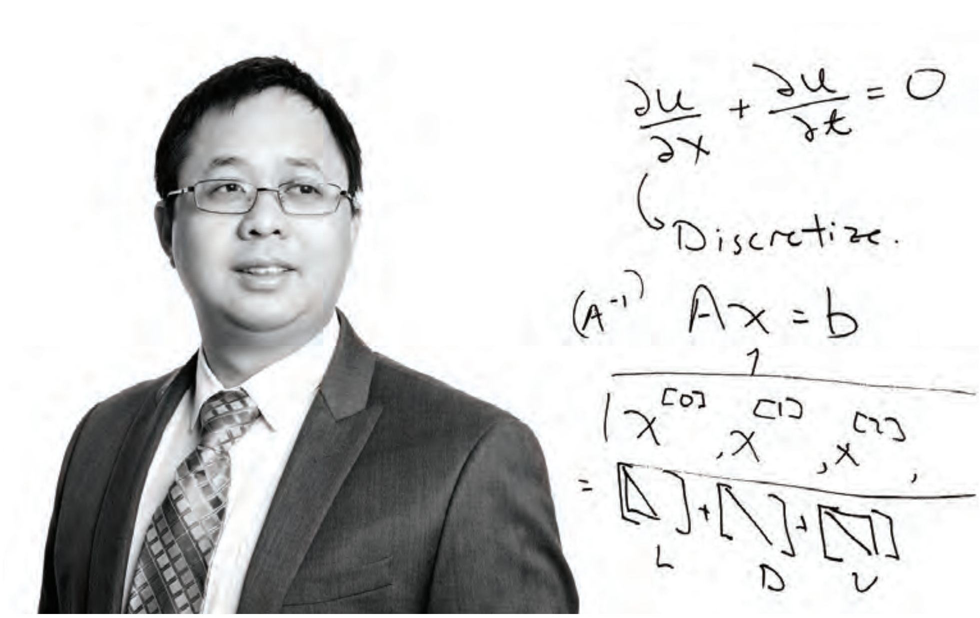
THE BALLET IN PARALLEL

Another misconception about math: Show your work; a single right answer means a single methodology. Models may be right or wrong—but there's no silver bullet. Many mathematicians tackle similar problems with many different approaches.

Cécile Piret, associate professor of applied math, contributes to research in physics and geology. It is a tension in the difference between what is observed in experiments and what a model predicts that drives the field, she says: "Why does the simulation not represent what happens in nature? Either the mathematical representation of the phenomenon is wrong, or it is correct, in which case the computational method used is inaccurate. Part of my job is to ensure that the method used is as accurate as possible."

Accuracy is not the only demand; efficient and computationally inexpensive methods are also prized. Geologists, physicists, and other scientists are not mathematicians, and some of their analytical tools do not meet the rigorous standards of applied math, which presents opportunities that applied mathematicians happily delve into. When given enough time, these collaborations drive innovation and foster new techniques.

Mathematician Benjamin Ong



Piret works with a relatively new mathematical tool called radial basis functions method, or the stoic acronym RBF. The method can describe complex geometries with exquisite accuracy—the curve of a rock formation, the plane of an aquifer, the slippery slope of a muddy hill about to give way. Instead of relying on meshes and grids, the RBF method just requires a set of points that naturally follows the complexities of the domain.

Another way to look at changes over time is to sketch it out first. Benjamin Ong, assistant professor of computational mathematics, tackles mathematical problems in computing. Sketching data is a method that Ong and his students study by looking at the underlying structures in a dataset that could help speed up computation. For example, if you know the data is linear, then it's easier to predict the slope and direction of the line rather than wasting time determining that it's not a logarithmic regression or parabola. In another project, Ong works on a family of methods called parallel-in-time; the idea, relatively new in the US, is to generate a solution quickly to ensure that the simulation is on track. Using the parallel-in-time method, the model makes a prediction then simultaneously assesses it while making another. In parallel steps, the model predicts and assesses, constantly improving its outputs as it goes.

"It's problem agnostic," Ong says. "Applied mathematics is about versatility."

UNDERGROUND AND SEE-THROUGH, A FINALE

Versatility takes applied mathematics into unexpected spaces—like deep in a subterranean labyrinth with a fleet of drones or through walls.

"If someone is standing on the other side of a wall, how do you know?" asks Jiguang Sun, professor of applied math, who often works with geophysicist collaborators interested in developing ways to see deep into the earth using electromagnetic waves; the challenge is figuring out what is what based on the wave signatures. "How can you tell the difference? What are the reflection patterns?"

Sun and his team were able to develop pattern recognition for ultrawideband radar tech using an algorithm called a fast Fourier transform. As Sun puts it, it all comes down to wave equations and those equations are treated all the same in math, so finding differences in the equations means pulling in enough data to separate the signal from the noise. "Big Data does not simply mean lots of data," he

says. "It's about extracting useful information."
In the case of pulling a fast Fourier on through-wall detection, the solution came down to predictable periodic movement—a person's breath. Inhaling and exhaling created enough stir in the wave equations to reveal a person on the other side of the wall.

"MATH DOES NOT BELONG TO SCIENCE, TECHNOLOGY, AND ENGINEERING. IT IS A DIFFERENT PERSPECTIVE, A PRECISE WAY TO UNDERSTAND, EXPLAIN, AND VIEW THE WORLD."
—JIGUANG SUN

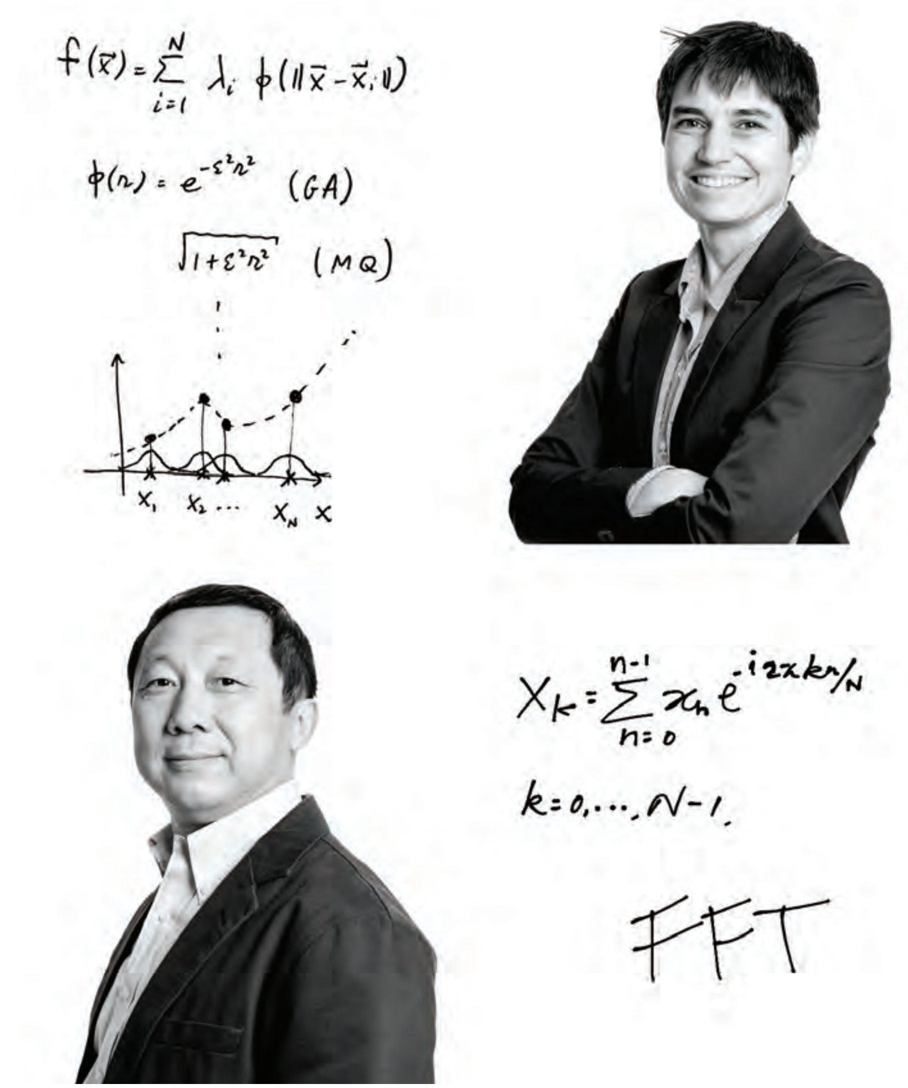
In essence, this is what all research is about: Starting with a question and following a clear logic to seek an answer. This deceptively simple idea is one of the reasons math is so ubiquitous in the other STEM fields. And in practice the math and the applications only get more complex.

"You learn to abstract away the complexity to get to the crux of a difficult problem," says Sarah Kitchen, a research scientist with the Michigan Tech Research Institute (MTRI), who leads a project called Bayesian Adaptive Robot Control System (or BARCS, a good Husky name). BARCS placed second in the virtual track during the latest round of Defense Advanced Research Projects Agency's (DARPA) Subterranean Challenge last October. The demanding environment, a partially collapsed mine with many obstacles being explored by a fleet of drones, looks like a video game. Successfully navigating it draws on Kitchen's background in representation theory, and while she doesn't use this form of pure math directly, it drives her thinking on challenging system-scale problems. Working with robotics engineers and software developers now, Kitchen takes tools from different math fields and finds new applications, using a mathematical eye to cut through complex strings of equations and algorithms to get at the heart of the system's components and how they relate.

Kitchen's MTRI colleagues, including Susan Janiszewski, Mark Stuff, Ismael Xique, Joseph Lindgren, Meryl Spencer, Sean Kelly, and Erick Vega, also draw on their math backgrounds to solve difficult engineering and ecological problems. Janiszewski loves the challenge of figuring out how to apply mathematical frameworks to real-world conundrums.

"When people think of graphs, it's visual," Janiszewski says, bringing up another misconception about mathematics: Math can always be visualized. "But it's really about relationships and once those relationships are on a graph we can use graph theory. When you get into graphical representation, then all of linear algebra is at your disposal."

To put it back into the broader context: Math is not static. Math is not just about the numbers, solving for the right answer, or how it plots on a graph. Math is more versatile and dynamic than any non-mathematician could imagine, which is why we all keep coming back to them with our STEM challenges. But rather than seeking them out for mere number-crunching, we can take a moment with the final note hanging in the air to appreciate the artistry that is the mindset and practice of applied mathematics.



Mathematicians Cécile Piret and Jiguang Sun

>>>Go backstage and see the research behind the scenes:
mtu.edu/mtri
mtu.edu/math

The Village of L'Anse, Michigan, installed a community solar array.

SOLAR RISING

At home, in the lab, and in the community: Michigan Tech researchers and students turn sunlight into energy.

Cloudy with a chance of snow. Though some may regard this sort of forecast negatively, weather like this makes the Keweenaw the perfect location to test solar photovoltaics (PV) in less-than-ideal conditions. The interdisciplinary work encompasses all levels of solar development: improving panel materials, demonstrating how solar works in a home setting, helping a town go solar, and tackling the red tape of renewable energy policies.

SOLAR'S ELEMENTAL COMPONENTS

Silicon, which makes up a lot of Earth's sand, is the second-most abundant mineral in the Earth's crust. It's a cheap material to use as an absorber for solar cell fabrication; however, cells made with one absorber have a maximum efficiency of just 33 percent. Finding the next material to raise the efficiency is something of a holy grail quest. The obstacles? Compatibility, durability, cost.

Chito Kendrick, managing director of Michigan Tech's Microfabrication Shared Facility and adjunct assistant professor in electrical and computer engineering, works with students to create test silicon solar cells.

"We help them become aware of the fabrication steps that are used to make both solar cells and electric devices that need microscale features," Kendrick says. "These test solar cells can be used as a base structure for the incorporation of a second absorber. The question is then which absorber to use?"

Potential candidates: 2D transition metal dichalcogenides (TMDs), made from highly abundant sulfur and selenium. Stacking TMDs on top of silicon creates a solar cell that absorbs two different parts of the visible spectrum, which overcomes what's known as the Shockley-Quiesser limit—how efficiently a solar cell can convert sunlight to electricity.

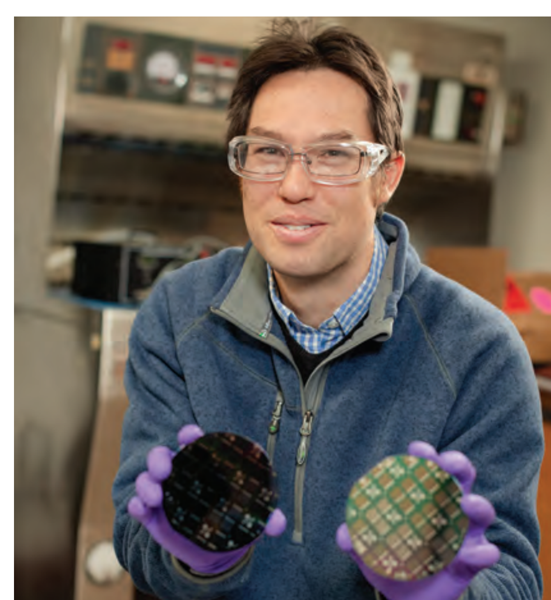
"If you stack two different absorbers on top of one another, with the right band gaps—the amount of energy that needs to be overcome to produce electrons, the free carriers that produce power—you can increase the efficiency limit to 45 percent," Kendrick says.

Still, 45 percent isn't 100, but it's an improvement, which will also encourage more widespread solar adoption.

>>>Explore the Microfabrication Shared Facility: mtu.news/microfab

SAVING MONEY AND ENERGY

Jay Meldrum was skeptical. He knew solar power works where there's abundant sunshine year-round, but the snowy, often cloudy Upper Peninsula is a far cry from the Sunshine State. He installed a solar panel behind the Keweenaw Research Center (KRC) to prove solar PV couldn't pay off here.



Chito Kendrick's microfab students learn to create test silicon solar cells in the lab.

▲ Chelsea Schelly and Richelle Winkler work on community energy autonomy.

"Energy prices are so high that I tried to find some way to save money for the KRC," says Meldrum, KRC director and also the executive director of campus sustainability and faculty advisor to the Alternative Energy Enterprise (AEE) team. "Surprisingly, solar worked."

Fun fact: On average, there are 184 sunny days per year in Houghton; the US average is 205 days. But cloudy days don't preclude solar. Meldrum discovered that even on cloudy days, the panel produced about 30 percent of the output it produced on a sunny day. Since then, he has pieced together a 20-kilowatt (kW) system, saving the KRC about $5,000 in annual energy costs. The center also hosts other panels in addition to the KRC array. For example, a California-based company is testing its product to determine the effect of snow on panels tilted at various angles.

Another campus testbed: the AEE team's Sustainability Demonstration House, where six student tenants demonstrate energy-saving sustainable living practices. In addition to aquaponics, hydroponics, app-monitored energy flows, low-flow faucets, high-efficiency appliances, and LED lightbulbs, students monitor the 8.6-kW solar array that powers the house at 100 percent in the summer and 50 percent in the winter. Future plans include upgrading battery storage to increase winter solar power supply to 75 percent.

"The students are modeling a living situation that's moving closer to net zero," Meldrum says. "Lifestyle changes need to be considered: use less. The easiest way to save on energy bills is to use less energy."

>>>Learn more about the Sustainability Demo House: mtu.news/demohouse

POWER BY THE PEOPLE

Travel south down US-41 to the village of L'Anse and see how solar power has become a community way of life. In summer 2019, L'Anse installed a 300-panel, 110 kW solar array with room to grow. Village residents and businesses can buy one or more panels and earn credits back on their bills for the energy generated. The AEE team provided a conceptual design and feasibility study for a senior design project along with the municipal utility WPPI and the Western Upper Peninsula Planning and Development Region office. Richelle Winkler and Chelsea Schelly, social sciences associate professors, along with graduate and undergraduate students, worked with community members to gauge how open they were to the project and how the team could design a localized program that fit their needs.

"We learned that people were excited about the community aspect of it," says Winkler, associate professor of demography and sociology. "They saw this as a chance for L'Anse to be a leader and as a way to demonstrate community pride. They recognized their community spirit and desire to come together to benefit the local community."

L'Anse made panel purchases affordable across the financial spectrum through payment plans and programs to help low-income families participate. There's less hassle and risk involved because residents can take advantage of a municipally maintained solar array rather than individually installing solar panels at their homes.

>>>Read more about L'Anse community solar: mtu.news/solar

SOLAR FOR EVERYONE?

Research by Joshua Pearce, Richard Witte Endowed Professor of Materials Science and Engineering and professor of electrical engineering, has been working on the economics of solar feasibility since 2011. Since then, the cost has plummeted—often, it's the least expensive energy option. So why don't we see solar panels on every roof in the neighborhood?

"The policies that impact its adoption are primarily those that limit the amount of solar on the grid from distributed generation," Pearce says. "For example, here in Michigan we were limited to only 1 percent distributed generation. Recently the Michigan cap doubled to a whopping 2 percent. There is no technical reason for this limit—in fact we can have over 15 percent of the grid be solar without any changes and over 25 percent with modest changes."

Additionally, federal subsidies to solar are significantly lower than subsidies to coal, oil, and gas. But solar costs are so low that subsidies are not necessary. In a study last year, Pearce points out that only 79 ultrawealthy Americans could fund a complete US solar transition in our electric grid and make money while doing it.

"We need policies that simply allow solar to compete on a level playing field so people who want it can get it," Pearce says, also noting that many large corporations are transitioning to using solar power.

In November 2019, McDonald's announced large-scale solar and wind power purchase agreements—enough to power 2,500 restaurants and aid in meeting its corporate goal to cut overall greenhouse gas emissions by 36 percent.

"There are incredible environmental benefits to solar," Pearce says. "In the short term, replacing all coal with solar would reduce premature deaths from air pollution by about 52,000 Americans per year. In the long run, a transition to PV will help slow climate change. At the same time, solar is good for the wealthy and those with modest incomes alike—if they are allowed to own it and interact with the grid, they will have more financial security."

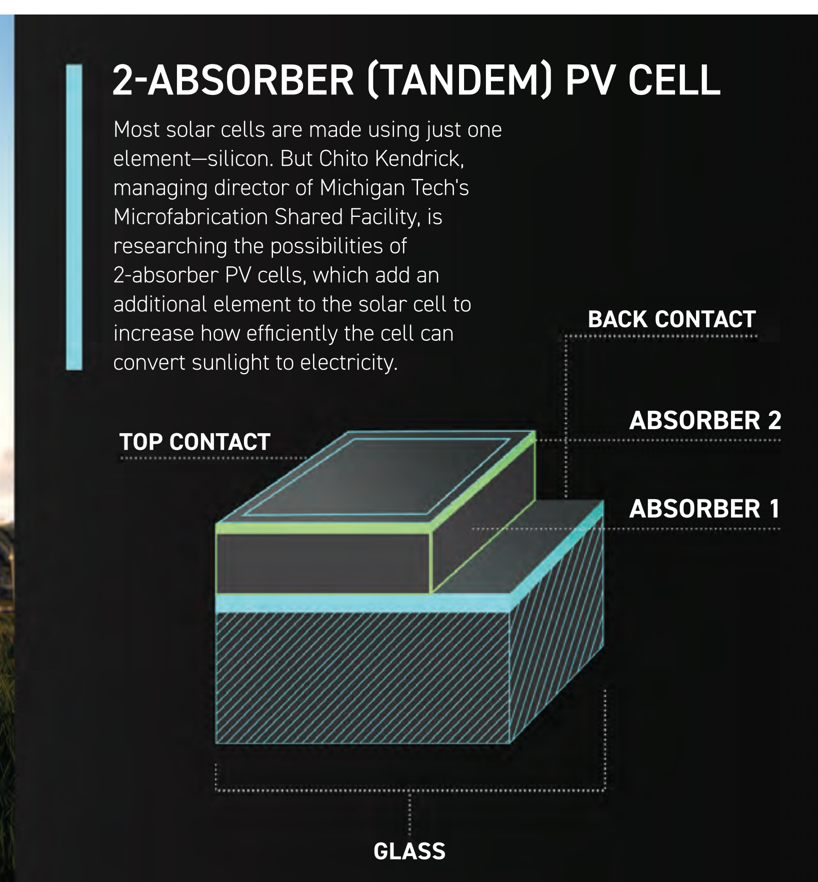
In a time of transitions and global discussions about how best to provision energy, Michigan Tech researchers are at the forefront of the conversation materially and in communities, and are positioned to cast light on decisions made at national and global scales.

>>>Watch the video on solar research: mtu.edu/magazine/solar-rising

ENERGY TRANSITIONS

Kathy Halvorsen, associate vice president for research development and university professor of natural resource policy, is the principal investigator on a $3.7 million National Science Foundation Convergence Research grant titled "Foundations for a Convergent Discipline in Socio-Technological System Transitions through Research on Michigan Community and Anishinaabe Renewable Energy Sovereignty [MICARES]". The five-year project, in partnership with the Sault Tribe of Chippewa Indians, Keweenaw Bay Indian Community, Michigan State University, and six non-Native American communities around the state, will examine renewable energy transitions in the communities.

>>>Read more about MICARES: mtu.news/micares



Awards

BHAKTA RATH RESEARCH AWARD

The Bhakta Rath Research Award recognizes a doctoral student and their Michigan Tech faculty advisor. The pair earns the award for research that dares to be cutting edge while remaining focused on the social contribution of the work. The award was established by Bhakta B. Rath and his wife, Sushama Rath, to promote and reward excellence in scientific and engineering research at Michigan Tech.

BRUCE LEE

associate professor of biomedical engineering

AMEYA NARKAR

PhD graduate, biomedical engineering

What we do: Engineer smart adhesives that stick and unstick based on a set of defined conditions.

Why we do it: To form temporary attachments that can be removed and reapplied without damage. No more ripping off that Band-Aid.

mtu.news/leenarkar

NATIONAL SCIENCE FOUNDATION CAREER AWARD

The National Science Foundation's faculty early career development (CAREER) award program supports big research ideas for new faculty.

KUILIN ZHANG

associate professor of civil and environmental engineering, affiliated associate professor of computer science

What I do: Improve automated driving decisions using real-time, predictive feedback.

Why I do it: Autonomous vehicle advances can't stop at a single car. Cars must communicate and anticipate traffic like human drivers.

mtu.news/zhang

MICHIGAN TECH RESEARCH AWARD

The Michigan Tech Research Award recognizes outstanding scholarly achievement by a faculty member. It is based on the impact of the person's research, particularly sustained research or a noteworthy breakthrough. The Michigan Tech Research Award is symbolic of the University's high standard for research endeavors.

ZHANPING YOU

professor of transportation engineering

What I do: Research roads and how best to make them with what materials for climate, sustainability, and use.

Why I do it: Roads are public projects that people depend on to be built well.

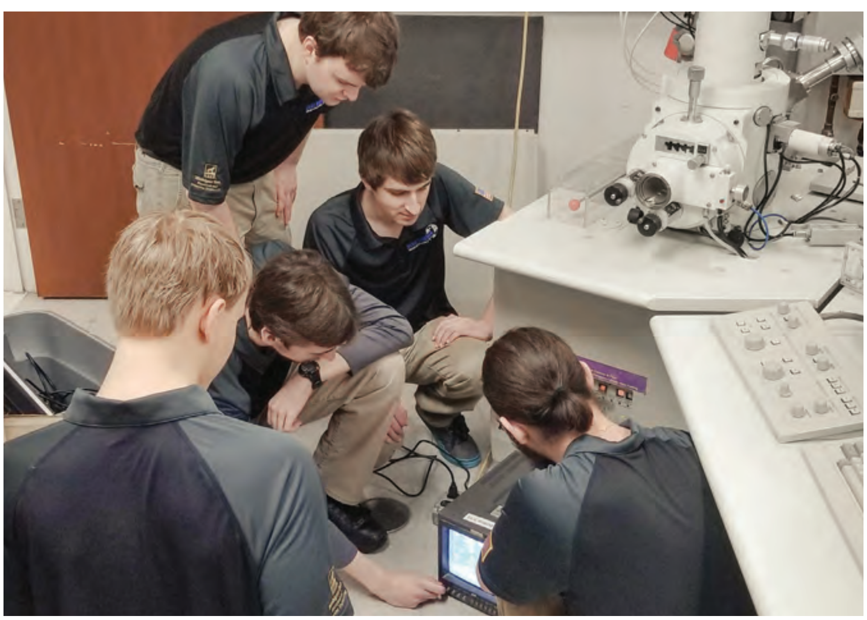
mtu.news/zhanpingyou

Beyond the Lab

$100 ANSWER TO A $100,000 PROBLEM

More than two years ago, Blue Marble Security, born out of Tech's Enterprise program, was given a daunting, albeit straightforward challenge—make something old new again. Ford Motor Company had a problem: An important piece of analytical equipment, an older-model JEOL 6300 scanning electron microscope (SEM), uses monitors with cathode ray tubes (CRT), essentially old-school TV tubes. CRTs are expensive, becoming hard to find, and environmentally hazardous to dispose. Because JEOL was running out of spare monitors for its 6300, Ford's 6300 SEM would become useless without new displays. A problem that would cost the company more than $100,000 to remedy.

Blue Marble took up the challenge, find a way to replace the CRT monitors with off-the-shelf LED displays, similar to what you would find in most office computers. Success didn't come early or easily.



The group's first efforts involved examining the CRT's video signals. This was ruled unsafe because of the high voltage involved. Using printed schematics and manuals from a similar SEM at Michigan Tech, Blue Marble found what they were looking for—a low voltage signal in an early video display protocol pioneered by IBM called monochrome display adapter.

"In the end, the video signal was available and adaptable to modern display protocols with a low-cost, commercial, off-the-shelf adaptor," says Glen Archer, Blue Marble's faculty advisor and interim chair of the Department of Electrical and Computer Engineering. After taking their final exams in April, members of Blue Marble drove to the Ford lab in Dearborn, Michigan, and in about two hours had installed their new system on the JEOL 6300. The total system cost less than $100.

The team members on this project were Dayton Aardema, Alex Newman, Zarek Pirkola, Phillips Munter, John Hughes, and Jonathan Boik.

Blue Marble Security is a student Enterprise, a University entrepreneurship program now in its 20th year.

Superior Ideas

When researchers have the next big idea, we want to make sure they have every opportunity to carry out their project. So, we created a pretty big idea: crowdfunding research, using a University-operated platform. Since October 2012, we bring together donors and researchers, ideas and innovation.

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122 funded projects

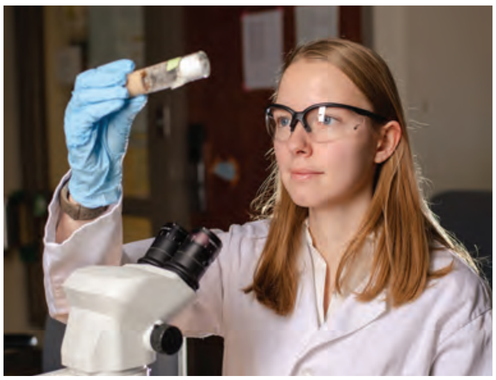
1707 donations through Superior Ideas

347K more than $347,060 raised

78K more than 78,562 unique users to the site

Student Research

UNDERGRADUATE STUDENT



Tessa Steenwinkel is Michigan Tech's 11th recipient of the prestigious Barry M. Goldwater Scholarship. This national scholarship is awarded to college sophomores and juniors based on academic excellence, research experience, and an intent to pursue a STEM career. Besides this, she also became the Departmental Scholar in Biological Sciences and won the Provost's Award for Scholarship, a Summer Undergraduate Research Fellowship (SURF), and a Songer Research Award—all in 2019.

Steenwinkel met her advisor Thomas Werner while on a tour of his lab during the University's annual Preview Day. She immediately knew that she wanted to come to Michigan Tech and work in his lab. In her first two years on campus, she became lead researcher of her own independent project. She uses tiny fruit flies in her research, which are important model organisms used in human health research because they share about 70 percent of disease-causing genes with humans. "My current research looks at how different qualities and quantities of food affect fertility, fecundity, and longevity," she says.

Steenwinkel is already co-author on a book and two research articles, and more of her papers are expected to be published before she graduates. Her time at Michigan Tech is, perhaps, best summed up by Werner: "I'm very, very proud of Tessa, and a bit sad because I'm pretty sure I will never get a student like her again. She is the best student I have ever witnessed in my entire career."

GRADUATE STUDENT

"There's no place like home" could be Rose Turner's motto. Turner graduated from Michigan Tech in December 2018, when she was the student commencement speaker.

After exploring options in the renewable energy industry and making the difficult decision to turn down a scholarship opportunity at the esteemed Iceland School of Energy at Reykjavik University, the environmental engineering alumna returned to Michigan Tech. This time she's back as the recipient of a National Science Foundation Graduate Research Fellowship (NSF-GRFP).

Turner is back in the lab with her undergraduate advisor Daisuke Minakata, associate professor of civil and environmental engineering. She even has her old address back—the Sustainability Demonstration House, where she serves as project manager.

She says other opportunities were intriguing but Tech had its advantages. "You can't guarantee anywhere else has the resources or would support my research interests like Tech does," she says. There was another resource she couldn't find elsewhere—Minakata. "At another school, I would have to work with a new advisor. It is really an advantage to continue my research with Dr. Minakata."

Her research involves perfluoroalkyl and polyfluoroalkyl substances, commonly known as PFAS, more than 4,000 classes and categories of durable chemicals used in virtually every aspect of life that have found their way into the world's water supply.

Turner says conventional water treatment doesn't degrade PFAS. "The carbon fluorine bond is very strong. It's up to researchers to find a way to degrade these compounds."

Shared Facilities

mtu.edu/research/shared

Advanced Power Systems Research Center
Jeremy Worm, jjworm@mtu.edu

Applied Chemical and Morphological Analysis Laboratory
Owen Mills, opmills@mtu.edu

Geospatial Research Facility
Donald Lafreniere, djlafren@mtu.edu

Microfabrication Facility
Paul Bergstrom, paulb@mtu.edu

Marine Research Assets Facility
Andrew Barnard, arbarnar@mtu.edu

Microanalytical Facility
Andrew Burton, ajburton@mtu.edu

High Performance Computing Facility
Gowtham, g@mtu.edu

Research Centers and Institutes

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Advanced Power Systems Research Center (APSRC)
Jeremy Worm, jjworm@mtu.edu

Center for Agile and Interconnected Microgrids (AIM)
Wayne Weaver, wwweaver@mtu.edu

Center for Technology & Training (CTT)
Tim Colling, tkcollin@mtu.edu

Earth, Planetary, and Space Science Institute (EPSSI)
Will Cantrell, cantrell@mtu.edu

Ecosystem Science Center (ESC)
Andrew Burton, ajburton@mtu.edu

Great Lakes Research Center (GLRC)
Andrew Barnard, arbarnar@mtu.edu

Health Research Institute (HRI)
Caryn Heldt, heldt@mtu.edu

Institute for Policy, Ethics, and Culture (IPEC)
Jennifer Daryl Slack, jdslack@mtu.edu

Institute of Computing and Cybersystems (ICC)
Timothy Havens, thavens@mtu.edu

Institute of Materials Processing (IMP)
Steve Kampe, kampe@mtu.edu

Keweenaw Research Center (KRC)
Jay Meldrum, jmeldrum@mtu.edu

Michigan Tech Aerospace Engineering Research Center (MARC)
Greg Odegard, gmodegar@mtu.edu

Michigan Tech Research Institute (MTRI)
Robert Shuchman, shuchman@mtu.edu
Nikola Subotic, nsubotic@mtu.edu

Michigan Tech Transportation Institute (MTTI)
Jake Hiller, jhiller@mtu.edu

Multi-Scale Technologies Institute (MuSTI)
Craig Friedrich, craig@mtu.edu

Pre-College Innovative Outreach Institute (PIOI)
Cassy Tefft de Muñoz, catefft@mtu.edu

Research and Innovation in STEM Education Institute (RISE)
John Irwin, jlirwin@mtu.edu

Center for Leadership and Innovation for Transformation (LIFT)
Lorelle Meadows, lameadows@mtu.edu

Sustainable Futures Institute (SFI)
David Shonnard, drshonna@mtu.edu

The Elizabeth and Richard Henes Center for Quantum Phenomena (CQP)
Jacek Borysow, jborysow@mtu.edu
Ravindra Pandey, pandey@mtu.edu


"I worked on a vaccine for Zika because I want to do research with real impact. The disease is carried by tropical mosquitoes, so refrigeration and cost matter to affected communities. That's why we want to make affordable, thermo-stable vaccines."
Brenna Rosso
undergraduate researcher
biological sciences
Studying how to develop candidate vaccines against infectious viral disease requires attention to detail. Knowing the smallest details of virus proteins and their location help biologists make a big difference in many people's lives. Rosso, working in Ebenezer Tumban's lab, uses bacteriophage virus-like particles as a platform to display proteins from human viruses and to elicit immune responses.
Tomorrow needs biologists.
Tomorrow needs Michigan Tech.
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Kaitlyn Roose is the director of Esports at Michigan Tech. She helps student-athletes on the Esports team keep their head in the game—and she studies how other people do, too. She assesses decision making, problem solving, and attention in games through the Department of Cognitive and Learning Sciences. From Athletics to the new College of Computing, from the classroom to research labs, the digital world is at our fingertips.

Tomorrow needs gamers. Tomorrow needs Michigan Tech.

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